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ORIGINAL ARTICLE

Patient record assessment of results and related resources spent during 1 year after initiation of root canal treatment in a Swedish public dental organization

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Abstract

Aim: To document treatment outcomes and related resources, in patients undergoing root canal treatment (RCT) in county public dental clinics, by monitoring patient records for 12 months from treatment start.

Methodology: The subjects comprised 243 patients starting RCT at 20 public dental clinics in Västra Götaland county, Sweden. Their computerized dental records were monitored prospectively for a year after starting their endodontic treatment. Treatment was completed with either a root filling or extraction. The following treatment-specific variables were registered: number of appointments and days until treatment was completed, possible complications and prescriptions for antibiotics, and for the root filled teeth: type of coronal restoration and further procedures undertaken within the year. The treatment outcomes were compared with the preoperative variables and in a logistic regression analysis.

Results: Complete data were available for 240 patients (98.8%): 128 women and 112 men, with a mean age of 48.5 years (SD = 16.3). Molar teeth predominated (n = 113, 47.1%). Most cases were completed with a root filling (n = 169, 70.4%). The remainder were extracted (n = 32, 13.3%) or were still uncompleted (n = 39, 16.3%). On average, a root filling was completed in 2.4 (SD = 0.9) appointments, or extraction at the third appointment (SD = 1.6). The molars were less often completed and often predominant among the extracted teeth. The indication for extraction was often for endodontic or RCT-related reasons. Most complications were registered in the molars and antibiotics were prescribed in 20 cases. Most root filled teeth were restored with a direct restoration. Four root filled teeth (2.4%) were extracted within the time period.

Conclusions: Patient records, followed from the start of treatment, show that 12 months on, the root filling had not been completed in just under 30% of the teeth. Of these, about half were extracted. Of particular concern is the outcome for endodontic treatment of molar teeth. In the general practice setting, molar endodontics

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are not only technically challenging but also very demanding in terms of chairside resources. In the present study, a successful outcome was achieved in just over half the cases.

KEYWORDS

endodontics, general dental care, prospective cohort study, root filling, tooth extraction, treatment outcome

INTRODUCTION

In recent years, there has been an overall improvement in dental health in several western countries (Marthaler, 2004), including Sweden (Norderyd et al., 2015). Concomitantly, life expectancy has increased (Statistikmyndigheten, 2021). It has been assumed that as increasing numbers of people retain their natural dentition into old age, more teeth will be at risk of caries and subsequent pulpal disease (Bjørndal & Reit, 2004). Consequently, root canal treatment (RCT) remains a highly relevant, routine procedure in general dental practice (Pak et al., 2012). In Sweden, approximately 200 000 (2.7%) of the adult population undergo RCT and root filling each year (Fransson et al., 2016). Most such procedures are undertaken by general dental practitioners in the private (67%) or public sector (33%) (Fransson et al., 2016).

In a previous publication (Wigsten et al., 2019), we presented baseline data about a consecutively recruited cohort of patients about to undergo root canal therapy, 243 teeth in total. The participants were enrolled in the study at their first root filling appointment at one of twenty public dental clinics. Molar teeth predominated (47.7%) and most of the teeth (83.5%) had previously been restored. Dental caries was recorded in 127 teeth (62.9%). In 64.9% of cases, the initial appointment was for emergency treatment, for relief of symptoms.

With respect to the long-term outcome of RCT in terms of pain relief, there are several follow-up studies from university- and specialist clinics. In a systematic review by Nixdorf et al. (2010), the frequency of persistent pain after endodontic procedures was estimated to be 5.3%. In a cross-sectional study, patients undergoing a routine check-up at 23 Swedish public dental clinics reported pain or discomfort in 4.9% of root filled teeth (Jonsson Sjögren et al., 2019).

In a patient-focused follow-up questionnaire to our cohort of 243 patients, approximately 50% of those whose RCT had been completed were still experiencing pain after 1–3 years. However, most patients were highly satisfied with their decision to try to preserve their natural dentition, even though greater than one in four molars had been extracted, or RCT had not yet been completed (Wigsten et al., 2021).

In a systematic review of tooth survival following RCT (Ng et al., 2010), the pooled proportion of teeth surviving for a 2–10-year period ranged between 86% and 93%. In a study based on the register of the tax-funded Swedish Social Insurance Agency (SSIA) of all those whose root fillings had been reported as completed in 2009, 9.3% (n = 20 255) were subsequently registered as extracted, 5 years after completion of the root filling (Fransson et al., 2021). In the logistic regression model, molar teeth exhibited a twofold odds ratio of being extracted (56.3%, OR = 1.9) compared with the reference tooth group ('mandibular premolar'; n = 1772, 6.4%). To the best of our knowledge, in all studies on tooth survival, the baseline is a completed RCT with a permanent root filling.

There are few health economic analyses of RCT procedures (Balevi & Shepperd, 2007; Maryniuk & Haywood, 1990; Reit, 1987), and no published empirical studies on the cost-effectiveness of RCT (Statens Beredning för Medicinsk Utvärdering, 2010). However, in an additional analysis of the data in the SSIA explored by Fransson et al. (2016), we could report the total sum of all fees paid by the patients themselves and or the insurance for the RCT and additional interventions such as restorations, endodontic retreatments, re-restorations and so on for 5–6 years (Wigsten et al., 2018). The overall mean fee charged for a root filling was approximately 332 Euro, and the total mean fee for the preservation of a root filled tooth was 717 Euro. Altogether 178 million Euro was spent in attempting to preserve 248 299 teeth in need of RCT over a 5–6-year period. During the same period, 25 228 teeth (10.2%) failed to achieve 5–6-year survival and were extracted. The register does not disclose information about the number of teeth in which RCT was initiated, but was instead extracted before completion, or the resources expended on this treatment.

The present study is based on patient records, followed for 1 year after initiation of the endodontic therapy. The aim was to evaluate the treatment outcome with respect to the completion of RCT and tooth survival. A further aim was to estimate the chairside resources spent on these procedures.

MATERIALS AND METHODS

Ethical approval

The study protocol was approved by the regional ethical committee in Gothenburg, Sweden, in 2015 (Dnr:

857–14). The study was outlined according to the STROBE checklist and statement. The authors deny any conflict of interests.

Study population and baseline registrations

The study design and baseline characteristics have been described previously (Wigsten et al., 2019). In short, the subjects were recruited from patients attending one of 20 county public dental clinics in Västra Götaland, Sweden. Over 2 months, patients (>18 years) who were about to undergo RCT were informed of the study and invited to participate. Written consent was obtained from each participant at the start of treatment. The recruitment period was from May 2015 to February 2017: 243 patients were enrolled who contributed data from 243 teeth. All clinics were affiliated with the SSIA.

The following baseline characteristics were registered: age, gender, number of remaining teeth, dental arch, tooth group, number of restored surfaces, type of restoration, type of decay, loss of tooth substance, the presence of symptoms, pain intensity and reason for initiating RCT: pulpal and periapical diagnoses. The amount of tooth substance loss was analysed radiologically and classified as: small or none, less than one-third (small), one-third (medium) or loss of more than one-third of the dental crown (i.e., large).

One year follow-up of initiated root canal treatment

All 243 teeth were followed prospectively by reading the computerized dental records during the 12 months following the initial appointment which represented the baseline. Teeth were excluded if the records could not be followed for 365 days after the first appointment. All patient-related data were handled anonymously by allocation of unique identification numbers in the Excel data sheet (Microsoft Corp.). When data for a variable were missing, the data sheet cell was left blank and designated in the analysis as missing.

Two core outcome events were noted from each individual dental record: completed root filling or tooth extraction. In the remaining teeth, RCT had still not been completed with a permanent root filling. The main reason for extraction was noted. The total number of appointments was registered and the interval elapsed between treatment start and completion with a root filling or extraction.

Moreover, the number of cases was registered where the treating dentist had registered any type of intraoperative complication, as well as any prescription for antibiotics. Finally, the type of coronal restoration was registered and whether any of the teeth with completed root fillings had been extracted within the same year.

Statistical analyses

The SAS System version 9.4 was applied for statistical analysis. The categorical variables are presented as numbers and percentages, and for the continuous variables, the distribution is expressed as mean, SD, median, minimum and maximum. For comparison between two groups, for example, male versus female, Fisher's non-parametric permutation test was used for continuous variables. For comparison between ordered categorical groups, for example, age groups, Jonckheere–Terpstra rank test was used for continuous variables. For comparison between non-ordered categorical groups, for example, 'root filled', 'not completed' and 'extracted', Kruskal–Wallis test was used for continuous variables and ordered categorical variables and the chi-squared test for dichotomous variables and non-ordered categorical variables. Logistic regression was used to calculate the odds ratio and 95% confidence interval. A multivariable logistic regression analysis was performed. The variables were chosen from a stepwise backward model selection from the significant preoperative variables with age and gender forced into each step of the selection. All tests of significance were two-sided and conducted at the 5% significance level.

RESULTS

From the patient records, 1-year follow-up data was available for 240 (98.8%) of the 243 patients: 128 women (53.3%) and 112 men (46.7%) with a mean age of 48.5 years (SD = 16.3; range =19–88). Molar teeth predominated (n = 113, 47.1%), followed by premolars (n = 78, 32.5%) and anterior teeth (n = 49, 20.4%). Patient-based and tooth-specific characteristics are presented in Table 1. A flow chart of how the cohort has been studied is presented in Figure 1.

Outcomes at 1-year follow-up

One hundred and sixty-nine teeth (70.4%) had been root filled, 32 (13.3%) had been extracted and in 39 teeth (16.3%) RCT was not yet completed (Table 1). Amongst the latter, 7 teeth (2.9%) had been referred to a specialist endodontic clinic. The statistical analyses revealed that differences in the age cohorts and tooth groups had a significant influence on the outcome (Table 1).

TABLE 1 Baseline preoperative characteristics of 240 teeth about to undergo root canal treatment. Treatment outcomes were compared 12 months after initiated root canal treatment

Variable	Total ($n = 240$)	Root filled ($n = 169$)	Not completed ($n = 39$)	Extracted ($n = 32$)	p-Value
Preoperative factors, patient-based					
Age	48.5 (16.3) 48.5 (19;88)	48.9 (16.2) 50.0 (19;84)	44.2 (17.1) 39.0 (19;88)	51.4 (15.1) 51.0 (22;88)	.14
<40 years	76 (31.7%)	49 (29.0%)	21 (53.8%)	6 (18.8%)	
40–60 years	104 (43.3%)	77 (45.6%)	10 (25.6%)	17 (53.1%)	
>60 years	60 (25.0%)	43 (25.4%)	8 (20.5%)	9 (28.1%)	.015
Gender					
Male	112 (46.7%)	79 (46.7%)	19 (48.7%)	14 (43.8%)	
Female	128 (53.3%)	90 (53.3%)	20 (51.3%)	18 (56.3%)	.92
Number of remaining teeth[a]	27.3 (4.2) 28 (10;32)	27.3 (4.1) 28.0 (10;32)	27.3 (5.1) 29.0 (11;32)	27.4 (3.3) 27.5 (18;32)	.70
Preoperative factors, tooth-specific					
Jaw					
Maxilla	138 (57.5%)	99 (58.6%)	20 (51.3%)	19 (59.4%)	
Mandible	102 (42.5%)	70 (41.4%)	19 (48.7%)	13 (40.6%)	.69
Tooth group					
Incisor/canine	49 (20.4%)	40 (23.7%)	7 (17.9%)	2 (6.3%)	
Premolar	78 (32.5%)	64 (37.9%)	9 (23.1%)	5 (15.6%)	
Molar	113 (47.1%)	65 (38.5%)	23 (59.0%)	25 (78.1%)	.0005
Previous restoration					
No restoration	16 (6.7%)	14 (8.3%)	2 (5.1%)	0 (0.0%)	.23
Direct restoration	120 (50.0%)	85 (50.3%)	18 (46.2%)	17 (53.1%)	.84
Indirect restoration	22 (9.2%)	14 (8.3%)	5 (12.8%)	3 (9.4%)	.69
Amalgam	27 (11.3%)	18 (10.7%)	3 (7.7%)	6 (18.8%)	.31
Temporary filling	32 (13.3%)	23 (13.6%)	4 (10.3%)	5 (15.6%)	.80
Unknown	23 (9.6%)	15 (8.9%)	7 (17.9%)	1 (3.1%)	.085
Number of restored surfaces[a]					
Non-restored	16 (7.0%)	14 (8.6%)	2 (5.9%)	0 (0.0%)	
1–2	86 (37.9%)	58 (35.8%)	13 (38.2%)	15 (48.4%)	
3–4	80 (35.2%)	56 (34.6%)	11 (32.4%)	13 (41.9%)	
5–6	45 (19.8%)	34 (21.0%)	8 (23.5%)	3 (9.7%)	.38
Dental caries: primary, secondary or primary and secondary[a]					
Non-carious	74 (37.2%)	60 (42.9%)	6 (19.4%)	8 (28.6%)	
Primary	66 (33.2%)	42 (30.0%)	15 (48.4%)	9 (32.1%)	
Secondary	43 (21.6%)	28 (20.0%)	6 (19.4%)	9 (32.1%)	
Primary and secondary	16 (8.0%)	10 (7.1%)	4 (12.9%)	2 (7.1%)	.13
Tooth substance loss[a]					
Little or none	12 (5.1%)	12 (7.3%)	0 (0.0%)	0 (0.0%)	
Minor (<1/3)	28 (11.9%)	22 (13.3%)	2 (5.3%)	4 (12.5%)	
Medium (1/3)	28 (11.9%)	19 (11.5%)	4 (10.5%)	5 (15.6%)	
Large (>1/3)	167 (71.1%)	112 (67.9%)	32 (84.2%)	23 (71.9%)	.20
Preoperative factors, derived from the questionnaire					

TABLE 1 (Continued)

Variable	Total (n = 240)	Root filled (n = 169)	Not completed (n = 39)	Extracted (n = 32)	p-Value
Presence of diagnosed symptoms[a]					
Asymptomatic	81 (35.1%)	65 (39.6%)	7 (18.9%)	9 (30.0%)	
Pain, vital pulp	69 (29.9%)	44 (26.8%)	15 (40.5%)	10 (33.3%)	
Pain, necrotic pulp	81 (35.1%)	55 (33.5%)	15 (40.5%)	11 (36.7%)	.17
Pain intensity (VAS)[a]	3.34 (3.31) 3.0 (0;10)	3.08 (3.28) 2.0 (0;10)	4.51 (3.47) 5.0 (0;10)	3.33 (3.09) 3.0 (0;9)	.054
Pulpal and periapical diagnoses					
No previous root filling[a]					
Vital pulp	87 (36.3%)	58 (34.3%)	16 (41.0%)	13 (40.6%)	.65
Necrotic pulp without AP	20 (8.3%)	16 (9.5%)	3 (7.7%)	1 (3.1%)	.45
Necrotic pulp with AP	90 (37.5%)	66 (39.1%)	13 (33.3%)	11 (34.4%)	.78
Other reasons[b]	18 (7.5%)	15 (8.9%)	1 (2.6%)	2 (6.3%)	.40
Previous root filling					
Without AP	4 (1.7%)	4 (2.4%)	0 (0.0%)	0 (0.0%)	.45
With AP	14 (5.8%)	8 (4.7%)	4 (10.3%)	2 (6.3%)	.42

Note: The subjects comprised 240 patients attending 20 different Swedish public dental clinics. The smallest unit analysed was the tooth. For continuous variables mean (SD)/median (Min;Max) is presented. For categorical variables, n and percentages are presented for each variable and outcome. For each of the four columns the percentages of the categorical variables sum to 100%. The preoperative factors are described in detail in a previous study (Wigsten et al., 2019), as well as the general dental practitioners' registered reasons for starting treatment. The indication for treatment was classified as asymptomatic or symptomatic ('pain'), depending on the status of the pulp.

Abbreviations: AP, apical periodontitis; n, number; VAS, visual analogue scale.

[a]The following data were missing: 'Number of remaining teeth': 19 cases, 'Number of restored surfaces': 13 cases, 'Dental caries: primary, secondary or primary and secondary': 41 cases, 'Tooth substance loss': 5 cases, 'Presence of diagnosed symptoms': 9 cases, 'Pain intensity (VAS)': 6 cases and 'No previous root filling' under 'Pulpal and periapical diagnoses': 7 cases.

[b]Other registered non-specific factors were: cusp and dental fractures or root canal treatment initiated at another dental clinic.

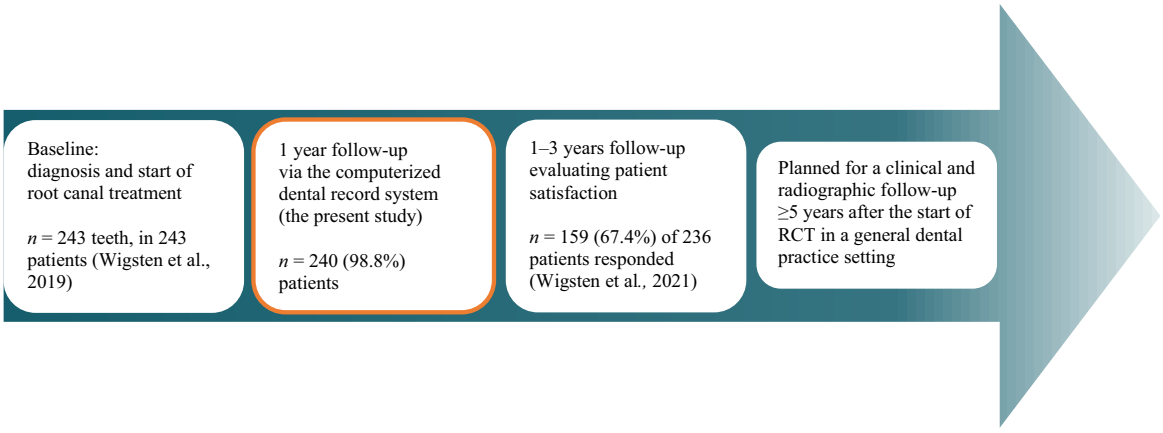

FIGURE 1 Flow chart for the study population. Two hundred and forty-three adult patients (>18 years) started a root canal treatment during a specific 8-week period at 20 public dental clinics in Västra Götaland, Sweden (Wigsten et al., 2019). This study presents a 1-year detailed follow-up after initiation of endodontic therapy based on patient records. Patient satisfaction with root canal treatment has also been studied based on a patient-focused questionnaire (Wigsten et al., 2021)

Root canal treatment completed with a root filling within 1 year

The univariable analyses of *completed RCT* within 1 year showed that molar teeth were less frequently root filled (odds ratio [OR] = 0.30, p = .0042) compared to the reference, incisors (Table 2). Teeth with major substance loss (>1/3) were less frequently root filled than more intact teeth (OR = 0.64, p = .022). Moreover, teeth with symptomatic vital pulps at baseline were more seldom root filled than the reference teeth with 'no symptoms' (OR = 0.43, p = .026).

In the multivariable analysis, *completed RCT* remained less frequent amongst molars (OR = 0.30, $p = .012$) compared to the reference, incisors (Table 2). Again, teeth with major substance loss were less frequently root filled than more intact teeth (OR = 0.56, $p = .010$). On average, 2.4 appointments (SD = 0.9; median = 2.0; range = 1–6) were needed to complete the RCT and treatment was completed between 0 and 335 days after the initial appointment (mean = 60.1; SD = 69.6; median = 37.0). Twenty-two teeth (13.0%) were root filled during the first visit.

The majority of the root filled teeth were restored with direct restorations ($n = 128$, 75.7%) within follow-up and 32 (18.9%) were restored with indirect restorations. Twenty teeth (11.8%) were restored with an indirect post (i.e., fabricated by a dental technician). For 9 teeth (5.3%), no coronal restoration was registered at follow-up, other than the temporary filling.

Amongst the teeth with completed root fillings, four (2.4%) were extracted during the first year. The reasons given in the records were: pain, tooth fracture or a dentinal crack in the pulp cavity. The teeth were extracted between 45 and 210 days after completed root filling (mean = 155.3; SD = 74.9; median = 183.0).

Root canal treatment ended with extraction

In the univariate analysis of *tooth extraction*, there was only one statistically significant variable (Table 2). Twenty-five molars (22.1%) had been extracted (OR = 6.68, $p = .012$) compared to the reference incisors, only 2 of which (4.1%) had been extracted. On average, the tooth was extracted at the third appointment (mean = 3.0; SD = 1.6; median = 2.0; range = 2–9). The time elapsing from initial appointment for RCT to extraction varied between 1 and 337 days (mean = 90.8, SD = 89.8, median = 55.0). Eighteen teeth (56.3%) were extracted at the second appointment. For the majority of the extracted teeth, the treating dentist recorded an endodontic- or RCT-related indication for extraction ($n = 17$, 54.8%), such as apical periodontitis, perforation, instrument fracture or dentinal crack. Seven teeth (22.6%) were extracted due to tooth substance loss. In the other cases, the tooth ($n = 7$, 22.6%) was extracted, for various reasons, at the request of the patient.

Recourses required for root canal treatment in a general dental practice setting

The dentists had recorded 'complications' (i.e., dentinal cracks and fractures, instrument fractures, perforations and inadequate technical quality of root filling) in 40 teeth (16.7%). Thirty-six (90.0%) of the teeth with complications were molars. In the multivariate logistic regression analysis, except for molar teeth (OR = 37.97, $p = .0014$; Table S1), the odds of higher frequency of complications increased with age (OR = 10.16, $p = .0002$; OR = 8.95, $p = .0082$). At the same time the analysis revealed that if the tooth had ≥4 surfaces restored at start (OR = 0.65, $p = .011$) or exhibited large tooth substance loss (OR = 0.57, $p = .044$), complications were less frequent.

Twenty-four (60.0%) teeth were completed with a root filling and fourteen (35.0%) were extracted, the others were either not yet completed or had been referred to a specialist endodontic clinic ($n = 2$, 5.0%). Three teeth were prescribed antibiotics during the RCT procedure. The majority of the root filled teeth were restored with a direct restoration ($n = 17$, 70.8%).

Twenty patients (8.3%) were prescribed antibiotics during the RCT procedures. Two patients had received 2 prescriptions on two separate occasions. Twelve (60.0%) of those prescribed antibiotics had initially presented with symptomatic apical periodontitis: this was the only significant variable (OR = 4.52, $p = .024$) associated with antibiotic prescription in the univariable logistic regression model.

On average, 2.4 appointments (SD = 1.1; median = 2.0; range = 1–9) were required for RCT of the 240 teeth included in the study: this included scheduled and non-scheduled appointments. The number of appointments was significantly associated with the following baseline variables: age ($p = .011$), jaw ($p = .046$), tooth group ($p = .0006$), type of previous restoration ($p = .0040$) and diagnosis ($p = .0009$; Table 3).

For teeth which were either root filled or extracted ($n = 201$), the interval between treatment start and completion varied from 0 to 337 days (mean = 65.0; SD = 73.8; median = 40.0). The interval was significantly associated with the following baseline variables: tooth group ($p < .0001$), type of previous restoration ($p = .001$), type of decay ($p = .011$) and diagnosis ($p = .01$; Table 3).

DISCUSSION

This study presents a 1-year detailed follow-up of a patient cohort who began RCT at 20 county public dental clinics in Västra Götaland, Sweden.

The decision to recruit subjects and set the initial appointment for RCT as the baseline is unusual, and to the best of our knowledge has not previously been done for studies based on general dental practice. In most follow-up studies, retrospective as well prospective, completion of RCT with a permanent root filling has been set as the baseline (Ng et al., 2007).

TABLE 2 Univariate and multivariate logistic regression analysis of preoperative variables related to the core outcomes: completed root filling or extraction within one year

	RCT completed ($n = 169$)					Tooth extraction ($n = 32$)		
		Univariable		Multivariable*			Univariable	
Variable	***n* (%)**	**OR (95% CI)**	***p*-Value**	**OR (95% CI)**	***p*-Value**	***n* (%)**	**OR (95% CI)**	***p*-Value**
Preoperative factors, patient-based								
Age[c]								
<40 years	49 (64.5%)	1.00		1.00		6 (7.9%)	1.00	
40–60 years	77 (74.0%)	1.57 (0.83–2.99)	.17	2.22 (1.08–4.53)	.029	17 (16.3%)	2.28 (0.85–6.09)	.10
>60 years	43 (71.7%)	1.39 (0.67–2.90)	.37	1.52 (0.67–3.46)	.32	9 (15.0%)	2.06 (0.69–6.15)	.20
Gender[c]								
Male	79 (70.5%)	1.00				14 (12.5%)	1.00	
Female	90 (70.3%)	0.99 (0.57–1.72)	.97	0.92 (0.50–1.68)	.78	18 (14.1%)	1.15 (0.54–2.42)	.72
Number of remaining teeth[a,d]								
10–<27	51 (71.8%)					11 (15.5%)		
27–<30	57 (76.0%)					10 (13.3%)		
30–32	55 (73.3%)	1.00 (0.93–1.07)	.95			7 (9.3%)	1.01 (0.91–1.11)	.92
Preoperative factors, tooth–specific								
Jaw[c]								
Maxilla	99 (71.7%)	1.00				19 (13.8%)	1.00	
Mandible	70 (68.6%)	0.86 (0.49–1.51)	.60			13 (12.7%)	0.91 (0.43–1.95)	.82
Tooth group[c]								
Incisor	40 (81.6%)	1.00		1.00		2 (4.1%)	1.00	
Premolar	64 (82.1%)	1.03 (0.41–2.60)	.95	1.29 (0.46–3.62)	.62	5 (6.4%)	1.61 (0.30–8.64)	.58
Molar	65 (57.5%)	0.30 (0.14–0.69)	.0042	0.30 (0.12–0.77)	.012	25 (22.1%)	6.68 (1.51–29.42)	.012
Previous restoration[c]								
No restoration	14 (87.5%)	1.00				0 (0.0%)	0.18 (0.01–3.41)	.25
Direct restoration	85 (70.8%)	0.35 (0.07–1.61)	.18			17 (14.2%)	1.00	
Indirect restoration	14 (63.6%)	0.25 (0.04–1.39)	.11			3 (13.6%)	1.06 (0.30–3.78)	.93
Amalgam	18 (66.7%)	0.29 (0.05–1.54)	.14			6 (22.2%)	1.79 (0.64–5.00)	.27
Temporary filling	23 (71.9%)	0.37 (0.07–1.94)	.24			5 (15.6%)	1.18 (0.41–3.41)	.76
Unknown	15 (65.2%)	0.27 (0.05–1.48)	.13			1 (4.3%)	0.39 (0.07–2.30)	.30

(Continues)

TABLE 2 (Continued)

	RCT completed ($n = 169$)					Tooth extraction ($n = 32$)		
		Univariable		Multivariable*			Univariable	
Variable	***n* (%)**	**OR (95% CI)**	***p*-Value**	**OR (95% CI)**	***p*-Value**	***n* (%)**	**OR (95% CI)**	***p*-Value**
Number of restored surfaces[a,d]								
0–<2	38 (77.6%)					5 (10.2%)		
2–<4	68 (66.0%)					18 (17.5%)		
4–6	56 (74.7%)	1.00 (0.85–1.18)	1.00			8 (10.7%)	0.95 (0.77–1.18)	.65
Dental caries: primary, secondary or primary and secondary[a,c]								
Non-carious	60 (81.1%)	1.00				8 (10.8%)	1.00	
Primary	42 (63.6%)	0.41 (0.19–0.88)	.022			9 (13.6%)	1.30 (0.47–3.60)	.61
Secondary	28 (65.1%)	0.44 (0.19–1.02)	.057			9 (20.9%)	2.18 (0.77–6.17)	.14
Primary and secondary	10 (62.5%)	0.39 (0.12–1.25)	.11			2 (12.5%)	1.18 (0.23–6.16)	.85
Tooth substance loss[a,d]								
Little or none	12 (100.0%)					0 (0.0%)		
Minor (<1/3)	22 (78.6%)					4 (14.3%)		
Medium (1/3)	19 (67.9%)					5 (17.9%)		
Large (>1/3)	112 (67.1%)	0.64 (0.44–0.94)	.022	0.56 (0.36–0.87)	.010	23 (13.8%)	1.18 (0.75–1.87)	.48
Preoperative factors, derived from the questionnaire								
Presence of diagnosed symptoms[a,c]								
Asymptomatic	65 (80.2%)	1.00				9 (11.1%)	1.00	
Pain, vital pulp	44 (63.8%)	0.43 (0.21–0.90)	.026			10 (14.5%)	1.36 (0.52–3.56)	.54
Pain, necrotic pulp	55 (67.9%)	0.52 (0.25–1.07)	.075			11 (13.6%)	1.26 (0.49–3.22)	.63
Pain intensity (VAS)[a,d]								
0–<0.5	65 (80.2%)					9 (11.1%)		
0.5–<5.5	52 (65.0%)					14 (17.5%)		
5.5–10	48 (65.8%)	0.92 (0.85–1.00)	.058			8 (11.0%)	1.00 (0.89–1.12)	.98
Pulpal and periapical diagnoses[c]								
No previous root filling[a]								
Vital pulp	58 (66.7%)	1.00				13 (14.9%)	1.00	

TABLE 2 (Continued)

	RCT completed ($n = 169$)					Tooth extraction ($n = 32$)		
		Univariable		Multivariable*			Univariable	
Variable	*n* (%)	OR (95% CI)	*p*-Value	OR (95% CI)	*p*-Value	*n* (%)	OR (95% CI)	*p*-Value
Necrotic pulp without AP	16 (80.0%)	1.85 (0.58–5.88)	.30			1 (5.0%)	0.42 (0.07–2.57)	.35
Necrotic pulp with AP	66 (73.3%)	1.37 (0.72–2.61)	.34			11 (12.2%)	0.80 (0.34–1.87)	.60
Other reasons[b]	15 (83.3%)	2.23 (0.63–7.97)	.22			2 (11.1%)	0.84 (0.19–3.69)	.81
Previous root filling								
Without AP	4 (100.0%)	4.54 (0.17–122.53)	.37			0 (0.0%)	0.61 (0.02–16.93)	.77
With AP	8 (57.1%)	0.66 (0.21–2.08)	.48			2 (14.3%)	1.10 (0.24–5.05)	.90

Note: The smallest unit analysed was the tooth. For categorical variables *n* (%) is presented. *Multivariable logistic regression model including 'Age', 'Gender', 'Tooth group' and 'Tooth substance loss' (at tooth level and total). Area under ROC-curve with 95% CI for multivariable model = 0.71 (0.64–0.78). The multivariable model was selected through backward model selection from all significant preoperative risk factors. Age and gender were purposely selected into all steps of the selection.

Abbreviations: AP, apical periodontitis; CI, confidence interval; *n*, number; OR, odds ratio; RCT, root canal treatment; ROC, receiver operating characteristic; VAS, visual analogue scale.

All tests were performed with univariable logistic regression.

[a]The following data were missing: 'Number of remaining teeth': 19 cases, 'Number of restored surfaces': 13 cases, 'Dental caries: primary, secondary or primary and secondary': 41 cases, 'Tooth substance loss': 5 cases, 'Presence of diagnosed symptoms': 9 cases, 'Pain intensity (VAS)': 6 cases and 'No previous root filling' under 'Pulpal and periapical diagnoses': 7 cases.

[b]Other reasons were for example cusp and dental fractures.

[c]For the following categories, a comparison (OR) was made against a so-called 'reference', which is assigned the value of 1.00.

[d]For the following categories, a comparison (OR) was made either made by assigned values (1, 2, 3, etc.) for each step or by comparing the impact of a 1-unit change.

TABLE 3 The total mean number of appointments for all 240 teeth in the year following initiation of root canal treatment. The number of days from the start, until treatment was completed with a root filling or the tooth was extracted instead, is also presented

		Number of appointments			Number of days	
Variable	***n***	**M (SD); Median (Min; Max)**	***p*-Value**	***n***	**M (SD); Median (Min; Max)**	***p*-Value**
Age						
<40 years	76	2.05 (0.88); 2 (1;5)		55	57.3 (72.1); 34 (0;294)	
40–60 years	104	2.56 (1.20); 2 (1;9)		94	69.4 (76.4); 47 (0;337)	
>60 years	60	2.50 (1.19); 2 (1;8)	.011	52	65.2 (71.4); 36 (0;305)	.34
Gender						
Male	112	2.40 (1.06); 2 (1;8)		93	61.7 (65.7); 45 (0;301)	
Female	128	2.37 (1.18); 2 (1;9)	.85	108	67.9 (80.3); 35 (0;337)	.56
Jaw						
Maxilla	138	2.25 (1.10); 2 (1;9)		118	60.1 (73.6); 35 (0;337)	
Mandible	102	2.56 (1.13); 2 (1;8)	.046	83	72.0 (73.9); 48 (0;305)	.26
Tooth group						
Incisor/canine	49	2.00 (0.91); 2 (1;6)		42	35.6 (48.6); 19 (0;205)	
Premolar	78	2.26 (0.90); 2 (1;5)		69	63.8 (80.9); 33 (0;335)	
Molar	113	2.64 (1.28); 2 (1;9)	.0006	90	79.7 (74.3); 52.5 (0;337)	<.0001
Previous restoration						
No restoration	16	2.19 (0.98); 2 (1;5)		14	50.6 (90.0); 17.5 (0;335)	
Direct restoration	120	2.38 (1.00); 2 (1;6)		102	57.0 (54.4); 42 (0;266)	
Indirect restoration	22	1.91 (0.87); 2 (1:4)		17	29.8 (33.7); 22 (0;138)	
Amalgam	27	3.07 (1.38); 3 (1;8)		24	102.1 (84.3); 77.5 (3;301)	
Temporary filling	32	2.38 (1.50); 2 (1;9)		28	67.4 (96.3); 32.5 (0;337)	
Unknown	23	2.22 (0.74); 2 (1;4)	.0040	16	106.2 (103.9); 53 (0;296)	.0010
Dental caries: primary, secondary or primary and secondary[a]						
Non-carious	74	2.22 (0.82); 2 (1;4)		68	44.0 (45.7); 32.5 (0;205)	
Primary	66	2.67 (1.49); 2 (1;9)		51	86.7 (96.0); 49 (0;337)	
Secondary	43	2.40 (1.16); 2 (1;6)		37	54.8 (68.5); 30 (0;305)	
Primary and secondary	16	2.44 (1.03); 2.5 (1;5)	.35	12	85.3 (67.8); 73.5 (8;259)	.011
Tooth substance loss[a]						
Little or none	12	2.17 (1.03); 2 (1;5)		12	57.8 (95.7); 19 (0;335)	
Minor (<1/3)	28	2.50 (0.75); 2.5 (1;4)		26	67.3 (61.7); 55.5 (0;218)	
Medium (1/3)	28	2.86 (1.63); 3 (1;9)		24	74.8 (89.3); 38.5 (0;337)	
Large (>1/3)	167	2.34 (1.06); 2 (1;8)	.16	135	65.2 (71.9); 42 (0;305)	.88
Presence of diagnosed symptoms[a]						
Asymptomatic	81	2.12 (1.02); 2 (1;6)		74	56.9 (76.7); 27 (0;305)	
Pain, vital pulp	69	2.67 (1.20); 3 (1;8)		54	76.8 (76.5); 54 (0;335)	
Pain, necrotic pulp	81	2.36 (0.87); 2 (1;5)	.0009	66	62.7 (61.1); 45.5 (0;294)	.010
Pulpal and periapical diagnoses						
No previous root filling[a]						
Vital pulp	87	2.59 (1.21); 2 (1;8)		71	72.5 (80.4); 46 (0;335)	
Necrotic pulp without AP	20	2.00 (0.73); 2 (1;3)		17	33.7 (24.4); 35 (0;69)	

TABLE 3 (Continued)

Variable	Number of appointments			Number of days		
	n	M (SD); Median (Min; Max)	*p*-Value	*n*	M (SD); Median (Min; Max)	*p*-Value
Necrotic pulp with AP	90	2.37 (1.01); 2 (1;6)		77	72.4 (74.3); 49 (0;301)	
Other reasons[b]	18	2.06 (0.73); 2 (1;3)		17	35.7 (31.2); 35 (0;105)	
Previous root filling						
Without AP	4	1.75 (0.50); 2 (1;2)		4	13.5 (13.9); 11.5 (0;31)	
With AP	14	2.00 (0.78); 2 (1;4)	.063	10	36.2 (31.4); 35 (3;96)	.065

Note: The number of appointments includes all appointments for root canal treatment, that is, not only scheduled appointments for instrumentation and root filling but also unplanned emergency appointments, and also for the treatment of teeth which were eventually extracted or cases where root canal treatment had not been completed within the year. The smallest unit analysed was the tooth.

Abbreviations: AP, apical periodontitis; *n*, number; VAS, visual analogue scale.

[a]The following data were missing 'in number of appointments': 'Dental caries: primary, secondary or primary and secondary': 41 cases, 'Tooth substance loss': 5 cases, 'Presence of diagnosed symptoms': 9 cases, and 'No previous root filling' under 'Pulpal and periapical diagnoses': 7 cases. The following data were missing 'in number of days': 'Dental caries: primary, secondary or primary and secondary': 33 cases, 'Tooth substance loss': 4 cases, 'Presence of diagnosed symptoms': 7 cases and 'No previous root filling' under 'Pulpal and periapical diagnoses': 5 cases.

[b]Other registered non-specific factors were for example cusp and dental fractures.

In the present study, RCT had not been completed in almost 30% ($n = 71$) of the teeth. In 13.3% ($n = 32$) of cases, RCT had been discontinued and the tooth extracted within the first 365 days. This highlights the important influence this shift in perspective may have on the concept of RCT as the treatment of choice in the view of patients, the dentist as well as third-party stakeholders.

In a previous study (Wigsten et al., 2021), the patients' perceptions of their treatment were examined. One to 3 years after starting RCT, patient satisfaction was generally ranked as high, despite the loss or incomplete treatment of 30% of the teeth and reports of present pain by half the patients. However, not surprisingly, respondents whose RCT was yet to be completed, or whose tooth had been extracted were more likely to regret their decision to undergo RCT (54.5%) than those with a completed RCT (13.0%).

The poor outcome of the RCTs may be attributable to a number of factors; from diagnosis, selection of cases, technical and biological difficulties related to the tooth, but also to factors related to both dentists' and patients' preferences.

Previous studies within the same county public dental service have reported that dentists experience high levels of stress and frustration in relation to RCT (Dahlström et al., 2017). Loss of control was often reported in relation to several steps in the RCT procedures. The participants expressed several reasons for their feelings of uncertainty during treatment, including challenging anatomy and lack of visibility in concealed spaces of the root canal system. Most of the dentists also reported that they were unable to complete a case within the limitations set by the remuneration system.

As can be seen from the overall picture of this follow-up, extensive resources are expended in terms of the number of appointments, not only for those patients who eventually have their tooth root filled but also for those who have undergone extraction or whose treatment is yet to be completed. The findings raise questions about the cost-effectiveness of RCT undertaken by the public dental service, in comparison with alternative treatment, including extraction with or without replacement of the tooth with an implant or fixed prosthodontic construction (Morris et al., 2009; Pennington et al., 2009; Wigsten et al., 2020).

In particular, the analyses highlighted issues associated with the endodontic treatment of molar teeth. The difficulties vary, but on the whole, the complexity is often significantly greater than for other tooth groups. This applies to anatomy, diagnosis, access, asepsis, instrumentation, antiseptic irrigation, root filling and coronal restoration (Peters, 2016). It may be argued that the pattern revealed is valid only for the cohort of patients under study. For more general conclusions and comparisons, similar studies with inception at treatment start, should be undertaken in other settings, including other general dental practitioners-, specialist- and university clinic settings.

Following this cohort over time will provide information on long-term survival of the root filled teeth and eventually also the outcome with respect to the treatment objective of ensuring healthy periapical conditions. The finding that 4 teeth (2.4%), 2 of which were molars, were extracted within the same year as the completed root filling is compatible with findings from register studies in Sweden (Fransson et al., 2016, 2021; Göransson et al.,

2021; Kebke et al., 2021). Based on previous epidemiological studies, it may be hypothesized that amongst surviving root filled teeth the incidence of persistent or recurrent apical periodontitis is around 25% (Frisk et al., 2008; Pak et al., 2012).

Whilst the findings should be interpreted with caution, these results, together with findings in previous publications (Dahlström et al., 2017, 2018) give cause for reflection as to the possibility of improvement in RCT procedures in the county public dental services. Several possible measures could be considered.

There is evidence that extensive training of general dental practitioners in root canal instrumentation (including dentists in the public dental service), can achieve significant improvements in the technical results of root fillings (Dahlström et al., 2011; Molander et al., 2007). An educational intervention was undertaken in a similar Swedish county public dental health service resulted in a general improvement in endodontic treatment procedures (Koch et al., 2014) and fewer extractions (Koch et al., 2015). One potential means could therefore be to increase continuing education in endodontics amongst general dental practitioners, with emphasis on the treatment of molars (Simons & Williams, 2013).

However, endodontic procedures, particularly in molars, are demanding and it may be argued that providing extensive post-graduate training in endodontics for every general dental practitioner may not be realistic or cost-effective. If dental health continues to improve further and if today's adolescents and young- and middle-aged adults maintain their generally good dental health as they age, there will be less demand for RCTs in Sweden and comparable countries. In a number of studies, various aspects of the complete cohort of root fillings undertaken in Swedish adults in 2009 ($n = 248\ 299$ root fillings in 217 047 individuals) have been reported (Dawson et al., 2017; Fransson et al., 2016, 2021; Landt et al., 2018; Markvart et al., 2021; Olsson et al., 2019; Wigsten et al., 2018). These studies were all based on statistics from the SSIA, which continuously registers all dental treatments in adults undertaken by Swedish dentists. Current data retrieved from this source show a decrease in annually reported root fillings. In 2019 the total number of root fillings was reported to be 188 570, a reduction of 24.1% since 2009 (Försäkringskassan, 2021).

Thus, not all general dental practitioners will treat sufficient patients to maintain the competence and skills at the high level required: continuous training through clinical experience is the best way to develop and maintain skills. Consequently, RCT in molar teeth in particular may be regarded and defined as highly specialized care (Utredningen om Högspecialiserad Vård, 2015).

If patients had been given the option, many more would have preferred referral to a specialist in endodontics (Dugas et al., 2002; Hamasha & Hatiwsh, 2013) than is currently the case. One possible way for future development of endodontic care, in Sweden, is therefore to educate and train enough specialists in endodontics, so that most RCTs, at least in molars, are undertaken by specialists. However, such a change must take place gradually and be scientifically compared, in terms of costs and results, with what is achieved with the current system. It should not be taken for granted that a comparison would disclose significantly better results or higher cost-effectiveness. Moreover, the present study highlights the importance of establishing treatment initiation as the study baseline and not, as has usually been the case, on completion of the root filling.

CONCLUSION

This practice-based prospective follow-up study of RCTs undertaken in public dental clinics in a Swedish county, using treatment start as a baseline, reveals a different and less positive pattern of treatment outcome, particularly in molar teeth. The results raise questions about the need for post-graduate training and organization with respect to this very demanding procedure.

ETHICAL APPROVAL

Authors affirm that this is an original work, which has not been previously published elsewhere. Furthermore, the paper reflects the authors' research and analysis wholly and truthfully. All sources used are appropriately disclosed and cited. We also affirm that authors have been personally and actively involved in substantial word leading to the paper and will take public responsibility for its content.

AUTHOR CONTRIBUTIONS

All authors have contributed to the development of this original research. In addition, all authors have read, revised, and approved the manuscript. The authors Emma Wigsten and Thomas Kvist have also contributed to: the original study design, interpretation of data and preparation of text and manuscript. The Statistiska Konsultgruppen in Gothenburg was used for the statistical analysis.

CONFLICT OF INTEREST

The authors deny any conflicts of interest.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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