



# Impact of type of tooth on outcome of non-surgical root canal treatment

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## Abstract

**Objectives** We assessed the impact of type of tooth on the outcome of root canal treatment (RCT) according to factors potentially weakening the prognosis such as preoperative apical periodontitis (AP) and treatment modality (primary or secondary RCT).

**Materials and methods** We scrutinized patient documents including pre- and postoperative radiographs of 640 permanent teeth receiving non-surgical RCT at Helsinki University Clinic in 2008–2011. Of teeth, 44% were molars, 32% premolars, and 24% anterior teeth. Patients' mean age was 51.5 years; 51% were male. AP was present in 60.5% of teeth preoperatively. We used the periapical index (PAI) to assess the radiographs and defined radiographically “healthy” and “healing” cases as successful. Statistical evaluation included chi-squared tests, Fisher's exact tests, *t* tests, and logistic regression modeling.

**Results** The overall success rate (SR) was 84.1%; 88.3% for primary and 75.5% for secondary RCT ( $p < 0.001$ ). The SRs for anterior teeth, premolars and molars were 85.6%, 88.8%, and 79.7%, respectively. Teeth with and without AP had SRs of 77.3% and 94.5%, respectively ( $p < 0.001$ ). The RCTs were more likely to succeed in anterior teeth and premolars than in molars (OR 1.7; 95% CI 1.1–2.7) and in females than in males (OR 1.9; 95% CI 1.2–3.1).

**Conclusions** Apart from existing AP and retreatment scenario, also, the type of tooth and gender had a significant influence on the outcome of RCT in this study.

**Clinical relevance** The prognosis of RCT varies by type of tooth; special attention should be given to RCT of molar teeth.

**Keywords** Endodontic · Periapical index (PAI) · Outcome · Root canal treatment · Tooth type

## Introduction

Previous reports on outcome of root canal treatment (RCT) have introduced apical periodontitis (AP) as a prominent factor weakening the prognosis of RCT [1–5]. The prognosis may also depend on the type of tooth, although earlier evidence is contradictory [6–10], and the results by type of tooth are rarely stratified by periapical status.

Type of tooth is important in clinical work when assessing treatment options and informing patients.

However, it has seldom been included in multifactorial models examining factors possibly affecting the prognosis of RCT. Periapical healing seems to follow RCT more frequently in premolars and anterior teeth than in molars [6–8] and in single-rooted than in multirouted teeth [11, 12]. A systematic review of primary RCTs concluded, however, that there was no difference in outcome by type of tooth, but discussed that the evidence is weakened by the fact that the studies had not stratified their results by periapical status [13].

Previous studies have shown consistently that AP preceding RCT affects the outcome negatively; success rates (SRs) vary between 92 and 96% for teeth without AP and between 74 and 86% for teeth with AP in primary (first-time) RCTs [2, 12, 14]. Secondary (retreatment) RCTs are mostly indicated by the presence of AP, resulting in SRs between 62 and 83% [7, 12, 14].

This retrospective study investigated the impact of type of tooth on the outcome of RCT taking into account the presence of preoperative AP and treatment modality (primary or secondary RCT).

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## Material and methods

### Ethical consideration

This study was approved by the Department of Social Services and Health Care of the City of Helsinki (HEL 2012-012378). Data were collected from electronic patient records and radiographs and stored in a database using running numbers as patient identification.

### Setting and cases

All RCTs, with no restriction by type of tooth, were performed by fourth- and fifth-year dental students under tight individual supervision of qualified endodontists. Dental students at the University of Helsinki performed their clinical training at Helsinki University Clinic as part of the public oral health service of the City of Helsinki. Since 2001, these services have been open to all citizens. The patients receiving RCT were either admitted for comprehensive dental care by making an appointment themselves or upon referral for RCT by dentists working in other units of the public services. RCT followed a strict protocol emphasizing aseptic control.

Patients who underwent RCT at Helsinki University Clinic between 2008 and 2011 formed the target population. The inclusion criteria were as follows: a follow-up radiograph taken a minimum of 6 months after root canal filling, diagnosable pre- and postoperative radiographs available, adequate patient records of the RCT available, no fractured instrument existing in the canals preoperatively, and no endodontic surgery preplanned for the case.

### Data recordings

Data collected from patient documents included the type of tooth as anterior (incisors and canines), premolars, and molars, separately for maxillary and mandibular teeth. We recorded preoperative periapical status as apical periodontitis (AP) or no apical periodontitis (NAP) and treatment modality as primary (first-time) or secondary (retreatment) RCT. Patients' details included gender and age in years.

### Clinical protocol

The general protocol for endodontic treatment at Helsinki University Clinic at the time of the investigation is detailed below.

Before RCT, a preoperative radiograph is taken and the tooth is assessed in terms of restorability, periodontal status, and relevance in occlusion. The tooth is anesthetized (when needed), and caries and defective restorations are removed. An access cavity is made, root canals localized, rubber dam placed, and working field disinfected with 0.5% chlorhexidine

+ 96% ethanol solution (Klorhexol<sup>®</sup>; Takeda OY, Helsinki, Finland). Working length is determined using an electronic apex locator and confirmed with a radiograph when needed. Chemo-mechanical debridement is carried out with nickel-titanium (NiTi) hand files (K-files) and with rotary NiTi instruments (Profile<sup>®</sup>; Dentsply Sirona, Inc., York, PA, USA) with a minimum apical preparation size #35, taper 4%. For retreatment cases, the gutta-percha is removed using rotary instruments (R-endo<sup>®</sup>; Micro-Mega<sup>®</sup> SA, Besancon Cedex, France, or Protaper<sup>®</sup> Universal D1-3; Dentsply Tulsa Dental Specialties, Johnson City, TN, USA) and chloroform, if needed. Copious amounts of 0.5–1.0% sodium hypochlorite are used for irrigation. At the end of the preparation, the smear layer is removed with 17% ethylenediaminetetraacetic acid (EDTA). Klorhexol<sup>®</sup> is used for final irrigation. Most RCTs (94%), including treatments of vital teeth, are carried out on multiple visits for scheduling reasons. Between visits, the root canals are dressed with calcium hydroxide. A master cone radiograph is taken before the root canal filling. The root canals are obturated using the cold lateral condensation technique with gutta-percha and sealer (AH Plus<sup>®</sup>; Dentsply Sirona, Inc., York, PA, USA), and a postoperative radiograph is taken. The tooth is either restored in the same visit or temporized with two layers of temporary filling material (Cavit<sup>™</sup>-G; 3M<sup>™</sup>, St. Paul, MN, USA; and IRM<sup>®</sup>; Dentsply Caulk, Milford, DE, USA; or Cavit<sup>™</sup>-G and resin-modified glass ionomer) until final restoration.

### Assessment of radiographs

A majority of images were intraoral periapical radiographs. In some cases, if a panoramic radiograph was available and diagnosable, it was used in addition or solely (9% of cases) for assessment. Periapical radiographs were taken using a beam-guiding device and the paralleling technique. All radiographs were digital. The radiographs were assessed separately from clinical information, in a room with dimmed lights and a high-quality computer screen (EIZO<sup>®</sup> RadiForce MX220W; EIZO Corporation, Ishikawa, Japan). The periapical status was defined using the periapical index (PAI), a five-step scoring system with each step representing a shift from healthy periapical tissues to severe AP [15]. Preceding the assessment of PAI, the two examiners (a qualified endodontist, A.K., and an endodontics postgraduate student, E.L.) observed a set of 50 various radiographs. Written instructions and reference radiographs were available while examining the radiographs. For multirrooted teeth, a PAI score was assigned to each root but recorded by tooth as the greatest score of the roots. If in doubt between scores, the greater PAI score was chosen. The two examiners evaluated the radiographs by discussing them to reach consensus. In addition, an oral and maxillofacial radiologist was consulted about radiographs of maxillary molars because of their complex anatomy and position.

Outcome was recorded as follows:

1. Healthy: healthy periapical tissues (PAI scores 1–2)
2. Healing: apical radiolucency considerably smaller in follow-up radiograph than in preoperative radiograph, but not completely disappeared (PAI scores 3–4) in 4 years
3. No healing:
  - a) Periapical radiolucency remained the same (PAI scores 3–5)
  - b) Teeth extracted for endodontic reasons (persisting apical infection, fistula) or for reasons not recorded in documents available after root filling
  - c) Teeth receiving periapical surgery
4. Deteriorated: periapical radiolucency enlarged or a new periapical radiolucency emerged (PAI scores 3–5)

The outcome was then dichotomized as successful (healthy and healing) or unsuccessful (no healing and deteriorated).

## Statistical analysis

To evaluate differences between the groups, we used chi-squared tests and Fisher's exact test for frequencies and *t* tests for mean values. We considered *p* values below 0.05 to be statistically significant. Further, we analyzed factors related to outcome. We applied logistic regression modeling and calculated odds ratios (ORs) and their 95% confidence intervals (95% CIs). The Hosmer and Lemeshow test was used to assess goodness of fit for the models.

## Results

### Characteristics of cases

The mean age of all patients was 51.5 years (standard deviation [SD] 15.0; range 10–83). For patients receiving primary RCT, the mean age was 50.0 years (SD 15.7; range 10–83), and for patients receiving secondary RCT, 54.6 years (SD 13.0; range 21–83). This age difference was statistically significant ( $p < 0.001$ ). Of patients, 51% were male and 49% female.

A total of 640 permanent teeth with RCT were subject to analysis. Of these teeth, 44% were molars, 32% premolars, and 24% anterior teeth. The characteristics of root canal-treated teeth and patients are presented in Table 1.

AP occurred preoperatively in 60.5% of teeth and varied by type of tooth; mandibular anterior teeth had AP more often than other types of teeth (77.1% vs. 59.1%;  $p = 0.014$ ). Male patients had AP more often than female patients (64.5% vs. 56.2%;  $p = 0.032$ ).

## Outcome

The overall success rate (SR) for all RCTs was 84.1%. The time range of outcome assessment was 6–71 months. Only the most recent follow-up of each tooth was included in the data. The SRs for different lengths of follow-up are presented in Table 2.

Premolars had a significantly greater SR than molars (88.8% vs. 79.7%;  $p = 0.007$ ), but no such difference existed when premolars were compared with anterior teeth (88.8% vs. 85.6%;  $p = 0.363$ ) or anterior teeth were compared with molars (85.6% vs. 79.7%;  $p = 0.128$ ). No statistically significant difference was present in SRs of maxillary and mandibular teeth.

Teeth with primary RCT had a significantly greater SR than teeth with secondary RCT (88.3% vs. 75.5%;  $p < 0.001$ ). The difference between primary and secondary treatments existed also according to the type of tooth (anterior, premolars, molars). The greatest SRs were with primary RCTs of maxillary and mandibular premolars, 93.7% and 93.9%, respectively. The smallest SRs were for secondary RCTs of mandibular anterior teeth and maxillary and mandibular molars, 66.7%, 70.0%, and 70.6%, respectively (Table 3).

The SR for teeth with AP preoperatively, including both primary and secondary RCTs, was significantly smaller than for teeth without AP (77.3% vs. 94.5%;  $p < 0.001$ ). The difference varied by type of tooth; maxillary premolars ( $p = 0.001$ ), mandibular premolars ( $p = 0.025$ ), and mandibular molars ( $p < 0.001$ ) showed the greatest differences (Table 4). The SR was smallest for mandibular molars with AP preoperatively and greatest for maxillary premolars without AP, 71.3% and 100%, respectively.

Table 5 presents logistic regression modeling for evaluating the outcome of RCT. Success was more likely for anterior teeth and premolars than for molars (OR 1.7; 95% CI 1.1–2.7), in the absence than in the presence of AP (OR 4.3; 95% CI 2.4–7.8), in primary than in secondary RCT (OR 2.3; 95% CI 1.4–3.6), and in female patients than in male patients (OR 1.9; 95% CI 1.2–3.1). The age of the patient or the location of the tooth (maxilla vs. mandible) had no impact on the success of RCT.

## Discussion

This study investigated the impact of type of tooth on the outcome of RCT. We found an overall SR of 84.1%, which is comparable to rates reported in recent international studies [3, 5, 7, 12, 16]. The success was poorer in molars, in teeth with preoperative AP, in secondary RCTs, and in male patients. The impact of preoperative AP on the outcome of RCT varied by type of tooth.

The diversity of our sample speaks for the generalizability of our findings. The patients of this study came from the

**Table 1** Characteristics of root canal-treated teeth ( $n = 640$ ) enrolled in the study

Characteristic	All treated teeth		Primary RCT		Secondary RCT		<i>p</i> value
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	
Location and type of tooth							
Maxilla (all teeth)	335	52	224	35	111	17	0.226
Anterior	105	16	77	12	28	4	
Premolars	122	19	79	12	43	7	
Molars	108	17	68	11	40	6	
Mandible (all teeth)	305	48	204	32	101	16	0.144
Anterior	48	7	33	5	15	2	
Premolars	84	14	49	8	35	6	
Molars	173	27	122	19	51	8	
Patients' gender							
Male	327	51	226	35	101	16	0.219
Female	313	49	202	32	111	17	
Patients' age (years)							
< 35	92	15	75	12	17	3	0.010
35–44	92	14	65	10	27	4	
45–54	172	27	113	18	59	9	
55–64	151	24	95	15	56	9	
≥ 65	133	20	80	12	53	8	
Total	640	100	428	67	212	33	

*p* values based on chi-squared test refer to differences between primary and secondary root canal treatments (RCTs). Cell percentages refer to proportions of all RCT teeth ( $n = 640$ )

general population, which bodes well for the absence of a selection bias. The wide age range of the patients (10–83 years) ensures representative data. Compared with previous studies, where 17–31% of RCT teeth were molars [6, 7, 17], in our material, molars were slightly over-represented (44%). The distribution of RCT teeth in our data is, however, similar to that in a large Finnish survey material consisting of 6101 panoramic radiographs [18]. The overall SR reported in different studies may depend on proportions of various types of teeth in the study sample [19] and the proportion of teeth with AP preoperatively [20]. Our study sample contained 60.5% teeth with AP, which is more than in many earlier studies (35–57%) [7, 8, 11, 12, 21]. A limitation of this study is that the material is collected from patient documents only.

However, a similar approach has been used in many previous reports [9, 10, 22–24].

The RCTs of this study were carried out by fourth- and fifth-year dental students, which could be considered a limitation of this study. However, under the strict supervision by endodontists, the RCTs performed by students succeed well. Similar clinical settings are common in many previous outcome studies, too [1, 8, 9, 14, 17].

We defined the success of RCT by periapical radiography, which is still considered the standard examination [25] and is in everyday use despite the increasing utilization of cone-beam computed tomography. For a minority (9%) of cases, we used panoramic radiography. Panoramic radiographs are usually considered less sensitive in periapical diagnosis, but

**Table 2** Success (%) of root canal treatments according to the length of follow-up

Follow-up (months)	Success, healthy/healed		Success, healing		Success, total			
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%		
6–11	121	19	72	59.5	24	19.8	96	79.3
12–24	298	47	209	70.1	41	13.8	250	83.9
> 24	221	34	170	76.9	22	10.0	192	86.9
Total	640	100	451	70.5	87	13.6	538	84.1

Success, healthy (teeth with no initial apical periodontitis)/healed (teeth with initial apical periodontitis) = radiographic findings scored as “healthy” at follow-up. Success, healing = radiographic findings scored as “healing” at follow-up

**Table 3** Success (%) of root canal treatment (RCT) according to treatment modality and type of tooth; *p* values refer to differences between primary and secondary RCT

Type of tooth by jaw	Primary RCT		Secondary RCT		Total		<i>p</i> <sup>a</sup> value
	<i>n</i>	Success <sup>b</sup> (%)	<i>n</i>	Success <sup>b</sup> (%)	<i>n</i>	Success <sup>b</sup> (%)	
Anterior							
Maxilla	77	89.6	28	82.1	105	87.6	0.304
Mandible	33	87.9	15	66.7	48	81.3	0.081
Total	110	89.1	43	76.7	153	85.6	0.050
Premolars							
Maxilla	79	93.7	43	81.4	122	89.3	0.061
Mandible	49	93.9	35	80.0	84	88.1	0.053
Total	128	93.8	78	80.8	206	88.8	0.004
Molars							
Maxilla	68	85.3	40	70.0	108	79.6	0.057
Mandible	122	83.6	51	70.6	173	79.8	0.052
Total	190	84.2	91	70.3	281	79.7	0.007
Total	428	88.3	212	75.5	640	84.1	< 0.001

<sup>a</sup> Statistical evaluation by means of chi-squared tests or Fisher’s exact test

<sup>b</sup> Success = radiographic findings scored as “healthy” or “healing” at a minimum 6-month follow-up

contemporary panoramic radiographs with improved quality can be as accurate or even more accurate than periapical radiographs in molar regions [26]. We took teeth instead of roots as units of evaluation to avoid the possible skewness related to root-based analyses. All of the radiographs were assessed by two authors, who discussed the findings to reach consensus. Consequently, the inter-observer agreement was not measured, which is a limitation of this study.

We considered both “healthy” and “healing” teeth as successful as the follow-up period varied. In other words, we used “loose criteria,” as suggested by a systematic review [27]. Six months was the minimum follow-up. Almost 90% of periapical lesions that are going to heal eventually show signs of healing by 12 months, and reversal of the healing process is considered to be rare [28]. The healing can, however, be visible in radiographs rather soon after the RCT [21, 29]. For

**Table 4** Success (%) of root canal treatment according to preoperative periapical status and type of tooth

Type of tooth by jaw	NAP		AP		<i>p</i> <sup>a</sup> value	RD
	<i>n</i>	Success <sup>b</sup> (%)	<i>n</i>	Success <sup>b</sup> (%)		
Anterior						
Maxilla	45	93.3	60	83.3	0.124	10.0
Mandible	11	90.9	37	78.4	0.662	12.5
Total	56	92.9	97	81.4	0.053	11.5
Premolars						
Maxilla	53	100.0	69	81.2	0.001	18.8
Mandible	36	97.2	48	81.3	0.025	15.9
Total	89	98.9	117	81.2	< 0.001	17.7
Molars						
Maxilla	43	88.4	65	73.8	0.057	14.6
Mandible	65	93.8	108	71.3	< 0.001	22.5
Total	108	91.7	173	72.3	< 0.001	19.4
Total	253	94.5	387	77.3	< 0.001	17.2

*p* values refer to differences between NAP and AP teeth

NAP no apical periodontitis, AP apical periodontitis, RD rate difference in percentage points

<sup>a</sup> Statistical evaluation by means of chi-squared tests or Fisher’s exact test

<sup>b</sup> Success = radiographic findings scored as “healthy” or “healing” at a minimum 6-month follow-up

**Table 5** Success of root canal treatment (RCT) evaluated by means of logistic regression modeling

	Estimate	SE	OR	95% CI	<i>p</i> value
Type of tooth	0.541	0.239	1.7	1.1–2.7	0.023
Maxilla vs. mandible	0.143	0.234	1.2	0.7–1.8	0.542
NAP vs. AP	1.459	0.306	4.3	2.4–7.8	0.000
1° vs. 2° RCT	0.828	0.234	2.3	1.4–3.6	0.000
Age	0.004	0.008	1.0	1.0–1.0	0.644
Female vs. male	0.662	0.237	1.9	1.2–3.1	0.005
HL = 0.519					

Success = radiographic findings scored as “healthy” or “healing” at a minimum 6-month follow-up. Type of tooth = anterior and premolars vs. molars

1° RCT primary root canal treatment, 2° RCT secondary root canal treatment, AP apical periodontitis, NAP no apical periodontitis, SE standard error, OR odds ratio, CI confidence interval, HL Hosmer and Lemeshow’s test for goodness of fit

reasons related to the patient’s or student’s schedules, some follow-ups took place later than planned, which can be considered a limitation of our study. Similar variation in outcome assessment periods exists, however, in many previous studies [1, 5, 16, 17]. In case the lesion was not fully healed in 4 years, we considered the treatment failed according to the ESE guidelines [30], even though on rare occasions, healing can take considerably longer [23].

The overall SR (84.1%) found here is in line with many earlier studies [3, 5, 7, 12, 16] and with a meta-analysis [31] reporting a cumulative SR around 83%. We found RCT in molars less likely to succeed than in anterior teeth and premolars. The impact of type of tooth on outcome has been evaluated before with varying results [6–10, 13], but rarely in a multifactorial model including other factors consistently shown to worsen the prognosis.

We found the SR for teeth with AP to be less than the rate for teeth without AP, supporting the conclusions from systematic reviews [13, 32]. The impact of AP on outcome varied by type of tooth. In the presence of AP, maxillary and mandibular molars had the smallest SRs, but the rate differences (RD) between teeth with and without AP were greatest for maxillary premolars and mandibular molars. In a French study with 91 patients, the risk of failure was seven times greater for posterior than for anterior teeth without AP [33]. In teeth with AP, the same study reported a fourfold higher risk of failure for multirooted teeth than for single-rooted teeth. A study investigating 100 teeth with AP found an overall SR of 95% [17], but only 17% of teeth in their study were molars and the results were not presented by type of tooth. Therefore, the results cannot be compared with ours. A recent Swedish study examined only maxillary molars ( $n = 73$ ), 86% of which had AP preoperatively, and reported an SR of 81% [34], which is close to our result for maxillary molars (79.6%).

We found primary RCTs to be more likely to succeed than secondary RCTs, consistent with many previous studies [7, 12, 16, 17]. A prospective study, however, revealed no such difference [5]. In our study, there was a significant difference in SRs between primary and secondary RCTs also for the type of tooth (anterior, premolars, and molars). A study using multifactorial analysis separately for primary and secondary treatments found molars to be less likely to succeed than anterior teeth and premolars, but only for secondary treatments [4]. Another study investigating secondary treatments reported no difference in outcome by type of tooth [35]. In our study, the SR of secondary RCTs of mandibular anterior teeth was relatively small, but their amount was insufficient to show a statistical difference, and therefore, further investigation is needed to establish the prognosis of RCTs in mandibular anterior teeth.

The age of the patient had no impact on the success of RCT, which is in line with many earlier studies [11, 12, 35, 36], although some contradictory findings also exist [8, 16]. We found RCT to be twice as likely to succeed in women than in men, consistent with a study published in 1983 analyzing 20-year endodontic success [24] and another study published in 2001 [37]. This gender difference is difficult to interpret and is contrary to some previous studies [2, 3, 9, 10, 14, 22]. A recent epidemiological study in Finland found men to have AP more often than women, despite root-filled teeth being less frequent in men [38]. In our sample, AP occurred preoperatively more often in men.

All RCTs evaluated in this study were carried out under a strict protocol, which adds to the value of our findings. The results indicate that the success of RCT is to be expected, even in unexperienced hands, when guidelines are followed and good aseptic control is maintained. Epidemiological studies reflect the outcome of RCTs in general dental practice, and they show AP in 16–44% of root canal-treated teeth [38–40]. Many general dentists find RCTs difficult and stressful to perform [41], and cite economic and time constraints as reasons for accepting substandard quality in root fillings [42]. Attention should be given to the circumstances in which RCTs are performed and especially to the apparently infrequent use of a rubber dam [43].

## Conclusion

The overall outcome of RCT was comparable to that found in recent international studies. Apart from existing AP and retreatment, which consistently have been shown to worsen the prognosis, also, the type of tooth and gender of the patient had a significant influence on the outcome of RCT. The prognosis is not the same for every RCT; special attention should be given to RCTs of molars.

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## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

**Ethical approval** This article does not contain any studies with human participants or animals performed by any of the authors.

**Informed consent** For this type of study, formal consent is not required.

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