

Root Canal Treatment in a Swedish Public Dental Service

Studies of indications and results

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Root Canal Treatment in a Swedish Public Dental Service

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To my family

ABSTRACT

Despite the marked overall improvement of oral health in Sweden, root canal treatment is still a common procedure in general dental practice. The reasons are unclear. Few studies of root canal treatment have been undertaken in general dental practice and there are no studies which monitor treatment from the initial appointment to completed root filling. There are moreover, few studies which take patients' perspectives into account. The main objective of this thesis was to broaden overall understanding of factors which influence the outcomes of root canal treatment undertaken in general dental practice. The studies are based on three patient cohorts. In **Study I** (cohort 1) information was retrieved from the Swedish Social Insurance Agency's data register, in order to estimate fees associated with root canal treatments. In 2009, root fillings were registered in approximately 250,000 teeth. The fees for all root fillings, including any further related treatment in the subsequent 5 to 6 years, were estimated to be approximately SEK 1,600 million (SEK 6,400/tooth). **Studies II-IV** (cohort 2) were based on a sample of 243 patients who started root canal treatment, during a recruitment period of 2 months, at 20 different public dental clinics in the Public Dental Service of the Region Västra Götaland. Study II revealed that most root canal treatments were initiated in symptomatic (65%), previously non-root filled teeth (93%). Almost half were molars (48%). In Study III, the status of these teeth, one year later, was registered from the patients' dental records. In 70% of cases, the root filling had been completed. However, 13% of the teeth had been extracted and in 16% root canal treatment was not yet completed. The least favorable outcomes were for molar teeth: not only had more molars been extracted, but root canal treatment was as yet not completed in significantly more molars than in the other tooth groups. Study IV is based on a questionnaire 1-3 years after the start of treatment. Half the patients reported symptoms. Of the patients whose root filling had been completed, the majority (87%) responded that they did not regret their decision to choose root canal treatment. **Study V** (cohort 3) is based on 85 patients treated in 6 public dental clinics, who had either started root canal treatment or had a tooth extracted. The aim was to study quality of life and QALY weights (quality-adjusted life year). A questionnaire, comprising the instruments OHIP-14, EQ-5D-5L and questions about the root canal treatment, was issued at the initiation of treatment and again after one month. There was some improvement in the health-related quality of life of the patients who had started root canal treatment. Patient satisfaction was generally high. The results of these five studies confirm that root canal treatment was most often initiated because of toothache. In the 12 months since the initial appointment, the root filling had been completed in only 70% of cases. A large proportion of patients reported pain after 1 year. Although root canal treatment has a positive effect on quality of life, it is unclear whether it is cost-effective compared with the alternative (extraction), especially in molar teeth.

Keywords: coronal restoration; dental fees; dental records; general dental care; pain intensity; patient satisfaction; quality of life; questionnaire; test-retest reliability analysis; tooth extraction

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SAMMANFATTNING PÅ SVENSKA

Trots att tandhälsan generellt sett är god i Sverige, så är det oklart varför rotbehandlingar fortfarande är så pass vanliga och nödvändiga. De flesta behandlingar görs i allmäntandvården, men trots det så är de flesta studier gjorda på universitet eller på specialistkliniker. Det saknas idag forskning som följer tanden från att behandlingen påbörjas till att den avslutas med en rotfyllning. Forskning som efterfrågar patientens perspektiv på sin behandling är också ovanlig. Det övergripande syftet är att ge en ökad kunskap om rotbehandling i den svenska allmäntandvården och särskilt inom Folk tandvården. Studierna i avhandlingen baseras på tre olika patientgrupper.

För **studie I** (patientgrupp 1) inhämtades material från Försäkringskassans dataregister, med syftet att undersöka hur stora vårdavgifterna var för de 250,000 tänder som registrerades som rotfyllda under 2009. Avgiften för rotfyllning och fortsatt tandvård under 5 till 6 år uppskattades till ungefär 1,6 miljarder svenska kronor (6,400 SEK/tand).

I **studier II-IV** (patientgrupp 2) deltog 20 folktandvårdskliniker i Västra Götalandsregionen. Först inkluderades 243 patienter, som alla påbörjade en rotbehandling, under en tidsbestämd period om 2 månader per klinik. De flesta behandlingar påbörjades hos tänder med symptom (65%), de flesta var utan tidigare rotfyllning (93%) och var ofta kindtänder (48%) (studie II). Tänderna följdes sedan via journalsystemet (studie III). Vid 1-års uppföljningen var de flesta tänder rotfyllda (70%). De övriga var antingen borttagna (13%) eller så var behandlingen fortfarande inte avslutad (16%). Till skillnad mot andra tandgrupper blev kindtänderna mindre ofta rotfyllda, och fler hade tagits bort. Ett till 3 år efter påbörjad rotbehandling skickades en enkät ut (studie IV), där hälften av patienterna registrerade smärta eller obehag runt sin tand. Majoriteten av patienter (87%) som fick sin tand rotfylld skulle ha valt samma behandling igen.

I **studie V** (patientgrupp 3) deltog 85 patienter från sex folktandvårdskliniker i Västra Götalandsregionen. De hade antingen påbörjat en rotbehandling eller fått en tand borttagen. Syftet var att studera livskvalitet och QALY-vikter (kvalitetsjusterade levnadsår). En enkät skapades, vilken innehöll OHIP-14, EQ-5D-5L och frågor specifika för rotbehandlingen. Enkäten gavs ut i samband med behandling, och skickades sedan hem efter en månad. En viss förbättring kunde ses avseende hälsorelaterad livskvalitet hos de patienter som påbörjade rotbehandling, samma förändring kunde inte ses hos de patienter som fick sin tand borttagen. Patienterna var generellt sätt nöjda med sin rotbehandling.

Studierna visar att i Folktandvården påbörjades ofta rotbehandlingar på grund av tandvärk. Efter 1 år var endast 70% av tänderna rotfyllda och en stor andel av patienterna rapporterade smärta eller obehag. Patienternas livskvalitet påverkades positivt av rotbehandling. Däremot är det oklart om behandlingen är kostnadseffektiv i jämförelse med att ta bort tanden, vilket särskilt gäller för kindtänderna.

PREFACE

This thesis is based on the following studies, referred by their Roman numerals in the text:

- I Wigsten E, Kvist T, Dawson VS, Isberg PE, EndoReCo, Fransson H. Comparative analysis of general dental practitioners' fees and scheduled fees for root canal treatment and coronal restorations in the adult population of Sweden: a 5-year follow-up of data from the Swedish Dental Register. *Int Endod J*. 2018;51(2):141-7.
- II Wigsten E, Jonasson P, EndoReCo, Kvist T. Indications for root canal treatment in a Swedish county dental service: patient- and tooth-specific characteristics. *Int Endod J*. 2019;52(2):158-68.
- III Wigsten E, EndoReCo, Kvist T. Patient record assessment of results and time related resources spent during one year after initiation of root canal treatment in a Swedish public dental organisation. *In manuscript*.
- IV Wigsten E, Al Hajj A, Jonasson P, EndoReCo, Kvist T. Patient satisfaction with root canal treatment and outcomes in the Swedish public dental health service: A prospective cohort study. *Int Endod J*. 2021;54:1462–72.
- V Wigsten E, Kvist T, Jonasson P, EndoReCo, Davidson T. Comparing Quality of Life of Patients Undergoing Root Canal Treatment or Tooth Extraction. *J Endod*. 2020;46(1):19-28 e1.

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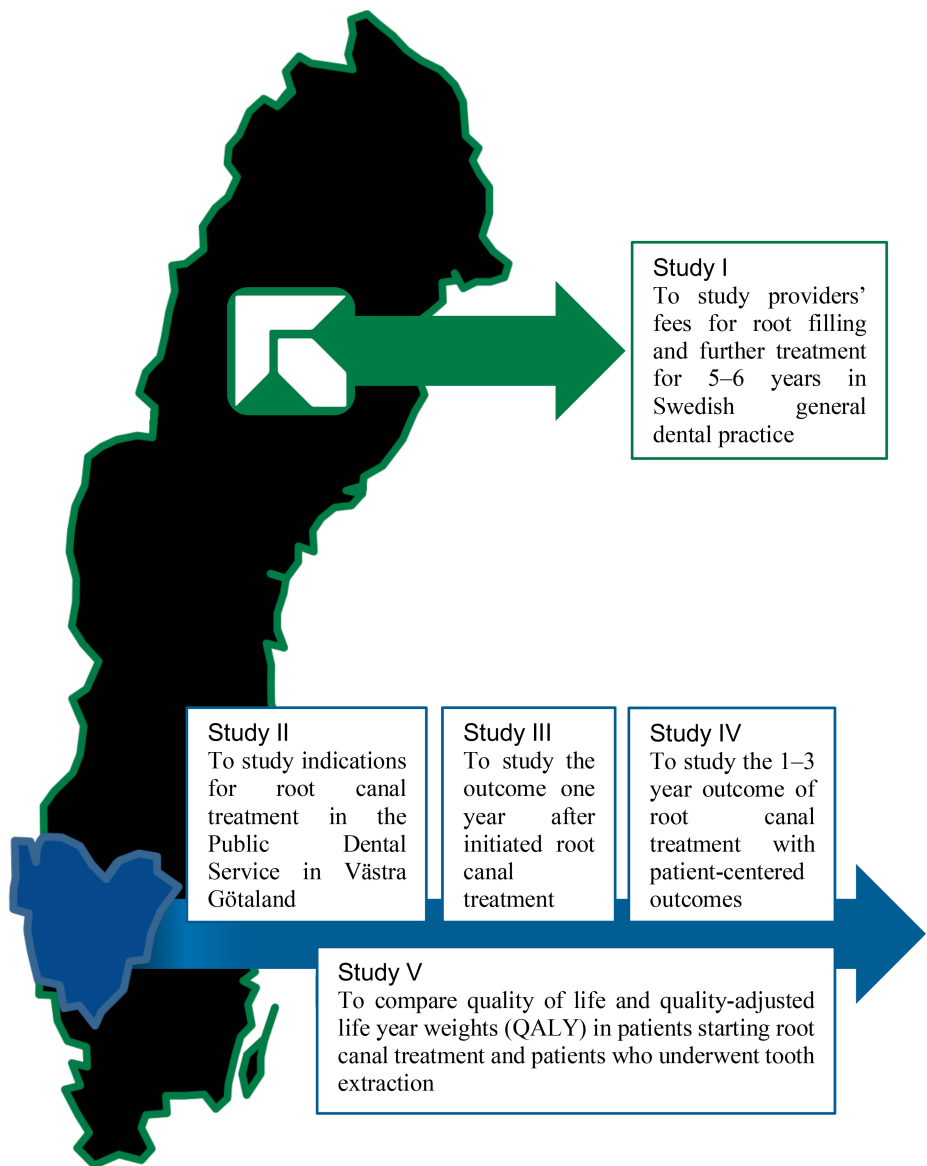
ABBREVIATIONS

AP	Apical Periodontitis
EndoReCo	Endodontic Research Collaboration in Scandinavia
EQ-5D-5L	EuroQol 5-Dimensions 5-Levels
GDP	General Dental Practitioner
HRQoL	Health-Related Quality of Life
ICC	Intra-Class Correlation
Max	Maximum
Min	Minimum
N	Number/s
OHIP	Oral Health Impact Profile
OHRQoL	Oral Health-Related Quality of Life
PREM	Patient-Reported Experience Measure
PROM	Patient-Reported Outcome Measure
QALY	Quality-Adjusted Life Year
QoL	Quality of Life
RCT	Root Canal Treatment
SD	Standard Deviation
SEK	The Swedish krona
SSIA	Swedish Social Insurance Agency (Försäkringskassan)
STROBE	STrengthening the Reporting of OBservational studies in Epidemiology
TLV	Dental and Pharmaceutical Benefits Agency (Tandvårds- och läkemedelsförmånsverket)
VAS	Visual Analogue Scale
WHO	World Health Organization

DEFINITIONS IN BRIEF

HRQoL	Health-Related Quality of Life is intended to reveal how the individual's perception of their state of health affects the quality of life by studying the perception of, for example, physical, mental, emotional, and social aspects affected by current well-being and function (1)
OHRQoL	Oral Health-Related Quality of Life is intended to reveal how the individual's perception of their oral health affects their quality of life, by studying the perception of, for example, comfort while eating and social interaction, but also satisfaction with regard to the effects of current oral health status (2)
QALY weight	A QALY weight is a summary outcome measure of the health effect given in the selected population. The index value often varies between 1 and 0, where 1 represents a state of full health, and zero a state equal to death (3)
QALY/s	Quality-Adjusted Life Years are usually used as an outcome measure in health economic calculations of the effect of a certain health condition over time, calculated by multiplying the value of the health state (<i>i.e.</i> QALY weight) by the specified duration of the condition (3)
QoL	Quality of Life is defined according to the WHO's definition: "an individual's perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns" (4)

AN OVERVIEW OF THE THESIS



An overview of Studies I-V showing the 3 different cohorts and the respective overall aims.

1 INTRODUCTION

Dental caries is generally considered to be the main cause of pulpal and periapical pathology (5, 6). In root canal treatment (RCT), the pulp tissue is removed by chemomechanical preparation of the root canal system, followed by filling with an inert root filling material. Treatment is often initiated because the patient presents with symptoms such as pain or tenderness (5-8). The short-term aim of treatment is relief of symptoms, and in the longer term to preserve the root filled tooth as a functional unit, with healthy periapical tissues. The general dental practitioner (GDP) can perceive RCT not only as technically demanding but also stressful (9, 10). The alternative treatment option is extraction, with or without a prosthetic replacement. The root filled tooth is at increased risk of failure as a result of dentinal fracture, caries or signs of infection and inflammation, *i.e.* apical periodontitis (AP) (11).

In recent years, caries prevalence has decreased in many parts of Western Europe (12), including Sweden (13). As caries is generally acknowledged to be the main cause of pulpal inflammation, a corresponding decrease in the need for RCT would be expected. On the contrary: a Danish study by Bjørndal *et al.* (14) reported an almost 20% increase in the number of RCTs over a 25-year period. Thus RCT is still a common procedure, mostly undertaken by GDPs. In 2009, the number of teeth registered in the Swedish Social Insurance Agency's (SSIA) data register as having been root filled was a quarter of a million (15). The material included just over 200,000 patients, *i.e.* approximately 2% of the adult population had a tooth root filled during that year (15). In the Public Dental Service in the Region Västra Götaland, approximately 15,000 root fillings, and 3,500 emergency appointments for endodontic treatment were registered in 2009 (16). Ten years later, fewer teeth were registered with a completed root filling (approximately 11,000), but a similar number of endodontic emergency treatments was registered (approximately 11,500) (16). The treatment code covering emergency treatment for toothache is described as "emergency trepanation and extirpation of the pulp chamber".

The reasons for initiating RCT have been described by Barbakow *et al.* (8), Reit *et al.* (7) and Bjørndal *et al.* (5). The question which arises, 15–40 years later, is why RCT is still such a common treatment, despite improved oral health, and what criteria are applied as indications for such treatment. By studying the cause, preventive measures can also be considered, for example whether stepwise caries excavation could preserve the vital pulp, or how the number of endodontic retreatments could be reduced. By prospectively following initiated treatment, it would also be possible to determine what

resources are required in order to achieve the goal of a functional, root filled tooth.

The fee for root filling and further interventions

In Sweden, adults usually pay for their own dental care. The current Dental Care Benefits Scheme was introduced in 2008, in order to maintain good dental health and to support those with greater dental treatment needs through the high-cost protection scheme (17). The Dental and Pharmaceutical Benefits Agency determines which treatment items are eligible for reimbursement and how the scheduled fees (*i.e.* reference prices) are to be calculated (18). The service provider's fee and the scheduled fee then determine how much of the treatment is to be compensated through SSIA and thus also how much the patients must pay for their dental care (18).

Although RCT is a common procedure in general dental practice, it is unknown what the overall fees are, nor what resources are required to achieve the goals of a root filling, including preserving the root filled tooth as a functional unit over time. The set service provider's fee for RCT and root filling in the general Public Dental Service in the Region Västra Götaland currently ranges from 3,655 to 6,150 SEK (2021), depending on the number of root canals. There may also be additional fees, for example in cases of complicated root canal localization, subsequent coronal restoration and further endodontic treatment to preserve the tooth as a functional occlusal unit. Dawson *et al.* (19) reported that 3.2% ($n = 7,979$) of all root filled teeth treated by GDPs in Sweden required further endodontic treatment within a five-year period. Of all teeth restored by direct restoration (corresponding to a direct resin composite), 30.3% ($n = 43,363$) needed further restorative treatment within the same time period. This raises some questions about the total cost. Does government reimbursement cover the true cost of a root filling? What does it cost to preserve a root filled tooth in the dentition over time? Are there any differences between the types of coronal restoration? There are only limited health economics studies in endodontics (6). The few available studies have primarily analyzed the cost-effectiveness through modeling, comparing different treatment alternatives (20-23).

Evaluating the outcome of root canal treatment

RCT outcomes can be evaluated in different ways, usually by applying clinical and/or radiographic outcome measures (24-28). The most common outcome measures relate to assessment of healing of periapical tissues, tooth survival and postoperative pain. Overall, the prognosis for healing of the periapical

tissues is generally considered to be good, with success rates of 80–96% (24, 25, 28). The survival of the root filled tooth is also considered to be high, with studies registering a survival of 87–95% over a 4–10-year period (15, 29, 30). A systematic review by Nixdorf *et al.* (31) reported that most root filled teeth were asymptomatic 6 months after treatment, with postoperative pain reported in only 5% of cases ($n = 168$ teeth). Based on the above studies, RCT can be considered as a predictable and successful treatment.

In many studies, the reported outcomes reflect a selected sample of patients and clinicians. Most of the studies have been undertaken at universities, dental hospitals or specialist clinics. It is of interest to note that there are few clinical studies of outcomes of endodontic treatment undertaken in the general dental practice setting (6). Most RCTs are in fact undertaken by GDPs (6, 15) and treatment provided in this setting therefore warrants evaluation. A registry-based study by Fransson *et al.* (15) reported a survival rate of approximately 90% for teeth root filled by Swedish GDPs in 2009. Kebke *et al.* (32) also registered a mean incidence loss of 2% per year among patients treated in public dental clinics in Norrbotten, Sweden. Jonsson Sjögren *et al.* (33) in a study of patients treated at 23 different public dental clinics in Örebro, Sweden, reported that approximately 5% of patients experienced pain or discomfort from their root filled teeth.

There are few prospective clinical studies assessing healing of periapical tissues after RCT in general dental practice (6). Three Scandinavian epidemiological studies indicate that healthy periapical tissues were registered in only 50–75% of the root filled teeth (34–36). In a radiographic follow-up study by Laukkanen *et al.* (37) the RCT outcomes in molar teeth were significantly poorer than for other tooth groups, not only with respect to the technical quality of the root filling, but also in terms of the absence of healing of the periapical tissues. Root filled teeth in need of further treatment constitute a large proportion of referrals to a specialist endodontic clinic in the Region Västra Götaland, with molar teeth predominating (38).

Another concern in follow-up studies of RCT is that the baseline chosen for most studies is completion of the root filling and not the initial appointment. It is therefore not known how many teeth in which treatment was started actually progressed to the final phase of a root filling. It is reasonable to assume that not all teeth in which RCT is initiated are finally root filled as planned. The choice of baseline can therefore result in systematic bias in the evaluation of the outcomes, by excluding teeth in which treatment was initiated but never completed. It seems more appropriate to study the actual number of teeth diagnosed with pulpal and periapical pathology in which treatment was initiated, rather than the selected sample of teeth in which RCT was completed.

By including all teeth from the start of treatment, it is also possible to record the overall resources required to achieve the goal of a functional root filled tooth, such as the number of appointments, prescription of antibiotics and possible complications. Using the initial appointment as the baseline also discloses how many teeth were - for various reasons - not root filled but extracted instead. There are currently few prospective observational cohort studies of RCT by GDPs. Such studies are important, contributing to a better understanding of RCT in general dental practice.

Evaluation based on patient-centered outcome measures

Success or failure of treatment is determined according to predefined goal(s) (39, 40). To supplement the objective outcome measures for evaluation of the RCT, the outcome could also be assessed from the patient's perspective. Including information about patients' experiences or how they were affected by the experience could complement clinical evaluation of treatment.

The concept of patient-centered care has received increasing attention in recent years. Although RCT is a common procedure in general dental practice, there are few studies to date of patients' perceptions of their treatment. To study how the patient is affected, or experiences his or her treatment, concepts such as quality of life (QoL) and patient satisfaction may be applied (41-44). Different questionnaires are available for this purpose. They may be general, so-called generic, or disease-specific, *i.e.* for studying a certain disease or a certain condition.

Oral health-related quality of life and root canal treatment

There are few studies of oral health-related quality of life (OHRQoL) with respect to RCT undertaken in general dental practice (45), or in connection with treatment (43, 46), or which study change in perception over time (43, 45, 46). The available studies reveal that patients have a negative perception of the effect of pulpal and periapical pathology on OHRQoL (41, 42) and this perception improves after RCT (43).

One of the most widely used instruments for measuring QoL related to oral health is the Oral Health Impact Profile (OHIP). Its purpose is to measure OHRQoL based on the patient's self-reported perception of possible dysfunction, discomfort and disability attributable to oral disease. (47, 48). The original version, constructed by Slade and Spencer, consisted of 49 questions (OHIP-49) (47). Subsequently, a shorter version of 14 questions was introduced (OHIP-14), which showed comparable reliability and validity (48). The theory is based on Locker's model of the potentially negative

consequences of oral diseases for daily life: impairment, disability, and handicap (47, 49).

The instrument measures the individual's perception of his or her oral health from seven different aspects (dimensions), namely: functional limitation, physical pain, psychological discomfort, physical disability, social disability, and handicap. The questions are designed to explore the negative consequences of poor oral health and thus the impact on QoL. All questions begin in the same way: the subject ranks how often he or she has experienced the situation as a result of his or her oral condition. The answer options are ranked on a 5-point scale: 'never' (score 0), 'hardly ever' (score 1), 'occasionally' (score 2), 'fairly often' (score 3) and 'very often' (score 4). (48, 50, 51).

Health-related quality of life and root canal treatment

To our knowledge, there are to date no studies in the field of endodontics, of health-related quality of life (HRQoL) and RCT with the EQ-5D (EuroQol-5 Dimensions). The instrument is well-established, standardized, and non-disease-specific, intended to describe health and measure HRQoL (52-55). The instrument was developed by an international research group, the EuroQol Group, and is considered to be valid and reliable (52-54).

The instrument has two sections: a descriptive system and a Visual Analogue Scale (VAS scale). Whereas the previous version had 3 response levels (3L), the newer version has been expanded to five (5L), with the aim of increasing the instrument's sensitivity and reliability and reducing the ceiling effect. The instrument measures the patient's perception of their health, using 5 questions (dimensions) with 5 response levels, classifying severity from: no difficulties ('no problems') to severe difficulties ('unable to'/'extreme problems'). A unique numerical description of a health state is then created for each individual, where the EQ-5D-3L has 243 unique health states (53) and the EQ-5D-5L has 3,125 (54). For each health state, there is a single summary number (index value), ranging from full health ('1') to a state equivalent to death ('0'). (54, 56). The index values usually correspond to the general populations' perspective of the various health conditions by using different value sets obtained from different countries or regions. The questionnaire concludes with a VAS scale (EQ-VAS), on which the patient is instructed to evaluate their overall health, ranging from the end point 'worst imaginable health state' (score 0) to 'best imaginable health state' (score 100). (52-56).

One of the important features of the EQ-5D is that the summary index value can also be used as a quality-adjusted life year (QALY) weight. (52, 53). The QALY weight, in combination with the time in the specific health state, can

give the outcome measure QALY, which is a common measure in health economics studies (3). By using QALYs, different disorders and interventions can be compared, as is common in cost-effectiveness analyses (3). To our knowledge, there are to date no published studies of cost-effectiveness and QALYs in the field of endodontics.

Patient satisfaction with root canal treatment

Patient satisfaction is a measure of the patient's experience of the care received (PREM), based on his or her needs, expectations, and experiences (57, 58). The perception of satisfaction is thus highly subjective, and is usually explored by means of a questionnaire (59). Dugas *et al.* (44) developed an instrument specifically to study patient satisfaction with RCT. The questions concerned factors which usually cause the greatest dissatisfaction, such as pain during treatment, postoperative aesthetics, chewing ability and costs. The few studies available show that patients were generally satisfied with their treatment (44, 60).

By combining different instruments in a specific population, such as a cohort of patients starting RCT, various aspects of OHRQoL and HRQoL can be studied, as well as patient satisfaction. Most studies assessing patients' experiences, or how they were affected by an RCT, have been conducted in university, dental hospital, or specialist dental clinic settings, mostly on referred patients (41-44, 46, 60-62). However, it is particularly important to study the outcomes in the setting where most RCTs are undertaken. Comparison with a relevant control group over time would also be essential. Such a group might comprise patients undergoing extraction instead of RCT. The question to be addressed is whether there is a difference between the groups with respect to perceived QoL and QALYs.

2 AIM

General aim

The overall aim of the thesis was to broaden understanding of RCT undertaken by Swedish GDPs, with special reference to the Public Dental Service. Indications for RCT and the treatment outcomes were evaluated in terms of patient-centered and treatment-specific outcome measures. Three different cohorts were investigated.

Specific aims

The specific aims of the study were to:

- I Calculate overall fees for root filling and further treatment by Swedish GDPs, over a follow-up period of 5 to 6 years. Comparisons were made between types of coronal restoration, tooth groups and the root filled teeth which survived, versus those which were extracted
- II Investigate indications for RCT in public dental clinics of Region Västra Götaland, by registering patient- and tooth-specific characteristics associated with the initiation of RCT
- III Document the treatment outcomes, the number of root filled or extracted teeth, and the related chairside time 1 year after starting RCT
- IV Examine patients' satisfaction with their RCT outcomes 1 to 3 years after starting treatment, and assess the reliability of the responses
- V Study the effect of RCT in terms of QoL and QALY weights, by comparing patients who started RCT with a control group of patients who underwent tooth extraction

3 MATERIALS AND METHODS

An overview of the studies

This thesis is based on 5 studies, with 3 different cohorts and 2 different study designs: one registry-based and 4 cohort studies, in three of which data have been collected prospectively. An overview of the studies is presented in Table 1. A more detailed description of the studies is presented in this section.

Table 1. *An overview of the studies in the thesis. The participants are presented in numbers (n), mean age (SD) and the percentage distribution of the females*

Variable	Study I	Study II	Study III	Study IV	Study V
Study design	Registry-based cohort study	Cohort study	Prospective cohort study	Prospective cohort study	Prospective cohort study with control group
Setting	SSIA	The Public Dental Service in the Region Västra Götaland			
Cohort	I	II	II	II	III
Study population	248,299 teeth registered as root filled in the SSIA's data register (15)	Patients treated at one of 20 public dental clinics	(This study is a follow-up from Study II)	(This study is a follow-up from Study II)	Patients treated at one of 6 public dental clinics
Inclusion period	1/1-31/12 2009	11/5 2015-3/2 2017			22/8-1/12 2017
Data collection	SSIA's data register	Dental records Questionnaire Radiographs	Dental records	Questionnaire	Dental records Questionnaire Radiographs
Follow-up period	5–6 years		1 year	1–3 years ¹	1 month
Participants	<i>n</i> = 217,047	<i>n</i> = 243	<i>n</i> = 240	<i>n</i> = 159	<i>n</i> = 85
Age	55.1 (15.5)	48.3 (16.4)	48.5 (16.3)	52.5 (15.7)	51.1 (16.8)
Females	49.8	52.7	53.3	54.1	50.6

¹The mailouts took place between September 2017 and April 2018.

Study I

Setting

The population of Sweden in 2009 was approximately 9.3 million. The Dental Care Benefits Scheme is administered by the tax-funded SSIA and covers the adult population. Most adult residents (>20 years) are entitled to this public financial support. SSIA's data register therefore contains information on patients who have been reimbursed for their dental care under the high-cost protection scheme, regardless of whether the care has been provided privately or at a public dental clinic. (17, 18).

Study population

All items of dental treatment in the Dental Care Benefits Scheme have specific three-digit codes. Codes 501-504 represent RCT and correspond to the number of root filled canals. The treatment code is applied when the treatment is completed, and a fee is to be charged. A search for the specific RCT codes in SSIA's data register shows that in 2009, 248,299 teeth underwent RCT and were registered as completed with a root filling (15).

A total of 217,047 patients (49.8% women and 50.2% men) with a mean age of 55.1 years (SD = 15.5, range: 20-102 years) participated in the original study (15). During the follow-up period of 5 to 6 years, 25,228 teeth (10.2%) were registered as extracted (treatment codes 401-404). The survival of teeth root filled by Swedish GDPs was 89.8%.

An overview of the study and its population is presented in Table 1.

Data collection

Root filled teeth

For each root filled tooth identified, the following information was tracked in SSIA's data register: tooth number, dental care provider, the actual fee charged and the scheduled fee for the root filling, whether any additional tooth-specific treatment codes were registered and, if so, which codes they were. All root filled teeth were followed until 31 December 2014 (a period of 5 to 6 years) or until the tooth was registered as extracted (codes 401-404).

Type of coronal restoration

The first tooth-specific treatment code for coronal restoration was registered within the time period of 6 months after root filling. The type of restoration

was classified as direct, indirect or unspecified, according to the different treatment codes (Table 2).

Table 2. *The following treatment codes were identified and classified as direct, indirect, or unspecified restorations. A description of the different codes is also presented*

Coronal restoration	Treatment code	Description
Direct	701–707	Corresponding to direct resin composite Depending on the tooth group and the number of restored surfaces (1-5) or full cover crown (707)
Indirect	801, 805–809	Corresponding to a tooth-supported crown, onlay or inlay fabricated by a dental technician
Unspecified		No tooth-specific treatment code corresponding to a direct or indirect restoration was found within the time period of 6 months after root filling

If both indirect and direct treatment codes were registered within the time period, the tooth was classified as indirectly restored.

Further dental interventions

After the root filling had been noted as registered in the SSIA's data register, further treatment over the ensuing 5 to 6 years was tracked by searching for tooth-specific treatment codes corresponding to nonsurgical and surgical retreatment, extraction, and subsequent coronal restorations (Table 3). Treatment which was not registered as tooth-specific, such as preventive care or periodontal treatment, was not included in the study.

When a treatment code was registered on more than one occasion on the same day, only the first treatment was included in the analysis. This applied to nonsurgical and surgical retreatment and to extraction. Treatment was also excluded if the tooth number was not specified.

Analysis of study population

The outcomes were analyzed by both descriptive and analytical statistics. The population was studied by comparing the service provider's fee for the root filling and the scheduled fee between the different service providers, the total fee for 5 to 6 years representing root filling procedures and subsequent further treatment, depending on the type of coronal restoration and tooth group. Comparison was also made of the root filled teeth which survived and the teeth which were extracted over time.

Table 3. The following treatment codes were identified during the follow-up period. A description of the different codes is also presented

Treatment	Treatment code	Description
Endodontic treatment	501–504	Root canal treatment or nonsurgical retreatment corresponding to the number of root filled canals
	521	Corresponding to emergency treatment involving pulp extirpation
	522	Additional fee for complicated root canal localization
	523	Removal of constructions such as posts
	541–542	Surgical retreatment, for one tooth and an additional tooth
Extraction	401–404	Corresponding to the degree of difficulty, from uncomplicated extraction (401) to surgical removal (404)
Direct restoration	701–707	Corresponding to a direct resin composite restoration Depending on the tooth group and the number of restored surfaces (1-5) or full crown (707)
	708	Corresponding to placement of post
Indirect restoration	801–803,	Corresponding to a tooth-supported crown, onlay or inlay fabricated by a dental technician Other constructions such as posts, temporary crown with metallic framework also belong to this category
	805–809	

Studies II-IV

Setting

The Västra Götaland region has the second largest population in Sweden, with just over 1.7 million residents. About half a million live in the Gothenburg area. The county Public Dental Service has approximately 154 dental clinics, providing both general and specialist dental care (63). About 40% of all adults in the county are patients of the Public Dental Service (63).

Study population

The subjects were recruited from 20 general Public Dental Service clinics in the Region of Västra Götaland. In 2015 these clinics represented approximately one-fifth of the region's clinics ($n = 109$, 21%) with different socio-economic conditions and geographic locations. Five clinics were located in Gothenburg and the others in smaller cities or communities. There was a distance of 220 km, as the crow flies, between the most northerly and the most southerly of the selected clinics. The number of GDPs also varied, from 2 to

10 per clinic. In all, 113 GDPs participated in the recruitment process. All clinics were affiliated with SSIA.

An overview of the study and its population is presented in Table 1. A flow chart of Studies II-IV, showing recruitment procedures and the number of participants in the evaluation of initiated RCT is presented in Figure 1.

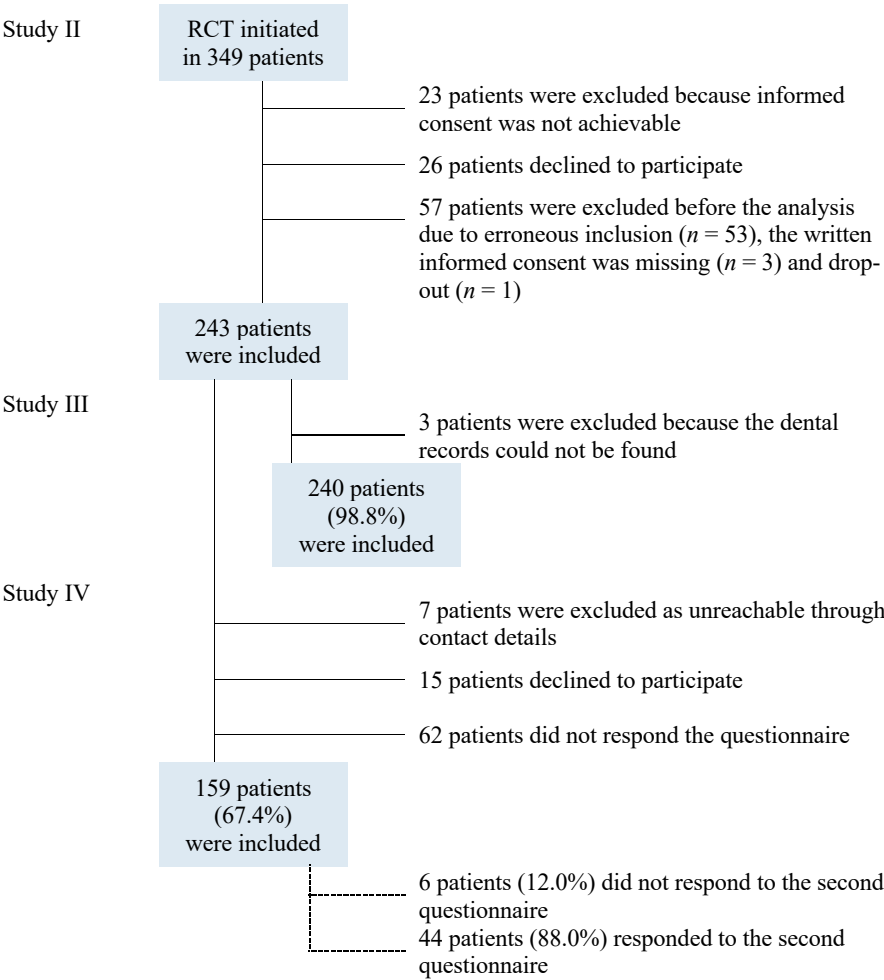


Figure 1. Flow chart for Studies II-IV. 243 patients started root canal treatment at 20 public dental clinics (Study II). Two patients had two teeth treated during the time period, but only the first was included. After 1 year, treatment outcomes were recorded from the dental records (Study III) and by mailouts 1 to 3 years after initiated treatment (Study IV). In Study IV, the first 50 respondents received a second mailout.

Study II

Recruitment of patients

The subjects were consecutively enrolled during a predetermined period of 8 weeks per clinic. The inclusion criteria were: (i) RCT was started, (ii) the patient was over 18 years of age and (iii) could give voluntary informed consent, written in Swedish. The number of ineligible patients was noted, *i.e.* those who declined to participate, or those with language difficulties or physical or mental illnesses. The recruitment period lasted from May 2015 to February 2017. (Table 1; Fig. 1).

Data collection

The questionnaire

For each participating patient, the GDPs noted the indication for initiating RCT on a specially designed questionnaire. The questionnaire was developed specifically for this study. The following data were requested: date of initiation of treatment, participant's social security number and tooth position. The GDPs were instructed to select one out of 5 predefined endodontic diagnoses: pulpitis, pulpal necrosis with/without AP, root filled tooth with/without AP, and a section for non-specific diagnoses, such as cusp and dental fractures. The GDPs also noted whether the tooth was symptomatic or asymptomatic.

The patients were asked to rate their present pain intensity on a VAS scale (10 centimetres; Mundipharma). The given end points were 'no pain or discomfort' (score 0) and 'pain as bad as it could be' (score 10) (64).

The dental records

Dental data were also retrieved from the patients' computerized dental records and the associated radiographs. The following preoperative patient- and tooth-specific characteristics were registered:

- *Patient-based:* age (years), gender (male, female), number of remaining teeth (1-32), whether a regular dental attender or not and whether the appointment was scheduled, or a so-called emergency appointment
- *Tooth-specific:* jaw (maxilla, mandible), tooth group (incisor/canine, premolar, molar), previous restoration (no restoration, direct restoration, indirect restoration, amalgam, temporary filling, unknown), number of restored surfaces (0-

6), dental caries (non-carious, primary, secondary (defined as a lesion associated with a restoration), any loss of tooth substance (analyzed in terms of the radiographic proportion of coronal tooth substance loss), proximity of the caries lesion to the pulp (in the enamel, to the dentin-enamel junction, in the dentine, in the inner third of the dentine) and if there was a previous registration of dental trauma

Analysis of study population

The population was studied with reference to the GDPs' registrations, the questionnaires, and the participants' computerized dental records with associated radiographs. The outcomes were presented with both descriptive and analytical statistics. Comparisons were also made with respect to gender and age.

Study III

Study population

Two hundred and forty (98.8%) of the 243 patients who started RCT were followed for one year *via* the computerized dental record system (Table 1; Fig. 1). The written consent of each participating patient had been obtained in Study II. Two exclusion criteria applied: when the patient could no longer be tracked in the dental record system or chose to leave the study.

Data collection

The dental records

The 240 teeth were monitored through the computerized dental records for one year or until the tooth was extracted. The following treatment-specific characteristics were registered:

- *Completed treatment*: the first completed treatment was registered, as: root filling or extraction. The remainder were registered as root filling not yet completed. The reason for extraction was registered
- *Treatment-specific variables*: if antibiotics were prescribed (number of prescriptions), possible complications (such as dentinal cracks, instrument fractures, perforations, and substandard quality of the completed root filling), referral to a specialist endodontic clinic, and the number of

appointments, and the interval in days between treatment start and completion

If the tooth was extracted after the root filling had been completed, the reason, and the number of days after completion of the root filling were registered

- *Type of coronal restoration*: the initial coronal restoration, within a year of completion of the root filling, was registered. The type of restoration was classified as: direct or indirect, or as unspecified, in cases where the only restoration was the temporary filling used during the RCT. Posts were classified as directly or indirectly fabricated

Analysis of study population

The population was studied with reference to selected treatment variables in each individual's dental records. The outcomes were presented with both descriptive and analytical statistics, where the treatment outcomes were compared with the preoperative, baseline patient- and tooth-specific characteristics and the data derived from the questionnaires in Study II. Comparisons were also made of the number of appointments and the interval in days between the initial appointment and completion of treatment.

Study IV

Study population

Two hundred and thirty-six (97.1%) of the 243 patients who started RCT were contacted by post after ≥ 1 year (Table 1; Fig. 1). The written consent of each participating patient had been obtained in Study II. Two exclusion criteria applied: if contact details were missing, or if the patient declined to participate in this particular study.

Data collection

The questionnaire

The questionnaire was designed to investigate the patient's perspective of the RCT outcomes after 1 year. Attached to the questionnaire was a cover letter with a brief reminder about the study and a guide as to the relevant tooth. A pre-addressed return envelope was also attached. If there was no response, a reminder was sent out three weeks later, along with an extra phone call. The

mailouts took place between September 2017 and April 2018. All material was in Swedish.

The questionnaire contained eight questions and is presented in Table 4. The first question concerned the status of the tooth. Questions 2 and 3 concerned the present pain intensity and its characteristics. The following four questions, adapted from Dugas *et al.* (44), evaluated patient satisfaction, covering their memory of pain during RCT, aesthetics, function and costs. Finally, the patient was asked if in retrospect they would still have chosen the same treatment (Question 8).

Patients who declared that the tooth was missing were requested to answer Questions 4 and 8.

Questions 1, 3 and 8 were multiple-choice questions. The responses to Question 2 and Questions 4-7 were on VAS scales with different predefined end points. The VAS scales were 10 centimeters long and ranged from the positive (score 0) to the negative (score 10).

The first 50 respondents received a follow-up questionnaire to evaluate the reliability of the registrations.

The number of days between the start of RCT and the response to the first questionnaire was registered. For the respondents who received the second mailout, the number of days between the first and the second questionnaire was also registered.

Table 4. The questionnaire comprised 8 questions about the tooth’s present status and the outcomes of root canal treatment. Question 2 and Questions 4-7 were responded to on VAS scales, with different predefined end points ranging from positive to negative (0-10)

The questionnaire					
1	What has happened to the tooth?		<input type="checkbox"/>	The tooth is root filled	
			<input type="checkbox"/>	The root canal treatment is not yet completed	
			<input type="checkbox"/>	The tooth has been extracted and has been or has not been replaced	
2	Mark how the tooth feels today:		no pain or discomfort	--	pain as bad as it could be'
3	If you experience symptoms from the tooth, choose the option/s that best describe the character:				
	burning sensation	dull/achy	tender	numbness	(electric) shooting
	stabbing	throbbing	feels too high	swelling	pricking
					sensitive to touch
4	I experienced the root canal treatment as:		not at all painful	--	very painful
5	I feel that my tooth looks:		very good	--	very bad
6	I feel that chewing on the tooth is:		unhindered	--	impossible
7	I feel that the root canal treatment was:		absolutely worth the cost	--	absolutely not worth the cost
8	In retrospect would you have chosen root canal treatment for this tooth?		<input type="checkbox"/>	Yes	
			<input type="checkbox"/>	No	
			<input type="checkbox"/>	Uncertain	

The questionnaire has been translated into English and the layout has also been altered for the thesis.

Analysis of study population

The population was studied with reference to the responses to the questionnaires. The outcomes are presented with both descriptive and analytical statistics. A non-response analysis was undertaken with respect to the preoperative baseline registrations. The tooth groups were compared with the preoperative baseline patient- and tooth-specific characteristics, the data derived from the questionnaires in Study II, and the responses in this study. A reliability analysis of the first and second questionnaires was undertaken.

Study V

Setting

The study was conducted in the Public Dental Service in the Region Västra Götaland.

Study population

The subjects were recruited from 6 general dental clinics in the Public Dental Service of the Region Västra Götaland. The clinics represented different socio-economic conditions and geographical areas in the region. The clinics were located in smaller cities and in rural municipalities. There was a distance of 190 km, as the crow flies, between the most northerly and the most southerly clinic. The number of GDPs employed at the clinics varied from 3 to 10. A total of 47 GDPs participated in the recruitment process. All clinics were affiliated with SSIA.

An overview of the study and its population is presented in Table 1. A flow chart of the recruitment procedure and the number of participants is presented in Figure 2.

Recruitment of patients

The subjects were consecutively enrolled during a predetermined period of 8 weeks per clinic. The inclusion criteria were: (i) RCT was started, or a tooth was extracted, (ii) the patient was over 18 years of age, (iii) could read the Swedish language, and (iv) was capable of giving voluntary informed consent. The number of patients who declined to participate or were ineligible to participate due to language difficulties, or physical or mental illnesses, was registered and the planned treatment was noted. The recruitment period lasted from August to December 2017. (Table 1; Fig. 2).

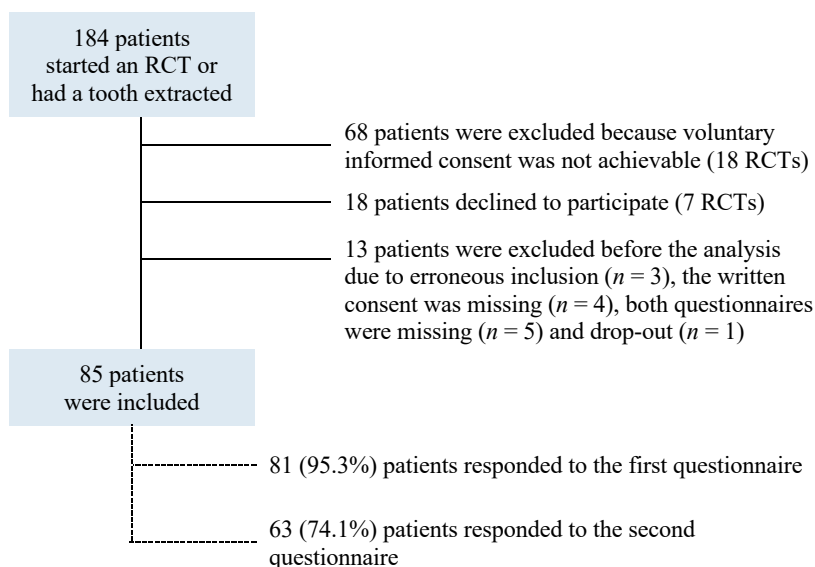


Figure 2. Flow chart for Study V. 85 patients from 6 public dental clinics were included. Four patients had two teeth treated during the time period: only the first tooth was included (3 extractions and 1 RCT). 48 patients underwent extraction and 37 started root canal treatment.

Data collection

The questionnaire

The first questionnaire was distributed at the start of treatment, representing baseline. The same questionnaire was then sent by post a month later. The front page contained a brief description of the study. A pre-addressed return envelope was also attached to the questionnaire. If there was no response, a reminder was sent out three weeks later, along with an extra phone call. The mailouts took place between August 2017 and February 2018. All material was in Swedish.

The questionnaire contained four different instruments: (i) OHIP-14 (Appendix), (ii) EQ-5D-5L and EQ-VAS (55), (iii) 9 disease-specific questions adapted from Dugas *et al.* (44), about present pain intensity and patient satisfaction (Table 5), and (iv) 6 questions on demographic data, with questions about the subject's employment, additional costs associated with the appointment, etc.

A Swedish validated version was used for OHIP-14 (50, 51). The neutral 'don't know/not applicable' response option was applied in this version of OHIP-14, and treated as missing in the statistical analysis (48, 50). The registered scores

for each individual were summed up: the higher the total score (maximum 56 points), the greater the impact on oral health and thus a poorer perceived OHRQoL (47, 48).

The research group received permission from the EuroQol Group to use the translated Swedish version in Study V (date of approval: 2017-05-29).

Patient satisfaction was scored on VAS scales (10 centimeters), ranging from score 0 (positive) to score 10 (negative). The scales were constructed with different predefined end points. The patient’s experience of RCT was studied, followed by the patient’s perception of the aesthetics and function of the tooth, the total experience and finally the present pain intensity.

Table 5. *The 9 disease-specific questions were responded to on VAS scales with different predefined end points, ranging from positive to negative (0-10)*

Disease-specific questions			
I experienced my root canal treatment as:	pleasant	--	unpleasant
	pain free	--	painful
	quick	--	time consuming
	inexpensive	--	expensive
	worth the cost	--	not worth the cost
I feel that my tooth has:	good aesthetics	--	poor aesthetics
	good chewing ability	--	poor chewing ability
I was overall:	very satisfied	--	very dissatisfied ... with the treatment
Mark how the tooth feels today:	no pain or discomfort	--	pain as bad as it could be'

The questionnaire has been translated into English and the layout has also been altered for the thesis.

The demographic information requested was: main occupation (employee, student/senior citizen, other), if leave was taken to keep the dental appointment, what means of transport was used to attend the dental clinic, whether the appointment involved additional costs such as paid parking, possible sick leave, and the patient’s highest level of education (elementary/high school, university or other $\leq/\geq 2$ years). The questions were open-ended and with multiple-choice responses.

Patients starting RCT were instructed to respond to all questionnaires. Patients whose tooth had been extracted were asked to respond to OHIP-14, EQ-5D-5L and EQ-VAS, and the section on demographic data.

The number of days between the baseline appointment and the responses was registered.

The dental records

Patient-based and tooth-specific characteristics were obtained from each participant's dental records and the associated radiographs. The following preoperative variables were registered: age (year), gender (male, female), number of remaining teeth (1-32), and tooth-specific variables such as: jaw (maxilla, mandible), tooth group (incisor/canine, premolar, molar), tooth position (#), presence of diagnosed symptoms (asymptomatic, pain from vital or necrotic pulp), reason for initiating treatment (endodontic diagnosis), type of treatment (RCT, tooth extraction) and date of first appointment.

Analysis of study population

The population was studied in terms of the responses to the questionnaires and selected variables from the dental records and the associated radiographs. The outcomes are presented with both descriptive and analytical statistics, where comparisons were made between the two treatment methods and over time, by comparing the responses to the first and second questionnaires.

For the analysis of QALY weights, the tariffs 3L (Crosswalk) (65, 66) and 5L (67) tariffs representing the population in the United Kingdom (UK) were used.

Statistical methods

An overview of the statistical methods applied in the Studies I-V is presented in Table 6.

IBM SPSS Statistics for Windows, versions 22.0–26.0 (IBM Corp., Armonk, NY, USA) and the SAS system, version 9.4 (SAS Institute Inc., Cary, NC, USA) were used for the statistical analysis.

All tests of significance were two-sided and conducted at the 5% significance level ($P < 0.05$).

Table 6. *The statistical methods applied in the studies and the way in which they were applied*

	Study				
	I	II	III	IV	V
Descriptive analyses: mean, SD, median, minimum; maximum for continuous variables and numbers and % for categorical variables	X	X	X	X	X
<i>For comparison between two groups:</i>					
Fisher's Exact test for dichotomous variables		X	X	X	X
Chi-Square test for non-ordered categorical variables		X	X	X	X
The Mann-Whitney U-test for continuous variables not normally distributed		X		X	
Fisher's non-parametric permutation test for continuous variables			X		X
The two-sample T-test for continuous variables normally distributed	X				
Mantel-Haenszel Chi-square test for ordered categorical variables		X	X	X	X
<i>For comparison between three unordered groups:</i>					
Analysis of covariance (ANOVA) for comparing continuous variables in three groups followed by Tukey's test	X				
Kruskal-Wallis test comparing continuous non-normal variables in three groups			X	X	
<i>For comparison of three ordered groups:</i>					
Jonckheere-Terpstra rank test for continuous variables		X	X		
Univariable and Multivariable logistic regression analysis for predicting dichotomous outcome variable			X		
<i>For comparison within groups:</i>					
Wilcoxon Signed Rank test for continuous variables				X	X
Sign test for ordered categorical variables and dichotomous variables				X	X
<i>Test - Retest - Reliability:</i>					
ICC, Intra individual SD, CV (coefficient of variance) and distribution of differences for continuous variables				X	
% agreement and Kappa for categorical variables				X	

4 RESULTS

Study I

Fees for root fillings in Sweden 2009

The total fees for the 248,278 root fillings, including the fee actually charged and reimbursement from SSIA, was 82.3 million Euro (736 million SEK). The mean fee was 332 Euro (2,964 SEK) per root filled tooth. Conversion from SEK to Euro was based on the exchange rate as of January 1st, 2012: 1 Euro = 8.94 SEK.

The total mean difference between the charged and scheduled fee was 13 Euro (115 SEK; Table 7). There was a pronounced difference in distribution of registered root fillings between the private and the public sector (67.0% and 32.8%, respectively). On average, the private sector charged 18 Euro (161 SEK) over the scheduled fee and the public sector 3 Euro (29 SEK; $P < 0.0001$). The maximum difference in relation to the scheduled fee was -504 and 664 Euros (-4,510 and 5,940 SEK, respectively).

Table 7. Comparison of different sectors according to the difference between the fee charged and the scheduled fee (in Euro), analyzed with one-way ANOVA followed by Tukeys' post-hoc test. In the pairwise comparisons of the three groups, all three P -values were < 0.0001 . Twenty-one root filled teeth were excluded because the scheduled fee was registered as zero. The original table is presented in Wigsten et al. (68)

Provider	Root fillings (n, %)	Mean	SD	95% Confidence Interval		Min	Max	P-value
				Lower limit	Upper limit			
Private	166,278 (67.0)	18.0	48.4	17.7	18.2	-504	664	
Public	81,401 (32.8)	3.3	45.8	2.9	3.6	-504	291	
Dental school	599 (0.2)	-86.9	95.3	-94.6	-79.3	-393	22	<0.0001
Total	248,278 (100.0)	12.9	48.5	12.7	13.1	-504	664	

Max, maximum; Min, minimum; SD, standard deviation.

The total fee for a root filled tooth over 5 to 6 years

The total mean fee for the 248,299 root filled teeth was 717 Euro (6,407 SEK) per tooth during the follow-up period, *i.e.* the initial root filling, coronal restoration and any additional tooth-specific treatment. The lowest fee was 0 Euro (0 SEK) and the highest was 4,375 Euro (39,110 SEK). The material comprised a total of 749,680 tooth-specific treatment codes.

Most of the teeth (57.7%) were registered as having direct coronal restorations and 22.5 percent with indirect restorations. The remaining (19.7%) lacked a predefined tooth-specific coronal registration 6 months after root filling.

For indirectly restored root filled teeth, the total mean fee was higher than for directly restored teeth (1,105 Euro, SEK 9,879, and 610 Euro, 5,453 SEK respectively) and for the unspecified restorations (585 Euro, 5,230 SEK; $P < 0.001$). With respect to tooth groups, the highest total mean fee was for the molars (747 and 757 Euro, 6,676 and 6,767 SEK, respectively; $P < 0.0001$). All pairwise comparisons were statistically significant ($P < 0.0001$) according to Tukey's post-hoc test.

The register showed that 25,228 (10.2%) teeth were extracted during the follow-up period. The total mean fee for the extracted teeth was on average 58 Euro greater than for the retained root filled teeth (521 SEK; $P < 0.001$).

Study II

Study population

Two hundred and forty-three patients began RCT: 128 (52.7%) women and 115 (47.3%) men. The mean age was 48.3 years (SD = 16.4). (Table 1; Fig. 1). Most of the patients ($n = 201$, 82.7%) were registered as regular dental attendees at the clinics. Two (0.8%) patients started treatment of two teeth at the same appointment. The first registered tooth was included in the study.

Indications for root canal treatment

Two hundred and thirty-six (97.1%) questionnaires were completed by the GDPs. Seven (2.9%) questionnaires went missing. More than one indication was registered for 38 (16.1%) teeth, and for 9 (3.8%) teeth the indication registered did not correspond with the dental records. The indication for starting RCT was altered for these 47 (19.9%) teeth in accordance with the dental records and reported pain intensity.

In most cases, RCT was initiated because of pulpal necrosis ($n = 111$, 47.0%) with AP ($n = 90$, 38.1%). Treatment of the vital pulp was the second most common indication ($n = 89$, 37.7%): in most such cases the patient presented with symptomatic pulpitis ($n = 71$, 79.8%). Overall, the teeth were often symptomatic at the start of treatment ($n = 152$, 64.9%). Nonsurgical retreatment was initiated in 18 cases (7.4%). Overall, the molar teeth ($n = 116$, 47.7%) predominated, in particular the mandibular molars ($n = 69$, 59.5%).

One hundred and fifty-two (64.1%) patients reported present pain intensity above '0' on the VAS scale (mean = 3.35, SD = 3.3).

Summary of the tooth-specific characteristics

Most of the teeth ($n = 203$, 83.5%) were already restored when RCT began, most commonly with a direct restoration corresponding to composite ($n = 120$, 49.4%). Dental caries was recorded in 127 teeth (62.9%). In most of the teeth ($n = 169$, 71.3%) tooth substance loss was greater than one third of the crown. In seven cases, previous trauma could be traced in the dental records (2.9%).

Study III

Study population

Of 243 patients enrolled in the study as starting RCT, 240 (98.8%) could be monitored in the dental record system 1 year later: 128 (53.3%) women and 112 (46.7%) men. The mean age was 48.5 years (SD = 16.3). (Table 1; Fig. 1). Molars predominated ($n = 113$, 47.1%). Three (1.3%) patients had changed clinic during the follow-up period.

Outcomes at one year follow-up

Most teeth were root filled ($n = 169$ teeth, 70.4%). However, 32 (13.3%) teeth had been extracted and in 39 (16.3%) RCT was not yet completed. On average, 2.4 (SD = 0.9) appointments were needed for completion of RCT. In cases resulting in extraction, the number of appointments was 3.0 (SD = 1.6). The indications for extraction were primarily endodontic or RCT-related ($n = 17$, 54.8%).

Root filling was less often completed within a year in molars, than in incisors ($n = 65$, 57.5%; OR = 0.30, $P = 0.0042$). More molars, than incisors, were also extracted ($n = 25$, 22.1%; OR = 6.68, $P = 0.012$). Compared to the anterior teeth, molars required on average more appointments ($P = 0.0006$) and a greater time interval to complete the treatment, either by a root filling or extraction ($P = 0.011$). Complications during RCT were also more common in

molars ($n = 36$, 90.0%), than in incisors (31.9%, OR = 22.44, $P = 0.0025$). Twenty patients were prescribed antibiotics during the treatment period.

In most cases the root filled teeth were restored with a direct restoration ($n = 128$, 75.7%). Four (2.4%) root filled teeth, two of them molars, were extracted within the time period because of pain, tooth substance fractures or a dentinal crack in the pulp cavity.

Study IV

Study population

Of 243 patients, 236 (97.1%) were contacted by post 1 to 3 years after starting RCT. One hundred and fifty-nine (67.4%) patients responded to the questionnaire: 86 (54.1%) women and 73 (45.9%) men. Their mean age was 52.5 years (SD = 15.7). (Table 1; Fig. 1). Compared with those who failed to respond, the mean age of those who responded was higher ($P < 0.0001$) and the distribution of tooth groups, stratified as maxillary or mandibular, also differed ($P = 0.028$). The questionnaire was answered on average 1.8 years after starting treatment (SD = 114.4, range = 413-930 days).

Patients' experience of root canal treatment

A majority of the respondents replied that the RCT had been completed with a root filling ($n = 112$, 70.9%). Comparatively fewer molars were reported as root filled ($n = 46$, 59.7%; $P = 0.0044$) compared to the anterior teeth. Of the 31 (40.3%) molars that were not root filled, 4 (5.2%) were reported as not yet completed and 27 (35.1%) as extracted.

Fifty-nine (50.0%) patients reported no present pain in the tooth in question (VAS = 0), 45 (38.1%) reported mild pain (VAS >0-3) and the other 14 moderate to severe pain (VAS >3, 11.9%). Twenty-nine (19.1%) patients recalled RCT as painless (VAS = 0). The remainder reported mild (VAS >0-3, $n = 77$, 50.7%) to moderate or severe pain (VAS >3, $n = 46$, 30.3%).

The highest satisfaction was registered for chewing ability (mean = 1.6, SD = 1.9) and the lowest for perceived pain during RCT (mean = 2.6, SD = 2.5).

A majority of the patients ($n = 114$, 75.0%) reported that in light of their experience, they would still have chosen RCT. Of the patients who reported completion of their root filling, 87.0% ($n = 94$) stated that they would choose the same treatment again, compared to those whose treatment had ended with extraction or was not yet completed ($n = 20$, 45.5%; $P < 0.0001$). Of those who

experienced no pain or only mild pain, either currently or during treatment, 90.0% ($n = 90$) and 81.4% ($n = 83$) respectively reported that they would choose the same treatment again, compared to those who experienced more pain ($n = 6$, 42.9%, $P < 0.0001$; $n = 30$, 65.2%, $P = 0.04$).

Reliability of the responses

Forty-four (88.0%) patients responded to the second questionnaire between 2 and 10 weeks after the first mailout (mean = 33.5 days, SD = 8.8; Fig. 1). The highest consistency was registered for treatment completion and memory of pain (weighted Kappa = 0.933, ICC = 0.80). The highest inconsistency was for cost (ICC = 0.54).

Overall, there were no statistically significant differences between the responses to the first and second questionnaire ($P > 0.05$).

Study V

Study population

Eighty-five patients participated: 43 (50.6%) women and 42 (49.4%) men. The mean age was 51.1 years (SD = 16.8) (Table 1; Fig. 2). In four patients in whom two teeth were treated at the same appointment (1 RCT), only the first tooth was included. Forty-eight (56.5%) patients underwent extraction and 37 (43.5%) patients started RCT. The molars dominated ($n = 62$, 72.9%).

Patients who underwent extraction of the third molars ($n = 20$) differed with respect to age and number of remaining teeth. The extracted teeth were frequently maxillary third molars and were vital and asymptomatic at the time of extraction. After exclusion of third molars, two relevant and comparable groups were achieved, where the only significant difference was the number of previously root filled teeth ($P = 0.03$). The two groups comprised a total of 65 individuals: 28 underwent extraction and 37 started RCT.

Preoperative characteristics of the 65 patients

The cohort comprised 31 (47.7%) women and 34 (52.3%) men, with a mean age of 55.5 years (SD = 15.1). The majority were employed ($n = 41$, 66.1%) and for most the highest level of completed education was elementary or high school ($n = 46$, 74.2%). Sixty-two (95.4%) patients answered the first questionnaire, representing baseline ($n = 34$ RCTs).

In most cases, the teeth were symptomatic at the start of treatment ($n = 37$, 71.2%). The most common indications were pulpal necrosis ($n = 31$, 50.8%)

and apical periodontitis ($n = 30$, 49.2%), followed by treatment of the vital pulp ($n = 18$, 29.5%) mostly symptomatic ($n = 12$, 66.7%). Ten (15.4%) teeth had previously been root filled. The molars dominated in both the extraction and RCT group ($n = 42$, 64.6%).

Baseline registrations

There were no statistically significant differences between the groups regarding perceptions of the impact on oral health, either between the different questions or in terms of total scores. The majority of patients had experienced physical pain in the mouth at least once during the past month (Table 8).

There were no statistically significant differences between the groups regarding the distribution of the dimensions in EQ-5D-5L, EQ-VAS or in QALY weights. 'Usual activities' was the dimension where most registered problems (level 2-5) (Table 9).

When assessing overall satisfaction with RCT, the patients reported a mean value of 1.27 (SD = 1.95). The highest satisfaction was registered for chewing ability (mean value = 1.78, SD = 2.63) and the lowest was for cost (mean value = 5.38, SD = 3.53). The mean value for present pain intensity was 1.37 (SD = 2.04).

Outcomes at the 1-month follow-up

Fifty of 65 (76.9%) patients responded to the follow-up questionnaire (20 extractions, 30 RCTs). Forty-seven (72.3%) responded to both questionnaires. According to the dental records, 8 (21.6%) teeth had been root filled and 5 (13.5%) had been extracted within one month of initiated treatment.

At follow-up, most differences within or between given groups were small and not statistically significant.

More respondents in the extraction group reported embarrassment ($n = 8$) during the last 4 weeks than those who started RCT ($n = 3$; $P = 0.0063$). Many in the RCT group had registered physical pain in the oral cavity on one or more occasions during the previous four weeks ($n = 18$, 62.1%). In the extraction group the most common complaint was discomfort when eating ($n = 15$, 75.0%; Table 8).

Patients starting RCT registered a statistically significant improvement in QALY weights measured with EQ-5D-5L, both with the Crosswalk-value set ($P = 0.02$) (65, 66) and the 5L-value set ($P < 0.01$) (67). No such improvement

was observed in the extraction group (Table 10). ‘Usual activities’ continued to be the dimension where most registered problems (level 2-5; Table 9).

Patients registered overall satisfaction with their RCT: mean value 1.77 (SD = 2.53). The greatest satisfaction registered continued to be chewing ability (mean value = 1.56, SD = 2.19) and the lowest was the cost (mean value = 5.77, SD = 3.86). The mean value of present pain intensity was 1.25 (SD = 1.53). There were no statistically significant differences between baseline and the one-month follow-up.

Table 8. *Distribution of respondents’ responses to OHIP-14, and in comparison, between root canal treatment (n = 37) and extraction (n = 28) at baseline and follow-up. The questionnaire can be found in the Appendix section. The original table is presented in Wigsten et al. (69)*

		RCT Never (score 0)	Extraction	RCT Hardly ever - very often (score 1-4)	Extraction	RCT Fairly often - very often (score 3-4)	Extraction
<i>Functional limitation, n (%):</i>							
Q1	Baseline	27 (90.0)	18 (75.0)	3 (10.0)	6 (25.0)	0 (0.0)	1 (4.2)
	1 month	22 (88.0)	11 (61.1)	3 (12.0)	7 (38.9)	1 (4.0)	1 (5.6)
Q2	Baseline	26 (83.9)	21 (87.5)	5 (16.1)	3 (12.5)	1 (3.2)	0 (0.0)
	1 month	23 (88.5)	15 (83.3)	3 (11.5)	3 (16.7)	1 (3.8)	1 (5.6)
<i>Physical pain, n (%):</i>							
Q3	Baseline	6 (19.4)	5 (18.5)	25 (80.6)	22 (81.5)	6 (19.4)	5 (18.5)
	1 month	11 (37.9)	6 (31.6)	18 (62.1)	13 (68.4)	4 (13.8)	2 (10.5)
Q4	Baseline	16 (53.3)	9 (33.3)	14 (46.7)	18 (66.7)	5 (16.7)	3 (11.1)
	1 month	14 (48.3)	5 (25.0)	15 (51.7)	15 (75.0)	5 (17.2)	4 (20.0)
<i>Psychological discomfort, n (%):</i>							
Q5	Baseline	21 (72.4)	17 (63.0)	8 (27.6)	10 (37.0)	1 (3.4)	4 (14.8)
	1 month	22 (75.9)	8 (40.0)	7 (24.1)	12 (60.0)	1 (3.4)	1 (5.0)
Q6	Baseline	17 (56.7)	18 (69.2)	13 (43.3)	8 (30.8)	3 (10.0)	3 (11.5)
	1 month	17 (58.6)	12 (60.0)	12 (41.4)	8 (40.0)	1 (3.4)	2 (10.0)
<i>Physical disability, n (%):</i>							
Q7	Baseline	22 (75.9)	15 (57.7)	7 (24.1)	11 (42.3)	2 (6.9)	2 (7.7)
	1 month	19 (65.5)	13 (72.2)	10 (34.5)	5 (27.8)	1 (3.4)	3 (16.7)
Q8	Baseline	24 (77.4)	20 (76.9)	7 (22.6)	6 (23.1)	0 (0.0)	0 (0.0)
	1 month	26 (89.7)	14 (73.7)	3 (10.3)	5 (26.3)	1 (3.4)	1 (5.3)

Q, question; RCT, root canal treatment.

Table 8. Continued

		RCT	Extraction	RCT	Extraction	RCT	Extraction
		Never (score 0)		Hardly ever - very often (score 1-4)		Fairly often - very often (score 3-4)	
<i>Psychological disability, n (%):</i>							
Q9	Baseline	14 (43.8)	15 (57.7)	18 (56.3)	11 (42.3)	4 (12.5)	1 (3.8)
	1 month	13 (44.8)	10 (50.0)	16 (55.2)	10 (50.0)	4 (13.8)	1 (5.0)
Q10	Baseline	23 (79.3)	19 (73.1)	6 (20.7)	7 (26.9)	0 (0.0)	2 (7.7)
	1 month	24 (88.9)	11 (57.9)	3 (11.1)	8 (42.1)	0 (0.0)	1 (5.3)
<i>Social disability, n (%):</i>							
Q11	Baseline	11 (36.7)	14 (56.0)	19 (63.3)	11 (44.0)	3 (10.0)	2 (8.0)
	1 month	16 (55.2)	12 (60.0)	13 (44.8)	8 (40.0)	2 (6.9)	1 (5.0)
Q12	Baseline	19 (61.3)	19 (73.1)	12 (38.7)	7 (26.9)	2 (6.5)	0 (0.0)
	1 month	24 (82.8)	13 (68.4)	5 (17.2)	6 (31.6)	2 (6.9)	1 (5.3)
<i>Handicap, n (%):</i>							
Q13	Baseline	14 (45.2)	10 (40.0)	17 (54.8)	15 (60.0)	4 (12.9)	2 (8.0)
	1 month	18 (62.1)	11 (57.9)	11 (37.9)	8 (42.1)	2 (6.9)	1 (5.3)
Q14	Baseline	23 (79.3)	20 (80.0)	6 (20.7)	5 (20.0)	1 (3.4)	1 (4.0)
	1 month	24 (85.7)	14 (73.7)	4 (14.3)	5 (26.3)	1 (3.6)	1 (5.3)

Q, question; RCT, root canal treatment.

Sixty-two (95.4%) patients (28 extractions, 34 RCTs) responded to the first questionnaire and 50 (76.9%) to the follow-up questionnaire (20 extractions, 30 RCTs).

Table 9. Distribution of responses to EQ-5D-5L, and in comparison, between root canal treatment ($n = 37$) and extraction ($n = 28$) at baseline and follow-up. The original table is presented in Wigsten et al. (69)

	RCT	Extraction	RCT	Extraction
	No problems (level 1)		Any problems (level 2–5)	
<i>Mobility, n (%):</i>				
Baseline	29 (90.6)	27 (96.4)	3 (9.4)	1 (3.6)
1 month	26 (86.7)	16 (80.0)	4 (13.3)	4 (20.0)
<i>Self-care, n (%):</i>				
Baseline	28 (84.8)	23 (82.1)	5 (15.2)	5 (17.9)
1 month	25 (83.3)	16 (80.0)	5 (16.7)	4 (20.0)
<i>Usual activities, n (%):</i>				
Baseline	12 (36.4)	6 (21.4)	21 (63.6)	22 (78.6)
1 month	13 (43.3)	11 (55.0)	17 (56.7)	9 (45.0)
<i>Pain/discomfort, n (%):</i>				
Baseline	19 (57.6)	15 (55.6)	14 (42.4)	12 (44.4)
1 month	22 (73.3)	15 (75.0)	8 (26.7)	5 (25.0)
<i>Anxiety/depression, n (%):</i>				
Baseline	29 (90.6)	25 (92.6)	3 (9.4)	2 (7.4)
1 month	24 (82.8)	15 (75.0)	5 (17.2)	5 (25.0)

RCT, root canal treatment.

Sixty-two (95.4%) patients (28 extractions, 34 RCTs) responded to the first questionnaire and 50 (76.9%) to the follow-up questionnaire (20 extractions, 30 RCTs). 1 patient perceived extreme problems (level 5) at baseline (RCT, ‘self-care’) and 1 patient at follow-up (extraction, ‘anxiety/depression’).

Table 10. Distribution of EQ-VAS and QALY weights for patients undergoing either root canal treatment or extraction, where comparisons were made at one month follow-up (SD). The original table is presented in Wigsten et al. (69)

	Treatment	Baseline	Follow-up	Difference	<i>P</i> -value
EQ-VAS	RCT	79.5 (22.4)	81.4 (17.8)	2.7 (12.8)	0.47
	Extraction	80.6 (17.0)	80.3 (19.5)	2.5 (11.6)	0.45
EQ-5D-5L ¹	RCT	0.797 (0.196)	0.829 (0.174)	0.048 (0.091)	0.02
	Extraction	0.793 (0.157)	0.799 (0.254)	0.019 (0.189)	0.41
EQ-5D-5L ²	RCT	0.867 (0.160)	0.893 (0.135)	0.034 (0.065)	<0.01
	Extraction	0.869 (0.139)	0.866 (0.203)	0.010 (0.115)	0.67

QALY, quality-adjusted life year; RCT, root canal treatment; SD, standard deviation.

The value set with the Crosswalk¹ by Van Hout et al. (65, 66) and the value set² by Devlin et al. (67) for the general population in the UK was used.

MAIN FINDINGS

Study I

The mean fee for a root filling and further treatment during the ensuing 5 to 6 years was 717 Euro (SEK 6,407).

Study II

RCT was often initiated on teeth that were symptomatic, previously non-root filled, especially the molars, with dental caries and previous tooth substance loss.

Study III

The majority of the teeth had been root filled within one year, but fewer molars had been completed. Of the molars, fewer than two-thirds had a completed with a root filling. The remainder had either been extracted or were still under treatment.

Study IV

Many patients were satisfied with their RCT. About half the respondents reported pain at present. The treatment outcome and the perception of pain determined whether, in retrospect, the patients would have chosen the same treatment again.

Study V

Some improvement could be seen in HRQoL and QALY weights for the patients who started RCT, but not among the patients who had a tooth extracted. Patient satisfaction with RCT was generally high.

5 DISCUSSION

Methodological considerations

Study I

The aim was to study the fees incurred in the Swedish dental service, for provision of a root filling, coronal restoration and further tooth-specific treatment in the ensuing 5–6 years. The study was designed as a registry-based cohort study. Data were retrieved retrospectively from the SSIA's data register. The results are presented at tooth level.

The advantage of registry-based studies is that a specified treatment can be studied in a larger population. In this case, the retrieved data concerned RCT in the adult population of Sweden. The material thus presents the fees for all root fillings performed in 2009 and further dental treatment for the same teeth, registered in SSIA's data register. This provides an important overview of RCT undertaken by GDPs. The register does not provide clinical documentation such as dental records or radiographs, so it is not possible to explore more detailed, specific questions. Hence the preoperative status of the tooth is not disclosed, nor it is possible to distinguish between primary RCT and retreatment (nonsurgical retreatment).

Registration of dental treatment provided

Although service providers are required to report to SSIA all treatment undertaken, it is unlikely that this is the case. The reason may be that it has simply been overlooked or that no charge was made for treatment, for example if the patient has just paid for RCT, but because of complications the tooth is then extracted. It is also possible that the patient has undergone treatment abroad and this is therefore not entered in the register. There is also an uncertainty that when only tooth-specific measures are registered, to ensure that the fees applied to the specified tooth, fees charged for non-tooth-specific treatment may have been overlooked.

The first permanent coronal restoration was registered within 6 months of the registered root filling, and denoted as a direct or indirect restoration. The interval of 6 months was considered appropriate, after a study by Skupien *et al.* (70). It is possible that some teeth were permanently restored more than 6 months after registration of the completed root filling. This would explain in part why at 6 months, one-fifth of cases were denoted as having unspecified coronal restorations. There is also some uncertainty that previously indirectly

restored teeth may have been allocated to the direct group: the indirect group may therefore be somewhat under-represented.

The material is based on a large selection of reported data from SSIA's register. While the volume of data can also increase the risk of type I errors, the results are considered reasonable and clinically significant. However, the fees incurred for maintaining the root filled tooth for the subsequent 5-6 years may be somewhat underestimated. The results are based on GDP's registration of treatment using codes applied in the current Swedish dental care system: thus for countries with a different structure, external validity is low. More detailed study would require controlled prospective clinical cohort studies, with access to documentation such as dental records and radiographs (6).

Study II

The aim was to study the indications for RCT in general dental practice, with special reference to the Public Dental Service in the Region Västra Götaland. There are few studies which document the reasons for initiating RCT in general dental practice (5, 7, 8), nor have the outcomes been followed prospectively and studied over time. There is a lack of clinical follow-up studies in general dental practice settings (6, 71). The study was designed as a cohort study and the results are presented at both patient and tooth level.

Estimating pain intensity

The VAS scale was chosen for its ease of use in estimating pain intensity (64, 72, 73). In this study, the patient was instructed to indicate the degree of pain intensity at the initial appointment for RCT. Pain is highly subjective and also dynamic, which means that there is uncertainty in generalization (74). Patients who had taken analgesics before the appointment probably registered a lower value, and some other patients probably experienced pain prior to but not at the actual appointment. Nevertheless, the scale allows conversion of the subjective experience into a measurable phenomenon (72).

Reason for initiating root canal treatment

The reason given for initiating RCT may be considered as a reliable variable as it was registered by each GDP at the initial appointment. Preoperative patient- and tooth-specific variables considered relevant to the aim of the study were selected. Although some variables were considered more reliable than others, the results provide a description of the population at baseline. Though the real cause of treatment (*causality*) cannot be studied with the prevailing study design, reasonably associated variables are disclosed. Some findings are in accordance with previous studies (5, 7, 8).

Another limitation is uncertainty as to the actual number of treatments started, *i.e.* whether the registered patients correspond to the actual treatments provided. It may be the case that not all patients were invited to participate in the study, that this was simply overlooked or that for various reasons, the dentist refrained from asking. An alternative would be to review all patient records during the recruitment period. To increase the number of possible participating patients, communication has been maintained with the clinic's appointed contact person(s), who has had the role of reminding and supporting the service providers during the recruitment process.

The outcomes are based mainly on a descriptive analysis of the patients who started RCT in public dental clinics in the Region Västra Götaland. These results refer to a sample and represent the included population, but are not necessarily representative of the Swedish population or any international population. Despite these limitations, this is an important topic and could serve as a hypothesis for future clinical research. In order to increase the validity, and for comparison, patients treated in the private sector should also be included (15, 75).

Study III

The aim was to study the one-year, care-centered outcomes of the 243 teeth in which RCT had been initiated in a general dental practice setting. The study was designed as a prospective cohort study. The results are presented at both patient and tooth level. The original population and the associated teeth were described earlier in Study II, at the start of treatment.

Baseline

The decision to adopt the initial appointment as the baseline is unusual for studies of RCT. To our knowledge, recruitment of subjects at the beginning of RCT has not previously been applied in studies conducted in the general dental practice setting. In most follow-up studies, both retrospective and prospective, the baseline is set at completion of the RCT (76). However, in order to assess RCT outcomes, all teeth diagnosed with pulp and periradicular disease in which treatment is started should be included. Unless the initial appointment is adopted as the study baseline, it is not known how many of the teeth in which treatment was initiated actually reached the end point of a root filling. Nor is it possible to determine what resources were required for treatment, from the initial appointment onward, especially in cases in which RCT was not completed.

Treatment-specific variables considered relevant to the aim of the study were selected. The material is based on electronic documentation and treatment codes. Some variables were considered more reliable than others: the variables with more personal preferences, such as registration of complications, depend on the GDPs' interpretation and record keeping.

Outcomes at one year follow-up

The population was included on the same terms and then followed prospectively during the set follow-up period. In many studies, a follow-up period of one year after completion of the root filling is applied (77, 78), which may also be relevant for some of the treatments started. However, in the present study the aim was to study prospectively the short-term progress of RCT from initiation from a care perspective. This was done by including all teeth in which RCT was initiated, not just the possibly completed treatments and by studying in detail the treatment-specific resources required to reach the end point, namely a root filling. The study did not include radiographic examination, as periapical lesions may require longer to heal (25). This will be investigated in a future study.

Study III presented one year of detailed follow-up data in a population treated at public dental clinics in Region Västra Götaland, Sweden. The study baseline was initiation of RCT. The results provide a description of the population: whether the outcomes are representative of other Swedish clinics is unknown. A more detailed and representative picture of RCT undertaken in general dental practice would require a longer follow-up period and clinical and radiographic examination.

Study IV

The aim was to study the ≥ 1 year outcomes of RCTs with patient-centered outcome measures and to evaluate the reliability of the respondents. Few studies have investigated the patient's experiences of RCT in terms of patient satisfaction and especially treatment provided by GDPs (44, 60, 79, 80). The study was conducted as a prospective cohort study and the outcomes are reported at both patient and tooth level. The population has previously been described in Study II and III.

Patient satisfaction with root canal treatment

Patient satisfaction with RCT has been studied with different questionnaires, which have varied with respect to the number of questions and their structure, in options of multiple-choice questions or different response scales, and how the outcome measures are presented (44, 60, 79, 80). The VAS scale is

commonly used to measure satisfaction: an advantage is that it is sensitive enough to register a change (81). In this study, the numerical values were converted to so-called verbal descriptions, to provide a better description of the patients' experience. This has mainly been done to describe pain intensity within the field (80, 82-85). However, a similar division and verbal description have been used in the studies by Torabinejad *et al.* (80, 85). Because pain is highly subjective and a multidimensional experience, the question of present pain intensity was supplemented by offering a choice of one or more descriptive pain characters.

The response rate

To improve the response rate, various methods were used, such as attaching a pre-addressed postage-free response envelope (74, 86). One limitation is that those who did not respond ($n = 77$, 32.7%) may have differed from those who responded. Perhaps an electronic survey, or the use of so-called mixed-mode (87), or some form of incentive might have increased the number of participants (86). It may also be the case that different reminder procedure would have increased the number of respondents (74).

No respondents were excluded from the study. One questionnaire was incompletely answered, and the variables were therefore treated as missing. No questions were registered with ambivalent or multiple answers (except Question 3). The most missing answers were noted for Questions number 4 and 8 ($n = 7$, 4.4%).

The reliability of the responses

The reliability of the responses was good, as most patients gave similar answers on both occasions. To test the reliability of the answers, the interval between the two questionnaires should be short enough to ensure that the condition of the tooth has not changed, but nonetheless long enough to ensure that the patients cannot remember their original responses and therefore do not answer truthfully (74). In the study, the follow-up questionnaire was sent out 30 days after the first questionnaire. To our knowledge, this is the first study of reliability of patients' responses in this field; hence no comparison can be made with previous results (88, 89).

The different follow-up times from baseline to the questionnaire being answered may be another limitation (90). A longer follow-up period may offer a better overall description of the treatment, but it can also be a disadvantage. There is a risk that the patient will forget which tooth was treated and the circumstances surrounding the treatment. How much treatment has been performed also depends on the time elapsing since initiation of RCT.

The outcomes are based on an already existing population: all started RCT on the same terms, in a general dental practice setting: the same questionnaire was answered once or twice. The perceived satisfaction is highly subjective and can change over time. Nonetheless, the reliability of the responses was good.

Study V

The aim was to compare QoL and QALY weights in patients who had undergone RCT with those whose tooth had been extracted. The study was a prospective cohort study with control group, where the results are presented at patient and tooth level. The primary outcome measure was OHRQoL measured with OHIP-14.

OHIP-14 has been used in combination with other instruments in the field of endodontics, for measuring oral health (43, 45) or general psychological well-being (42). However, this was the first time that the EQ-5D-5L and associated VAS scale was used, and combined with OHIP-14, in a population of patients who underwent RCT.

OHIP-14

No respondent was excluded from the study due to missing registrations. Two patients left blank answers and one person registered 'don't know/not applicable' to all questions in OHIP-14 in the first questionnaire. At follow-up, 2 patients gave blank answers and two registered 'don't know/not applicable' to all questions, three of which were excluded from the analysis because the tooth concerned was a third molar. All other respondents answered at least one question. The third molars were included because RCT is in fact undertaken, on occasion, on these teeth (8, 15, 91).

In the study, the distribution of the answers was presented separately from the total score at the mean value level. The reason is that reporting only total scores, or the mean of the population's total scores, can give a blunt and non-informative presentation of patients' perceptions. The distribution is often skewed, because many individuals experience a low frequency of oral problems, hence frequent problems reported for one particular question may be overlooked. The advantage of presenting the results at group level is that comparisons can be made with other patient constellations and population norms (51, 92).

The follow-up interval was adapted by Liu *et al.* (43) who studied the effect on OHRQoL on three separate occasions. The frequency of reported impacts during the last month was studied (41, 42).

EQ-5D-5L

The instrument was designed for self-completion and could therefore be sent by post (52, 53, 55). There are published population norms for different countries and regions around the world, and this allows comparison with other populations (52, 53). The study used the value sets from the UK because there were no country-specific values published for EQ-5D-5L at the time (93, 94). Study V presents the outcomes from both the patients' views on their health and also the general population's perspective on the various health states.

The response rate

The first questionnaire was distributed at the start of treatment. Drop-out in the total group ($n = 85$) was 4.7% ($n = 4$). The second questionnaire was sent out one month after the start of treatment. Drop-out was 25.9% ($n = 22$). Whether the respondents' perceptions differ from those of the non-respondents on the different occasions is unknown. The range in response dates is explained by the reminder procedure and the fact that no questionnaires were excluded due to time.

At baseline, the questions with the greatest number of missing responses were: 'completely unable to function' ($n = 12$, 14.8%; OHIP-14), 'pain/discomfort' ($n = 4$, 4.9%; EQ-5D-5L) and 'cost' ($n = 13$, 38.2%; patient satisfaction) and at the one-month follow-up: 'difficulty pronouncing words' ($n = 10$, 15.9%; OHIP-14), 'anxiety/depression' ($n = 2$, 3.2%; EQ-5D-5L) and 'cost' ($n = 9$, 36.0%; patient satisfaction).

The intention of RCT is to preserve a compromised tooth as a functional unit in the dentition. The alternative is often extraction. Patients who started RCT were therefore compared with a group who underwent extraction. The validity of comparing these two groups, with each other and over time, may be questioned. It may have been more reasonable to randomize the patients to one treatment or the other. However, there may be not only ethical but also practical difficulties in conducting a randomized controlled study, given the resources that would be required. This is because patients who have a tooth extracted subsequently need a permanent replacement. However, for appropriate comparison of perceived QoL associated with RCT or extraction, randomization could have disclosed not only further differences, but also which treatment had the greatest impact on perceived QoL and QALY weights. Thus a randomized controlled study could have disclosed which treatment is more beneficial.

Other organized control groups have been used in the field of endodontics, for example patients receiving another type of endodontic therapy (46, 61), or

other treatment alternatives, such as periodontal maintenance (42), replacement with implants (62) or other unspecified treatment (45).

The outcomes apply to a population in which RCT is initiated, and a control group consisting of patients whose tooth is extracted, from 6 different public dental clinics in the Region of Västra Götaland. The perception of oral health, general health and one's own treatment is highly subjective and not necessarily representative of another population of Swedish or international dental patients. At follow-up, few statistically significant intra- and inter-group differences emerged. Few teeth had been root filled within a month and a longer follow-up period could provide a further description of the two treatment methods, especially once the root filled tooth had been permanently restored and the extracted tooth had been replaced with, for example, an implant.

General discussion

These studies were undertaken in order to provide a better understanding of the role of RCT in general dental care. Not only were the indications for initiating RCT noted, but also treatment outcome, through patient-centered and treatment-specific outcome measures. Three different cohorts were followed.

Resources required for root canal treatment in general dental practice

Although oral health is generally considered to be good in Sweden (13), RCTs are still common and most are undertaken in general dental practice (15). In 2009, a quarter of a million teeth were registered as root filled in SSIA's data register, *i.e.* at least 2.0% of the adult population of Sweden (15, 95). The number of root fillings has since decreased. In 2019 25% fewer root fillings ($n = 188,570$) were registered than in 2009 (95).

The total fees for root fillings in 2009 amounted to SEK 736 million (EUR 82.3 million): for the individual tooth the mean fee was SEK 3,000 (SEK 2,964, EUR 332). Moreover, additional fees are incurred through continued care, which hypothetically could imply a total fee of SEK 1.592 billion (EUR 178 million) over 5 to 6 years, with an average fee per tooth of SEK 6,407. Despite the declining need for root fillings, the procedure is still common and resource-intensive, entailing considerable expense for the individual and for third-party stakeholders.

Indications for root canal treatment

There are few studies documenting the reason for initiating RCT in general dental practice (5, 7, 8). The majority of the teeth had not previously been root

filled, molars predominated, and many had previous restorations and caries. This description is consistent with a previous study by Bjørndal *et al.* (5), which registered the reason why RCT was started, based on a questionnaire sent to 600 GDPs in Denmark. That most treatment was initiated in the teeth that were symptomatic at the start is also consistent with previous studies (5, 7, 8). The frequency of retreatments was low, and this is also in accordance with the findings of previous studies in general dental practice in Scandinavia (5, 7, 19, 29).

Strengths of the studies

Outcomes of root canal treatment in general dental practice

Most teeth were root filled within the year, but in a third of cases the RCT was either not complete, or the tooth had been extracted. This applied particularly to the molars, with RCT completed in fewer than two-thirds. The number of appointments and the resources required can be particularly disconcerting for those patients who eventually lost their tooth to extraction or for those in whom the RCT was never completed.

Four (2.4%) root filled teeth were extracted within the year. This outcome is in accordance with other studies of the survival of root filled teeth in Swedish general dental practice (11, 15, 32, 75).

The majority of patients reported that their tooth had been root filled 1 to 3 years after starting RCT, but about a quarter reported that their tooth had been extracted. Half the patients reported discomfort or pain: most reported mild pain. The frequency of symptoms after treatment differs from other studies. In a systematic review by Nixdorf *et al.* (31) 5.3% experienced symptoms, and in a study conducted at 23 general dental clinics in another county in Sweden, the frequency was 4.9% (33).

Including those teeth in which RCT is initiated, but which for various reasons is never completed, gives a less positive outcome with respect to tooth survival, as 30% of the teeth are lost even before completion of the root filling.

Outcomes of patient-centered care with respect to root canal treatment

In recent years, more studies have focused on evaluating RCT and its consequences for the recipient, namely the patient. Treatment can be studied either by allowing the patient to provide feedback on the care provided (PREM) or by measuring the effect of treatment with different instruments (PROM), for example by studying OHRQoL and HRQoL (96).

Most studies in the field of endodontics have used OHIP-14 to study OHRQoL (41-43, 45, 46, 61, 62, 83, 97-100). Some studies have applied the more disease-specific alternative OHIP-17 (44, 60, 101, 102). The effect can be studied by comparing the patient's perceptions at various stages, for example when RCT is started and when the treatment is completed. The few follow-up studies available have shown a positive effect on OHRQoL measured with both OHIP-14 (43, 46, 98, 99) and OHIP-17 (60, 101). Such a positive change was not disclosed in Study V. This may be attributable to the different inclusion criteria, the type of service providers, and the follow-up periods. One month may be too brief an interval after initiation of treatment for an effect to be observed. It may also be too short for relief of symptoms after treatment or for provision of a coronal restoration (103). A longer follow-up period can also provide a more comprehensive picture of patients' perceptions of RCT and its results (103). The instrument lacks a standardized method for analyzing the outcomes, which can also make it difficult to compare studies, despite similar methodologies.

As in many previous studies, patient satisfaction with RCT was high (44, 60, 62, 79, 80, 104). This may be attributable to selection bias, as satisfaction was studied in patients whose teeth had been preserved through treatment and completed with a root filling. There are few studies of patient satisfaction which compare completed RCT cases with those in which teeth were extracted (79). More patients would have chosen RCT again if it had been completed with a root filling. When comparing patients who underwent RCT with a group of patients who received an implant, both groups reported a high degree of satisfaction (62, 80). However, patients still prefer to retain the natural tooth if possible (62).

With respect to dissatisfaction, an important contributing factor is the cost (44, 60, 62, 69). Nevertheless, most patients stated that they would either recommend the treatment to others, or themselves choose to undergo the same treatment again (79, 105).

To our knowledge, EQ-5D and associated QALY weights have never previously been used in the field of endodontics. However, the instrument has been used in other areas of dental care, for example in estimating the costs of treating caries (106). More studies are needed to evaluate the treatment in the longer term but also to be able to enable prioritizing of different treatment alternatives.

Using the start of root canal treatment as baseline

The outcomes, when all initiated RCTs are included, are not particularly encouraging: 30% did not reach the end point of a root filling. A similar

outcome may well have been registered at a specialist- or university clinic if the tooth had been followed from the time treatment was started. The outcome may not be unique, it has just not been studied before.

Although RCT was completed in the majority of teeth, it is discouraging to note that about a third of the initiated treatment procedures did not result in completed treatment within the follow-up period: many of these teeth were extracted instead. The fact that so many teeth were extracted before completion also raises another concern, namely an underlying inability to identify which cases are suitable for RCT, *i.e.*: to be able to make a fair preoperative assessment of the prognosis. Moreover, in cases where the tooth was retained, half the patients reported discomfort or pain. Hypothetically, of the 70% of teeth that were root filled, a quarter will have periapical lesions (36), either due to failure of healing or development of a new periapical lesion. Three other Scandinavian studies have shown a varying presence of healthy periapical tissues around root filled teeth in 50 to 60% of cases (29, 34, 35). Hypothetically, of the 250,000 teeth which were registered as root filled in 2009, 62,000 to 124,000 would have an associated periapical lesion.

The molars differed particularly from other tooth groups. Of all RCTs started, root filling was completed in just over half the molars and about a quarter were extracted within the year. These teeth were also more subject to complications during treatment. Two of the root filled teeth extracted early in the study were molars.

It may be argued that the results are representative only of this cohort. It is not known whether the results reflect other cohorts within the same or other organizations within or outside Sweden's borders. However, it is acknowledged that not all teeth in which RCT is initiated are completed with a root filling as planned, despite the efforts and resources required. For more general conclusions and comparisons, similar studies would be required, preferably in both public and private general practice settings and also in specialist and university clinics.

Root canal treatment on molar teeth

RCT of molars is a common procedure in general dental practice (5, 15, 95). Several studies have reported not only poor technical quality of the root fillings but also absence of healing of periapical tissues around root filled molar teeth (36, 37, 91). With respect to molar teeth root filled in Swedish general dental practice settings, the reported survival rates are generally low (11, 15, 32, 75). There are a number of contributory factors. RCT of molars can be more complex and is technically more difficult than in other tooth groups (107).

They usually have more roots and a more complicated root canal anatomy and the posterior position in the dental arch makes access difficult. Not only is RCT of molars technically demanding, it also requires more resources (107).

Potential limitations of the studies

Some potentially major limitations should be addressed. Studies II-V report results from material which is limited not only in terms of population size and short follow-up periods, but also by the lack of generalizability. Whether RCT should reasonably be compared with extraction could also be questioned. It might have been preferable to randomize the different therapies, or to compare RCT and permanent restoration with extraction and replacement by implants or other prosthetic constructions. The results are based on data from public dental clinics: the private sector was not included. Whether there would be any difference between the groups is unknown.

The results showed few significant differences between baseline and follow-up. An improvement could be seen in HRQoL and QALY weights for the patients who started RCT. The selected instruments may not be sensitive enough to measure another effect of RCT or extraction. There may also be other reasons. For example, there may in fact be no major difference after undergoing treatment. It may not be possible to detect a major difference because the population is too small. It may not be possible to achieve a marked improvement over the baseline conditions, or a longer follow-up period than a month is needed.

For RCT, the ambition has been not only to retain the tooth in the dentition, but also to maintain or establish healthy periradicular tissues. There are primarily two basic criteria, defined by Strindberg (25) and Ørstavik (26). The studies in the thesis lack clinical and/or radiological outcome measures as an evaluation of completed treatment. The results are based either on the dental records or on the patient's experience of their treatment. It may well be that more teeth become asymptomatic over time.

Future research

For cohort 1, a 10-year follow-up study is planned, tracking service providers' fees charged for further treatment of the teeth registered in SSIA's data register as having been root filled in 2009.

For cohort 2, a 5-year clinical and radiological follow-up is planned, as well as an evaluation of patient-centered outcome measures in a longer perspective.

For cohort 3, the same questionnaire was sent home by post 6 and 12 months after starting treatment. It may now be possible to evaluate the outcome of the different therapies after completion, *i.e.* the root filled teeth have permanent coronal restorations and the extracted teeth have been replaced with another construction. A cost-effectiveness analysis will be undertaken for both forms of treatment.

In addition to these studies, it would be of interest to apply qualitative methodology to gain an understanding of what the patient would consider important in deciding the type of treatment (RCT or extraction), factors of importance in the treatment procedure and criteria that could be met to consider RCT as successful (40, 62, 108). It would also be of interest to evaluate patient satisfaction with respect to RCT over a longer period of time, and to compare the outcome with, for example, perceived symptoms or treatment outcome after the permanent coronal restoration, or when the tooth has been replaced with an implant or other prosthetic construction.

There is a need for more clinical follow-up studies using start of RCT as the baseline. Evaluation of clinical and radiological outcome measures would provide a more representative picture of the treatment performed in general dental practice. Moreover, the effect of treatment could also be studied through the use of patient-centered outcome measures. This applies not only to endodontic treatment provided in general dental practice, but also in the more controlled dental settings such as specialist clinics.

The future of root canal treatment in general dental practice

It is a concern that one third of all teeth in which RCT was started did not result in completed root fillings: treatment was not completed, or the teeth were extracted instead. This applies particularly to RCT of molar teeth, where only just over half had been root filled during the follow-up period. It is also of concern that of those who had retained their tooth, half reported symptoms.

A previous study within the same regional county council has reported that GDPs often experienced high levels of anxiety, stress, and frustration in relation to RCT (9). The treatment was often described as complex and perplexing and associated with loss of control in relation to several of the steps in the RCT procedures. Sometimes substandard treatment had to be accepted (10).

The outcome of RCT is of concern not only to the individual patient and the service provider, but also to third-party stakeholders. The results of the studies in this thesis show that there seems to be room for improvement, that there is

reason not to consider the treatment outcomes completely satisfactory. Molar treatment in particular can be both technically demanding and resource-intensive (107). Together with qualitative studies of the GDPs' perceptions of RCT (9, 10) this raises questions about the need for postgraduate education and critical review of the organization of care, in view of the complexity of the treatment. However, an issue to be further investigated, before drawing definite conclusions, is the healing of the periapical tissues of the teeth included in these studies. Previous epidemiological studies have reported high frequencies of radiographic evidence of periapical inflammation of teeth root filled in general practice (36, 109). There are no reasons to assume that our cohorts would differ significantly from this pattern.

One possible measure would be to implement continuing education courses in endodontics for GDPs, with emphasis on the treatment of molars (110). Previous studies conducted in general dental practice settings at various public dental clinics in Sweden have shown that continuing education for GDPs in instrumentation can improve technical aspects of the root filling (111-116). Although most GDPs showed a general improvement, no difference was noted in the group producing root fillings of substandard technical quality (111, 112, 114, 115).

It may however also be argued that it is not realistic or cost-effective to offer comprehensive endodontic training for every GDP. Not all dentists may be able to treat sufficiently large numbers of patients (9, 113), necessary to maintain the high-level skills and competencies required. The best way of acquiring and maintaining skills and competence is through continuous training and clinical experience. Thus, RCT of molars in particular can be considered and defined as highly specialized care (117).

An alternative strategy would be to limit the number of operators and to train more specialists in endodontics, ensuring that most RCTs, at least of molars, are undertaken by specialists. However, such a change must be introduced gradually and critically evaluated, not only in terms of resources and outcomes, but also by comparison with what can be achieved within the current system. It should not be assumed that a change would result in significantly better outcomes or higher cost-effectiveness. Studies comparing different service providers have revealed higher patient satisfaction associated with treatment by specialists, and the advantage of reduced chairside time (44, 60).

Ethical considerations

The studies were reviewed and approved by the regional review boards. The Regional Ethics Review Board in Lund approved Study I (Dnr: 2011/800). The Regional Ethics Review Board in Gothenburg approved Studies II-V (Dnr: 817-16, 857-14). Studies II and IV followed the guidelines in accordance with STROBEs' checklist and statements.

Study I

The study was a registry-based study: material was retrieved from SSIA's data register. The data did not contain any information that could identify the participants. No informed consent was obtained. The results were presented at group level.

Studies II-V

All participants gave verbal and written consent. A note was made of the number of patients who declined to participate, or who for various reasons were not invited to participate. The project was not intended to influence diagnosis, therapy, the treatment itself, or its follow-up. There was no immediate benefit or monetary compensation for the patients who consented to participate.

Dental records may contain sensitive personal data. It can be perceived as an infringement of the individual's integrity for a person other than the service provider to have access to the dental records and also information about treatment provided. The participants' anonymity was guaranteed by replacing the social security numbers with a unique code number. The code then followed the individual through the follow-up period and the statistical analysis. For each mailing (Study IV, V), contact information for the research group was attached in case the respondents had any questions or wished to withdraw consent, etc. The service providers were registered only in numbers. All results were presented at group level.

6 CONCLUSIONS

RCT remains a common, resource-intensive procedure in Swedish general dental practice, undertaken primarily to save severely compromised teeth with symptoms. When the initial RCT treatment appointment is used as the designated baseline for prospective investigations, the treatment outcomes are far from encouraging. The results indicate the need for further investigation into clinical outcome and cost-effectiveness of RCT in general dental practice. Intervention studies should be undertaken to explore the efficiency of alternative care strategies, such as general mandatory postgraduate education or referral of RCT cases, at least of molar teeth, to specially trained dentists.

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“as with any journey,
who you travel with
can be more important than the destination”
(Unknown)

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APPENDIX

OHIP-14

‘How often in the last month have you experienced the following, due to problems with your teeth, mouth, dentures or jaws?’ For each statement, mark the option that best corresponds to your experience. Use the alternative ‘Don’t know’ or ‘Not applicable’ if you think the statement does not apply to you

	Very often	Fairly often	Occas- ionally	Hardly ever	Never	Don't know/ not applic- able
<i>Functional limitation:</i>						
Q1	Trouble pronouncing words					
Q2	Altered sense of taste					
<i>Physical pain:</i>						
Q3	Painful aching					
Q4	Uncomfortable to eat					
<i>Psychological discomfort:</i>						
Q5	Self-conscious					
Q6	Felt tense					
<i>Physical disability:</i>						
Q7	Diet unsatisfactory					
Q8	Interrupts meals					
<i>Psychological disability:</i>						
Q9	Difficult to relax					
Q10	Been embarrassed					
<i>Social disability:</i>						
Q11	Irritable with others					
Q12	Difficulty doing tasks					
<i>Handicap:</i>						
Q13	Life less satisfying					
Q14	Totally unable to function					

Q, question.

The text has been translated into English and the layout has also been altered for the thesis.

