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Technical quality of root fillings and periapical status in root filled teeth in Jönköping, Sweden

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Abstract

Frisk F, Hugoson A, Hakeberg M. Technical quality of root fillings and periapical status in root filled teeth in Jönköping, Sweden. *International Endodontic Journal*, **41**, 958–968, 2008.

Aim To study changes in technical quality of root fillings and periapical status in root filled teeth in random samples of 20 to 70 year-olds between 1973 and 2003.

Methodology Data from dentate subjects aged 20–70 years from examinations conducted in 1973 (n = 498), 1983 (n = 530), 1993 (n = 547) and 2003 (n = 491) were used for the analysis. Length of root fillings were measured on radiographs to the nearest 0.1 mm. Adequate seal was defined as a root filling without lateral and/or apical voids. Periapical status was assessed according to the periapical index. All observations were made by one calibrated observer registered from full mouth radiographic examinations. Teeth with root fillings ending within the canal without lateral or apical voids were considered adequate. The association between root filling quality and periapical status was analysed by means of the Chi-squared test and a multilevel logistic regression analysis.

Results Adequately root filled teeth had a significantly lower frequency of apical periodontitis than inadequately root filled teeth (11.8% vs. 22.8%). The frequency of technically adequate root fillings increased statistically significant from 1973 (23.7%) to 2003 (36.4%) without a concomitant improvement of the periapical status in root filled teeth over time (24.5% vs. 24.6%).

Conclusions This study reports on an improving technical quality of root fillings over time, without a concomitant improvement of the periapical status in root filled teeth. A larger proportion of treated molars over time may be of importance for the result.

Keywords: apical periodontitis, cross-sectional, endodontic treatment, epidemiology, multilevel modelling.

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Introduction

Contemporary population surveys confirm the positive trend in oral health development which has been acknowledged for several decades (Hugoson *et al.* 2005). Decreasing frequency of edentulous individuals, increasing number of retained teeth in the elderly and a decreasing incidence of caries are major findings. Although decreasing apical periodontitis (AP) is still a prevalent finding in the population (Kirkevang *et al.* 2001a,b, Frisk & Hakeberg 2005) and although the incidence of caries has decreased, root canal treatment is still frequent (Björndal & Reit 2004). Thus, AP and endodontic treatment remain important public health issues in dentistry.

Endodontic treatment is widely recognized as a delicate task, and cross-sectional studies repeatedly demonstrate discouraging results with regard to treatment quality from a technical point of view (Ödesjö *et al.* 1990, Kirkevang *et al.* 2000, Skudutyte-Rysstad & Eriksen 2006). Clinical as well as epidemiological studies show that the quality of the root filling, as

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judged on an intra-oral radiograph, is associated with periapical status (Strindberg 1956, Ödesjö *et al.* 1990, Sjögren *et al.* 1990, Kirkevang *et al.* 2000). Thus, a root filling with lateral and/or apical voids providing a poor seal is predictive of presence of AP. Controlled clinical studies report on healing frequencies close to 90%, whilst epidemiological studies find AP in 25–50% of root filled (RF) teeth (Strindberg 1956, Ödesjö *et al.* 1990, Sjögren *et al.* 1990, Kirkevang *et al.* 2001a). Although it is not uncomplicated to compare these results, epidemiological studies can be interpreted as demonstrating what is achieved with endodontic treatment in general practice, whilst clinical studies show the potential in endodontic treatment.

In repeated cross-sectional studies, the frequency of adequate root fillings has been found to increase over time (Petersson 1993, Kirkevang *et al.* 2001b). However, the frequency of AP in conjunction with RF teeth has not decreased as a result. Petersson (1993) studied two similar populations in 1974 and 1985, respectively, and found that the technical quality of root fillings improved without a statistically significant improvement in periapical status. Kirkevang *et al.* (2001b) studied two populations in 1974–75 and 1997–98. They found an improving treatment quality over time but also an increasing frequency of AP in RF teeth. However, there were differences between the two populations that may have had an impact on the results. Skudutyte-Rysstad & Eriksen (2006) compared three populations of 35-year olds from Oslo, Norway, in 1984, 1993 and 2003. A statistically nonsignificant improvement in treatment quality was demonstrated with regard to length of the root fillings over time. Nonetheless, the frequency of AP in RF teeth was higher in 2003 than in 1993 and 1984.

Previously, a pilot study was conducted using cohorts of 50-year olds between 1973 and 2003 from the Study on Oral Health in Jönköping, Sweden. Frequency of AP in RF teeth was studied as well as changes in treatment quality. Preliminary data suggested that the treatment quality improved without a concomitant positive change in periapical status. The aim of the present study was to examine secular changes in endodontic treatment quality and AP in RF teeth between 1973 and 2003 in randomly selected subjects aged 20–70 years.

Material and method

In 1973 a random sample of subjects (n = 1000) aged 3, 5, 10, 15, 20, 30, 40, 50, 60 and 70 years from four parishes in the town of Jönköping, Sweden, were clinically and radiologically examined. Selection was based on date of birth between March and May, and all subjects in each age group were listed in chronological order, resulting in lists of 140–170 subjects in each age group. The first 100 individuals from each list were invited to a clinical and radiographic examination. In the event of nonattendance, the next individual on the list was invited, until the study sample consisted of 100 respondents in each age group. There were no information regarding differences between respondents and nonrespondents or reason for nonattendance (Hugoson & Koch 1979).

In 1983, 1993 and 2003, the study was repeated in the same geographical area with the same age groups as in 1973, with the addition of a cohort of 80-year olds. In each age group, 130 randomly selected individuals were invited for a clinical and radiographic examination. The participation rate was 77.2% in 1983, 75.4% in 1993 and 69% in 2003. The attendance rate for those aged 20–70 years was approximately 65–80%. For details regarding attendance rate and reasons for nonattendance, see Hugoson *et al.* (1986, 1995, 2005).

Radiographic examination

1973

For those aged 10–70 years, a full-mouth radiologic (FMR) examination was performed, consisting of 16 periapical and 4 bite-wing radiographs, using an Eggen film holder.

1983

Subjects aged 20–80 years were examined with both FMR and an orthopantomogram (OPG). In cases where an individual recently had had a radiographic examination, radiographs were obtained from the subject's dentist and if necessary supplemented with additional apical radiographs. All apical radiographs were taken with an Eggen film holder.

1993

In subjects aged 15–30 years 6 bite-wing radiographs and an OPG were taken. In cases with deep carious lesions and RF teeth, the examination was supplemented with apical radiographs. Subjects aged 40 years and older were examined with FMR and OPG. Apical radiographs were taken with an Eggen film holder.

Table 1 Number of dentate participants according to time of examination, age and gender

Age (years)	1973		1983		1993		2003	
	Men	Women	Men	Women	Men	Women	Men	Women
20	36 (40)	56 (60)	44 (45)	53 (55)	50 (50)	50 (50)	46 (46)	37 (38)
30	41 (51)	41 (49)	48 (50)	45 (48)	62 (63)	38 (39)	41 (42)	46 (50)
40	46 (48)	43 (51)	46 (47)	51 (52)	54 (54)	39 (39)	43 (47)	32 (36)
50	38 (40)	58 (60)	39 (42)	53 (57)	45 (45)	52 (52)	35 (41)	50 (50)
60	33 (34)	44 (50)	44 (46)	38 (38)	45 (45)	37 (38)	40 (44)	40 (42)
70	31 (32)	31 (31)	38 (38)	31 (32)	26 (26)	49 (51)	37 (40)	44 (47)
Total	225 (245)	273 (301)	259 (268)	271 (282)	282 (283)	265 (269)	242 (260)	249 (263)

Original sample of dentate participants in parenthesis.

2003

In subjects aged 10–40 years, an OPG and six bite-wing radiographs were taken. In cases with deep caries lesions and RF teeth, additional periapical radiographs were taken. Subjects aged 50–80 years were examined by means of FMR, consisting of 16 periapical and 4 bite-wing radiographs as well as OPG.

In the present study, only dentate individuals aged 20–70 years were examined, yielding the material presented in Table 1. As can be seen, an attrition of the original material has taken place because of loss of radiographs for unknown reasons.All periapical radiographs were examined using observer binoculars according to Mattson (1954), and for length measurement of root fillings, a magnifying device was used (Eschenbach, 7×, Eschenbach Optik of America, Ridgefield, CT, USA). The length between the root filling and the radiographic apex was measured to the nearest 0.1 mm and then categorized as shown in Table 2. In cases where periapical radiographs were lacking or unreadable, observations regarding periapical status and endodontic treatment were made from OPG from the examinations in 1983, 1993 and 2003. Periapical status was assessed according to the periapical index (PAI) from periapical radiographs as well as length and the presence of voids of root fillings (Table 3). Third molars were excluded. All recordings were made on a tooth level. In cases with multiple rooted teeth, the root with the most severe PAI score was recorded, both with regard to periapical status and quality of the root filling. If all roots were assessed as having the same PAI score, the root with the worst root filling quality was recorded.

One observer (FF) was calibrated by observing a set of 100 reference radiographs with different periapical expressions according to PAI (Ørstavik *et al.* 1986). For assessment of lateral and apical seal, a calibration was made between two of the authors (FF + MH), but all registrations were made by FF. Intra-observer agreement was calculated according to Cohen's kappa. Observer agreement to PAI scores from a set of reference radiographs was kappa = 0.70. Intra-observer agreement over 7 months after a re-recording of 67 cases for length of root filling, seal and periapical status

Table 2 Frequency (%) of apical periodontitis (AP) according to length of root filling and different length categorization (I and II)

Frequency of AP	
Length category (I)	
Overfilling	54.8 (235)
Flush	33.3 (56)
0.5–2 mm	14.6 (184)
>2 mm	21 (449)
Length category (II)	
Overfilling	54.8 (235)
<0.5 mm	33.3 (56)
0.5–1 mm	14.5 (65)
>1–2 mm	14.7 (119)
>2–3 mm	20.1 (121)
>3–4 mm	20.4 (92)
>4 mm	21.8 (236)

Absolute numbers in parenthesis.

Table 3 Variables recorded on apical radiographs regarding root filling quality and periapical status

Adequate seal	No voids lateral or apical to the root filling and the root filling should appear homogenous
Length	Distance between the root filling and radiographic apex measured on a scale to the nearest 0.1 mm
Periapical index score (Ørstavik *et al.* 1986)	1. Normal periapical structure 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

Table 4 Number of teeth and root filled teeth eligible for analysis of periapical status according to PAI and assessment of treatment quality

	1973		1983		1993		2003	
	Teeth (*n*)	RF (*n*)	Teeth (*n*)	RF (*n*)	Teeth (*n*)	RF (*n*)	Teeth (*n*)	RF (*n*)
Total number of teeth	10941	1291	12343	1209	13464	1007	12433	682
Teeth registered from OPG (*n*)	–	–	119	2	5455	1	6643	57
Teeth nonrecordable (*n*)	296	27	39	3	11	3	3	2
Teeth treated with pulp amputation (*n*)	–	13	–	11	–	6	–	1
Teeth treated with apical surgery (*n*)	–	32	–	24	–	13	–	7
Teeth eligible for analysis (*n*)	10645	1217	12185	1169	8009	984	5787	611

RF, root filled; OPG, orthopantomogram; PAI, periapical index.

according to PAI was 0.80, 0.73 and 0.73, respectively. PAI scores (1–5) were dichotomized to 1–2 (healthy) and 3–5 (disease).

When recordings were made from OPGs, the quality of the root fillings was not assessed and AP was recorded when the periapical membrane was widened to more than double width or an overt periapical lesion was present. Thus, when periapical status was studied on OPG, the PAI score was not used. This reduced the underlying material for analysis of root filling quality and periapical status. Also a number of radiographs were of poor quality, so assessment of root filling quality and/or periapical status was impossible. Teeth that had been treated with pulp amputation or apical surgery were omitted, leaving 3981 RF teeth for the analysis regarding the association between root filling quality and periapical status (Table 4).

Statistical method

Differences in means were analysed with the Kruskal–Wallis test and differences in frequencies and the association between quality of root fillings and periapical status were studied with the Chi-squared test. Multivariate logistic regression analyses were applied with the independent variables 'quality of root filling' (coded as 0 = adequate and 1 = inadequate root filling), age, gender, examination year and type of tooth. The dependent variable used was the PAI score dichotomized into 0 = no AP (PAI score = 1–2) and 1 = AP (PAI score: 3–5). The observational unit in the analyses were RF teeth. However, because of intraindividual correlations amongst two or more RF teeth/AP, i.e a significant portion of patients contributed with two or more RF teeth (73.5%) in the statistical analyses, multilevel logistic regression analyses were performed to account for such correlations. The statistical computer program used in the analyses was SPSS version 14 (SPSS, Inc., Chicago, IL, USA) and MLwin version 2.2 (University of Bristol, Bristol, UK). The level of significance was 5% in all analyses.

Results

Descriptive data

Cross-sectional

There was a significant loss of teeth with increasing age. Number of teeth with AP as well as number of RF teeth increased statistically significant with increasing age at all cross-sectional examinations (Table 5).

Repeated cross-sectional 1973–2003

Between 1973 and 2003, the number of teeth increased significantly in all age groups except in 20-year olds. However, number of teeth with AP decreased statistically significant in all age groups except for 70-year olds and number of teeth with RF decreased statistically significant in all age groups except for 60- and 70-year olds (Table 5).

Root filled teeth with AP

The frequency of RF teeth with AP varied between 21.1% and 24.8% between 1973 and 2003 without statistically significant differences (Table 6).

Quality of root fillings

In the total material there was a statistically significant association between length of the root filling and periapical status. A subanalysis showed that a root filling ending 0.5–2 mm from the radiographic apex was optimal with the lowest frequency of AP (Table 2). However, when cross-tabulation with adequate seal was performed, it was found that adequate seal explained the lower frequency of AP when the length 0.5–2 mm was compared to >2 mm, as there were no statistically significant differences between 0.5–2 mm and >2 mm within the respective seal category

Table 5 Number of teeth, root filled teeth and teeth with apical periodontitis

	Age group (years)					
	20	30	40	50	60	70
1973						
Teeth (*n*)	26.9 (26.6–27.3)	25.7 (25.2–26.3)	23.7 (22.8–24.6)	21.2 (20.0–22.4)	17.4 (15.9–18.8)	14.0 (12.3–15.7)
RF (*n*)	0.4 (0.2–0.5)	1.8 (1.2–2.3)	2.8 (2.3–3.2)	4.0 (3.4–4.6)	3.1 (2.5–3.6)	4.0 (3.2–4.8)
AP (*n*)	0.3 (0.1–0.4)	0.6 (0.4–0.8)	1.3 (1.0–1.6)	1.4 (1.1–1.7)	1.0 (0.7–1.3)	1.6 (1.2–1.9)
1983						
Teeth (*n*)	27.4 (27.2–27.6)	27.0 (26.7–27.3)	24.9 24.0–25.7)	22.8 (21.8–23.9)	18.7 (17.3–20.0)	15.7 (13.9–14.5)
RF (*n*)	0.1 (0.03–0.2)	0.9 (0.6–1.2)	2.4 (1.8–2.9)	3.4 (2.8–3.9)	4.0 (3.2–4.7)	3.5 (2.8–4.2)
AP (*n*)	0.1 (0.02–0.2)	0.3 (0.2–0.4)	0.9 (0.7–1.2)	1.0 (0.8–1.3)	1.1 (0.7–1.4)	1.4 (0.8–2.0)
1993						
Teeth (*n*)	27.3 (27.0–27.6)	27.3 (27.0–27.6)	26.6 (26.1–27.0)	24.8 (23.8–25.8)	21.9 (20.5–23.2)	17.9 (16.4–19.3)
RF (*n*)	0.1 (0.01–0.1)	0.5 (0.2–0.7)	1.1 (0.8–1.4)	2.4 (1.9–2.9)	3.5 (2.9–4.1)	4.5 (3.7–5.2)
AP (*n*)	0.01 (−0.01–0.03)	0.2 (0.1–0.3)	0.5 (0.3–0.6)	0.7 (0.5–0.9)	0.9 (0.7–1.2)	1.1 (0.9–1.4)
2003						
Teeth (*n*)	27.5 (27.2–27.7)	27.2 (26.9–27.5)	26.6 (26.0–27.2)	26.3 (25.7–26.9)	23.8 (22.5–25.1)	20.4 (18.9–21.9)
RF (*n*)	0.1 (−0.02–0.1)	0.3 (0.1–0.4)	0.7 (0.4–0.9)	1.4 (1.1–1.8)	2.6 (2.0–3.1)	3.4 (2.9–4.0)
AP (*n*)	0.02 (−0.01–0.1)	0.1 (0–0.1)	0.5 (0.3–0.7)	0.7 (0.5–0.9)	0.9 (0.6–1.1)	1.1 (0.8–1.3)

RF, root filled; AP, apical periodontitis.
Values given are mean in the different age groups (95% CI).

Table 6 Frequency (%) of total root filled teeth with AP according to tooth group

Year	$RFAP_{tot}$		RFAP	AdRF
1973	24.5	Molars	30.5 (64)	31.4 (66)
		Premolars	18.5 (99)	51.4 (275)
		Incisors	28.0 (132)	48.5 (229)
1983	23.8	Molars	23.8 (62)	34.5 (90)
		Premolars	19.2 (91)	59.3 (281)
		Incisors	27.2 (118)	50.7 (220)
1993	21.1	Molars	24.2 (67)	47.7 (132)
		Premolars	15.5 (60)	66.0 (256)
		Incisors	25.1 (80)	58.6 (187)
2003	24.6	Molars	31.9 (65)	51.0 (104)
		Premolars	18.4 (43)	70.1 (164)
		Incisors	23.7 (41)	67.1 (116)
Statistically significant changes between examinations				
RFAP ($P < 0.05$)	Molars	1983–2003, 1993–2003		
AdRF ($P < 0.05$)	Molars	1973–1993, 1973–2003, 1983–1993, 1983–2003		
	Premolars	1973–1983, 1973–1993, 1973–2003, 1983–1993, 1983–2003		
	Incisors	1973–1993, 1973–2003, 1983–1993, 1983–2003		

$RFAP_{tot}$, total root filled teeth at each examination; RFAP, apical periodontitis in root filled teeth according to type of tooth; AdRF, adequately root filled teeth.
Absolute numbers in parenthesis.

(Table 7). The higher frequency of AP when the root filling was flush with the apex or the root canal was overfilled was not explained by inadequate seal. Thus, the optimal technical result was shown to be a root filling with adequate seal ending within the root canal.

Over time, there was a statistically significant increasing frequency of root fillings ending 0.5–2 mm from the radiographic apex, except between 1993 and 2003. Parallel results were found for adequate seal. Further analysis used length and seal summarized in one variable, adequate or inadequate root filling. An adequate root filling was defined as having an adequate lateral and apical seal, ending within the root canal. Root fillings deviating from these criteria were classified as inadequate root fillings.

Although the frequency of adequate root fillings increased over time, the frequency of AP in conjunction with RF teeth did not decrease statistically significant. When analysing respective tooth group there was a statistically nonsignificant increase in AP in RF molars between 1973 and 2003 (Table 6). In RF incisors, there was a statistically nonsignificant decrease in the frequency of AP between 1973 and 2003 (Table 6). To understand why an improving root filling quality did not result in better periapical status in RF teeth, respective tooth group was analysed with regard to number/frequency of remaining teeth. It was found that almost 40% of the molars were missing in 1973 compared to 15% in 2003. For premolars, the corresponding figures were 22% in 1973 and 12.9% in 2003, and for incisors 9.4% in 1973 and 3.7% in 2003. Compared with premolars/incisors, a larger fraction of RF molars had AP (Table 6). A statistically significant smaller proportion of molars had adequate root fillings when compared with incisors/premolars. Moreover, in molars with adequate root fillings, the

Table 7 Distribution of root filled teeth according to length in each seal category

	Seal category					
	Adequate seal			Inadequate seal		
Length category	Frequency (%)	Absolute numbers	Frequency of AP (%)	Frequency (%)	Absolute numbers	Frequency of AP (%)
0.5–2 mm	77.1	969	10.2	22.9	287	29.6
>2 mm	54.1	1151	12.1	45.9	977	31.5
Flush	72.6	122	23.0	27.4	46	60.9
Overfilling	79	339	53.1	21.0	90	61.1

AP, apical periodontitis.

frequency of AP was significantly higher than in incisors/premolars with the corresponding root filling quality (Figs 1 and 2). In 2003, molars constituted a significantly larger proportion of RF teeth, 33.4%, compared to 17.3% in 1973. Thus, one could assume that the larger proportion of molars in 2003 has contributed to the result.

Risk estimates of inadequate root fillings on AP.
Three different logistic regression modelling procedures were applied to estimate the risk of having AP in relation to a RF tooth. Table 8 shows one model analysed with only the tooth as the observational unit not taking into account possible intra-individual correlation amongst teeth within the same subject. The second and the third model include both the tooth and individual analysed in the same regression analysis, thus exploring the variance components of each unit-level.

Model A showed an odds ratio (OR) of 2.88, indicating that an inadequate RF tooth had a significantly increased risk of having an AP, i.e almost three times higher risk compared with a tooth with an adequate root filling (Table 8). Model B does not differ substantially from the previous model, specifically with regard to the OR, estimated standard errors and confidence intervals. Model C, the full multivariable logistic regression analysis, revealed an OR of 3.257 indicating a higher risk for AP when having a nonadequate root filling compared with the other models. Moreover, the confidence interval was wider and the standard error larger than those estimated in models A and B, respectively, with respect to the variable quality of root filling. The covariates, age and gender, showed an OR of 0.98 and 076, respectively, with statistically significant values. In addition, the examination variable indicated a significance between teeth examined 2003 and 1973, with an increased risk

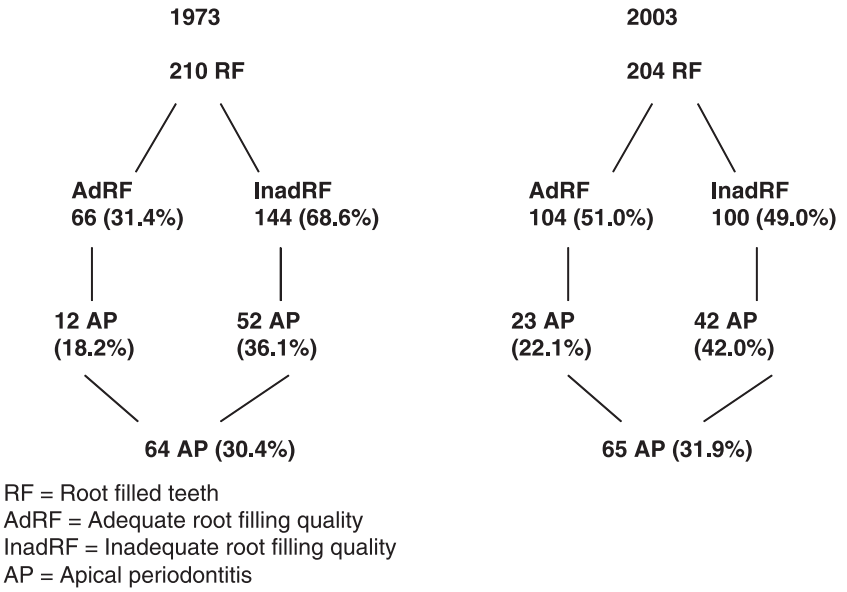

Figure 1 Comparing frequencies of adequate root fillings and apical periodontitis in root filled molars in 1973 and 2003.

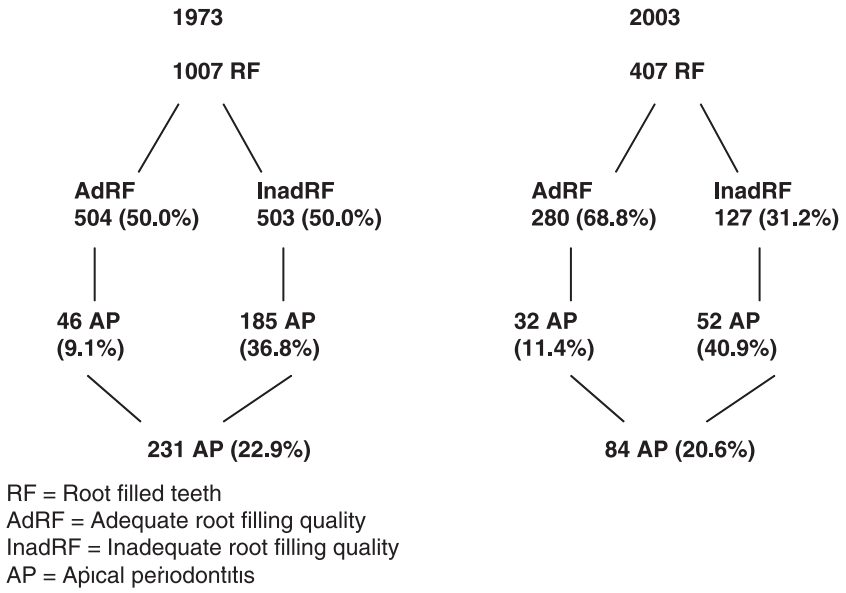

Figure 2 Comparing frequencies of adequate root fillings and apical periodontitis in root filled premolars and incisors in 1973 and 2003.

Table 8 Results of multilevel logistic regressions with apical periodontitis (AP) as dependent variable

	Regression coefficient, *B*	Standard error, SE	Odds ratio, OR	95% Confidence interval
Model A (tooth level)				
Quality of root filling, QR	1.058	0.103	2.880	2.353, 3.526
Model B (patient level)				
QR	1.096	0.108	2.990	2.421, 3.697
Model C (patient level)				
QR	1.181	0.111	3.257	2.121, 4.049
Age	−0.013	0.003	0.987	0.981, 0.993
Gender	−0.265	0.085	0.767	0.649, 0.906
Examination in 1983	−0.010	0.109	0.990	0.800, 1.223
Examination in 1993	−0.018	0.119	0.982	0.778, 1.240
Examination in 2003	0.285	0.138	1.330	1.015, 1.743
Premolars	−0.372	0.104	0.689	0.562; 0.845
Canines and incisors	0.316	0.106	1.370	1.114, 1.680

Reference categories: QR, adequate; Gender, male; Examination, 1973; Tooth type, molars.

of 1.33 for the former examination year. In comparison with tooth type molars, premolars had a protective effect for the risk of having AP, whilst incisors and canines showed an increased risk with an OR of 1.37. A statistical inference test for the intercept variance was performed by Wald's test, giving a test-statistic of 349.00 which when evaluated with the Chi-square distribution resulted in $P < 0.0001$. This means that there was a significant difference between patients. Moreover, the models B and C revealed that approximately 6% of residual variance of having AP was attributable to differences between individuals.

Discussion

This study reports on the frequency of AP in RF teeth and the association between root filling quality and periapical status. It was demonstrated that the treatment quality improved over time, but did not result in a decreasing frequency of AP in RF teeth.

Methodological problems in assessing periapical status have been discussed by several authors (Reit & Hollender 1983, Örstavik *et al.* 1986). A periapical radiolucency may represent other conditions than AP, as knowledge about the histological diagnosis was not available. However, it is acknowledged that AP is the most probable diagnosis when a periapical radiolucency is registered. Thus, misdiagnosis seems to be of minor concern in an epidemiological context (Bhaskar 1966, Ricucci *et al.* 2006). Also, observers tend to vary in their judgement whether the observed destruction is to be considered to be a pathological condition or not. In the present study, the PAI score was used to calibrate the observer to a set of reference radiographs assisted by examples of periapical expressions on the radiograph. The benefits of this system are that the periapical expression on the radiograph is validated against the histological expression and that the results of the study can be compared with other studies using PAI (Ørstavik *et al.* 1986). However, the problem of observer variation remains. In this study, calibration against the reference radiographs and re-recording after 7 months yielded acceptable kappa scores for observer variation.

When assessing the technical quality of root fillings from the radiograph, it has been shown that the two dimensional projection do not display the presence of voids properly (Eckerbom & Magnusson 1997). Thus, it may be questionable whether the apical radiograph is valid in displaying the seal of the root filling. However, in the present study as well as others, a statistically significant relationship between adequate seal and periapical status is repeatedly demonstrated (Kirkevang *et al.* 2000). Thus, in an epidemiological context, it seems justified to use the seal of the root filling as a variable in assessing root filling quality. As for periapical status the problem of observer variation remains. In the present study, determination of both seal and length of root filling yielded acceptable kappa scores.

In several repeated cross-sectional studies, an improvement in treatment quality over time has been reported. However, these studies have failed to show a decrease in the frequency of AP in conjunction to RF teeth (Petersson 1993, Kirkevang *et al.* 2001b, Skudutyte-Rysstad & Eriksen 2006). There are obvious limitations in a cross-sectional study that may account for this paradoxical finding.

A problem encountered when performing a cross-sectional study is if the periapical radiolucency represents a healing lesion or chronic lesion and if the lack of a periapical radiolucency represents a sound periapical status or a developing lesion. The latter may be the case as the periapical destruction must have a sufficient extent and involve the cortical bone to be detectible on the radiograph (Bender & Seltzer 1961). Findings from a longitudinal study suggest that this problem is of minor concern from an epidemiological point of view as the number of developing lesions and healing lesions was found to be similar (Petersson *et al.* 1991). However, Kirkevang *et al.* (2006) do not support this conclusion as they found that the number of RF teeth with AP that healed were higher than the number of RF teeth that developed new lesions during a 6 year follow-up.

Information is lacking on how and when the root canal treatments were performed. Probably one can assume that Swedish dentists at a given point of time use similar materials, medicaments and techniques, but as it is not known when the treatment has been performed, it is difficult to account for secular changes in clinical practice except for the youngest age group.

It is obvious that more teeth were extracted before 1973 than before 2003. One can assume that some of those teeth extracted were RF. However, the reason for extraction is unknown. A few studies suggest that other reasons than AP are common when RF teeth are extracted (Eckerbom *et al.* 1992, Caplan & Weintraub 1997). However, the great loss of molars in 1973 compared with 2003 could explain why the frequency of AP in conjunction with RF molars did not decrease between 1973 and 2003 despite an improvement in treatment quality. When analysing the incisors, the difference in loss between 1973 and 2003 was rather small and in this group a statistically nonsignificant decrease in the frequency of AP in RF teeth was demonstrated as well as an improvement in treatment quality (Fig. 2). In molars, the root filling quality was improved significantly, but the frequency of AP was high even in adequately RF molars. Because molars constituted a substantial fraction of RF teeth in 2003 compared with 1973, the observed improvement in technical quality in all RF teeth may have been distorted.

It was quite surprising to find that the length of the root filling, as long as it was maintained in the confines of the root canal did not have a statistically significant impact on the periapical status. Most clinical studies suggest that the root filling should end between 0.5 and 2 mm from the radiographic apex. However, the preoperative diagnosis was unknown. It may be that teeth without preoperative AP are less sensitive to deviation in length of the root filling, whilst deviations in teeth with AP result in lower healing frequency

(Kerekes & Tronstad 1979, Sjögren *et al.* 1990). Other studies demonstrate that a majority of RF teeth are treated for other reasons than AP and may explain the indifference to the length of the root filling in the present study (Björndal *et al.* 2006). Thus, it is not suggested that clinicians chose to abandon established guidelines for endodontic treatment, but the results may support that optimal length of the root filling is less important as long as it is confined to the root canal and no voids are present in teeth without AP.

By using a multilevel statistical method, a possible interdependence amongst teeth from the same indivdual may be estimated. The association between the quality of root fillings and presence of AP may not only be because of each and every tooth, i.e one tooth may not be considered as an independent observation in relation to any other tooth that is included in the sample. This phenomena occurs when one or more patients contribute with two or more teeth in the analysis. One of the first research groups to acknowledge this problem is found in the thesis presented by Strindberg (1956), where it was discussed whether 'there is an association between therapeutic results for two roots of the same tooth or between two teeth in the same mouth'? The research group consisting of an endodontist and three statisticians found that 'the association between some cases gives the impression of quite a strong association between teeth from the same subject', thus excluding individuals having five or more treated teeth in the study from statistical analysis. At the time no statistical method nor computer power were at hand to aid the researchers for an acceptable estimation, but today several statistical programs have multilevel analysis. Parallel designs and important applications within the field of dentistry are found in periodontology, e.g. toothsites/tooth/patients and implantology e.g. implants/patients. Such an approach seems to be necessary to achieve adequate results. The results show in this sample that there was a small but significant part of variance that was attributed to patients. Moreover, analysis revealed a statistically significant difference between patients. Interestingly, the risk for a RF tooth with an inadequate root filling to have AP increased slightly in the multilevel analysis model C. As expected the confidence interval became wider when patients were included as the second level in the logistic regression analysis, albeit less influenced than expected. This may be because of the large sample size and that a large fraction of individuals contributed with only one tooth in the analysis. A similar discussion concerning the unit of observation and dependency within patients is found in oral implant research. In a recent study by Herrmann *et al.* (1999), the impact of implant interdependency was evaluated with regard to success rates in clinical trials. The authors concluded that dependency amongst implants in the same patient existed and consequently the statistical results may be influenced which may jeopardize the main findings. As the multilevel analysis only revealed a small interdependence effect the tooth level was used as the unit in the bivariate analysis.

Findings from the multilevel analysis (model C) suggested ageing to be protective in terms of AP in conjunction to RF teeth, but however significant, the OR was close to 1. Female gender was also found to be protective. This may be explained by women being more health conscious and visiting the dentist more often (Frisk & Hakeberg 2006). In 2003 the risk for having AP in a RF tooth was greater than in 1973. Probably, this finding is because of larger proportion of RF molars in 2003. When type of tooth was analysed, incisors and canine teeth were found be at higher risk for having AP compared with molars. Similar results were found by Bergenholtz *et al.* (1973). Two factors may account for the result; maxillary lateral incisors have been found to have a lower healing frequency compared with other types of teeth in follow-up studies, probably because of a frequently complicated apical anatomy (Kerekes & Tronstad 1979). Also, it could be expected that RF incisors and canines having AP, more seldom are extracted than molars with similar status because of aesthetic considerations.

The results from this study concerning prevalence of AP differed from previously published results on the same populations (Hugoson *et al.* 2005). The identified differences should be explained by differences in criteria for AP and observer variation. In this study only one observer calibrated according to PAI performed all registrations. In Hugoson *et al.* (2005), several observers without presenting inter- or intra-observer variation made the observations according to Strindberg's criteria for AP (Strindberg 1956).

The results from this study should be representative as the samples were randomly selected from the population at each point in time. However, in 1973 nonattendees were replaced which may have implications on the representativeness. At the other examinations, the response rates were substantial ranging from 65% to 80%. Unfortunately, there was a loss of radiographs in some age cohorts, especially in 1973 where 8.8% of the original sample was lost.

Conclusions

This study reports on an improving quality of root fillings over time without a concomitant improvement of the periapical status in RF teeth. A larger proportion of RF molars may be of importance for the result.

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