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The prognosis of root canal therapy: a 10-year retrospective cohort study on 411 patients with 1175 endodontically treated teeth

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Purpose: To evaluate the 10-year prognosis of consecutively endodontically treated or retreated teeth and to investigate some of the prognostic factors which could predict the long-term outcome of endodontic therapy.

Materials and methods: This retrospective cohort study included any patient who had endodontically treated or retreated teeth from 1986 to 1998 by a single operator in a private practice. Outcome measures were clinical and radiographic success assessed by the operator, radiographic success assessed by an independent outcome assessor and complications evaluated 10 years after treatment. Descriptive statistics, life table, Kaplan–Meier and Cox regression analyses for success were fitted.

Results: A total of 411 patients with 1175 endodontically treated teeth were identified. Ten years after treatment 102 patients (24.8%) with 223 (19.0%) teeth were lost at the follow-up. The number of teeth that were originally treated and retreated were 704 and 471, respectively. Thirty-two teeth (2.7%) had one complication, which was successfully treated. A total of 988 (84.1%) teeth were considered a complete success, 46 (3.9%) a partial success, 52 (4.4%) a partial failure and 68 (5.8%) had to be extracted according to the treating clinician. For 21 teeth (1.8%) there was no follow-up information. The radiographic healing of 1086 teeth was evaluated by an independent assessor: 980 (90.2%) showed complete healing, 52 (4.8%) improvement, and 54 (5.0%) no change or worsening. The life-table analysis showed 93% of teeth surviving at 10 years after endodontic treatment. There were no differences for survival rates between teeth treated for the first time and those that were retreated (Kaplan–Meier). Teeth retreated because of symptoms or for a periapical/lateral radiolucency were more likely to fail.

Conclusions: Approximately 7% of endodontically treated teeth were extracted 10 years after treatment. Symptoms and radiolucency of teeth needing retreatment may be important predictors for failure.

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■ Introduction

The aim of endodontic therapy is to maintain tooth function, and in particular to remove the dental pulp and possible bacteria, to clean and shape the root canals and to obturate the canals to prevent infection or re-infection. A recent systematic review[1] evaluating the outcomes of root canal treatment and other dental therapies, when evaluating the success of endodontic therapy, included 12 studies with a follow-up ranging from 2 to 4 years, four studies with a follow-up of 4 to 6 years and only two studies with a follow-up longer than 6 years. There were also six additional studies reporting survival rates, with three studies having a follow-up longer than 6 years. According to the systematic review[1], the study presenting the largest sample size on success (405 treated teeth in an unknown number of patients)[2] also had the longer follow-up period (more than 6 years). When reading the original article[2], it was apparent that the retrospective study presented data of 914 teeth from an unknown number of patients with a mean follow-up of less than 3 years (range 0 to 10 years). From the above examples it is clear that reliable long-term data about the success of root canal therapy are lacking. Therefore long-term (10 years or more) evidence of the success rates of root canal treatment is still scarce, and it would be useful to have some reliable information in order to make informed evidence-based decisions.

The aim of the present retrospective cohort study was to evaluate the 10-year prognosis of consecutively endodontically treated or retreated teeth and to investigate some of the factors which could predict the long-term outcome of endodontic therapy. The present study was reported following the STROBE Statement (http://www.strobe-statement.org/) for observational studies.

■ Materials and methods

Any patient who had at least a single tooth endodontically treated or retreated by a single operator with extensive experience in endodontics (Federica Fonzar) in a private practice between 1986 and 1998 was included in the study. Periapical radiographs were taken according to a long-cone technique using a Rinn XCP film holder. For multi-rooted teeth, two periapical preoperative radiographs with different angles were taken to better evaluate root anatomy. Teeth with dubious vitality were subjected to a vitality test (cold, warm gutta-percha and, in a few cases, a cavity test). Caries lesions were restored and all patients were given oral hygiene instructions. Teeth to be endodontically treated were cleaned with abrasive paste, isolated with a rubber dam and cleaned with a cotton pellet with 3% sodium hypochlorite prior to opening of the pulp chamber with a diamond bur (Intensiv 6916, Intensiv, Grancia, Switzerland). Working length was determined on periapical radiographs taken with the parallel technique at 0.5 mm coronal to the radiographic apex until 1991 and thereafter using electronic apex locators (Neosono-D, Amadent Medial and Dental, Cherry Hill, NJ, USA; and after 1996 with Root ZX, Morita, Kyoto, Japan) at '0' reading position.

Between 1986 and 1993 all canals were prepared and root-filled with the Schilder technique[3,4]. Calcium hydroxide was used as an intermediate medication only for canals with exudation. Gutta-percha was compacted vertically with heat carriers (OP and OOP; and from 1991 Touch'n Heat, Analytic Technologies, Redmond, WA, USA). Back packing was accomplished with the Obtura (Obtura Spartan, Foothill Ranch, CA, USA) syringe.

From 1994, canals were prepared using a crown-down technique[5]. The coronal third of the canal was enlarged with Gates Glidden drills (Dentsply Maillefer, Ballaigues, Switzerland), while the remaining portion was instrumented with pre-curved stainless-steel Hedstrom files (Dentsply Maillefer) with decreasing diameters from the middle to the apical third, without apical pressure. Ultrasound (Piezon® Master 400, EMS, Nyon, Switzerland) was also used to clean the canals. No canal with exudation, symptomatic tooth, or tooth with periapical or lateral radiolucency was closed in one session. Calcium hydroxide paste was used as medication between endodontic sessions. An iodoform paste was used in cases of retreatment for radiolucency. Gutta-percha cones were used to obturate the canals. A cold lateral compaction technique was used. The master cone was dipped into cement and well adapted to the canal. Accessory gutta-percha cones where laterally compacted with spreaders. Excess gutta-percha was removed and vertically compacted with a heat carrier (Touch'n Heat).

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Three per cent sodium hypochloride was used to rinse the canal after each instrument size. Ethylenediaminetetraacetic acid (EDTA) (RC PREP™, Premier, Philadelphia, USA) was used in calcified canals in addition to ultrasound. Canals were dried with sterile absorbing paper cones.

At the end of the root filling, the coronal portion was provisionally closed with Cavit™ W (3M ESPE, Seefeld, Germany), and the definitive closure of the tooth was provided within 15 days or within 1 month for those patients who postponed appointments.

Patients were recalled every 3, 4 or 6 months depending on their oral hygiene and risk factors. The operator checked annually the clinical conditions of the treated teeth. Control periapical radiographs were taken at 6 months after treatment for only symptomatic teeth and teeth with areas of radiolucency. After the first year and thereafter every 2 years, radiographs were taken on all teeth to monitor the outcome of the endodontic therapy.

The following outcome measures were used.

- Clinical and radiographic success were assessed by the treating clinician in the following way: complete success (asymptomatic teeth with complete absence of periapical or lateral radiolucency on periapical radiographs); partial success (asymptomatic teeth showing any radiographic improvement); partial failure (asymptomatic teeth not showing any radiographic improvement or even worsening, and any symptomatic teeth); and complete failure (any extracted teeth). Multi-rooted teeth were scored according the root having the worst outcome. The reason for extraction was recorded.
- Radiographic success was assessed by one independent, blinded and experienced assessor (Piercarlo Buttolo) who compared the preoperative radiograph with that obtained at the 9- to 11-year follow-up. In the case of a missing radiograph or drop-out, the radiograph closer to the 10-year time interval was evaluated instead. The criteria used to score the radiographic changes were: complete healing (no visible periapical or lateral radiolucency); improvement (reduction of the periapical or lateral lesion); and no changes/worsening (radiolucency remained unaltered, increased over time, or a new radiolucency appeared). Periapical radiographs were examined on a radiograph dental viewer in a partially dark room using a ×4 magnifying lens.
- Complications were assessed by the treating clinician. Any endodontic complication that occurred after initial endodontic treatment over the 10-year study period such as persistent pain, abscesses, etc, was recorded, however only those that were successfully treated were reported as complications. The complications that determined the extraction of teeth were reported as failures.

Drop-outs were carefully documented, attempts were made to contact all patients and they were all invited to attend a 10-year post-endodontic treatment evaluation. The reasons for and dates when any patients dropped out were recorded, as well as the clinical conditions the last time the patient was seen.

Descriptive statistics were used. The data of all patients who did not attend the 10-year follow-up (dropouts) were retained using the data from the last control visit for statistical calculations. Life table and Kaplan–Meier statistics were used to determine teeth survival rates up to 10 years. These methods take into account 'censored' data, i.e. patients who were lost to follow-up prior to 10 years.

Cox proportional hazards models were fitted for the survival time to failure (tooth extraction), calculating robust standard errors to take into account the clustering of the teeth within patients using the software Stata version 10. One analysis included the number of canals (one versus more canals) as explanatory variable. The second model, performed on teeth treated for the fist time, included initial treatment reason (teeth treated for endodontic reasons versus those treated for other reasons), and number of canals. The third model included reasons for retreatment (radiolucency or symptoms versus asymptomatic faulty filling/seal) and number of canals.

Only the actual number of root-filled canals was accounted for, i.e. resected molars contributed to the total number of canals only for those canals that were retained.

Results

In total, 411 patients were consecutively treated: 250 females (60.8%) and 161 males (39.2%). The age at

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Table 1 Tooth type distribution.

	n = 1175 (%)
Incisors	202 (17.2)
Canines	96 (8.2)
Premolars	289 (24.6)
Molars	546 (46.5)
Wisdom teeth	42 (3.6)

Table 2 Number of teeth with one or more canals.

	n = 1175 (%)
1 canal	481 (40.9)
2 canals	221 (18.8)
3 canals	371 (31.6)
4 canals	100 (8.5)
5 canals	2 (0.2)

endodontic treatment ranged from 8 to 86 years (mean 43.5 years). A total of 168 patients (40.9%) were endodontic or prosthetic cases, whereas 243 patients (59.1%) were affected by generalised (more than 30% of the sites) severe periodontitis (at least one site with interproximal pocket probing depth of at least 6 mm after non-surgical cause-related periodontal therapy) and were rehabilitated with fixed prostheses. The total number of endodontically treated teeth was 1175 (2446 canals); 704 (59.9%) teeth were endodontically treated for the first time whereas 471 (40.1%) teeth were retreated. Tooth type and number of canals distributions are presented in Tables 1 and 2, whereas reasons for treatment and retreatment are presented in Table 3.

Of all the included teeth, 528 (44.9%) vital teeth were treated in a single session. Of the 176 (15.0%) necrotic teeth, 128 were treated without intermediate medications and 48 with intermediate medications. Of the 471 (40.1%) retreated teeth, 256 were treated without intermediate medications and 215 with intermediate medications.

Between 1986 and 1993, 523 (44.5%) teeth were treated according to the Schilder technique, whereas between 1994 and 1998, 652 (55.5%) teeth were treated according to a crown-down with lateral condensation technique. In total, 975 (83.0%) teeth were reconstructed with a fixed prosthesis whereas 200 (17.0%) teeth were simply obturated with amalgam, composite fillings or gold onlays.

After 10 years, 102 (24.8%) patients dropped out. Reasons for drop-outs are described in Table 4. The patients who decided not to attend the 10-year visit and those who moved away were asked about any dental symptoms or problems and none reported any.

A total of 32 teeth (2.7%) experienced one complication over the 10-year follow-up, which was successfully solved either by retreatment, surgery or with a rizectomy. For 25 teeth, the complication occurred within 2 years, for three teeth within 3 years and in four teeth after 5 years. For 18 teeth, the complication was resolved with surgery, in 11 with retreatment and in three with rizectomy. Two teeth had to be retreated twice. Reasons for complications are described in Table 5. For 27 teeth (84.4%), one clinical session was sufficient to resolve the complication, whereas for five teeth (35.6%) two clinical appointments were necessary to resolve the complication.

Success/failure rates as recorded by the treating dentist were the following: 988 (84.1%) teeth were a complete success; 46 (3.9%) a partial success; 52 (4.4%) a partial failure (however all these teeth are still in function); 68 (5.8%) were extracted (reasons for tooth extraction are reported in Table 6); and for 21 teeth (1.8%) no decision could be made since these patients were immediately lost at the follow-up.

Table 3 Reasons for endodontic treatment/retreatment.

Reasons for endodontic treatment	**n = 704 (%)**
Pulpitis	177 (25.1)
Necrosis without radiolucency	46 (6.5)
Necrosis with radiolucency	130 (18.5)
Rizotomy because of periodontitis	210 (29.8)
Not in axis for prosthetic preparation	78 (11.1)
Excessive tooth sensitivity	63 (8.9)
Reasons for endodontic retreatment	**n = 471 (%)**
Symptoms without radiolucency	3 (0.6)
Radiolucency with or without symptoms	200 (42.5)
Poor canal filling (underfilling, etc.)	152 (32.3)
Inadequate seal of the coronal portion	116 (24.6)

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Table 4 Reasons for drop-outs at the 10-year follow-up.

	n = 102 (%)
Not able to contact	44 (43.1)
Not willing to attend	21 (20.6)
Moved away	16 (15.7)
Died	16 (15.7)
Severely ill	2 (2)
Litigation	3 (2.9%)

Table 5 Reasons for complications of teeth that were successfully resolved with retreatment.

	n = 32 (%)
Unpleasant feeling/pain	15 (46.9)
Persisting lesion	8 (25)
Abscess	8 (25)
External root resorption	1 (3.1)

Table 6 Reasons for tooth extraction.

	n = 68 (%)	Retreated teeth only (n = 25)
Periodontitis	29 (42.6)	9
Tooth fracture	20 (29.4)	7
Endodontic	8 (11.8)	3
Caries	4 (5.9)	2
Replaced by implants	4 (5.9)	2
Perforation	2 (2.9)	2
External root resorption	1 (1.5)	0

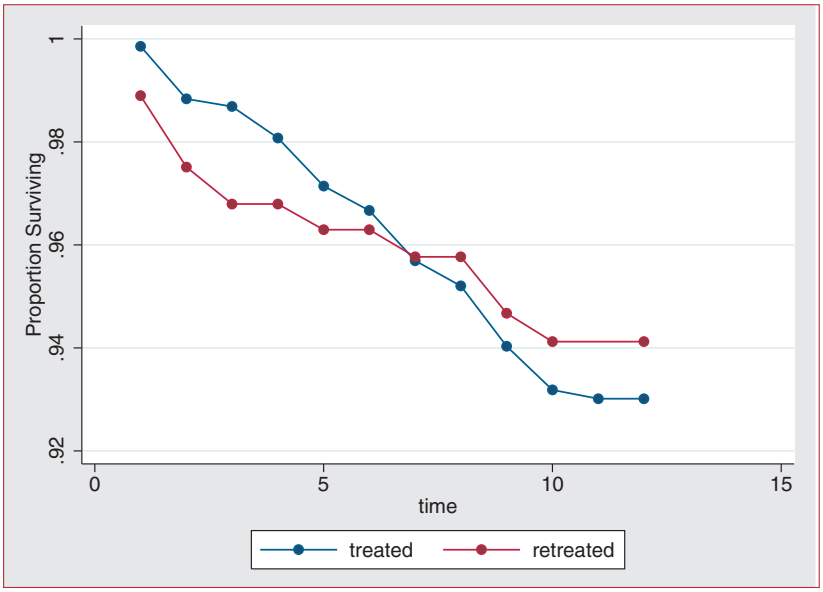

Fig 1 Kaplan–Meier survival analysis comparing teeth endodontically treated for the first time (blue line) with endodontically retreated teeth (green line).

The life-table analysis showed that the probability of teeth surviving 10 years after endodontic treatment was 93% (Table 7). There were no differences in probability of tooth survival when comparing teeth endodontically treated for the first time to teeth endodontically retreated using Kaplan–Meier statistics (log-rank test, chi-square 0.266, 1 degree of freedom, *P* value = 0.61) (Fig 1).

Readable periapical radiographs of 1086 (92.4%) teeth were available and were independently evaluated by a masked assessor for radiographic changes. The evaluated radiographs were those taken between year 9 and 11 after treatment. The radiographs of the 68 extracted teeth (5.8%) were not evaluated, but the most recent radiographs available for the patients who dropped out were assessed. A total of 980 teeth (90.2%) did not show any pathological sign; 52 teeth (4.8%) showed a reduction of the periapical lesion; and 54 teeth (5%) showed no changes or worsening of the radiographic signs. The results of the Cox regression models are given in Tables 8 to 10.

- There was no association between endodontically treated and retreated single- and multi-rooted teeth with 10-year tooth loss (Table 8).
- There was no association between the reason for endodontically treating teeth for the first time (teeth treated for endodontic reasons versus those treated for other reasons: root resection because of advanced periodontitis; not being in axis for prosthetic preparation and excessive tooth sensitivity) and single- and multi-rooted teeth with 10-year tooth loss (Table 9).
- Endodontic success of retreated teeth was associated with the reason for retreatment (*P* = 0.034), with teeth with faulty fillings/sealing having a better prognosis than teeth with symptoms and radiolucency (Hazard Ratio 0.33, 95% CI 0.12 to 0.92) (Table 10). There was no association for endodontically retreated single-rooted versus multi-rooted teeth with 10-year tooth loss (Table 10).

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Table 7 Life-table analysis of tooth survival 10 years after treatment. In total, 93% of the endodontically treated teeth survived at the end of the 10-year follow-up.

Interval start time	Number entering interval	Number withdrawing during interval	Number exposed to risk	Number of terminal events	Cumulative proportion surviving at end of interval
0	1175	36	1157.000	6	.99
1	1133	40	1113.000	13	.98
2	1080	22	1069.000	4	.98
3	1054	23	1042.500	4	.98
4	1027	18	1018.000	8	.97
5	1001	23	989.500	3	.97
6	975	25	962.500	8	.96
7	942	12	936.000	3	.95
8	927	16	919.000	11	.94
9	900	3	898.500	7	.94
10	890	0	890.000	1	.93

Table 8 Results of Cox proportional hazards model fitted for the survival time to failure and the number of canals (teeth with 1 versus 2 or more canals), taking into account the clustering of teeth within patients (1133 teeth in 388 patients).

Explanatory variable	Hazard ratio	Robust SE	*P* value	95% confidence interval
1 canal vs more canals	1.23	0.36	0.46	0.70–2.17

Table 9 Results of Cox proportional hazards models fitted for the survival time to failure and the covariate treatment reasons (teeth treated for endodontic reasons versus treated for other reasons) and number of canals (teeth with 1 versus 2 or more canals), taking into account the clustering of teeth within patients (693 teeth in 309 patients).

Explanatory variable	Hazard ratio	Robust SE	*P* value	95% confidence interval
Treatment reason	1.59[a]	0.50	0.14	0.85–2.95
1 canal vs more canals	1.19	0.43	0.63	0.59–2.41

a Direction of effect: teeth treated for endodontic reasons more successful than teeth treated for other reasons.

Table 10 Results of Cox proportional hazards models fitted for the survival time to failure and the covariate retreatment reasons (presence of symptoms and radiolucency versus asymptomatic faulty fillings/seals), and number of canals (teeth with 1 versus 2 or more canals), taking into account the clustering of teeth within patients (439 retreated teeth in 186 patients).

Explanatory variable	Hazard ratio	Robust SE	*P* value	95% confidence interval
Retreatment reason	0.33[a]	0.17	0.034	0.12–0.92
1 canal vs more canals	1.11	0.58	0.84	0.40–3.08

a Teeth retreated for endodontic symptoms or radiolucency had a statistically significantly higher probability of failure.

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Discussion

The present retrospective cohort study has shown that root canal therapy can lead to good success rates over a 10-year period. In particular, only 7% of the root-treated teeth had to be extracted. Another 4.4% of the treated teeth did not display improved radiographic signs, however these teeth were completely asymptomatic and fully functioning. Among the failed teeth, only 16% of the failures were for various endodontic-related reasons, whereas the great majority of extractions (42.6%) were caused by periodontitis. This apparently odd distribution of failure reasons can be easily understood when considering the type of patients included. The majority of patients (59%) treated at the practice were advanced periodontal cases rehabilitated with fixed prostheses, therefore it is understandable that a significant number of teeth were extracted because of recurrent periodontal disease over a 10-year period. The second most common cause of failure (29.4%) was tooth fracture.

A statistically significant difference was found when comparing teeth retreated for faulty filling/seal with teeth retreated because of symptoms/radiolucency. Teeth retreated only because they were not properly root filled tended to be more successful than teeth displaying clinical/radiographic symptoms. This may not be a surprising finding since those teeth with faulty or excessive fillings as detected on radiographs, in the absence of clinical radiographic symptoms, are less likely to be infected, and consequently they are less likely to fail.

Endodontic failures were not associated with teeth having multiple canals, which is in agreement with some studies[6] and not with others[7].

When evaluating complications, it should be observed that only the successfully treated complications were reported, since complications resulting in tooth extraction were counted as complete failures. Only 32 teeth (2.7%) experienced a complication and were retreated. A persistent asymptomatic lesion after treatment was not considered as a complication unless the tooth needed to be prosthetically restored or was close to a dental implant. Similar data (2.8% and 3.9% of successfully treated complications) were also reported in a large cohort of insured dental patients (109,452 and 44,613 patients, respectively) followed, on average, 22 months and 3.5 years, respectively, and treated by private dentists[8]. These data suggest that the incidence of complications in endodontic therapy is low, possibly around 5 to 10%, and that about half of these complications can be successfully treated whereas the remaining may lead to extraction of the affected teeth.

Among the main limitations of the present study, the following should be listed: the retrospective design, the unknown clinical outcome of about 60% of the patients that dropped out, and lack of radiographs of 21 teeth (1.8%). Ideally, the study should have been conducted prospectively with a specifically designed protocol. No research protocol was conceived prior to the initiation of the endodontic root canal treatments, however data has been recorded quite thoroughly, and from 2007 was systematically recorded in a prospective way. A drop-out rate of about 25% (102 patients) of the treated patients over a 10-year period in the present study is acceptable particularly when compared with 70 to 73% drop-out rates after 4 to 6 years[7,9] or 54% after 8 to 10 years[10] for other studies. Twenty-four patients, of those contacted by phone, reported no dental problems, though a few did not respond. In addition, 16 patients died, therefore about 40% of the dropouts unlikely had problems whereas the situation for the remaining 60% of patients who dropped out is unknown. The radiographic evaluation was performed by an independent assessor and only 1.8% of the radiographs were missing. When comparing the methodological quality of the present study with other previously published studies, the following observations should be made: studies presented as having 8[11] or 10-year[2] follow-ups did not actually have 8 or 10-year follow-ups on average. The actual mean observation time was either unknown[11], though probably shorter, or less than 3 years[2]. Other studies did not consider the teeth clustering effect in the same patient[2,6-9,11-13], and the great majority of similar studies did not report information on who performed the assessment or the number and reasons for drop-outs, with few exceptions[10].

The present study reported similar survival rates (93%) compared to the 92% average of those reported in a systematic review[1,] which included

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survival rates of four studies with a follow-up of 6 years or more. In two studies with an approximate 10-year follow-up, 10.7%[10] and 15.3%[6] of teeth were extracted. Several factors could explain this difference. For instance, in both studies with less favourable results[6,10], the endodontic therapies were performed by undergraduate dental students who had little or no clinical experience. In a large cohort of insured dental patients (44,613), followed on average for 3.5 years (minimum 2 years) and treated by private American general dentists and specialists, 5.6% of the endodontically treated teeth were extracted[8].

The results of the present study can be generalised to a wider patient population, keeping in mind that treatments were delivered in a private practice with a well organised recall and maintenance system by a single operator mostly dedicated to endodontic therapy. It would be interesting to follow this cohort of patients for another decade to acquire more information on the long-term prognosis of endodontic therapy.

Conclusions

Ten years after delivery of endodontic therapy, success rates can be above 90% with about 7% of teeth extracted. Teeth retreated for symptoms or radiolucency are more likely to fail.

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