Clin Oral Invest (2013) 17:2099–2104
DOI 10.1007/s00784-013-0926-2

ORIGINAL ARTICLE

Radiographic follow-up of periapical status after endodontic treatment of teeth with and without apical periodontitis

Sisko Huumonen · Dag Ørstavik

Received: 30 March 2012 / Accepted: 21 January 2013 / Published online: 5 February 2013

Abstract
Objectives The aim was to assess objectively the rate of changes in periapical status after endodontic treatment in relation to preoperative radiographic status (Periapical Index Score, PAI) and to tooth type.
Material and methods Radiographic data from a total of 1,410 teeth in seven prospective clinical studies was pooled. The periapical status was evaluated blindly using the PAI scoring system. The longest follow-up period was 4 years; intervals between controls varied from 3 months to 1 year.
Results Teeth with preoperative PAI score 1 maintained excellent periapical health throughout. Teeth with preoperative PAI score 2 showed some impairment in health over the first 6 months, but improved to approach 95 % healthy teeth at 2 years of observation. Teeth with PAI 3–5 at the start showed significant improvement at 3 months; 27 % were considered healthy (PAI 1 or 2) increasing to 41 % after 1 year. Improvement of periapical status was slower in PAI groups 4 and 5 compared with PAI 3 during the first year. After 2 years, improvement continued similarly in all preoperative PAI 3–5 groups of teeth. Upper lateral incisors showed the poorest healing rate.
Conclusions Healing of pre-existing periapical lesions is most pronounced from 3 months to 2 years. Teeth with initially healthy periapical structures predictably maintain good periapical health. Maxillary teeth, especially lateral incisors, showed poorer healing rates than mandibular teeth.
Clinical relevance Radiographic healing rates may vary among tooth groups within the dentition. Periapically healthy teeth that are root filled may not need postoperative controls.

Keywords Apical periodontitis · Developing · Healing · Tooth type

S. Huumonen (✉)
Institute of Dentistry, Faculty of Medicine, University of Turku,
Lemminkäisenkatu 2,
20520 Turku, Finland
e-mail: sisko.huumonen@utu.fi

S. Huumonen
Department of diagnostic imaging, Turku University Hospital,
Turku, Finland

S. Huumonen · D. Ørstavik
NIOM—Nordic Institute of Dental Materials, Oslo, Norway

D. Ørstavik
Department of Endodontics, Institute of Clinical Dentistry,
University of Oslo, Oslo, Norway

Introduction

The presence of a preoperative apical periodontitis lesion poses the most significant risk for endodontic outcome [1]. Endodontic success of roots with normal preoperative periapical structures is significantly higher than that of roots associated with apical periodontitis lesion [2, 3]. Most reports are based on success–failure analyses [4] and controls have been suggested until normal periapical structures can be seen on a radiograph. This often means many years of follow-up. In some cases healing may take 10 years or even longer [5–7]. The European Society of Endodontology [8] recommends 4 years of follow-up.

Development and healing of apical periodontitis lesions may take a considerable amount of time. For clinical decision-making, it is of interest to predict the prognosis of a tooth as early as possible after endodontic treatment. For design of clinical studies, knowledge of the time–course of healing or disease development is essential. While therapeutic variables have been extensively studied for their effect on final treatment outcome, less is known about the rate of healing and developing apical periodontitis in relation to preoperative

periapical status and tooth type. The aim of this study was to assess objectively the rate of changes in periapical status after endodontic treatment in relation to preoperative radiographic status (Periapical Index Score, PAI) for up to 4 years. Furthermore, the healing pattern of different tooth types was investigated.

Material and methods

Radiographic data from seven prospective clinical studies formed the basis of this study. A detailed description of the materials and methods has been published previously [9–15]. Endodontic treatment was conducted by senior dental students under supervision of clinic staff at university, by graduate students and staff at university, or by specialists in endodontics in private practice. While different sealers were used in the original studies, a standardized gutta-percha master point was used, and cold lateral condensation of accessory points completed the root filling in all studies.

A total of 1,410 teeth of 1,119 patients were included in this study. The frequencies of different tooth types at the start are shown in Table 1. Of all patients, dental students treated 86 %.

Radiographic technique and scoring

Periapical intraoral radiographs were taken with a beam-guiding device using paralleling technique. A radiograph was taken preoperatively and at filling. In the analysis the higher periapical index (PAI) score of these two was chosen (=PAI at start). Thereafter the patients participated in a recall program of clinical and radiographic examination. The time intervals varied from 3 months to a year. The total length of the control period in the original studies varied from 1 to 4 years.

The periapical status was assessed by means of PAI scoring on a scale from 1 to 5 [16] (Table 2). In multi-rooted teeth the root given the highest PAI score determined the periapical status of the tooth. It is inherent in the scoring system that each tooth is scored independently of other radiographs of that tooth. The PAI scores were used for quantitative analyses of the treatment results. For some analyses, scores 1 and 2 were pooled as a robust categorization of a healthy periapical status [16].

The data of original studies was used in this study. Before evaluation of radiographs in the original studies, all the observers had participated in a calibration course for the PAI system, which consisted of 100 radiographic images of teeth, some root filled and some not. Each tooth had to be assigned to one of the five PAI scores using visual reference for the five categories within the scale (Table 2). After scoring the teeth, the results were compared to a "silver standard" and a Cohen's Kappa value was calculated [16]. A Kappa value of 0.61 or higher is considered good reproducibility, allowing comparisons of data obtained by different observers in different studies [17]. Therefore, the observers had to obtain Kappa values of 0.61 or higher in order to participate in the evaluation. In different original studies Cohen's Kappa varied from 0.61 to 0.8, indicating good reproducibility.

Statistical analyses

SPSS 17.0 for Windows (SPSS Inc, Chicago, IL) was used for data processing and statistical analysis. All subjects having radiographic data at the start and follow-ups were included in this study.

As PAI scores were measured on an ordinal scale, non-parametric tests were used for the statistical analyses. First, Kruskal–Wallis test was used to test differences between the original studies in the PAI values at different time points. Because no differences were found, the original studies were pooled without weighting subjects. The Kruskal–Wallis test was also used to compare the PAI scores of different tooth types at individual time points. When appropriate, paired comparisons were performed using the Wilcoxon signed rank test.

Table 1 Number of different tooth types in different PAI score groups at start

Tooth group	PAI 1	PAI 2	PAI 3	PAI 4	PAI 5	Total
Maxillary centrals	17	15	24	22	5	83
Maxillary laterals	26	14	35	44	8	127
Maxillary canines	36	32	21	16	4	109
Maxillary premolars	51	53	57	59	5	225
Maxillary molars	101	56	53	47	0	257
Mandibular centrals	3	5	1	25	7	41
Mandibular laterals	5	8	5	17	5	40
Mandibular canines	20	14	11	19	4	68
Mandibular premolars	35	38	40	72	15	200
Mandibular molars	67	87	49	47	10	260
Total	361	322	296	368	63	1,410

Table 2 Description of the periapical index (PAI) scoring system [16]

1	Normal periapical structures
2	Small changes in bone structure
3	Changes in bone structure with some mineral loss
4	Periodontitis with well-defined radiolucent area
5	Severe periodontitis with exacerbating features

The process of healing between different time points was determined with the Friedman test. When appropriate, the Wilcoxon test was used for paired comparisons. A level of $p<0.05$ was chosen for statistical significance.

Results

Preoperative "normal" periapical status: PAI score 1 or 2 at start

If there were no signs of apical periodontitis at the start of endodontic treatment (PAI 1 and 2; $n=683$), a slight worsening of the periapical status was found during the first 2 years (Fig. 1), largely dependent on a change in the preoperative PAI 2 group to PAI 3. Development of apical periodontitis after start was seen in 9 % of the cases after the first year, and thereafter in 3, 2, and 1 % of the cases after the second, third, and fourth years, respectively (Table 3). The difference was statistically significant between the start and the first year.

Among different tooth types, maxillary canines showed the highest incidence of development of apical periodontitis during the first year (18 %). On the other hand, none of 30 maxillary centrals developed apical periodontitis during the first year (Table 4). The difference was statistically significant between maxillary canines and maxillary centrals as well as between maxillary canines and maxillary molars.

Preoperative apical periodontitis: PAI score 3, 4, or 5 at start

As a group, teeth with apical periodontitis (PAI 3, 4, or 5) at the start ($n=727$) showed clear signs of healing after 3 months ($p<0.05$; Table 3, Fig. 1). Improvement of the periapical status was fastest during the two postoperative years, but continued throughout the entire observation period (up to 4 years). The difference was statistically significant from start up to 3 years.

The proportion of improved and healed cases increased at different rates in different PAI score groups (Table 3). Healing was fastest in teeth having PAI 3 at start, and the significant difference continued up to 3 years compared with PAI 4, and up to 2 years compared with PAI 5 (Fig. 1). The healing pattern of different tooth types did not vary in PAI score 3, 4, or 5 at different time points.

Teeth having PAI value 3 at the start showed significant healing after 3 months compared to the start ($p<0.05$). Significant healing continued up to 2 years, thereafter more slowly up to 3 years, when the proportion of healed teeth (PAI 1 or 2) was 84 % (Table 3, Fig. 1).

During the first postoperative year teeth with PAI 5 at the start healed more slowly than those with PAI 4 ($P<0.05$). Thus, statistically significant healing continued up to 2 years. After 1 year the healing patterns became similar in the PAI score groups 4 and 5 (Table 3, Fig. 1). The numbers at recall at 3 and 4 years were low, but seemed to confirm this general trend of continued healing.

Teeth not showing healing

Of all 727 teeth with apical periodontitis, 156 teeth did not show improvement of periapical status during the first year. Of these, 83 teeth had PAI score 3, 71 teeth had PAI score 4, and 2 teeth had PAI score 5. Among different tooth types maxillary lateral incisors had the poorest healing rate and mandibular premolars the best during the first year (Table 5). A statistically significant difference was seen between maxillary laterals and maxillary canines and all types of mandibular teeth, as well as between maxillary molars and mandibular premolars.

Discussion

The primary interest in this study was to follow-up the teeth available as regards the rate of healing or developing apical periodontitis; thus, no analysis of the effect of treatment variables or postoperative restorative procedures was intended or performed. While it is unfortunate that the recall

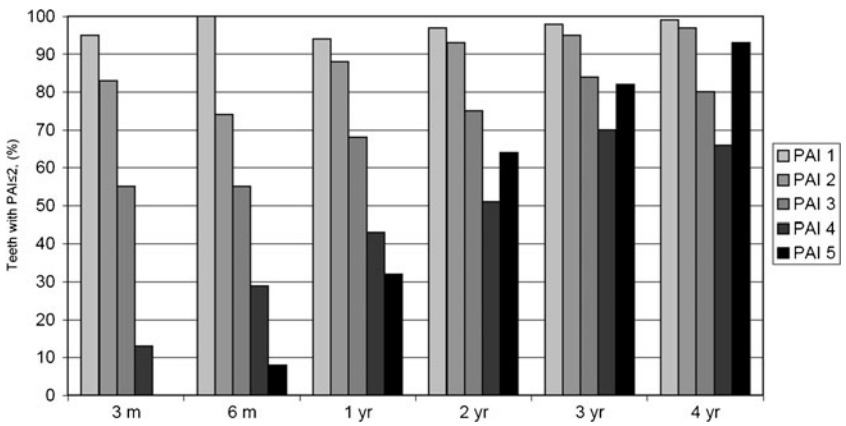

Fig. 1 Periapical conditions following root canal treatment of different PAI-score groups

Table 3 Teeth with PAI scores 1 or 2 at intervals after treatment by PAI score at start

PAI at start	*N* at start	*N* 3m	% 3m	*N* 6m	% 6m	*N* 1yr	% 1yr	*N* 2yr	% 2yr	*N* 3yr	% 3yr	*N* 4yr	% 4y-r
1	361	21	95	18	100	319	94	269	97	239	98	140	99
2	322	29	83	19	74	283	88	213	93	164	95	145	97
3	296	119	55	44	55	256	68	149	75	45	84	92	80
4	368	-	13	80	29	324	43	188	51	96	70	86	66
5	63	22	0	12	8	53	32	36	64	22	82	15	93
AR			87		83		52		80		74		47

N number, *m* month(s), *yr* year(s), *AR* Attendance rate (%)

rate declined over time in the pooled dataset, it seems arguable that the rates of disease healing or development may be little, if at all, affected by drop-outs during the studies. The studies included were chosen because the raw data was available and because they were done with the PAI scoring system for assessment of radiographic signs of disease using calibrated observers. A detailed discussion of the strengths and weaknesses of the PAI scoring system has been given before [16].

An endodontic recall program aims at selection of teeth in need of further controls or retreatment from healthy teeth. Controls are recommended until completely healthy periapical structures can be verified radiographically. Follow-ups of 3 to 4 years may be required to record a stable treatment outcome that reflects the true prognosis [5, 9, 18, 19]. Others have classified cases as success or failure after shorter periods [9, 20]. At 1-year control, no further controls are recommended if a patient is free of symptoms and without radiographic signs of apical periodontitis. When in doubt, the patient should be re-examined 3 years later, and any suspicion of periapical disease may justify re-treatment of the tooth [20]. It has also been suggested that follow-up of at least 1 year is required to reveal changes in periapical status [21]. On the other hand, all roots deemed to have healed at 4 years control showed improvement in periapical status already after 1 year [2]. After 10 years, the number of healed apical periodontitis lesions appears similar to the number of newly developed lesions [22]. In the long-term, successes will outnumber failures in teeth followed for a long time [23]. Although the root filling is the portal of entry for the periapical infection, with time the influence of other factors, such as delayed or insufficient coronal restoration, may cause root canal infection and confound the result of the endodontic procedure itself. Comparing the 4-year and 10-year follow-up, Strindberg [5] observed an increase of 16 % in healing rates.

Apical periodontitis is a sequel to bacterial infection of the dental pulp space [23]. The extent of a lesion is largely dependent on the amount of bacteria in the root canal [20, 23]. The presence and extent of the preoperative lesion has the strongest negative effect on endodontic outcome [3]. In addition, irrespective of initial lesion size, in most cases the size of the lesion decreases to 2 mm or less within 2 years after endodontic treatment [18]. Sometimes, the reduction in lesion size continues for 4–5 years [18] or even 8–9 years [5]. As long as there is a continuous decrease in the size of the lesion, there is no reason to judge a case a failure [18].

Table 4 Development of apical periodontitis (AP) at 1 year in teeth with PAI score 1 or 2 at start in different tooth groups

Tooth group	*N* of teeth	PAI 3–5	PAI 4–5	% developing AP
Maxillary centrals	30	0	0	0
Maxillary laterals	32	4	1	13
Maxillary canines	60	11	0	18
Maxillary premolars	88	10	1	11
Maxillary molars	147	6	1	4
Mandibular front teeth[a]	51	3	0	6
Mandibular premolars	64	6	0	9
Mandibular molars	133	11	1	8

At 1 year 605 teeth were available for comparisons

N number

[a] Incisors and canines

Table 5 Incomplete healing at 1 year of teeth with apical periodontitis in different tooth groups

Tooth group	*N* of teeth	PAI 3–5	PAI 4–5	*N* not improved	% not improved
Maxillary centrals	46	22	2	10	22
Maxillary laterals	76	46	17	32	42
Maxillary canines	63	23	2	8	13
Maxillary premolars	101	49	17	30	30
Maxillary molars	88	42	0	28	32
Mandibular front teeth[a]	85	49	12	15	18
Mandibular premolars	106	26	9	13	12
Mandibular molars	106	42	10	20	19

N number

[a] Incisors and canines

While there may be several reasons for apical periodontitis to heal at different rates or not to heal, e.g., residual infection and cementum chips forced into the periapical tissue during mechanical instrumentation [24], the influence of details of the preoperative radiographic status has not been looked at in detail. We found that teeth with PAI 3 improved faster than teeth with PAI 4 and 5 up to the 3-year control. From 3 years on healing continued similarly. Healing of apical periodontitis was fastest during the first postoperative year in all apical periodontitis groups of teeth in accordance with previous reports [2, 15]. In addition, this study showed that significant healing was already seen at the 3-month control. Most of the teeth with preoperative apical periodontitis healed during the first year, also in accordance with previous reports [2, 20, 25].

In the present study, teeth having normal preoperative periapical structures showed a transient impairment of periapical status at 6 months, mostly for the PAI 2 group. However, after that, a high and constant proportion of healthy teeth were seen throughout the 4-year observation period. Postoperative apical periodontitis is most probably associated with infection during the treatment procedures, and will require some time before radiographic changes become visible. Partly in accordance with these results, the 1-year control has been shown to be the most suitable for assessment of treatment outcome for these teeth [2, 20]. Our results here confirm previous studies [25–27], and indicate that the rationale for systematic postoperative controls is limited. With a predictable maintenance of good periapical health, it also follows that these teeth are poorly suited for comparative studies on treatment outcome.

Studies on the healing of apical periodontitis of different tooth types are sparse. Maxillary and mandibular canines and maxillary second premolars have a better prognosis than other teeth [19]. Other studies do not demonstrate a specific pattern [11, 13]. In this study, at the 1-year control, maxillary lateral incisors, maxillary molars, and premolars showed impaired healing relative to other teeth. Maxillary first molars often have two canals in the mesiobuccal root; one of these may be undetected, untreated, and unfilled, leading to persistent infection. Maxillary lateral incisors have anatomical variations, such as apical root curvature and thin roots, which may make it difficult to adequately clean and fill the root canal system. In addition, they have more often dens invaginatus than other tooth types [28]. Endodontic treatment of invaginated teeth may be complicated [29]. In selected cases, continued controls of these types of teeth may be indicated longer compared to other teeth.

Several clinical and epidemiological studies have used the PAI score system in the evaluation of periapical status [13, 16, 30, 31]. In this study, the treatment protocols of the original studies were similar. Calibrated observers analyzed the radiographs. Therefore, pooling several prospective clinical studies may be a good alternative to otherwise expensive and long-lasting studies. A limitation of this study was the substantial reduction of teeth at the recall appointments. The reasons for patients not appearing or the reason for the number of extracted teeth were not controlled, as the primary interest was in the temporal chances of the periapical status as it is visible in practical circumstances. While there may be bias due to the dropouts, the descriptive analysis of the healing pattern that was performed should not be affected to any great extent. Moreover, no comparison within groups, which could have been affected by drop-outs, was made in this study.

It may still be hypothesized that drop-outs from control appointments may shift results towards a more favorable outcome, as teeth with problems might be less likely to be picked up. In this context, the results for teeth with PAI scores 3 to 5 at start shown in Fig. 1 are of particular concern: complete healing (ending with a PAI score of 1 or 2) was in the order of 75 %. Even when just a reduction in PAI score was used as a criterion for success, a favorable outcome was found only in about 85 %.

In conclusion, based on data obtained with periapical radiographs, changes after 2 years affect only marginally overall evaluations of periapical health in groups of teeth. For teeth with apical periodontitis a first postoperative control 3 months postoperatively can be recommended. The period from 6 months to 2 years seem suitable for outcome studies. Preoperatively healthy teeth may not need follow-up, and are poorly suitable for follow-up studies of clinical variables. A differential response of specific tooth types cannot be ruled out; particularly, upper lateral incisors may show a different healing pattern compared to other tooth types.

Acknowledgment The authors deny any conflicts of interest. We have no financial affiliation for this paper.

References

1. Friedman S, Mor C (2004) The success of endodontic therapy—healing and functionality. J Calif Dent Assoc 32:493–503
2. Ørstavik D (1996) Time–course and risk analyses of the development and healing of chronic apical periodontitis in man. Int Endod J 29:150–155
3. Chugal NM, Clive JM, Spånberg LS (2001) A prognostic model for assessment of the outcome of endodontic treatment: effect of biologic and treatment variables. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 91:342–352
4. Kojima K, Inamoto K, Nagamatsu K, Hara A, Nakata K, Morita I et al (2004) Success rate of endodontic treatment of teeth with vital and nonvital pulps. A meta-analysis. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 97:95–99
5. Strindberg LZ (1956) The dependence of the results of pulp therapy on certain factors. Acta Odontol Scand 14(Suppl 21):1–175

6. Molven O, Halse A, Fristad I, MacDonald-Jankowski D (2002) Periapical changes following root-canal treatment observed 20–27 years postoperatively. Int Endod J 35:784–790
7. Fristad I, Molven O, Halse A (2004) Nonsurgically retreated root filled teeth-radiographic findings after 20–27 years. Int Endod J 37:12–18
8. European Society of Endodontology (2006) Quality guidelines for endodontic treatment: consensus report of the European Society of Endodontology. Int Endod J 39:921–930
9. Ørstavik D, Kerekes K, Eriksen HM (1987) Clinical performance of three endodontic sealers. Endod Dent Traumatol 3:178–186
10. Ørstavik D, Kerekes K, Molven O (1991) Effects of extensive apical reaming and calcium hydroxide dressing on bacterial infection during treatment of apical periodontitis: a pilot study. Int Endod J 24:1–7
11. Ørstavik D, Hørsted-Bindslev P (1993) A comparison of endodontic treatment results at two dental schools. Int End J 26:348–354
12. Kerosuo E, Ørstavik D (1997) Application of computerized image analysis to monitoring endodontic therapy: reproducibility and comparison with visual assessment. Dentomaxillofac Radiol 26:79–84
13. Trope M, Delano EO, Ørstavik D (1999) Endodontic treatment of teeth with apical periodontitis: single vs. multivisit treatment. J Endod 25:345–350
14. Waltimo TM, Boiesen J, Eriksen HM, Ørstavik D (2001) Clinical performance of 3 endodontic sealers. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 92:89–92
15. Huumonen S, Lenander-Lumikari M, Sigurdsson A, Ørstavik D (2003) Healing of apical periodontitis after endodontic treatment: a comparison between a silicone-based and a zinc-oxide eugenol-based sealer. Int Endod J 36:296–301
16. Ørstavik D, Kerekes K, Eriksen HM (1986) The periapical index: a scoring system for radiographic assessment of apical periodontitis. Endod Dent Traumatol 2:20–34
17. Landis JR, Koch GG (1977) The measurement of observer agreement for categorical data. Biometrics 33:159–175
18. Byström A, Happonen RP, Sjögren U, Sundqvist G (1987) Healing of periapical lesions of pulpless teeth after endodontic treatment with controlled asepsis. Endod Dent Traumatol 3:58–63
19. Kerekes K, Tronstad L (1979) Long-term results of endodontic treatment performed with a standardized technique. J Endod 5:83–90
20. Reit C (1987) Decision strategies in endodontics: on the design of a recall program. Endod Dent Traumatol 3:233–239
21. Eriksen HM, Orstavik D, Kerekes K (1988) Healing of apical periodontitis after endodontic treatment using three different root canal sealers. Endod Dent Traumatol 4:114–117
22. Petersson K, Håkansson R, Håkansson J, Olsson B, Wennberg A (1991) Follow-up study of endodontic status in an adult Swedish population. Endod Dent Traumatol 7:221–225
23. Molven O, Halse A (1988) Success rates for gutta-percha and Kloroperka N-0 root fillings made by undergraduate students: radiographic findings after 10–17 years. Int Endod J 21:243–250
24. Yusuf H (1982) The significance of the presence of foreign material periapically as a cause of failure of root treatment. Oral Surg Oral Med Oral Pathol 54:566–574
25. Adenubi JO, Rule DC (1976) Success rate for root fillings in young patients. A retrospective analysis of treated cases. Br Dent J 19:237–241
26. Barbakow FH, Cleaton-Jones P, Friedman D (1980) An evaluation of 566 cases of root canal therapy in general dental practice. 2. Postoperative observations. J Endod 6:485–489
27. Friedman S, Lost C, Zarrabian M, Trope M (1995) Evaluation of success and failure after endodontic therapy using a glass ionomer cement sealer. J Endod 21:384–390
28. Hamasha A, Alomari Q (2004) Prevalence of dens invaginatus in Jordanian adults. Int Endod J 37:307–310
29. Hűlsmann M (1997) Dens invaginatus; aetiology, classification, prevalence, diagnosis and treatment considerations. Int Endod J 30:79–90
30. Marending M, Peters OA, Zehnder M (2005) Factors affecting the outcome of orthograde root canal therapy in a general dentistry hospital practice. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 99:119–124
31. Valderhaug J, Jokstad A, Ambjørnsen E, Norheim PW (1997) Assessment of the periapical and clinical status of crowned teeth over 25 years. J Dent 25:97–105