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ORIGINAL ARTICLE

Periapical status and technical quality in root canal filled teeth in a cross sectional study in Jönköping, Sweden

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ABSTRACT

Objective: To investigate the quality of root canal fillings and frequency of apical periodontitis (AP) in root canal filled teeth in a Swedish population.

Material and methods: This study used data from a cross-sectional survey conducted in 2013. The root canal filling quality and periapical status were assessed in 491 root canal filled teeth in 196 individuals aged 20–70 years, randomly selected from the population of Jönköping, Sweden. All root canal filled teeth were examined with periapical radiographs. Three calibrated observers recorded length and density in root canal fillings as well as periapical status according to the Periapical Index. A root filling ending within 0.5–2 mm from the radiographic apex without lateral or apical voids was considered adequate. Data were analyzed in a generalized estimating equation (GEE) model with AP as dependent variable and gender, age, number of teeth, number of root filled teeth, tooth type, and root filling quality as independent variables.

Results: Teeth with technically inadequate root fillings were associated with AP in a simple GEE-analysis. In the multiple GEE-model, the association between technical quality and apical peridontitis was nonsignificant when controlling for tooth type and gender.

Conclusions: The quality of root canal fillings is poor and the prevalence of AP in root canal filled teeth is high, particularly in molar teeth, in a Swedish population.

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Introduction

In cross sectional studies endodontically treated teeth with inadequate root canal fillings (too short, overfilled, or with lateral voids) are generally associated with a higher frequency of apical periodontitis (AP) [1,2]. Also, in analysing prognostic factors for the outcome of root canal treatment, the quality of the root canal filling together with preoperative periapical status and quality of the restoration is of utmost importance for healing of the periapical tissues [3]. The causal relationship between the presence of microorganisms and development and/or persistence of AP is well established [4,5]. Spaces empty of root canal filling material leaves both nutrition and habitat for microorganisms behind [6]. Consequently, the relationship between the root canal filling quality and periapical status is best understood as to inadequate root canal fillings favour the presence of a microbiological biofilm which in turn sustains a periapical inflammation. Additionally, the quality of the root canal filling may be seen as a summary marker for various quality aspects of the root canal treatment, including access, instrumentation and irrigation, all crucial to achieve the prerequisites for good root canal filling quality.

The advent of nickel-titanium instrumentation in root canal treatment has been shown to improve instrumentation and root canal filling quality [7]. The technique has been promoted by educational interventions and is now widely spread also among clinicians in Sweden [8–10]. It is important to assess if the investments in new technology and education pay off. Theoretically, the educational efforts should result in a continued trend towards improving root canal filling quality seen in previous studies in Jönköping, Sweden, between 1973 and 2003 [7]. However, the frequency of AP in root filled teeth did not change significantly and has been regularly recorded as ~25%

The aim of this study was to assess the technical quality of root canal fillings and AP in root canal filled teeth in the city of Jönköping, Sweden, and to see if the results followed the aforementioned trend towards better root canal filling quality.

Material and method

In a series of cross-sectional examinations performed every 10 year since 1973 in Jönköping Sweden, data on oral health have been recorded from randomly selected inhabitants in the age groups 3, 5, 10, 15, 20, 30, 40, 50, 60, 70 and

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80 years from the same four perishes in the city of Jönköping [11].

In each age group, 130 randomly selected individuals were invited in 2013. All subjects received a written personal invitation to take part in a dental health examination. To ensure enough participants, additional random samples were invited in the age groups 30 ($N = 40$), 40 ($N = 40$) and 50 years ($N = 50$). Consequently, in total 910 individuals were invited in the age groups 20–70 years. The researchers informed the individuals about the purpose of the investigation, and of the details of the examination procedures. The reasons why individuals selected for the study did not participate were registered. The most common reasons for not participating were lack of interest, the individual could not be reached by letter or telephone or the invitee had moved. The participation rate for each age group was 58%, 56%, 57%, 58%, 64% and 72% in age groups 20, 30, 40, 50, 60 and 70 years, respectively, resulting in 544 participants. From this sample, dentate individuals with at least one root filled tooth were included ($N = 196$) in the present study (Table 1).

The 2013 survey was approved in 2012 by the Ethic Committee at the University of Linköping, Linköping, Sweden (Dnr 2012/191-31).

Radiographic examination

All participants had a panoramic radiograph and bite-wing exposed. When teeth with deep carious lesions or root canal filled teeth were recognized, a periapical radiographic examination was performed, as well. Intraoral radiographs were taken with sensors (Focus intraoral system; Instrumentarium; GE Healthcare, Finland and Sirona Schick; Sirona Dental; Salzburg, Austria), respectively. All periapical radiographs of root canal filled teeth in the present study were analysed on a monitor (Eizo Radi Force MX242W; resolution 1920×1200; Eizo Corporation, Ishikawa, Japan) using viewer software IMPAX (Agfa-Gaevert: Mortsel, Belgium).

Assessment of periapical status

Periapical status was assessed according to the periapical Index (PAI) [12]. PAI-scores were dichotomized to AP not present (PAI scores 1–2) and AP present (PAI-scores 3–5).

Assessment of root canal filling quality

In order to create a reference set for assessment of root canal filling quality (RFQS), one endodontist (FF) and one oral radiologist (MD) selected periapical radiographs of 60 root filled teeth from the Department of Oral and Maxillofacial radiology in Jönköping, with an even distribution among tooth groups. The radiographs were analysed individually by FF and MD at two occasions with a wash-out period of one month. The two specialists assessed the RFQS with respect to length in relation to radiographic apex and to the quality of seal. Furthermore, they measured the length of the root canal filling to the nearest 0.1 mm with the measuring device in the viewing software and then categorized the quality as adequate if the root canal filling ended within 0.5–2 mm from the radiographic apex. Root canal fillings ending >2 mm from the radiographic apex or flush or beyond the radiographic apex were categorized as inadequate. Finally, they assessed the seal as adequate if there were no visible voids lateral or apical of the root canal filling and the root canal filling appeared homogenous. At the first occasion FF and MD agreed substantially ($\kappa = 0.69$ for length and 0.69 for seal). At the second occasion the agreement was still substantial (0.75 for length and 0.76 for seal).

After the second occassion, FF and MD discussed those 24 cases where they disagreed (in 11 cases regarding length, in 10 cases regarding seal and in three cases both length and seal). By doing so, they reached consensus and the 60 cases reference set (RFQS) was established.

Observers of periapical radiographs

Three postgraduate students in endodontics at the Institute for postgraduate dental education in Jönköping, were invited and accepted to assess root canal filling quality and periapical status in root filled teeth.

Periapical status observer calibration

The three observers were calibrated to PAI by individually being exposed to a set of 100 reference radiographs according to Ørstavik et al. [12]. Each observer's agreement with

Table 1. Characteristics of contributing individuals (study sample) with at least one root filled tooth and frequencies of adequate root fillings and AP in relation to the Jönköping study participants

Variable	The Jönköping study participants Individuals in age groups 20–70 years	Study sample			
		Individuals	Root filled teeth (rf)	Frequency of Adequate rf	Frequency of AP
Total	$N = 544$ (100%)	$N = 196$ (100%)	$N = 491$ (100%)	$N = 142$ (28.9%)	$N = 167$ (34.0%)
Gender					
Male	240 (44.1)	93 (47.4)	231 (47.2)	61 (26.3)	91 (39.2)
Female	304 (55.9)	103 (52.6)	260 (52.8)	81 (31.2)	76 (29.2)
Age					
20	75 (13.8)	3 (1.5)	3 (0.6)	1 (33.3)	2 (66.7)
30	96 (17.6)	11 (5.6)	17 (3.5)	1 (5.9)	6 (35.3)
40	95 (17.5)	24 (12.2)	35 (7.1)	11 (31.4)	15 (42.9)
50	104 (19.1)	35 (17.9)	65 (13.2)	17 (26.2)	25 (38.5)
60	82 (15.1)	53 (27.0)	137 (27.8)	38 (27.7)	48 (35.0)
70	92 (16.9)	70 (35.7)	235 (47.8)	74 (31.5)	71 (30.2)

AP: apical periodontitis.
Data retrieved in 2013.

PAI-scores from the reference radiographs were calculated and presented with the kappa statistic.

Root canal filling quality observer calibration

The three observers were calibrated to the created set of 60 radiographs (RFQS) and each observer's agreement with the set was calculated and presented with the kappa statistic.

Radiological recordings

After calibration, all cases in the study were randomly and evenly divided between the three observers. Root canal filling quality was recorded as described. In the final analysis, root canal filling quality was dichotomized into adequate root canal fillings (adequate length and adequate seal) and inadequate root canal fillings (inadequate length and/or inadequate seal).

In multi-rooted teeth, the root with the highest PAI-score was recorded only. Teeth treated with pulp amputation or apical surgery was excluded. PAI scores were dichotomized into non-AP (PAI score 1–2) and AP (PAI-score 3–5).

Statistical methods

The observation unit in the study was the root canal filled tooth. The results of inter observer variation were analysed using Kappa statistics. Odds ratio for each independent variable was calculated with a simple generalized estimating equation (GEE) model with AP as dependent variable . The multiple GEE-model was built with those independent variables that were statistically significantly associated with AP in the simple GEE-analyses. The statistical computer program used in the analyses was SPSS 27 (IBM Corporation; Armonk, NY; USA). The level of significance was set at 0.05.

Results

In total 491 root canal filled teeth from 196 individuals in the age groups 20–70 was included in the study. 81 individuals contributed with one root canal filled tooth each, 46 individuals contributed with two root canal filled teeth, 25 individuals contributed with 3 root canal filled teeth and finally 44 individuals contributed with $\geq$4 root canal filled teeth. There was an even contribution of root canal filled teeth with respect to gender, 52.6% women and 47.4% men, respectively. The contribution of root canal filled teeth from different age groups was uneven with the lowest number of root canal filled teeth in the youngest age groups and with increasing numbers in the older age groups (Table 1). Of the 491 root canal filled teeth 41.1% were molars, 31.8% were premolars, and 27.1% were incisors or canines (Table 2).

Table 2. Distribution of the root filled teeth with respect to quality of root filling and AP.

Variable Total	Teeth $N = 491$ (100%)	Frequency of AP
Adequate root fillings	141 (28.7%)	38 (27.0%)
Inadequate root fillings	350 (71.3%)	129 (36.9%)

AP: apical periodontitis.

Table 3. Distribution of the root filled teeth with respect to tooth group and frequency of adequate root canal filling and AP.

Variable Total	Teeth 491 (100%)	Frequency of adequate rf	Frequency of AP
Incisors/Canines	133 (27.1%)	49 (36.8%)	39 (29.3%)
Premolars	156 (31.8%)	57 (36.5%)	35 (22.4%)
Molars	202 (41.1%)	35 (17.3%)	93 (46.0%)

AP: apical periodontitis; rf: root canal filling.

Observer variation

The three observers' agreement with respect to the calibration set for PAI was substantial ($\kappa = 0.7$ and 0.7 and 0.8, respectively).

The observers' agreement with the 60 cases reference set (RFQS) with respect to length was substantial ($\kappa = 0.71$, 0.71 and 0.74) and with respect to seal substantial to almost perfect (0.93, 0.91 and 0.64, respectively).

Root filled teeth with AP

Approximately one third (34%) of the root canal filled teeth were diagnosed with AP. Of the root canal filled teeth with apical periodontits 55.7% were molars, 21.0% premolars and 23.3% were incisors or canines (Table 2).

Quality of root canal fillings

Of the root canal filled teeth, 29% had adequate root canal filling quality (Table 2). In the group of root canal filled molars, 17% had adequate root canal filling quality (Table 3).

Association of independent variables and frequency of AP

Gender, root canal filling quality and tooth group were all statistically significantly associated with AP in the simple GEE-analyses, whilst age, number of root filled teeth and number of teeth were not. In the multiple GEE-model, the quality of the root canal filling was no longer statistically significantly associated with AP while gender (female gender compared to male gender (OR = 0.64; $p = .022$)) and tooth group (molars compared to incisors (OR = 2.00; $p = .006$)) were statistically significantly associated with presence of AP in root canal filled teeth (Table 4).

Discussion

The trend towards better root canal filling quality seen in previous studies (1973 23.7% adequate root canal fillings; 2003 36.4% adequate root canal fillings [10]) from this

Table 4. Simple and multiple GEE-analysis of individual and tooth specific independent variables on frequency of AP in root filled teeth.

	Simple analysis		Multiple analysis	
Variable	OR (95% CI)	*p* value	OR (95% CI)	*p*-value
Gender				
Male	Reference		Reference	
Female	0.66 (0.46–0.96)	.03	0.64 (0.44–0.94)	.022
Age				
20	4.00 (0.35–45.42)	.26		
30	1.09 (0.38–3.08)	.88		
40	1.50 (0.75–2.98)	.25		
50	1.46 (0.80–2.65)	.22		
60	1.07 (0.66–1.73)	.80		
70	Reference			
Number of teeth (*N*)	1.01 (0.96–1.07)	.66		
Number of root filled teeth (*N*)	1.01 (0.91–1.12)	.89		
Tooth group				
Incisors/canines	Reference		Reference	
Premolars	0.70 (0.41–1.17)	.17	0.69 (0.41–1.17)	.17
Molars	2.11 (1.31–3.41)	.002	2.0 (1.22–3.29)	.01
Quality of root filling				
Adequate	Reference		Reference	
Inadequate	1.64 (1.06–2.56)	.028	1.32 (0.84–2.06)	.23

AP: apical periodontitis; GEE: generalized estimating equation.

particular region in Sweden was broken and a high frequency (71%) of inadequate root canal fillings was registered in general. The finding is somewhat surprising since an increased use of rotary and reciprocal root canal instruments, overall, should be expected to yield an improved root canal filling quality [13]. In contrast, Connert et al. [14] found an increasing frequency of adequately root filled teeth over 20 years, however from a very low frequency (from 14% in 1993 to 35% 20 years later).

Furthermore, the frequency of AP in root canal filled teeth was ∼10% points higher than in previous studies (34% compared to 25% [7]). In molar teeth, the frequency of AP was as high as 46%.

Comparison with results from previous cross-sectional data on endodontic status from the same region [7] must be done with caution. Changes in methodology have been made between then and the present study, mainly in radiographic technique and assessment from radiographs. In the previous study, one observer made all registrations from analogue periapical radiographs. In the present study, all periapical radiographs were taken with digital technique, and were assessed by three observers, meticulously calibrated according to PAI and to a set of reference radiographs (RFQS) with different expressions of root canal filling quality evenly distributed among tooth groups. It cannot be ruled out that these changes may have an impact on the result. In light of these differences, it has not been justified or possible to make statistical comparisons with data from previous surveys. Thus, we merely compare trends in lieu of statistical calculations.

The study corroborated previous findings that the presence of AP in root filled teeth is associated with an inadequate root canal filling [15,16]. However, in our study, since molars dominated (41%) and furthermore was often associated with inadequate seal (83%) the statistically significant association between inadequate root canal filling quality and AP did not prevail when controlled for tooth group.

In contrast to previous studies from the same region, AP in root canal filled teeth was statistically significantly less frequent in women than men [17]. Other studies frequently report on women having less AP than men, both in root canal filled teeth and overall [18,19]. One possible reason for this association could be that women have been reported to experience more pain from root canal filled teeth with AP [20]. Consequently, they may be more prone to seek further treatment of AP, including extraction and retreatment.

Age was not statistically significantly associated with AP in root canal filled teeth. Huumonen et al. [19] did not find age to be a statistically significant risk indicator for AP in root canal filled teeth, and Kielbassa et al. [18] reported no systematic pattern between age and AP in root canal filled teeth.

In our study, we found that 34% of the root canal filled teeth had AP according to periapical radiographs. This result is in agreement with several contemporary studies reporting on the frequency of AP in root canal filled teeth [14,21,22]. Other contemporary studies with repeated cross sectional data are scarce. However, Connert et al. [14] in a repeated cross-sectional study report on a decrease in the frequency of AP in root filled teeth over 20 years, from 61% to 34%. Jakovljevic et al. [2], on the other hand, in a meta-analysis report on an increasing frequency of AP in endodontically treated teeth globally, between the years 2012 and 2020 from 35.9% to 41.3%.

When compared to previous studies in this region [7], the present frequency of AP in root canal filled teeth represents a deviation from a stable frequency between 21% and 25% during 1973–2003. The reason for this possible impairment is not clear. Of course, it may follow with changes in the studied population. Previous investigations in Jönköping exhibited an increasing frequency of root filled molars over time, from 17% of all root filled teeth in 1973 to 33% in 2003 [7]. In the present study the relative frequency of root canal filled molars continued to increase (41%). Molars are more technically challenging, which may explain a higher frequency of teeth with inadequate RFQS over all, as well as an increasing frequency of AP in root canal filled teeth.

In a recent study, Wigsten et al. [23], in a public dental service found that of 243 teeth undergoing root canal treatment, 47.7% were molars. We believe that this development reflects the patients will to retain their teeth rather than extracting them followed by prosthodontic treatment, and an overall improvement in oral health with more teeth retained at high age. It also mirrors the challenge dentists meet, and accept, when performing technically difficult treatment, such as root canal treatment on molars [24]. Laukkanen et al. [25] reported on the outcome of root canal treatment in general dental practice. They found that molars had the worst outcome compared to incisors and premolars, both with respect to technical quality of the root canal filling and healing of AP.

Somewhat surprisingly, we found that AP in root canal filled molars was evenly distributed between those with adequate and inadequate root canal filling quality, respectively. A possible explanation may be that it is difficult to correctly assess root canal filling quality in molars. By using computed cone beam tomography (CBCT) the estimation of root canal filling quality may be more adequate in multi-rooted teeth [26]. For example, Mashyakhy et al. [27] found in a CBCT investigation of 208 root canal filled teeth that 18% exhibited 'missed canals'. In maxillary first molars the prevalence was as high as 40.6%. The overall prevalence of AP among teeth with missed canals was 90%. Thus, it is possible and even likely that a significant fraction of teeth, in particulars molars, judged to have an adequate root canal filling quality in our study would have been judged differently (i.e. poor quality and missed canals) if CBCT had been used instead of intra oral radiographs.

Even though some studies have reported on improved root canal filling quality after educational efforts introducing Ni-Ti instrumentation techniques [8,9,28], and the use of such techniques nowadays is spread among clinicians our cross-sectional study does not give support for a tendency of better technical quality nor lower frequency of AP in root canal filled teeth. Norwegian researchers has recently challenged the efficacy of educational efforts to general practitioners [29]. Evaluation of the results of a two-day continuing education course in root canal treatment attended by Public Dental Service dentists in Norway did not exhibit neither improvement of the technical quality of root canal fillings nor periapical status associated with root canal filled teeth.

The in particular poor quality of root canal fillings and high frequency of AP in molars in our study gives reason to reflect on the future of root canal treatment in general dental practice in Sweden and possibly also in other countries where similar findings continue to be the result of epidemiological studies of endodontic status.

At least two possible strategies can be considered to achieve an improvement in the long run.

In many situations, that is, when facing a vital pulp, perhaps root canal treatment can be substituted by a less invasive and less technology and operator sensitive therapy, that is, direct pulp capping or pulpotomy [30].

Another track could be to better ensure that root canal treatment in molars is performed by specialists who have repeatedly been shown to exhibit good results with regard to root canal filling quality as well as periapical status [31]

Conclusion

The quality of root canal fillings continues to be poor and the prevalence of AP in root canal filled teeth high, particularly in molar teeth, in a Swedish population.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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