Prognostic Factors in Apical Surgery with Root-end Filling: A Meta-analysis

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Abstract

Introduction: Apical surgery has seen continuous development with regard to equipment and surgical technique. However, there is still a shortage of evidence-based information regarding healing determinants. The objective of this meta-analysis was to review clinical articles on apical surgery with root-end filling in order to assess potential prognostic factors. **Methods:** An electronic search of PubMed and Cochrane databases was performed in 2008. Only studies with clearly defined healing criteria were included, and data for at least two categories per prognostic factor had to be reported. Prognostic factors were divided into patient-related, tooth-related, or treatment-related factors. The reported percentages of healed teeth ("the healed rate") were pooled per category. The statistical method of Mantel-Haenszel was applied to estimate the odds ratios and their 95% confidence intervals. **Results:** With regard to tooth-related factors, the following categories were significantly associated with higher healed rates: cases without preoperative pain or signs, cases with good density of root canal filling, and cases with absence or size ≤5 mm of periapical lesion. With regard to treatment-related factors, cases treated with the use of an endoscope tended to have higher healed rates than cases without the use of an endoscope. **Conclusions:** Although the clinician may be able to control treatment-related factors (by choosing a certain technique), patient- and tooth-related factors are usually beyond the surgeon's power. Nevertheless, patient- and tooth-related factors should be considered as important prognostic determinants when planning or weighing apical surgery against treatment alternatives. *(J Endod 2010;36:957–973)*

Key Words

Apical surgery, healing predictors, meta-analysis, prognostic factors, root-end filling

Apical surgery is often a last resort to maintain an endodontically treated tooth with a persistent periapical lesion. After the introduction of microsurgical principles and new materials for apical obturation in endodontic surgery in the early 1990s, healed rates of apical surgery with root-end filling have improved but remain around 80% to 90% (1).

In order to enhance the outcome of a surgical procedure, three different strategies may be considered: (i) improvement of technical equipment/instruments, (ii) changes in surgical technique, and (iii) appropriate case selection. The choice of treatment, however, is often based on individual experience and skill rather than on evidence-based prognostic factors. The latter would allow narrowing the indication for a certain treatment by weighing various predictors and thereby increasing the likelihood of a favorable outcome.

Limited information is available with regard to prognostic factors in apical surgery. Most clinical studies on apical surgery evaluate the outcome with respect to the root-end filling material. Only a few clinical studies have assessed potential prognostic factors in apical surgery, such as the age and sex of the patient, the type of treated tooth, or the presence of a radicular post. Studies evaluating multiple prognostic factors with regard to healing outcome of periapical surgery are sparse (2–6). The number of subjects within a single study may often be too small to find a statistically significant difference comparing two or more categories with regard to healing outcome. Systematic reviews and meta-analyses may provide additional and important information to the clinician in order to weigh apical surgery against treatment alternatives such as conventional endodontic (re-) treatment or tooth extraction and prosthodontic replacement.

The first systematic review of endodontic surgery by Peterson and Gutmann (7) evaluated the outcome of resurgery cases. They reported that 35.7% of cases healed successfully after resurgery, 26.3% healed with uncertain results, and 38% did not heal at the 1-year follow-up. A systematic review of the in vivo performance of retrograde obturation materials was published by Niederman and Theodosopoulou (8). Most of the included studies compared amalgam with a competitor material. They reported a significant caveat because there were only two randomized clinical trials (RCTs) and only one controlled clinical trial for each material. Mead et al (9) performed an electronic and manual search to investigate the levels of evidence for the outcome of endodontic surgery. They wrote that the majority of frequently quoted "success and failure" studies were case series (level of evidence 4 according to the Centre for Evidence-based Medicine at Oxford). Del Fabbro et al (10) performed a systematic review comparing the outcome of surgical versus nonsurgical retreatment. The finding that healed rates, at least in the short-term, were higher for cases treated surgically as compared with those treated nonsurgically was based on two RCTs only. They also found in a single RCT that healed rates in the medium- to long-term were very similar

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TABLE 1. Included Clinical Studies ($N = 38$)

Author(s)	Follow-up	Study design	N teeth initial/N teeth final	Drop-out rate (%)	Assessed factor(s)
Persson, 1982 (116)	1 year	Prospective	27/26	4	Type of tooth
Dalal & Gohil, 1983 (117)	6 months	Prospective	40/40	0	Retrofilling material
Skoglund & Persson, 1985 (118)	6 months-7 years (mean 3 years)	Retrospective[a]	Unknown/27	NA	Age, sex
Dorn & Gartner, 1990 (119)	6 months-10 years	Retrospective	Unknown/488	NA	Retrofilling material
Friedman et al, 1991 (120)	6 months-8 years	Retrospective	Unknown/136[b]	NA	Age, sex, type of tooth
Lustmann et al, 1991 (2)	6 months-8 years	Retrospective	Unknown/136[c]	NA	**Type of restoration, percussion sensitivity**, preoperative signs, length of root-canal filling, density of root-canal filling, presence of post, size of lesion, **outline of lesion, experience of surgeon**
Waikakul & Punwutikorn, 1991 (121)	6 months-2 years	Prospective	66/62	6	Retrofilling material
Cheung & Lam, 1993 (122)	Minimum 2 years	Retrospective	Unknown/32	NA	Type of tooth
Pantschev et al, 1994 (123)	3 years	Prospective	Unknown/103	NA (21% patients)	Retrofilling material
Jesslén et al, 1995 (124)	5 years	Randomized clinical trial[d]	105/82	22	Retrofilling material
August, 1996 (125)	Minimum 10 years	Retrospective[e]	Unknown/19	NA	Type of tooth
Danin et al, 1996 (126)	1 year	Prospective[f]	19/19	0	Length of root canal filling, size of lesion
Rud et al, 1997 (127)	2-4 years	Retrospective	909/551	39	Type of tooth, **root canal filling related to resection level**
Bader & Lejeune, 1998 (128)	1 year	Prospective	320/254	21	Technique of root-end cavity preparation, **use of laser irradiation**
Testori et al, 1999 (129)	1-6 years (mean 4.6 years)	Retrospective[g]	Unknown/302	NA	Type of tooth, technique of root-end cavity preparation, retrofilling material
Zuolo et al, 2000 (130)	1-4 years	Prospective	114/102	11	Age, sex, type of tooth, **histopathology of lesion**
Rahbaran et al, 2001 (3)	Minimum 4 years	Retrospective[h]	Unknown/176	NA	Age, gender, type of tooth, **coronal seal**, preoperative pain, preoperative signs, **presence of root canal filling**, density of root-canal filling, endodontic re-treatment, presence of post, presence of lesion, type of surgery, **type of surgeo**n, technique of root-end cavity preparation, retrofilling material
Jensen et al, 2002 (4)	1 year	Randomized clinical trial	134/122	9	Retrofilling material
Rubinstein & Kim, 2002 (131)	5-7 years	Prospective[i]	91/59	35	Type of tooth
Vallecillo et al, 2002 (132)	1 year	Prospective	29/24	17	Technique of root-end cavity preparation
Chong et al, 2003 (133)	2 years	Randomized clinical trial	131/108	18[j]	Retrofilling material
Maddalone & Gagliani, 2003 (134)	3 years	Prospective	146/120	22	Type of tooth, presence of post
Schwartz-Arad et al, 2003 (135)	6-45 months (mean 11 months)	Retrospective[k]	262/122	53	Type of surgery, retrofilling material
von Arx et al, 2003 (136)	1 year	Prospective	129/115	11	Use of endoscope

(Continued)

TABLE 1. (*Continued*)

Author(s)	Follow-up	Study design	N teeth initial/N teeth final	Drop-out rate (%)	Assessed factor(s)
Wesson & Gale, 2003 (137)	Minimum 5 years	Prospective	1007/790	22	Age, sex, type of tooth, presence of lesion, buccal bone plate
Sahlin Platt & Wannfors, 2004 (138)	1 year	Randomized clinical trial	34/34	0	Length of root canal filling, retrofilling material
Wang et al, 2004 (5)	4-8 years	Prospective[l]	155/90	42	Age, length of root canal filling, endodontic retreatment, size of lesion, type of surgery, **use of hemostatic agent**, **intraoperative complications**, **restoration at follow-up**
Wang et al, 2004 (139)	6 months-12 years	Retrospective	238/194	18	Type of surgery
Gagliani et al, 2005 (140)	5 years	Prospective	185[m]/164[m]	11	Type of tooth, type of surgery
Lindeboom et al, 2005 (141)	1 year	Randomized clinical trial	100/100	0	Retrofilling material
Taschieri et al, 2005 (142)	1 year	Randomized clinical trial	50/46	8	Type of tooth, presence of post, **type of microtip**
Filippi et al. 2006 (143)	1 year	Prospective	114/110	4	Type of tooth, preoperative pain, presence of post, use of antibiotics
Taschieri et al, 2006 (144)	1 year	Randomized clinical trial	80/71	11	Type of tooth, presence of post, use of endoscope
Tsesis et al, 2006 (145)	6 months-4 years	Retrospective	110[n]/71[n]	35	Technique of root-end cavity preparation
de Lange et al, 2007 (146)	1 year	Randomized clinical trial	399/290	27	Type of tooth, technique of root-end cavity preparation
von Arx et al, 2007 (6)	1 year	Prospective	194/191	2	Age, sex, **smoking**, type of tooth, preoperative pain, preoperative signs, length of root-canal filling, presence of post, presence of lesion, size of lesion, **marginal bone level**, type of surgery, use of antibiotics, retrofilling material, **postoperative complications**
Wälivaara et al, 2007 (147)	1 year	Prospective	56/55	2	Type of tooth
Taschieri et al, 2007 (148)	1 year	Prospective	30/27	10	Presence of post

NA, not available.

Boldface font indicates that no other study had assessed this prognostic factor; hence, this factor was not further evaluated.

[a]In 3 out of 27 teeth (11%) no root-end filling was placed.

[b]Unit = root.

[c]Unit = root; in 13 out of 136 roots (10%), no root-end filling was placed; same sample as Friedman et al (1991) but data not duplicated.

[d]Same sample as Zetterqvist et al (1991) (108)

[e]Apicectomies with and without retrofilling, but data coud be extracted for retrofilling cases.

[f]Randomized study comparing conventional retreatment and apical surgery; only surgical cases included for this analysis.

[g]Unit = root; all cases with standard retropreparation were retrofilled with amalgam, and all cases with ultrasonic retropreparation were filled with SuperEBA.

[h]In 22 out of 176 teeth (12.5%), no root-end filling was placed; the very low healing rate was attributed to several factors by the authors (ie, no "incomplete healing" category, more complex profile of referred cases, 4-year follow-up).

[i]Unit = root; same sample as Rubinstein & Kim (1999) (110); study started originally with 128 cases; only successful 1-year-cases were assessed after 5-7 years.

[j]Forty-five of 131 (34%) failed to attend the 2-year follow-up, but 22 cases with complete healing when reviewed at 1 year were included in the "complete healing" category for the 2-year review.

[k]Only radiographic (not clinical) determination of healing; "incomplete healing" was defined as "uncertain healing" according to specified criteria.

[l]In 15 out of 155 teeth (10%), no root-end filling was placed.

[m]Patients (but evaluation unit = root, n = 231 roots); "incomplete healing" was defined as "uncertain healing" according to specified criteria.

[n]Patients (but evaluation unit = tooth, n = 88 teeth).

TABLE 2. ORs and CIs of Prognostic Factors with Two Categories

	OR	CI (0.95) Lower limit	Upper limit	P value	Test for homogeneity P value
Patient-related factors					
Age	1.07	0.84	1.36	0.6	0.13
Sex	0.85	0.67	1.07	0.17	0.61
Tooth-related factors					
Preoperative pain	0.48	0.29	0.77	<0.01	0.13
Preoperative signs	0.63	0.39	1.02	<0.01	0.07
Length of RCF	0.77	0.5	1.19	0.24	0.49
Density of RCF	2.00	1.19	3.36	<0.01	0.74
Endodontic retreatment	1.56	0.77	3.16	0.22	0.66
Presence of post/screw	0.76	0.53	1.09	0.13	0.65
Presence of lesion	0.73	0.55	0.97	0.01	0.21
Size of lesion	1.82	1.13	2.92	0.01	0.43
Treatment-related factors					
Type of surgery	2.06	1.46	2.91	<0.01	<0.01
Use of antibiotics	0.66	0.32	1.36	0.27	0.28
Use of endoscope	2.43	0.99	5.97	0.05	0.77
Technique of root-end cavity preparation	0.32	0.24	0.44	<0.01	0.01

CI, confidence interval; OR, odds ratio; RCF, root canal filling.

for the two procedures. The authors concluded that there is currently scarce evidence for a sound decision-making process among alternative re-treatments of periradicular pathosis.

Friedman (11) published a thorough review about the prognosis and expected outcome of apical surgery. The article comprehensively evaluated pre- and intraoperative factors that may influence the outcome of apical surgery. The review covered the material published until early 2005. With regard to preoperative factors, the outcome was found to be better in teeth with small lesions and excessively short or long root canal fillings, and it was poorer in teeth treated surgically for the second time. With regard to intraoperative factors, the choice of the root-end filling material and the quality of the root-end filling were found to influence the outcome. The objective of the present study was to perform an updated meta-analysis to assess potential prognostic factors for healing outcome in apical surgery with root-end filling by reviewing all levels of clinical evidence.

Material and Methods

The main inclusion criterion for the selection of a clinical study was that it had evaluated apical surgery with placement of a root-end filling. Studies on apical surgery with orthograde root canal filling or about apicectomy alone without root-end filling were excluded. In addition, experimental and animal studies were excluded. The literature search with PubMed and Cochrane databases was conducted in 2008, including articles published from 1980 to 2007 in the following languages: English, German, French, Spanish, Italian, Portuguese, and Scandinavian languages. The search strategy was based on the following Medical Subject Heading (MeSH) terms: "(apical surgery) OR (apical microsurgery) OR (periapical surgery) OR (periradicular surgery) OR apicoectomy OR apicectomy OR (tooth apex surgery) NOT (case report OR case reports) NOT (in vitro) NOT experimental."

Additionally, a hand search was performed of the following journals: *Journal of Endodontics, International Endodontic Journal*, *Oral Surgery Oral Medicine Oral Pathology* (name changed to *Oral Surgery Oral Medicine Oral Pathology Oral Radiology and Endodontics* in 1995), *Endodontics and Dental Traumatology* (name changed to *Dental Traumatology* in 2001), *Journal of Oral and Maxillofacial Surgery*, and *International Journal of Oral and Maxillofacial Surgery*. The assessed outcome had to be periapical healing based on radiographic and clinical parameters. Studies reporting other outcomes (eg, postsurgical morbidity/quality of life, soft tissue healing, and so on) were excluded. The clinical studies had to have a minimum of 10 subjects with a minimum follow-up period of 6 months. Apical surgery had to include the placement of a root-end filling. In addition, only studies with clearly defined radiographic and clinical healing criteria were accepted, and healing had to be reported for at least two categories of a specific prognostic factor. All studies were assessed separately by two of the three authors to decide on inclusion or exclusion and in case of disagreement consensus was reached after discussion.

To simplify the evaluation, the prognostic factors were divided into patient-related, tooth-related, and treatment-related factors. To allow for comparison, an eligible prognostic factor had to have two or more categories. If only a single study reported data on a prognostic factor, this factor was not included in this analysis. Data from two or more studies on a specific prognostic factor were pooled to assess whether a statistically significant difference could be calculated for percentages of healed cases across the categories of the prognostic factor.

Clinical and radiographic measures were used and combined for a dichotomous outcome classification: healed versus not healed (5). Teeth were classified as healed when there were no clinical signs and symptoms and the periapical tissues presented radiographically with complete or incomplete (scar tissue) healing according to the criteria established by Rud et al (12) and Molven et al (13). The percentage of healed teeth was defined as the "healed rate."

Statistics

In order to analyze binary factors, the estimated odds ratio and its confidence interval were calculated as well as the corresponding p value for the null hypothesis of an odds ratio equal to 1. Forest plots were generated for every such factor in order to have a better understanding of the influence of the included studies. These plots include Mantel-Haenszel odds ratios with corresponding confidence intervals. Here, a p value for the null hypothesis of homogeneity was computed in addition to performing Woolf's test.

In contrast, categoric factors with three or more possible outcomes were analyzed by computing the estimator and the corresponding confidence region of the healed rate for each category

TABLE 3. Estimated Healed Rates and 95% CIs of Prognostic Factors with More than Two Variables

	Estimated healed rate (%)	Confidence interval (95%) Lower limit (%)	Upper limit (%)	Pairwise comparisons	P value
Type of treated tooth (with jaw specification)					
Maxillary anterior teeth	85.2	80.7	89.0	vs maxillary premolars	0.126
				vs maxillary molars	0.108
				vs mandibular anterior teeth	0.927
				vs mandibular premolars	0.525
				vs mandibular molars	0.004*
Maxillary premolars	70.8	65.8	75.4	vs maxillary molars	0.917
				vs mandibular anterior teeth	0.237
				vs mandibular premolars	0.785
				vs mandibular molars	0.304
Maxillary molars	71.6	67.7	75.3	vs mandibular anterior teeth	0.254
				vs mandibular premolars	0.793
				vs mandibular molars	0.178
Mandibular anterior teeth	87.8	78.7	94.0	vs mandibular premolars	0.568
				vs mandibular molars	0.069†
Mandibular premolars	75.3	65.0	83.8	vs mandibular molars	0.344
Mandibular molars	63.7	60.6	66.9		
Type of treated tooth (without jaw specification)					
Anterior teeth	76.6	73.4	79.5	vs premolars	0.720
				vs molars	1.0
Premolars	74.2	70.8	77.4	vs molars	0.682
Molars	76.6	73.8	79.1		
Retrofilling material					
Amalgam	57.9	54.3	61.5	vs GIC	0.470
				vs IRM	0.052†
				vs MTA	<0.001*
				vs SuperEBA	0.086†
				vs Retroplast	0.020*
				vs other	0.147
GIC	51.2	42.2	60.1	vs IRM	0.059†
				vs MTA	0.002*
				vs SuperEBA	0.087†
				vs Retroplast	0.026*
				vs other	0.091†
IRM	71.6	66.2	76.6	vs MTA	0.097†
				vs SuperEBA	0.852
				vs Retroplast	0.491
				vs other	0.777
MTA	91.4	85.9	95.2	vs SuperEBA	0.072†
				vs Retroplast	0.449
				vs other	0.367
SuperEBA	69.8	64.4	74.9	vs Retroplast	0.401
				vs other	0.705
Retroplast	80.0	72.6	86.2	vs other	0.835
Other	75.9	65.3	84.6		

GIC, glass ionomer cement; IRM, intermediate restorative material; MTA, mineral trioxide aggregate; EBA, ethoxy benzoic acid.

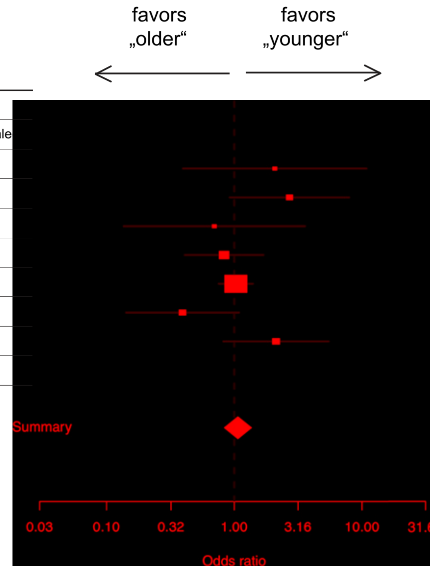
*$p < 0.05$.

†$p < 0.1$.

separately. Finally, pair-wise comparisons between each category of these factors were performed using the Fisher exact test of independence of rows and columns in a contingency table with fixed marginals. Because of the explorative nature of the study, no correction of the p values for multiple testing was applied. All analyses were performed with the statistical program R (R 2.9.0; The R Foundation for Statistical Computing, Vienna, Austria).

Results

The initial literature search yielded a total of 695 articles. Based on their abstracts, 555 papers were excluded because they were case reports, experimental animal studies, or in vitro studies. The remaining 140 clinical articles were screened for data on prognostic factors. An additional 102 articles had to be excluded for the following reasons: (i) the apical surgery did not include the placement of a root-end filling or the study included various surgical procedures (14–39); (ii) the study did not give details about prognostic factors related to periapical healing or the study assessed an outcome other than periapical healing (40–74); (iii) only one category of a specific prognostic factor had been assessed (ie, there was no comparison of two or more categories; eg, only males instead of males vs females) (75–99); (iv) two categories of a prognostic factor had been assessed, but only a single study provided data on this prognostic



		Younger		Older		95% confidence intervals		
Author	N total	N healed	% healed	N healed	% heale	Odds ratio	Lower	Upper
Skoglund & Persson (118)	27	7/16	43.8	3/11	27.3	.07	0.4	10.84
Friedman et al. (120)	136	55/116	47.4	5/20	25.0	.7	0.92	7.93
Zuolo et al. (130)	102	66/73	90.4	27/29	93.1	.7	0.14	3.58
Rahbaran et al. (3)	176	15/59	25.4	34/117	29.1	.83	0.41	1.69
Wesson & Gale (137)	754	298/503	59.2	147/251	58.6	.03	0.76	1.4
Wang et al. (5)	90	26/38	68.4	44/52	84.6	.4	0.14	1.09
von Arx et al. (6)	191	54/60	90	106/131	80.9	.12	0.82	5.49
Total	1476	521/865	60.2	366/611	59.9	.07	0.84	1.36

Figure 1. Table and forest plot of the OR of age: younger versus older.

factor (100–106); (v) same study published in other language or same material published in a previous article with a shorter follow-up (107–112); and (vi) study excluded for other reason (113–115).

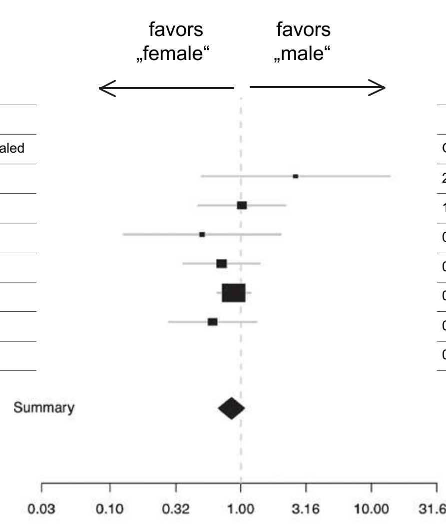
The final number of included clinical studies was 38 (Table 1). The number of studies per prognostic factor ranged from 6 to 7 for patient-related factors, from 2 to 16 for tooth-related factors, and from 2 to 13 for treatment-related factors. The odds ratios (ORs), 95% confidence intervals (CIs), and p values of prognostic factors with two categories are shown in Table 2. The estimated healed rates and confidence intervals (0.95) of prognostic factors with more than two categories are presented in Table 3.

Patient-related Factors

Seven studies provided data regarding age (3, 5, 6, 118, 120, 130, 137) (Fig. 1). Cutoff ages dividing patients into younger or older categories were 40 years (3), 41 years (118, 120, 130), and 45 years (5, 6, 137). Healed rates did not differ significantly between younger and older patients (OR = 1.07; 95% CI, 0.84-1.36; $p = 0.6$). Six studies reported data on sex as prognostic factor (3, 6, 118, 120, 130, 137) (Fig. 2). Healed rates did not differ significantly between males and females (OR = 0.85; 95% CI, 0.67-1.07; $p = 0.17$). Smoking as a prognostic factor had only been assessed in one study (6) and was not further evaluated in this analysis.

Tooth-related Factors

A total of 12 studies provided information with regard to healed rates of treated tooth groups (6, 116, 120, 122, 125, 127, 129, 130, 137, 142, 144, 147) comparing maxillary and mandibular anterior teeth and premolars and molars (Table 4), and 16 studies reported healed rates pooling anterior teeth, premolars, and molars irrespective of jaw (3, 6, 120, 122, 125, 127, 129–131, 134, 140, 142–144, 146, 147) (Table 5). Maxillary anterior teeth (85.2%) and mandibular anterior teeth (87.8%) showed higher estimated healed rates than the other



		Male		Female		95% confidence intervals		
Author	N total	N healed	% healed	N healed	% healed	Odds ratio	Lower	Upper
Skoglund & Persson (118)	27	7/15	46.7	3/12	25.0	2.63	0.5	13.73
Friedman et al. (120)	136	16/36	44.4	44/100	44.0	1.02	0.47	2.19
Zuolo et al. (130)	102	36/41	87.8	57/61	93.4	0.51	0.13	2.01
Rahbaran et al. (3)	176	18/75	24.0	31/101	30.7	0.71	0.36	1.4
Wessσn& Gale (137)	790	160/288	55.6	294/502	58.6	0.88	0.66	1.18
von Arx et al. (6)	191	68/85	80.0	92/106	86.8	0.61	0.28	1.32
Total	1422	305/540	56.5	521/882	59.1	0.85	0.67	1.07

Figure 2. Table and forest plot of the OR of sex: male versus female.

		Pain		No pain			95% confidence intervals	
Author	N tota l	N healed	% healed	N healed	% he	dds ratio	Lower	Upper
Rahbaran et al. (3)	176	18/75	24.0	31/101	30.7	71	0.36	1.4
Filippi et al. (143)	110	40/48	83.3	61/62	98.4	08	0.01	0.68
von Arx et al. (6)	191	63/82	76.8	97/109	89.0	41	0.19	0.9
Total	477	121/205	59.0	189/272	69.5	48	0.29	0.77

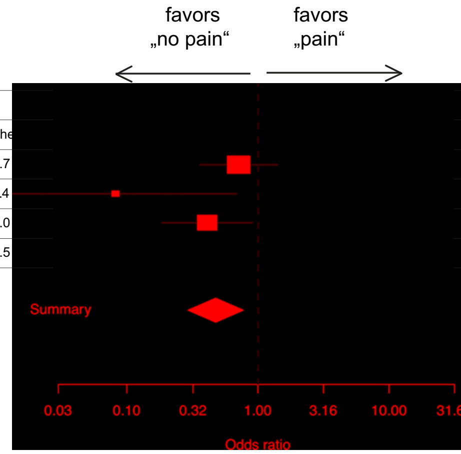


Figure 3. Table and forest plot of the OR of preoperative pain: pain versus no pain.

tooth groups, whereas mandibular molars had the lowest estimated healed rate (63.7%) (Table 3).

The following tooth-related factors showed significant differences when the reported healed rates of their categories were compared: (i) preoperative pain (3, 6, 143) (Fig. 3): cases with preoperative pain had a significantly lower healed rate than cases without preoperative pain (OR = 0.48; 95% CI, 0.29-0.77; $p < 0.01$), (ii) preoperative signs (2, 3, 6) (Fig. 4): cases with preoperative signs had a significantly lower healed rate than cases without preoperative signs (OR = 0.63; 95% CI, 0.39-1.02; $p < 0.01$); (iii) density of root canal filling (2, 3) (Fig. 5): cases with good radiographic density of the existing root canal filling had a significantly higher healed rate than cases with poor density (OR = 2.00; 95% CI, 1.19-3.36; $p < 0.01$); (iv) presence of lesion (3, 6, 137) (Fig. 6): cases with a radiographically visible periapical lesion had a significantly lower healed rate than cases without such a lesion (OR = 0.73; 95% CI, 0.55-0.97; $p = 0.01$), and (v) size of lesion (2, 5, 6, 126) (Fig. 7): cases with a radiographic lesion size ≤5 mm had a significantly higher healed rate than cases with a lesion size >5 mm (OR = 1.82; 95% CI, 1.13-2.92; $p = 0.01$).

In contrast, the factors length of root canal filling (2, 5, 6, 126, 138) (Fig. 8), endodontic retreatment before apical surgery (3, 5) (Fig. 9), and the presence of post/screw (2, 3, 6, 134, 142–144, 148) (Fig. 10) were not significant when the healed rates of their categories were compared. With regard to the definition of the length of root canal filling, two studies defined inadequate length as overfilled or >2 mm underfilled (2, 6), two studies as >3 mm underfilled (126, 138), and one study did not specify the definition (5).

For each of the following tooth-related factors, only one study reported data: type of permanent restoration (2), quality of coronal seal/restoration (3), percussion sensitivity (2), presence of root canal filling (3), outline of lesion (2), marginal bone level (6), extent of buccal bone plate (137), presence of tunnel lesion (106), distance between root canal filling and resection level (127), histopathology of lesion (130), and type of restoration at follow-up (5). Therefore, these factors were not further assessed in the present study.

Treatment-related Factors

The following treatment-related factors showed significant differences when the reported healed rates of their categories were compared:

1. Type of surgery (3, 5, 6, 135, 139, 140) (Fig. 11): cases with first-time surgery had a significantly higher healed rate than resurgery cases (OR = 2.06; 95% CI = 1.46-2.91; $p < 0.01$). However, the included material was not homogenous ($p < 0.01$).
2. Technique of root-end cavity preparation (3, 128, 129, 132, 145, 146) (Fig. 12): cases in which the root-end cavity preparation was done with a bur had a significantly lower healed rate than cases

		Signs		No signs			95% confidence intervals	
Author	N tota l	N healed	% healed	N healed	% heale	dds ratiio	Lower	Upper
Lustmann et al. (2)	101	34/89	38.2	8/12	66.7	31	0.09	1.11
Rahbaran et al. (3)	176	18/62	29.0	31/114	27.2	1	0.55	2.18
von Arx et al. (6)	191	34/47	72.3	126/144	87.5	38	0.17	0.84
Total	468	86/198	43.4	165/270	61.1	63	0.39	1.02

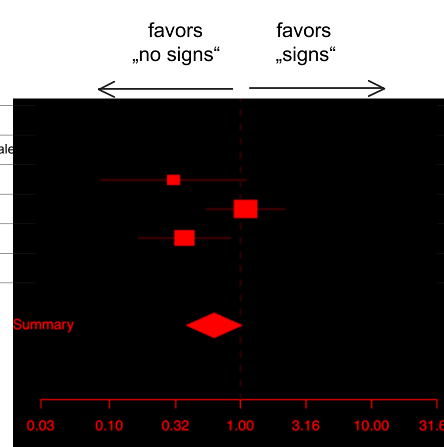


Figure 4. Table and forest plot of the OR of preoperative signs: signs versus no signs.

TABLE 4. Tooth-related Factors: Type of Tooth with Jaw Specification (maxillary anterior teeth,* maxillary premolars, maxillary molars, mandibular anterior teeth,* mandibular premolars, and mandibular molars [N = 2,318])

Author(s)	Total (*N*)	No. of healed/total maxillary anterior teeth	% healed maxillary anterior teeth	No. of healed/total maxillary premolars	% healed maxillary premolars	No. of healed/total maxillary molars
Persson, 1982 (116)	26	—	—	—	—	14/18
Friedman et al, 1991 (120)	136	—	—	38/82	46.3	6/12
Cheung & Lam, 1993 (122)	32	—	—	11/14	78.6	3/5
August, 1996 (125)	16	3/5	60.0	5/6	83.3	2/5
Rud et al, 1997 (127)	551	74/88	84.1	78/108	72.2	121/137
Testori et al, 1999 (129)	302	48/62	77.4	50/66	75.8	54/62
Zuolo et al, 2000 (130)	102	33/34	97.1	18/19	94.7	17/20
Wesson & Gale, 2003 (137)	790	—	—	—	—	149/262
Taschieri et al, 2005 (142)	46	18/21	85.7	4/4	100.0	2/2
Taschieri et al, 2006 (144)	71	24/26	92.3	8/8	100.0	—
von Arx et al, 2007 (6)	191	46/54	85.2	35/42	83.3	22/24
Wälivaara et al, 2007 (147)	55	13/14	92.9	7/10	70.0	11/13
Total	2318	259/304	85.2	254/359	70.8	401/560

*Anterior teeth = incisors and canines.

with microtip preparation (OR = 0.32; 95% CI, 0.24-0.44; $p < 0.01$). However, the included material was not homogenous ($p = 0.01$).

The use of an endoscope (136, 144) (Fig. 13) showed a borderline significance (OR = 2.43; 95% CI, 0.99-5.97; $p = 0.05$) (ie, cases using an endoscope during surgery tended to show a higher healed rate than cases without using an endoscope). No significant difference was found for healed rates in cases treated with or without antibiotics (6, 143) (Fig. 14) (OR = 0.66; 95% CI, 0.32-1.36; $p = 0.27$).

With regard to the retrofilling material, a total of 13 studies compared at least two different materials (3, 4, 6, 117, 119, 121, 123, 124, 129, 133, 135, 138, 141) (Table 6). Mineral trioxide aggregate (MTA) was found to have the highest estimated healed rate (91.4%) compared with the competitor materials (Table 3).

Treatment-related factors for which there were data from only one study included: experience of surgeon (2), type of surgeon (3), use of hemostatic agent (5), type of microtip (142), use of laser irradiation (128), and occurrence of intraoperative or postoperative complications (5). Six studies evaluated the use of a regenerative technique in apical surgery (101-106); however, each study had assessed a different technique and data could not be pooled.

Discussion

The present meta-analysis aimed at evaluating possible prognostic factors for healing outcome in apical surgery with root-end filling. The consideration of prognostic factors should become a standard tool for case selection and treatment in apical surgery. Advantages and disadvantages of alternative treatments, such as conventional endodontic revision or tooth extraction as well as tooth or root resection for multirooted teeth, should be carefully weighed against apical surgery during case evaluation. Therefore, information about healing predictors might be important in the process of deciding on the best therapeutic option. However, the present

TABLE 5. Tooth-related Factors: Type of Tooth without Jaw Specification (anterior teeth,* premolars, and molars [N = 2,488])

Author(s)	Total (*N*)	No. of healed/total anterior teeth	% healed anterior teeth	No. of healed/total premolars	% healed premolars	No. of healed/total molars	% healed molars
Friedman et al, 1991 (120)	136	—	—	43/96	44.8	16/40	40.0
Cheung & Lam, 1993 (122)	32	—	—	14/19	73.7	6/13	46.2
August, 1996 (125)	16	3/5	60.0	5/6	83.3	2/5	40.0
Rud et al, 1997 (127)	551	96/117	82.1	93/126	73.8	260/308	84.4
Testori et al, 1999 (129)	302	55/69	79.7	63/81	77.8	111/152	73.0
Zuolo et al, 2000 (130)	102	37/39	94.9	23/24	95.8	33/39	84.6
Rahbaran et al, 2001 (3)	176	36/129	27.9	7/33	21.2	6/14	42.9
Rubinstein & Kim, 2002 (131)	59	22/23	95.7	16/17	94.1	16/19	84.2
Maddalone & Gagliani, 2003 (134)	120	57/62	91.9	27/30	90.0	27/28	96.4
Gagliani et al, 2005 (140)	231	19/28	67.9	49/56	87.5	113/147	76.9
Taschieri et al, 2005 (142)	46	29/32	90.6	7/8	87.5	6/6	100.0
Filippi et al, 2006 (143)	110	64/69	92.8	25/26	96.2	12/15	80.0
Taschieri et al, 2006 (144)	71	45/49	91.8	21/22	95.5	—	—
de Lange et al, 2007 (146)	290	49/58	84.5	79/97	81.4	92/135	68.1
von Arx et al, 2007 (6)	191	52/60	86.7	45/55	81.8	63/76	82.9
Wälivaara et al, 2007 (147)	55	14/15	93.3	9/13	69.2	21/27	77.8
Total	2,488	578/755	76.6	526/709	74.2	784/1024	76.6

*Anterior teeth = incisors and canines.

% healed maxillary molars	No. of healed/total mandibular anterior teeth	% healed mandibular anterior teeth	No. of healed/total mandibular premolars	% healed mandibular premolars	No. of healed/total mandibular molars	% healed mandibular molars
77.8	—	—	—	—	5/8	62.5
50.0	—	—	5/14	35.7	10/28	35.7
60.0	—	—	1/3	33.3	5/10	50.0
40.0	—	—	—	—	—	—
88.3	22/29	75.9	15/18	83.3	139/171	81.3
87.1	7/7	100.0	13/15	86.7	57/90	63.3
85.0	4/5	80.0	5/5	100.0	16/19	84.2
56.9	—	—	—	—	302/528	57.2
100.0	11/11	100.0	3/4	75.0	4/4	100.0
—	21/23	91.3	13/14	92.9	—	—
91.7	6/6	100.0	10/13	76.9	41/52	78.8
84.6	1/1	100.0	2/3	66.7	10/14	71.4
71.6	72/82	87.8	67/89	75.3	589/924	63.7

		Good density		Poor density			95% confidence intervals	
Author	N total	N healed	% healed	N healed	% heale[illegible]	[illegible]dds ratio	Lower	Upper
Lustmann et al. (2)	134	30/56	53.6	30/78	38.5	[illegible]	0.92	3.7
Rahbaran et al. (3)	142	27/79	34.2	12/63	19.0	[illegible]	1.01	4.82
Total	276	57/135	42.2	42/141	29.8	[illegible]	1.19	3.36

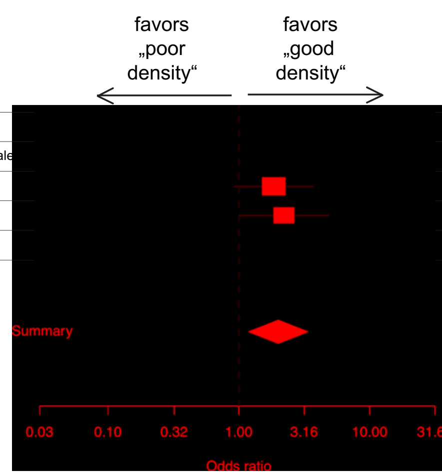


Figure 5. Table and forest plot of the OR of the density of the root canal filling: good density versus poor density.

		Lesion		No lesion			95% confidence intervals	
Author	N total	N healed	% healed	N healed	% heale[illegible]	[illegible]dds ratio	Lower	Upper
Rahbaran et al. (3)	176	34/141	24.1	15/35	42.9	[illegible]	0.2	0.92
Wessen & Gale (137)	774	301/532	56.6	149/242	61.6	[illegible]	0.6	1.11
von Arx et al. (6)	191	144/174	82.8	16/17	94.1	[illegible]	0.04	2.35
Total	1141	479/847	56.6	180/294	61.2	[illegible]	0.55	0.97

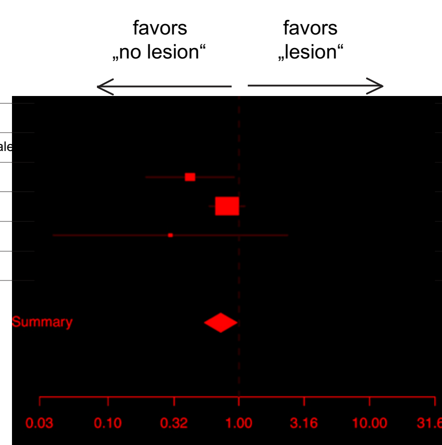


Figure 6. Table and forest plot of the OR of the presence of a lesion: lesion versus no lesion.

		size≤ 5 mm		Size > 5 mm			95% confidence intervals	
Author	N total	N healed	% healed	N healed	% heale	dds ratio	Lower	Upper
Lustmann et al. (2)	136	47/105	44.8	13/31	41.9	12	0.5	2.52
Danin et al. (126)	19	8/13	61.5	3/6	50.0	6	0.23	11.27
Wang et al. (5)	90	48/56	85.7	22/34	64.7	27	1.17	9.14
von Arx et al. (6)	191	106/121	87.6	54/70	77.1	09	0.96	4.55
Total	436	209/295	70.8	92/141	65.2	82	1.13	2.92

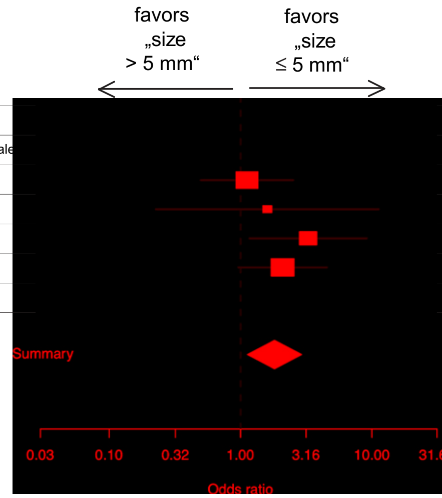


Figure 7. Table and forest plot of the OR of the size of the lesion: ≤5 mm versus >5 mm.

meta-analysis has shown that only a few clinical studies have assessed multiple prognostic factors in apical surgery. The majority of published clinical studies correlate the outcome of apical surgery with the retrofilling material. In order to determine the value of a specific prognostic factor in apical surgery with root-end filling, data from systematically selected studies were pooled to increase the statistical power. Prognostic factors were categorized as patient-related, tooth-related, or treatment-related factors.

Although the included clinical studies may differ with regard to study design, case selection criteria, surgical techniques, and healing assessment, this possible shortcoming was compensated for by the fact that studies were only included if they reported and compared data on at least two categories of a specific prognostic factor. This means that all categories of a specific study were characterized by the same bias.

Out of the 38 included studies in this meta-analysis, only 8 studies were RCTs. In five studies, the subjects were randomly allocated to different groups with regard to the retrofilling material.

Patient-related Factors

Neither of the patient-related factors (age and sex) showed significantly different healed rates for the assessed categories. The lack of significant influence of age on healed rates means that apical surgery should be considered as a treatment option also in older patients. An advanced age appears not to compromise periapical healing once a bacteria-tight apical seal has been accomplished.

Smoking as a prognostic factor was not further evaluated in this meta-analysis because only one study had reported data on this factor. In a recent review article by Duncan and Pitt Ford (149), the authors found that the literature shows a paucity of evidence relating smoking with endodontic disease and prognosis. Systemic health was not assessed as a prognostic factor in any of the included clinical studies.

With the current data, patient-related factors do not appear to be of predictive value for the outcome of apical surgery. In addition, patient-related factors are not controllable (age and sex) or are outside the control of the surgeon (smoking cessation protocol and management of systemic health problems). Despite the lack of evidence, the clinician

		Adequate length		Inadequate length			95% confidence intervals	
Author	N tota l	N healed	% healed	N healed	% heale	dds ratio	Lower	Upper
Lustmann et al. (2)	134	20/51	39.2	40/83	48.2	69	0.34	1.41
Danin et al. (126)	19	9/15	60.0	2/4	50.0	5	0.16	13.75
Sahlin Platt & Wannfors (138)	34	13/18	72.2	10/16	62.5	56	0.37	6.62
Wang et al. (5)	90	26/38	68.4	44/52	84.6	39	0.14	1.09
vonA rx et al.(6)	191	103/123	83.7	57/68	83.8	99	0.44	2.22
Total	468	171/245	69.8	153/223	68.6	77	0.5	1.19

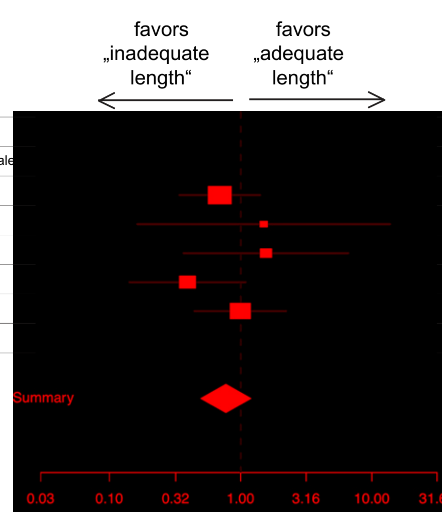


Figure 8. Table and forest plot of the OR of the length of the root canal filling: adequate length versus inadequate length.

		Retreatment		No retreatment			95% confidence intervals	
Author	N total	N healed	% healed	N healed	% heale	dds ratio	Lower	Upper
Rahbaran et al. (3)	83	13/31	41.9	18/52	34.6	36	0.55	3.4
Wang et al. (5)	90	27/32	84.4	43/58	74.1	88	0.61	5.78
Total	173	40/63	63.5	61/110	55.5	56	0.77	3.16

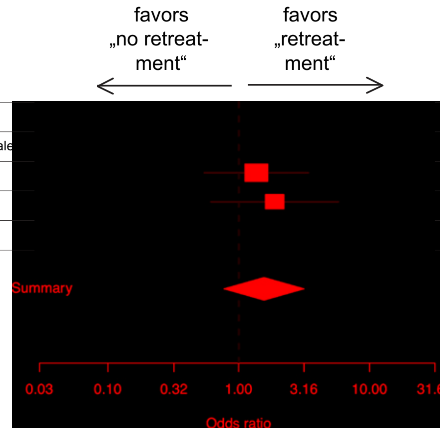


Figure 9. Table and forest plot of the OR of endodontic retreatment before apical surgery: retreatment versus no retreatment.

should be cautious about performing apical surgery in patients with local or systemic conditions that may affect hard and soft-tissue healing, such as irradiated tissue, bisphosphonate medication for malignant conditions, and poorly regulated diabetes.

Tooth-related Factors

Tooth-related factors describe the type of tooth to be treated and its condition or its associated apical lesion. Tooth-related factors, such as the quality of the existing root canal filling and the quality of the restoration, are important when considering therapeutic alternatives, in particular endodontic retreatment.

With regard to the type of tooth (tooth location), some studies pooled anterior teeth, premolars, and molars, whereas other studies distinguished between maxillary and mandibular anterior teeth, premolars, and molars. The latter and more detailed distinction provided interesting differences of estimated healed rates with regard to tooth location. Maxillary and mandibular anterior teeth showed relatively high estimated healed rates (above 85%), whereas mandibular molars had a low estimated healed rate of 63.7%. This finding may be correlated with the complex endodontic anatomy but also with the rather difficult access to the apices in mandibular molars. The clinician is advised to exercise caution in selecting mandibular molars for apical surgery and to consider treatment alternatives.

The factors preoperative pain and preoperative clinical signs of inflammation (sinus tract and swelling) were found to influence the outcome of apical surgery (ie, cases with preoperative pain or cases with preoperative signs had a significantly lower probability [$p < 0.01$] of healing compared with cases without pain or without signs). The reasons for this difference are not yet fully understood, but one may speculate that preoperative pain or signs may be associated with a (sub)acute rather than a chronic stage of infection that may compromise the healing potential of the surgical wound. Clinical signs of exacerbation, abscesses, and draining sinuses have been associated with extraradicular infections, in particular extraradicular actinomycosis (150). One may speculate that apical surgery may not always completely eradicate these bacteria with the risk of subsequent extraradicular reinfection.

		Post/screw		No post/screw			95% confidence intervals	
Author	N tota l	N healed	% healed	N healed	% heale	dds ratio	Lower	Upper
Lustmann et al. (2)	136	30/67	44.8	30/69	43.5	05	0.54	2.07
Rahbaran et al. (3)	176	21/92	22.8	28/84	33.3	59	0.3	1.15
Maddalone & Gagliani (134)	120	49/56	87.5	62/64	96.9	23	0.05	1.14
Taschieri et al. (142)	46	27/30	90.0	15/16	93.8	6	0.06	6.29
Filippi et al. (143)	110	42/45	93.3	59/65	90.8	42	0.34	6.02
Taschieri et al. (144)	71	45/49	91.8	21/22	95.5	54	0.06	5.09
von Arx et al. (6)	191	107/128	83.6	53/63	84.1	96	0.42	2.19
Taschieri et al. (148)	27	10/14	71.4	11/13	84.6	45	0.07	3.04
Total	877	331/481	68.8	279/396	70.5	76	0.53	1.09

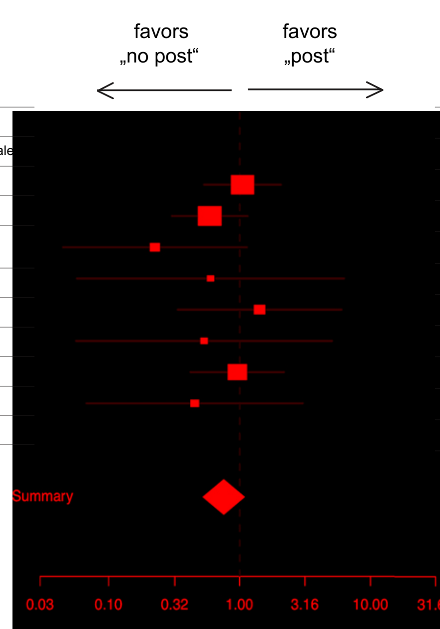


Figure 10. Table and forest plot of the OR of the presence of a post/screw: post/screw versus no post/screw.

Author	N total	1^st^time surgery N healed	% healed	Resurgery N healed	% heale	dds ratio	95% confidence intervals Lower	Upper
Rahbaran et al. (3)	176	32/126	25.4	17/50	34.0	66	0.33	1.34
Schwartz-Arad et al. (135)	122	50/103	48.5	4/19	21.1	54	1.1	11.38
Wang et al. (5)	90	65/82	79.3	5/8	62.5	29	0.5	10.57
Wang et al. (139)	194	100/154	64.9	17/40	42.5	51	1.23	5.09
Gagliani et al.(140)	231	140/162	86.4	41/69	59.4	35	2.25	8.39
von Arx et al. (6)	191	146/173	84.4	14/18	77.8	54	0.47	5.05
Total	1004	533/800	66.6	98/204	48.0	06	1.46	2.91

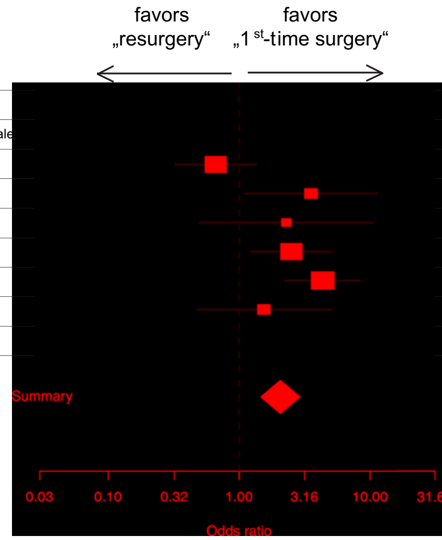


Figure 11. Table and forest plot of the OR of the type of surgery: first-time surgery versus resurgery.

Author	N total	Bur N healed	% healed	Microtip N healed	% heale	dds ratio	95% confidence intervals Lower	Upper
Bader & Lejeune (128)	254	70/106	66.0	137/148	92.6	16	0.07	0.33
Testori et al. (129)	302	141/207	68.1	81/95	85.3	37	0.2	0.7
Rahbaran et al. (3)	176	37/150	24.7	12/26	46.2	38	0.16	0.9
Vallecillo et al. (132)	24	3/7	42.9	12/17	70.6	31	0.05	1.94
Tsesisetal.(145)	88	19/43	44.2	41/45	91.1	08	0.02	0.25
de Lange et al. (146)	290	100/141	70.9	120/149	80.5	59	0.34	1.02
Total	1134	370/654	56.6	403/480	84.0	32	0.24	0.44

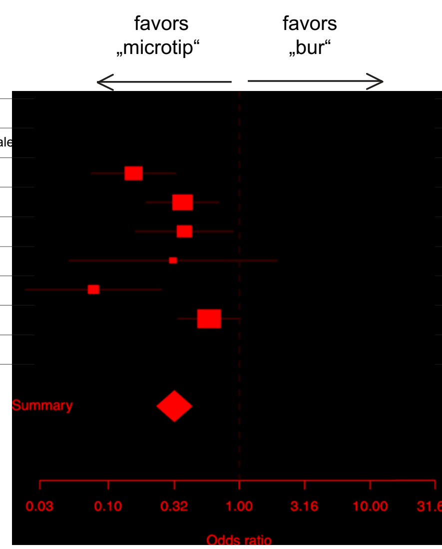


Figure 12. Table and forest plot of the OR of the technique of root-end cavity preparation: bur versus microtip.

TABLE 6. Treatment-related Factors: Retrofilling Materials: Amalgam; GIC, Glass Ionomer Cement; IRM, Intermediate Restorative Material; MTA, Mineral Trioxide Aggregate; SuperEBA, Ethoxy Benzoic Acid; Retroplast; Other (N = 1889)

Author (s) (reference)	Total (N)	Healed/total amalgam (N)	Healed, amalgam (%)	Healed/total GIC (N)	Healed GIC (%)	Healed/total IRM (N)	Healed, IRM (%)
Dalal and Gohil, 1983 (117)	40	10/15	66.7	5/10	50.0	—	—
Dorn and Gartner, 1990 (119)	488	171/294	58.2	—	—	95/129	73.6
Waikakul and Punwutikorn, 1991 (121)	62	16/23	69.6	—	—	—	—
Pantschev et al, 1994 (123)	103	27/52	51.9	—	—	—	—
Jesslén et al, 1995 (124)	82	35/41	85.4	35/41	85.4	—	—
Testori et al, 1999 (129)	302	141/207	68.1	—	—	—	—
Rahbaran et al, 2001 (3)	154	24/94	25.5	—	—	—	—
Jensen et al, 2002 (4)	122	—	—	19/62	30.6	—	—
Chong et al, 2003 (133)	108	—	—	—	—	41/47	87.2
Schwartz-Arad et al, 2003 (135)	103	10/23	43.5	—	—	40/80	50.0
Sahlin Platt and Wannfors, 2004 (138)	34	—	—	7/16	43.8	—	—
Lindeboom et al, 2005 (141)	100	—	—	—	—	43/50	86.0
von Arx et al, 2007 (6)	191	—	—	—	—	—	—
Total	1889	434/749	57.9	66/129	51.2	219/306	71.6

GIC, glass ionomer cement; IRM, intermediate restorative material; MTA, mineral trioxide aggregate; SuperEBA, ethoxy benzoic acid.

		Endoscope		No endoscope			95% confidence intervals	
Author	N tota l	N healed	% healed	N healed	% heale	dds ratio	Lower	Upper
von Arx et al. (136)	115	48/54	88.9	46/61	75.4	61	0.93	7.3
Taschieri et al. (144)	71	37/39	94.9	29/32	90.6	91	0.3	12.22
Total	186	85/93	91.4	75/93	80.6	43	0.99	5.97

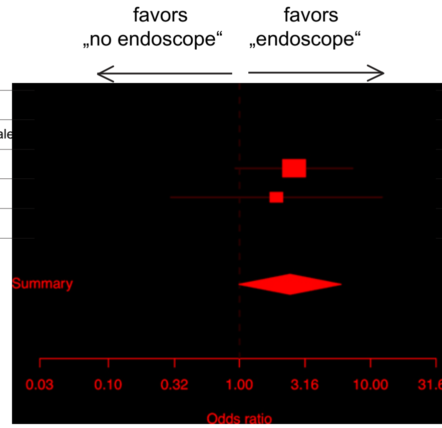


Figure 13. Table and forest plot of the OR of the use of an endoscope: endoscope versus no endoscope.

A number of studies have addressed the endodontic status of the tooth, with assessment of the following prognostic factors: presence of post (or screw), length of root canal filling, density of root canal filling, and endodontic retreatment before apical surgery. From the endodontist's perspective, conventional root canal retreatment should always be considered before carrying out apical surgery, provided there are no technical limitations to performing the revision and no risks for further tooth damage (151, 152). The pooled data from two studies showed higher healed rates for cases with endodontic retreatment before apical surgery than for cases without endodontic revision, but the calculated healed rates were not significantly different. With regard to the length of the existing root canal filling, the present analysis found no difference in healed rates between cases with inadequate and cases with adequate length of root canal filling. In contrast, the density of the root canal filling was found to be a significant prognostic factor ($p < 0.01$). This finding also supports the use of nonsurgical retreatment in teeth with a poorly condensed root canal filling. The presence (n = 877) or absence (n = 396) of a post (or screw) was evaluated in the largest number of cases with regard to endodontic factors. This prognostic factor did not prove significant with regard to healing outcome. From a clinical perspective, the length of an existing post may be more relevant in apical surgery than the presence of a post. Current recommendations in apical surgery include a root-end resection of 3-mm length and a root-end filling of 3-mm depth (153). Hence, a long post violating these distances may compromise the technique of root-end cavity preparation and obturation. Further, post placement and root canal treatment were shown to be the major predisposing factors of vertical root fractures (154, 155). However, cases failing because of root fracture during the observation period after apical surgery should be excluded from the study material because the reason for failure is not (directly) related to apical surgery.

Further tooth-related factors included the presence and size of the lesion, and neither was found to be prognostic determinants. Cases with radiographically visible lesions had a significantly lower probability of healing than cases without a periapical lesion. Cases with a radiographically measured lesion size ≤5 mm showed a significantly higher probability of healing than cases with a lesion size >5 mm. This phenomenon might be explained by the fact that the healing time for a large lesion is longer or a large lesion may show scar tissue healing, making radiographic healing determination more difficult. Others have hypothesized that a small apical lesion requires surgical enlargement of the crypt to gain access, resulting in complete eradication of the pathologic tissue. When the lesion is large, access may be adequate and the crypt is not enlarged, and subsequent curettage of the pathological tissue may be incomplete (11). In addition, the "fresh" osseous wound created by

Healed/total MTA (N)	Healed, MTA (%)	Healed/total SuperEBA (N)	Healed, SuperEBA (%)	Healed/total Retroplast (N)	Healed, Retroplast (%)	Healed/total other (N)	Healed, other (%)
—	—	—	—	—	—	9/15 (gutta-percha with ZnO eugenol)	60.0
—	—	49/65	75.4	—	—	—	—
—	—	—	—	—	—	34/39 (gold leaf)	87.2
—	—	29/51	56.9	—	—	—	—
—	—	—	—	—	—	—	—
—	—	81/95	85.3	—	—	—	—
—	—	19/49	38.8	—	—	4/11 (unknown)	36.4
—	—	—	—	44/60	73.3	—	—
56/61	91.8	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	16/18 (compomer)	88.9
46/50	92.0	—	—	—	—	—	—
46/51	90.2	42/55	76.4	72/85	84.7	—	—
148/162	91.4	220/315	69.8	116/145	80.0	63/83	75.9

		Antibiotics		No antibiotics			95% confidence intervals	
Author	N total	N healed	% healed	N healed	% heale	dds ratio	Lower	Upper
Filippi et al. (143)	110	40/43	93.0	61/67	91.0	31	0.31	5.55
von Arx et al. (6)	191	96/119	80.7	64/72	88.9	52	0.22	1.24
Total	301	136/162	84.0	125/139	89.9	66	0.32	1.36

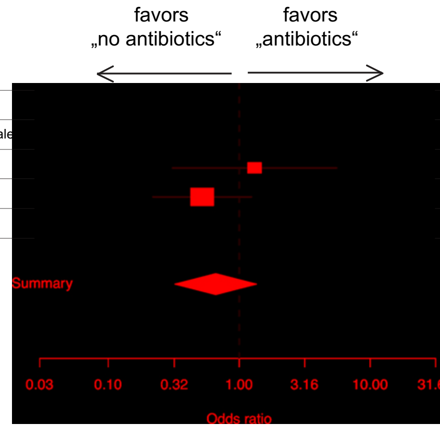


Figure 14. Table and forest plot of odds ratio of the use of antibiotics: antibiotics versus no antibiotics.

the surgical enlargement of small lesions might activate bone formation, which would not be the case for the cortical bony walls of (long-standing) large lesions.

Treatment-related Factors

In contrast to patient- and tooth-related factors, most of the treatment-related factors can be influenced by the surgeon. The best documented treatment-related factor is the retrofilling material. MTA was found to have the highest (91.4%) and glass ionomer cement the lowest (51.2%) estimated healed rate. Although MTA has consistently shown high success rates above 90%, two randomized controlled trials showed no significant differences between MTA and IRM (133, 141). Future long-term studies will show if MTA can fulfill the expectations of many clinicians who use this highly biocompatible material for root-end filling.

With regard to the type of surgery, cases were classified either as first-time surgery or resurgery. First-time surgery cases had a significantly higher healed rate than resurgery cases. However, the included studies were not homogeneous ($p < 0.01$), mainly because of the study by Rahbaran et al (3) that had an OR that differed widely from the OR of the other included studies. Peterson and Gutmann (7) conducted a systematic review with regard to endodontic resurgery. They reported a weighted average success rate of 64.2% for first-time surgery but only 35.7% for resurgery. They speculated that the sample population that underwent resurgery may have different etiologies that delay apparent healing, or different bacteria may be present or possibly anomalous dental anatomy that lead to difficulties, all influencing the overall healing outcome in a negative way. The fact that resurgery is performed in a "negative" selection of cases (failure of previous surgery) calls for a careful evaluation, and treatment alternatives should be considered.

There was no statistically significant difference in healed rates with regard to antibiotics. In a randomized controlled trial, Lindeboom et al (66) also found no benefit of antibiotic therapy with regard to the early postsurgical course (initial 4 weeks) after periapical surgery ($p = 0.448$). That study was not included in this systematic review because it did not provide information about the periapical healing. With the present data, the routine administration of antibiotics is not recommended in apical surgery unless medical conditions require systemic antimicrobial therapy.

Cases treated with the use of an endoscope during apical surgery tended to have a higher healed rate than cases without the use of an endoscope ($p = 0.05$). However, only two studies with a total of 186 treated cases had assessed this prognostic factor. One may speculate that the endoscope, with its high magnification, provides better identification of microstructures at the cut root end and as such may enhance the retrograde obturation of possible leakage areas. In vitro studies have documented the benefit of using an endosocpe for the detection of isthmuses and dentinal cracks at the resection plane (156, 157).

Six studies have assessed the technique of root-end cavity preparation as a prognostic factor. Cases with bur preparation had a significantly lower healed rate than cases with microtip (retrotip) preparation of the root-end cavity. However, the included studies were not homogeneous ($p = 0.01$). The reason of the heterogeneity was the widely differing OR of the studies of Bader and Lejeune (128) and of de Lange et al (146), which both had relatively large material samples. The amount of pooled material was large with a total of 1,134 cases (654 bur cases and 480 microtip cases). The data support the use of microtips for root-end cavity preparation, a technique that was introduced in the early 1990s. The use of burs is no longer recommended for root-end cavity preparation.

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