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ORIGINAL ARTICLE

Radiographic outcome of root canal treatment in general dental practice: tooth type and quality of root filling as prognostic factors

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ABSTRACT

Objective: This study evaluated the radiographic outcome of root canal treatments (RCTs) performed by general dental practitioners (GDPs) with focus on tooth type and quality of root filling.

Materials and methods: The target population included all patients receiving root filling by GDPs in City of Helsinki in 2010–2011. Equal numbers of each tooth type (anteriors, premolars, molars) by jaw were included, resulting in 426 teeth. Pre- and post-operative periapical radiographs were assessed to evaluate periapical status and quality of root filling. Statistical evaluation utilized Chi-squared tests, Cohen's kappa and logistic regression modelling.

Results: The overall success rate of RCT was 67.4%, being 76.8%, 69.7% and 55.6% ($p < .001$) for anteriors, premolars and molars, respectively. The quality of root fillings varied by tooth type ($p < .001$); optimal fillings were least frequent (43%) in molars. In multifactorial analysis, RCTs were more likely to succeed in non-molars (OR = 1.8), in teeth with optimal root fillings (OR = 3.6) and in teeth without apical periodontitis (OR = 3.2).

Conclusion: The quality of root fillings and radiographic outcome of RCTs varied considerably according to tooth type; success was least likely in molars. Improvement is needed in quality of RCTs by GDPs.

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Introduction

Root canal treatment (RCT) is an important procedure in conservative dentistry, the failure of which may cause discomfort, pain and adverse effects on an individual's general health. Most studies evaluating the quality and outcome of RCT have been conducted in controlled settings at teaching or specialist clinics. These studies show that 67–90% of RCTs result in adequate root fillings, and that success rates (SRs) are 87–94% for adequately and 68–77% for inadequately root-filled teeth [1–3].

On the other hand, little is known about success of RCT in actual clinical practice. Longitudinal studies on the outcome of RCT in terms of periapical health – as defined by the European Society of Endodontology [4] – are rare [5–7]. Some studies have examined the survival of RCTs performed in general dental practice [8–10], but these studies ignore the possible presence of apical periodontitis (AP). Cross-sectional studies from various populations represent the findings of RCT in general practice, and demonstrate that only 19–52% of root fillings are adequate [11–13]. Inadequate fillings associate with AP, and are most frequent in molars [14,15]. Overall, AP is worryingly frequent (36%) in root-filled teeth according to a systematic review and meta-analysis of cross-sectional studies [16].

The outcome of RCT in highly controlled settings has been well established, while the RCTs in real-life general dental practice settings are far less studied. Therefore, the aim of this study was to evaluate the radiographic outcome of RCTs performed by general dental practitioners (GDPs) in a public oral health care unit with focus on type of tooth and the quality of root filling.

Materials and methods

This study was approved by the Department of Social Services and Health Care of the City of Helsinki (HEL 2018-004616). Data are based on radiographs in electronic patient records. The patients were solely identified by running numbers in the database formed for the study.

The target population came from the City of Helsinki and included all patients ($n = 2362$) receiving at least one root filling carried out by GDPs during 2010–2011. In the target population, proportions of root-filled teeth by tooth type were as follows: maxillary anteriors 27%, premolars 18%, molars 13%, mandibular anteriors 10%, premolars 13% and molars 18%. Sample size calculation was performed in order to find a 20% difference (70% vs. 90%) in the outcome of RCT between tooth types at the 95% confidence level and 80% power, indicating a minimum of 59 teeth/tooth type.

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Stratified random sampling by tooth type was performed to collect 71 teeth (sample size calculation + 20%) of each tooth type (anterior, premolar, molar), separately for both jaws, resulting in 426 permanent teeth for analysis. For patients having more than one RCT during the investigation period, only one tooth was randomly selected. The inclusion criteria for the selected cases were a root-filled permanent tooth and diagnosable periapical radiographs before RCT and at follow-up, a minimum of 6 months after root filling. Teeth with signs of trauma-induced resorption or retrograde fillings were excluded.

All radiographs were digital periapical radiographs; due to the practice-based character of the study, the technique of imaging was not standardized. No clinical data were available during the examination of the radiographs. The assessment was carried out from Digora® software in a room with dimmed lights and a high-quality computer screen. Two of the authors, both specialized in endodontics, assessed the radiographs separately; the tools for the enhancement of radiographs were available in the software to be used as needed. All radiographs were first assessed by one of the authors (EL) to evaluate the technical quality of the root fillings and pre- and post-operative periapical status; the evaluation took five separate sessions (radiographs of approximately 80 teeth per session, 2–3 h each), and was carried out within 1 month. For intra-examiner reliability of recordings, EL re-assessed the periapical status of 60 (14%) RCTs (10 teeth of each tooth type) 2–3 months later in one session. In addition, another author (AK) assessed the periapical status for the same 60 RCTs, in one session, to calculate the inter-examiner reliability.

The Periapical Index (PAI) [17] served for classifying the periapical status. The assessors were calibrated beforehand by viewing 50 various periapical radiographs. The PAI was recorded for each tooth on two occasions: before RCT and at the most recent follow-up. In multirooted teeth, the greatest PAI score of the roots was assigned for the tooth. The technical quality of the root filling was recorded as either optimal: root filling length 0–2 mm from radiographic apex, root filling density homogeneous and no empty root canal space visible in any part of the root(s), or suboptimal: short filling (>2 mm from apex), overfilling, filling density not homogeneous or empty root canal space visible. Type of tooth was recorded by jaw as anterior, premolar and molar and treatment modality as primary (first-time) or secondary (retreatment) RCT. Patient's details included age and gender.

The outcome of RCT was defined according to PAI: scores 1–2 in the most recent follow-up were considered healthy. Teeth with initial AP were considered healing when radiolucency was smaller in follow-up than preoperatively, and the duration of follow-up was less than 4 years. Both 'healthy' and 'healing' cases were considered successful.

To evaluate inter- and intra-examiner reliability of PAI recordings, Cohen's kappa (κ) and the percentage agreement were calculated for the dichotomized outcome (success/failure). Chi-squared tests served for evaluation of differences in frequencies between subgroups. Analyses by type of tooth first included all six types, later combined by jaw into three types and finally as a dichotomy of molars and non-molars. Descriptive statistics included success rate (SR) defined as percentages by type of tooth or jaw. Logistic regression modelling was applied to assess factors related to the outcome of RCT, producing odds ratios (ORs) and their 95% confidence intervals (95% CIs). The Hosmer and Lemeshow test assessed the goodness of fit for the models. p Values $<.05$ were considered statistically significant.

Results

Patients' mean age was 44.2 years (standard deviation [SD] 23.2; range 9–93). Of the 426 patients, 56% were female and 44% male. Characteristics of cases are presented in Table 1. AP was present in 55% of cases preoperatively. The preoperative periapical status varied by type of tooth ($p = .005$). The vast majority (91.3%) of RCTs were initial (first-time) RCTs. The frequencies of different types of teeth varied between age groups ($p < .001$).

Table 1. Characteristics of study patients and root canal-treated teeth ($N = 426$).

	Anterior		Premolar		Molar			
Characteristic	Maxilla *n* (%)	Mandible *n* (%)	Maxilla *n* (%)	Mandible *n* (%)	Maxilla *n* (%)	Mandible *n* (%)	Total *n* (%)	*p* Value
Total	71 (16.7)	71 (16.7)	71 (16.7)	71 (16.7)	71 (16.7)	71 (16.7)	426 (100)	
Preoperative periapical status								
AP	40 (56.3)	44 (62.0)	28 (39.4)	39 (54.9)	32 (45.1)	49 (69.0)	232 (54.5)	
NAP	31 (43.7)	27 (38.0)	43 (60.6)	32 (45.1)	39 (54.9)	22 (31.0)	194 (45.5)	.005
Treatment modality								
Initial RCT	65 (91.5)	69 (97.2)	66 (93.0)	64 (90.1)	63 (88.7)	62 (87.3)	389 (91.3)	
Retreatment	6 (8.5)	2 (2.8)	5 (7.0)	7 (9.9)	8 (11.3)	9 (12.7)	37 (8.7)	.361
Patients' gender								
Female	36 (50.7)	34 (47.9)	48 (67.6)	42 (59.2)	39 (54.9)	40 (56.3)	239 (56.1)	
Male	35 (49.3)	37 (52.1)	23 (32.4)	29 (40.8)	32 (45.1)	31 (43.7)	187 (43.9)	.227
Patients' age (years)								
<15	17 (23.9)	6 (8.5)	1 (1.4)	0 (0.0)	6 (8.5)	9 (12.7)	39 (9.2)	
15–24	11 (15.5)	10 (14.1)	10 (14.1)	9 (12.7)	23 (32.4)	20 (28.2)	83 (19.5)	
25–34	6 (8.5)	1 (1.4)	11 (15.5)	10 (14.1)	7 (9.9)	9 (12.7)	44 (10.3)	
35–44	4 (5.6)	4 (5.6)	15 (21.1)	7 (9.9)	10 (14.1)	10 (14.1)	50 (11.7)	
45–54	4 (5.6)	9 (12.7)	17 (23.9)	10 (14.1)	11 (15.5)	7 (9.9)	58 (13.6)	
55–64	8 (11.3)	9 (12.7)	6 (8.5)	11 (15.5)	8 (11.3)	12 (16.9)	54 (12.7)	
>65	21 (29.6)	32 (45.1)	11 (15.5)	24 (33.8)	6 (8.5)	4 (5.6)	98 (23.0)	<.001

Statistical evaluation: Chi-squared tests. AP: apical periodontitis; NAP: no apical periodontitis; RCT: root canal treatment.

The kappa coefficients for inter- and intra-examiner reliability of PAI recordings were $\kappa = 0.85$ and $\kappa = 0.81$, respectively, and the percentage agreements were 93% and 91%, respectively.

In total, the technical quality of root filling was optimal in 57% of the studied teeth; no difference existed by jaw ($p = .625$). The quality of root fillings varied by type of tooth ($p < .001$; Table 2). In anteriors, premolars and molars, the root fillings were considered optimal in 71%, 57% and 43% ($p < .001$), respectively. Optimal root fillings were most frequent in mandibular anteriors (73%) and least frequent in maxillary molars (35%). By type of tooth, no significant difference existed between jaws in the quality of root fillings, but in maxillary molars the quality of root fillings tended to be poorer than in mandibular molars (35% vs. 51% optimal; $p = .062$).

The length of follow-up (time from root filling to the latest follow-up) varied between 6 and 105 months, the mean being 45 (SD 25) months. Table 3 presents success of RCT by type of tooth (anteriors, premolars, molars) according to preoperative periapical status, quality of root filling and length of follow-up. The overall SR of RCT was 67.4%. The outcome varied by type of tooth; the SRs was greatest in anteriors, and smallest in molars. No significant difference existed in the SRs by jaw (maxillary 65.3% vs. mandibular teeth 69.5%; $p = .352$; data not shown). Teeth with preoperative AP had a significantly smaller SR than teeth without AP ($p < .001$). The difference between SRs according to preoperative periapical status (AP vs. no AP) was significant by type of tooth both in premolars and molars, but not in anteriors. Overall, the impact of type of tooth on outcome of RCT only existed in AP teeth ($p = .001$) and in teeth with suboptimal root fillings ($p = .037$). Initial RCTs had an SR of 68.1% and retreatments 59.5%; this difference was non-significant ($p = .283$; data not shown). Teeth with optimal root fillings had greater SR than teeth with suboptimal root fillings ($p < .001$). Similar differences in SRs according to the quality of root filling were also found separately for each tooth type: anteriors, premolars and molars.

Simultaneous assessment of factors impacting the outcome of RCT is presented in Table 4. The results in this multifactorial model showed that non-molars were almost two times more likely to succeed than molars (OR = 1.8, 95% CI = 1.1–2.8). Success was 3.6 times more likely in teeth with optimal quality root fillings than in teeth with suboptimal fillings (OR = 3.6, 95% CI = 2.3–5.6) and 3.2 times more

Table 2. Quality of root fillings ($n = 426$), *n* (%), according to type of tooth by jaw.

Jaw and quality	Anterior *n* (%)	Premolar *n* (%)	Molar *n* (%)	Total *n* (%)	*p* Value (by tooth type)
Both jaws					
Optimal	101 (71)	81 (57)	61 (43)	243 (57)	<.001
Suboptimal	41 (29)	61 (43)	81 (57)	183 (43)	
Maxilla					
Optimal	49 (69)	45(63)	25 (35)	119 (56)	<.001
Suboptimal	22 (31)	26 (37)	46 (65)	94 (44)	
Mandible					
Optimal	52 (73)	36 (51)	36 (51)	124 (58)	.007
Suboptimal	19 (27)	35 (49)	35 (49)	89 (42)	
p Value (by jaw)	.579	.127	.062	.625	
Total	142 (33.3)	142 (33.3)	142 (33.3)	426 (100)	

Statistical evaluation: Chi-squared tests.
Root filling quality: optimal = root filling length flush (0–2 mm from radiographic apex) and root filling density optimal, otherwise suboptimal.

Table 3. Success,[a] *n/n* (%), of root canal treatments ($n = 426$) by type of tooth (combined by jaw) according to preoperative periapical status, quality of root filling and length of follow-up (months).

	Anterior *n/n* (%)	Premolar *n/n* (%)	Molar *n/n* (%)	Total *n/n* (%)	*p* Value (by tooth type)
Preoperative periapical status					
AP	60/84 (71.4)	38/67 (56.7)	34/81 (42.0)	132/232 (56.9)	.001
NAP	49/58 (84.5)	61/75 (81.3)	45/61 (73.8)	155/194 (79.9)	.320
p Value	.070	.001	<.001	<.001	
Quality of root filling					
Optimal	85/101 (84.2)	62/81 (76.5)	46/61 (75.4)	193/243 (79.4)	.301
Suboptimal	24/41 (58.5)	37/61 (60.7)	33/81 (40.7)	94/183 (51.4)	.037
p Value	.001	.041	<.001	<.001	
Length of follow-up (months)					
6–11	11/12 (91.7)	9/13 (69.2)	4/6 (66.7)	24/31 (77.4)	.318
12–23	27/33 (81.8)	14/15 (93.3)	13/24 (54.2)	54/72 (75.0)	.011
24–47	32/48 (66.7)	27/41 (65.9)	30/48 (62.5)	89/137 (65.0)	.903
>48	39/49 (79.6)	49/73 (67.1)	32/64 (50.0)	120/186 (64.5)	.004
p Value	.177	.213	.561	.223	
Total	109/142 (76.8)	99/142 (69.7)	79/142 (55.6)	287/426 (67.4)	.001

Statistical evaluation: Chi-squared tests.
AP: apical periodontitis; NAP: no apical periodontitis.
Quality of root filling: Optimal = root filling length flush (0–2 mm from radiographic apex) and root filling density optimal, otherwise suboptimal.
[a]Radiographic findings scored as 'healed' or 'healing' at follow-up (6–105 months).

Table 4. Factors related to the success[a] of root canal treatment (RCT) ($N = 426$) by means of logistic regression modelling.

	Estimate	SE	OR	95% CI	*p* Value
Type of tooth (non-molar vs. molar)	0.570	0.235	1.8	1.1–2.8	.016
Quality of root filling (optimal vs. suboptimal)	1.272	0.230	3.6	2.3–5.6	<.001
Preoperative periapical status (AP absent vs. present)	1.173	0.239	3.2	2.0–5.2	<.001
Treatment modality (initial RCT vs. retreatment)	0.078	0.384	1.1	0.5–2.3	.839
Constant	−0.844	0.399	0.430		
HL = 0.657					

AP: apical periodontitis; RCT: root canal treatment; SE: standard error; OR: odds ratio; CI: confidence interval; HL: Hosmer and Lemeshow test for goodness of fit.
[a]Radiographic findings scored as 'healed' or 'healing' at follow-up (6–105 months).

likely in teeth with no preoperative AP than in teeth with AP (OR = 3.2, 95% CI = 2.0–5.2).

Discussion

This is one of the few investigations on RCT outcome in general dental practice in terms of periapical healing. This study investigated the quality of root fillings and the radiographic outcome of RCTs performed in a public oral health care unit by type of tooth. The SR of RCT (67.4%) in this practice-based study fell below those obtained in various studies from teaching or specialist clinics. The outcome varied by type of tooth; RCTs in molars were 1.8 times less likely to succeed. Likewise, the technical quality of root fillings was poorest in molars; optimal root fillings were achieved only in 43% of molars. Both, the quality of root filling and the presence of preoperative AP were significant predictors of outcome of RCT.

The material of this study is from general dental practice and all the studied RCTs were performed by GDPs. The patients are inhabitants of Helsinki City in all ages (9–93 years). Thus, the present findings reflect the outcome of RCTs in real-life general dental practice, in contrast to many previous studies from teaching or specialist clinics. While the real-life aspect is a strength of this study, it inevitably entails variation in the clinical experience of the GDPs, which in turn may be seen as a limitation. To evaluate differences between tooth types, equal numbers of each tooth type were included.

The outcome of RCT by means of periapical healing has seldom been studied in general dental practice, which makes the present study unique. In line with many endodontic studies, the radiographic outcome of RCT was defined by periapical radiography. Despite the superiority of cone-beam computed tomography in the evaluation of periapical status, periapical radiography is still considered the standard examination of periapical status [18]. The dichotomization of the outcome (success/failure) supresses the information, since also uncertain cases have to fall into one of the categories. This approach, however, is common in endodontic studies [2,5,6,19–21]. In this study, kappa scores for the inter- and intra-examiner reliability of PAI recordings were high, thus indicating reliable measurement of the radiographic outcome. The lack of clinical data can be considered a limitation of this study. The impact of this limitation on our results is probably minor as advocated by a study, which found no difference in the outcomes of RCT defined by clinical and radiographic, or solely by radiographic findings [22]. The follow-up duration for the RCTs in this study varied from 6 to 105 months (over 8 years), and for 75% of cases the follow-up was more than 2 years. Follow-up periods of varying lengths have existed in previous RCT outcome studies, too [5,21,23].

The technical quality of the root filling reflects the quality of the entire RCT. This study found optimal root fillings in 57% of the studied teeth, which is more than reported in cross-sectional studies (22–56%) [16,24], but less than found in teaching clinics (67–81%) [1,19,25]. In cross-sectional studies, the data are based on RCTs performed by unknown practitioners, possibly not all GDPs. Therefore, comparison of the present findings with these studies is not straightforward. A fairly recent Swedish study described optimal root fillings in 38% of teeth treated by GDPs before an education intervention and in 51% after the intervention [26]. Another Swedish study examined 153 RCTs performed by GDPs in 19-year-olds and found adequate root fillings in 49% of teeth [5]. The present study found inadequate root fillings most frequently in molars, which is consistent with previous studies [5,11,19,24]. No significant difference in the quality of root fillings existed by jaw, but there tended to be a difference between maxillary and mandibular molars (35% vs. 52%; $p = .062$), which is clinically noteworthy.

The overall SR of RCT was 67.4%, given that equal numbers of all tooth types were included in the study. This SR falls well below that reached in RCTs performed by dental students in the same organization (84.1%) [3] and in various other studies from teaching or specialist clinics [1,2]. Only a few studies investigating periapical healing of RCTs provided by GDPs have been published. A study from the US compared the outcomes for different RCT providers and found an SR of 78.4% for civilian GDPs [21]. That study, however, consisted of initial RCTs only, while the present study included 9% retreatments. Another US study examined outcomes of RCT in private general practice and reported an SR of 81.9%, but approximately one-third of the RCTs were performed by endodontists, not GDPs [6]. A Swedish study investigated RCTs ($n = 153$) of 19-year-olds and found AP in 52% of root-filled teeth [5], thus the SR was only 48%. A study from the British armed forces reported 57% of cases to be definitely and 28% probably successful [27]. In the present study, preoperative AP weakened the success of RCT, as could be expected from previous studies [15]. Contrary to most previous studies [1,3,28], this study found no difference in SRs of initial RCTs and retreatments, but the number of retreatments was small ($n = 37$).

In the primary analyses, a noteworthy impact of type of tooth on the outcome of RCT was only found in teeth with preoperative AP or with suboptimal root fillings. In the multifactorial model, also tooth type had an independent impact on success of RCT; success was 1.8 times more likely in non-molars than molars. The more profound factors influencing

the outcome, however, were optimal quality of root filling (OR = 3.6) and the absence of preoperative AP (OR = 3.2).

Longitudinal outcome studies from teaching and specialist clinics have shown that it is possible to control and heal AP. Cross-sectional studies, however, have failed to show that the dental profession on a whole has succeeded in the control and elimination of AP [29]. Therefore, it can be postulated that discordance between the presumed standard of care and actual clinical practice exists [30]. In the teaching and specialist clinics, the common reasons for RCT failure, such as poor aseptic control, undetected root canals, inadequate instrumentation and inadequate temporary and permanent fillings, are strictly controlled [29]. A particular challenge for dentists are RCTs of molars, as they are demanding to treat and are treated nowadays more often than in past decades. A Swedish study found AP in root-filled teeth to be more frequent in 2003 than in 1973 and postulated that this might be due to the greater proportion of molars among root-filled teeth in 2003 [11]. Recent studies show improvement in the quality of RCT during the last decades [26,31], but further upgrading is still warranted.

Further longitudinal studies on the outcome of RCT in general dental practice are needed. The low frequency of optimal root fillings and the consequent poor success rate in molars treated by GDPs are alarming. GDPs might see RCT more as treating the symptoms of a patient than controlling the infection [32], which should be the main goal of RCT. Furthermore, many dentists find RCTs difficult and strenuous to perform and may therefore accept substandard quality in their root fillings [33]. Continuous education of dentists is essential. Equally important, is the possibility for division of work between dentists and endodontic specialists in more demanding cases, such as molars.

Conclusion

The radiographic outcome of RCT in general dental practice failed to reach the SRs presented in endodontic outcome studies from controlled settings. The technical quality of root fillings and the outcome of RCT were poorest in molars. Improvement in the quality of RCT by GDPs is called for.

Disclosure statement

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