Received: 20 July 2021 | Accepted: 22 November 2021

DOI: 10.1111/iej.13669

ORIGINAL SCIENTIFIC ARTICLE

INTERNATIONAL ENDODONTIC JOURNAL | WILEY

Effects of an individualized training course on technical quality and periapical status of teeth treated endodontically by dentists in the Public Dental Service in Norway: An observational intervention study

Kristin Jordal[1,2] | **Rasa Skudutyte-Rysstad**[3] | **Abhijit Sen**[2] | **Gerald Torgersen**[4] | **Dag Ørstavik**[1] | **Pia Titterud Sunde**[1]

[1]Department of Endodontics, Faculty of Dentistry, University of Oslo, Oslo, Norway

[2]Center for Oral Health Services and Research, TkMidt, Trondheim, Norway

[3]Department of Cariology and Gerodontology, Faculty of Dentistry, University of Oslo, Oslo, Norway

[4]IT Section, Faculty of Dentistry, University of Oslo, Oslo, Norway

Correspondence
Kristin Jordal, Department of Endodontics, Institute of Clinical Dentistry, Faculty of Dentistry, University of Oslo, Postboks 1142, Blindern, Oslo 0318, Norway.
Email: kristin_jordal@hotmail.com

Abstract

Aim: To investigate the effect of a continuing education course on technical quality and treatment outcome for root filled permanent teeth in Møre and Romsdal County, Norway.

Methodology: Fifty-two dentists employed in the Public Dental Service in Møre and Romsdal county, Norway, completed a two-day continuing education course in root canal treatment. Periapical radiographs of root filled teeth treated before and after the course, with at least one-year follow-up were identified and scored for technical quality and periapical status. Technical root filling quality was assessed by density and length and the treatment outcome by PAI scores. Treatment information was achieved from the county's electronic dental record system. Information regarding the dental practitioners' background and treatment procedure routines was collected by a questionnaire. Descriptive statistics analyses and mixed-effect logistic regression analyses were performed to evaluate the effect of the course.

Results: Radiographs were available for 224 teeth root filled before and for 221 teeth after the course. The proportion of teeth with adequate root filling quality was significantly lower after the course ($p = .006$), associated mainly with short root fillings ($p < .001$). No significant differences were observed in treatment outcome. There were, however, large differences in treatment outcome amongst subgroups of dentists. Further, there was evidence of effect modification by the continuing education course on periapical outcome by patient's age ($p_{\text{interaction}} = .0023$) suggesting that teeth in patients ≤18 years healed relatively better post-course compared to patients >18 years.

Conclusions: A two-day continuing education course in root canal treatment attended by Public Dental Service dentists in Norway did not improve the technical quality of root fillings or periapical status associated with root filled teeth.

KEYWORDS

apical periodontitis, continuing education, endodontics, general dental practitioner, reciprocating technique, root filling quality

INTRODUCTION

Root canal treatment performed at dental educational institutions or in specialist practice has a success rate of 75%–85% in teeth with apical periodontitis and regularly more than 90% in teeth without pre-operative apical lesions (Llena et al., 2020; Ng et al., 2011; Ricucci et al., 2011; Sjögren et al., 1990). However, epidemiological studies of endodontically treated teeth show that up to 50% are associated with apical pathosis, detected by conventional periapical radiography (Fransson et al., 2016; Kirkevang et al., 2000; Koch et al., 2015; Meirinhos et al., 2020; Ridell et al., 2006; Skudutyte-Rysstad & Eriksen, 2006). Data from Norway have shown a prevalence of apical periodontitis in root filled teeth of 25% amongst children and adolescents and 43% amongst 35-year-olds (Jordal et al., 2014; Skudutyte-Rysstad & Eriksen, 2006).

The technical quality of root fillings has been stated to influence the outcome of root canal treatment (Bołtacz-Rzepkowska & Pawlicka, 2003; Boucher et al., 2002; Dugas et al., 2003; Eriksen et al., 2002; Kirkevang & Hørsted-Bindslev, 2002; Kirkevang et al., 2000, 2014; Lupi-Pegurier et al., 2002; Ng et al., 2011; Ricucci et al., 2011; Siqueira et al., 2005; Sjögren et al., 1990; Tsuneishi et al., 2005). Quality guidelines on root canal treatment procedures have been published by the European Society of Endodontology (ESE, 2006); however, several studies have revealed that root canal treatments in general dental practice are not always performed to the same standard as recommended by the guidelines (Dahlström et al., 2018; Kirkevang et al., 2014; Malmberg et al., 2020; Markvart et al., 2018; Neukermans et al., 2015; Peciuliene et al., 2009; Peters et al., 2011).

Whilst it may be possible to change and improve the clinical routines of dentists and the technical quality of the root fillings through pedagogical interventions (Dahlström et al., 2015; Koch et al., 2009; Molander et al., 2007; Reit et al., 2007), a corresponding improvement in the treatment outcome does not necessarily follow (Dahlström et al., 2015; Koch et al., 2015; Molander et al., 2007). Studies on the effect of short endodontic hands-on courses on dentists in Norway have not been performed.

As part of a quality assurance programme in Endodontics, all dentists in the Public Dental Service (PDS) of Møre and Romsdal county in Norway were given a continuous education (CE) course designed to improve clinical understanding and procedures of root canal treatment. Findings from a recent questionnaire study indicated that the course had only a minor effect on participants' knowledge and insight in Endodontics (Jordal et al., 2021).

The objective of the present study was to investigate the effect of the CE course on the technical quality of root fillings and periapical status of root filled permanent teeth in Møre and Romsdal County, Norway. Also, the pooled data were used to analyse the performance of subgroups of the dentists regarding technical quality of root fillings and treatment outcome following root canal treatment.

MATERIAL AND METHODS

Study design

The project was presented to the Regional Ethics Committee (REC South-East Norway) without objections (ref no. 2015/265 B) and was approved by the Norwegian Center for Research Data, NSD (Ref no 39991). Because the attending dentists adopted a standard, nonexperimental treatment protocol, and because knowledge about health or disease *per se* is not the purpose of this study, this project falls outside the provisions of the Health Research Act, cf. section 4 and does not require local review board approval according to the European Guidelines for Good Clinical Practice (CPMP/ICH/135/95). The confidentiality and anonymity of patients and course participants were maintained in accordance with national and regional (Office of the Møre and Romsdal Public Dental Health Service) requirements. The manuscript was written in accordance with 'Strengthening the reporting of observational studies (STROBE)' recommendations (www.strobe-statement.org).

In 2015, all dentists of the PDS in the Norwegian County of Møre and Romsdal were invited to a CE course in root canal treatment, aiming to improve the technical quality and periapical outcome of root fillings. The course, consisting of two full-day sessions was implemented as compulsory post-graduate training (for details, see Jordal et al., 2021). Fifty-two of the 67 PDS employed dentists (78%) completed the course.

In short, the course comprised lectures with a comprehensive update on the aetiology and treatment principles of endodontic infections, including demonstrations and hands-on training with a reciprocating file system (RECIPROC VDW). The file system was presented in detail, and root canal preparation was demonstrated in

a video. The root filling technique in the course was a single cone supplemented, when necessary, with cold lateral condensation, demonstrated in a video and in one-to-one teaching sessions. Procedures were based on the ESE treatment guidelines (ESE, 2006). All dentists practised root canal instrumentation and filling in plastic molars ('Endo Training Tooth'; VDW). Practical training sessions were held under guidance by two experienced endodontists with academic as well as clinical background (DØ & KJ). The PDS provided the necessary equipment including engines and files ('Dentsply X-Smart Plus Wave One' engine with 'RECIPROC' files) to all clinics.

Inclusion criteria

Root filled teeth treated in PDS clinics before and after the course were identified from the county's electronic dental record system (EDR). Patients with at least one root canal treatment between 1 January 2014 and 31 December 2016, were identified via the EDR. Teeth were categorized into two groups based on whether they had been treated before or after the CE course. Inclusion criteria for evaluation of technical quality of root fillings and periapical outcomes were teeth treated by the 52 dentists who attended the course, and teeth with post-operative as well as follow-up radiographs of at least 1 year after treatment. Only one root filled tooth per patient was randomly selected for evaluation of periapical outcome. Radiographs had to be of adequate quality and include relevant anatomical structures.

Data collection

Information regarding the patients' gender and age, operator code, cases of retreatment and follow-up time was retrieved from the EDR system.

Information regarding the background characteristics of the dentists such as gender, place and year of education, as well as their endodontic treatment procedure routines, was retrieved from a questionnaire completed by the course participants (for details see (Jordal et al., 2021)).

Radiographic evaluation

All clinics used digital radiograph systems, either Digora phosphor storage plate (PSP) system (Soredex Orion Corp.) or Planmeca (Planmeca) intraoral sensor with Romexis (Planmeca) software.

The radiographs of root-filled teeth that met the inclusion criteria were coded and anonymously copied as TIFF files to a USB-flash drive. The radiographs were coded randomly to blind the examiner to whether the root filling had been performed before or after the course. The root filling quality was evaluated in follow-up radiographs by one examiner (KJ) using an extension of the image processing programme ImageJ (Rasband, 1997–2018, Schneider et al., 2012). The extension simplifies the measurements of endodontic parameters in periapical radiographs. For the evaluation of root curvature and length of the root filling, specific points are marked in the X-ray, and the application stores the coordinates to facilitate further calculations (Figure 1). Root filling density was recorded subjectively as either satisfactory (homogenous) or unsatisfactory (visible voids) (Figure 1). Overfilled root canals or fillings more than 2-mm short of root apex were considered of unsatisfactory length. Teeth with periapical extrusion of sealer were not considered as overfilled. Both density and length had to be satisfactory for the root filling to be considered of adequate quality. In cases of multirooted teeth, each root was assessed separately, and the tooth was assigned the score of the worst root. The coordinates defining canal entry, canal deviation, and root apex were used to calculate the root angle (a modified Schneider angle) in the same root (Schneider, 1971), which were labelled S angles and categorized into <25 and ≥ 25 degrees for no or slight versus marked curvature, respectively.

Periapical status was evaluated using the Periapical Index (PAI) (Ørstavik, 1996; Ørstavik et al., 1986) by two examiners (PTS and KJ). They were calibrated against 100 reference radiographs until an observer/reference agreement with a kappa value >0.61 was reached. The weighted kappa value for interobserver agreement of PAI scores was 0.86. After calibration, the two operators independently examined and PAI scored all radiographs. In cases of one PAI score value in difference, the higher score was chosen. The two observers agreed in 70% of all observations and in 98% whether the tooth was healthy (defined as PAI score 1 or 2) or not. In 14 of 251 cases of disagreement, the difference was of two or more PAI score values. These images were reviewed again, and a final consensus was reached after discussion with a third evaluator (DØ). Similar to the procedure for technical quality, in multirooted teeth, the root with the poorest status (highest PAI score) was selected for analyses.

When one patient had more than one tooth treated endodontically during the study period, one tooth per patient was randomly selected for evaluation of periapical status.

The outcome statistics used in calculations were

1. Technical quality: 'adequate' defined as root fillings without visible voids, ending ≤ 2 mm from the radiographic apex;

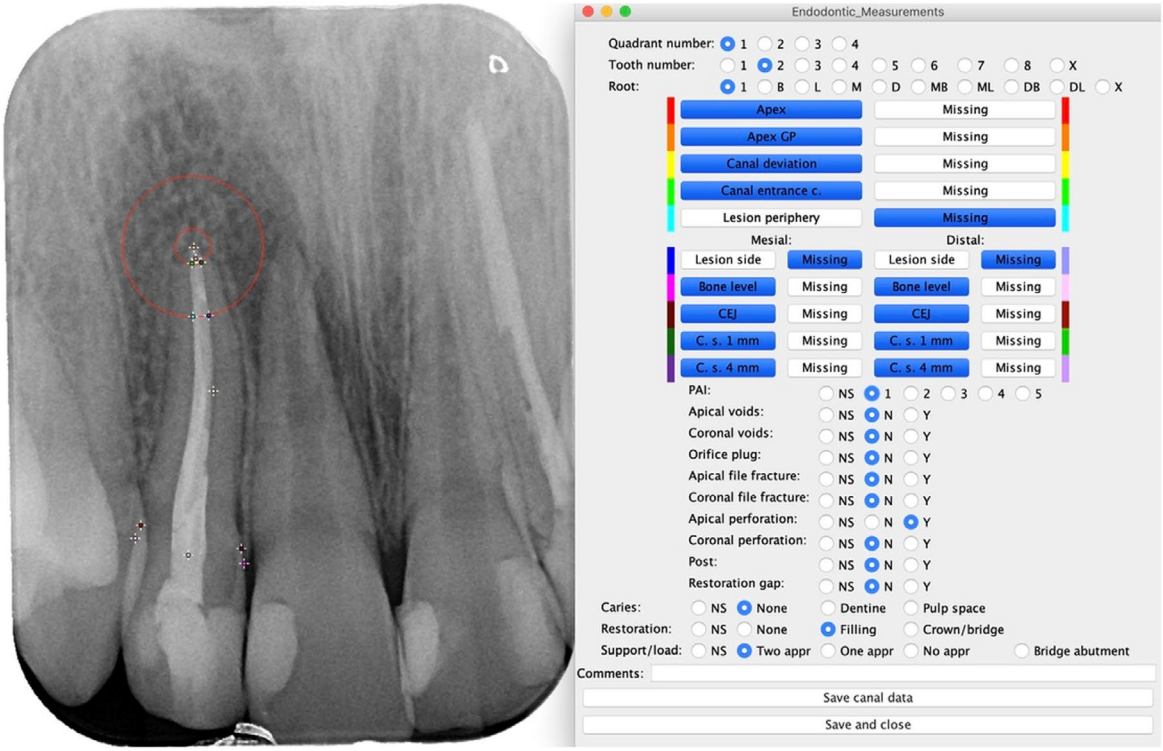

FIGURE 1 Screenshot of the ImageJ application interface

2. Periapical outcome: 'healthy' defined as all teeth with PAI 1 or 2 at follow-up (strict criterium); and
3. Periapical outcome: 'healing' defined as all teeth with PAI 1 or 2 at follow-up plus teeth with PAI 4 or 5 at start, which scored PAI 3 at follow-up (less strict criterium).

Statistical analyses

Descriptive statistics of the variables were presented as frequencies and percentages. Inter-group comparisons between categorical variables were assessed using Pearson's chi-squared test. Teeth-treated pre- and post-course were compared with regard to patient age (below or above 45 years), gender, tooth type (molars versus incisors/pre-molars), root canal curvature (S angle), preoperative periapical diagnosis (apical periodontitis versus healthy), retreatments, visible rubber-dam clamp in radiographs, and follow-up period (up to 2 years versus longer) as well as distribution of teeth according to PAI score. Furthermore, the quality of root filling (0 = not adequate, 1 = adequate) and periapical outcome (0 = not healthy, 1 = healthy) in teeth-treated pre- and post-course were assessed in relation to background characteristics of the dentists. The effect of the CE course on the technical quality of root filling (0 = not adequate, 1 = adequate), and on the probability of successful endodontic treatment outcome (0 = not healthy, 1 = healthy) was assessed. Due to the clustered structure of the data, mixed-effect logistic regression analyses with robust variance estimator were performed. Two-level analyses were carried out, with teeth at level 1 and dentists at level 2. The same set of exposures were used in the multivariable analyses. For regression analyses, only dentists who treated teeth both before and after the CE course were included. Two models were constructed. Model 1 was unadjusted, and Model 2 was adjusted for dentist gender (male/female), place of education (in Norway, abroad), and dentist's experience (<12 years vs. ≥12 years). In addition, sensitivity analyses were performed using a less strict definition for periapical health status (healing), where Healing = any PAI1 or 2 at follow-up plus any PAI 4 or 5 at start scored as PAI 3 at control.

In secondary analyses, the effect modification was assessed by tooth type (molars vs. nonmolars), root curvature by the S angle (≥25 vs. <25), patient age (<18 years vs. ≥18 years), dentist's experience (<12 years vs. ≥12 years), patient's follow-up time (up to 2 years vs. ≥2 years of follow-up), and technical quality of the root filling on successful endodontic treatment outcome. The relevant multiplicative interaction parameter was included in the models and assessed for statistical significance by likelihood ratio test.

Statistical analyses were performed using SPSS 26 version (SPSS Inc.; IBM) and the significance level was set at

$p < .05$. The mixed-effect logistic regression analyses were conducted using Stata version 15 (Stata Corp).

RESULTS

Five hundred one teeth were treated in the period from January 2014 until course-day 1 in October 2014 (pre-course) and 544 teeth in the period after course-day 2, from October 2015 to end of December 2016 (post-course). Post-operative and follow-up periapical radiographs were available for 224 of 501 teeth (45%) pre-course and 221 of 544 (41%) post-course. For evaluation of technical quality, 224 teeth pre-course and 221 teeth post-course were analysed. For evaluation of periapical outcome, one tooth per patient was randomly selected, excluding 17 teeth pre-course and 16 teeth post-course (see flow chart Figure 2). Participating dentists contributed with different number of teeth, both in total and in the proportion pre- and post-course (Table S1). Thirty-nine dentists contributed with teeth to the pre-course period and 48 dentists contributed to the post-course period. Thirty-five dentists contributed to both periods. The follow-up time ranged from 12 to 60 months. The pre-course treated teeth had relatively longer follow-up time than the post-course treated teeth, (60% vs. 37% >2 years) and more molar teeth were treated post-course (31% vs. 40%). No significant differences in the proportions of teeth with 'pre-operative apical periodontitis', 'retreatments', 'marked root curvature' and 'visible rubber-dam clamp on radiograph' were observed in the pre- and the post-course groups (Table 1).

Course effects on technical quality and treatment outcome

The distribution of teeth-treated pre- and post-course in relation to root filling quality is presented in Table 2. The proportion of teeth with adequate root filling quality (density + length) decreased significantly from 48% pre-course to 35% post-course ($p = .006$). The proportion of teeth with adequate root filling length *per se* were reduced significantly from 59% to 47%, mainly because short root fillings increased from 24% to 40% ($p < .001$).

For the entire material, no significant difference in outcome pre- and post-course was found either by strict criteria or by the less strict definition of healing as shown in Table 2. For teeth with pre-operative apical periodontitis, however, there was a significant reduction in the proportion of root filled teeth scored as 'healthy' after the course (56% vs. 39%, $p = .016$).

The distribution of teeth in relation to post-operative changes in PAI scores at follow-up is presented in Table 3. Although the proportions are fairly similar pre- and post-course, more of the definite lesions (PAI 4 + 5) did not heal (PAI1 + 2) post-course.

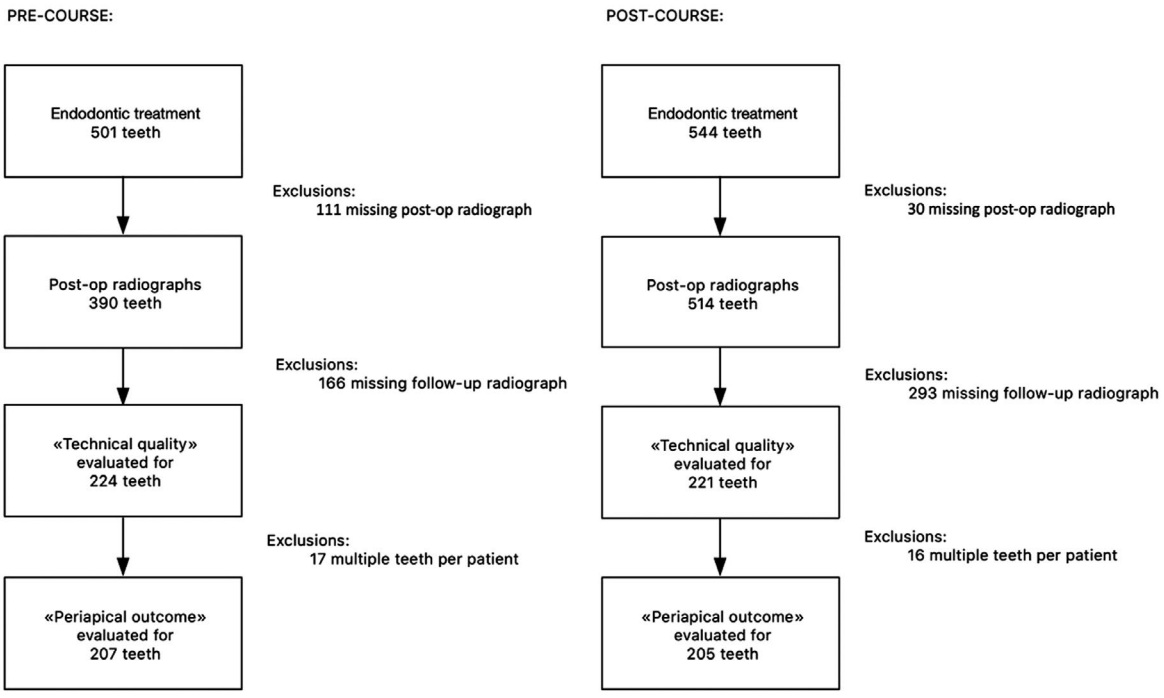

FIGURE 2 Flow chart of teeth-treated pre- and post-course

TABLE 1 Distributions of root filled teeth evaluated for periapical outcome

	Pre-course ($n = 207$) n (%)	Post-course ($n = 205$) n (%)	p-Value[a]
Molars	64 (31)	81 (40)	.079
Pre-operative apical periodontitis (PAI 3+4+5)	94 (45)	95 (46)	.921
Definite pre-operative apical periodontitis (PAI 4+5)	42 (20)	61 (30)	**.031**
Retreatments	13 (6)	9 (4)	.512
S angle ≥25	39 (19)	43 (21)	.623
Rubber-dam clamp on radiograph	104 (50)	108 (53)	.624
Follow-up >2 years	**124 (60)**	**75 (37)**	**<.001**

Note: Results significant at 5% level marked in bold.

Abbreviations: PAI, periapical index; S angle, Schneider angle, measure of root curvature.

[a]Chi-squared test.

TABLE 2 Distributions of teeth-treated pre- and post-course in relation to technical quality and periapical outcome

	Pre-course n (%)	Post-course n (%)	p-Value
Technical quality	($n = 224$)	($n = 221$)	
Adequate	**108 (48)**	**78 (35)**	**.006**
Satisfactory density	156 (70)	144 (65)	.313
Satisfactory length	**132 (59)**	**103 (47)**	**.003**
Too short	**53 (24)**	**89 (40)**	**<.001**
Too long	39 (17)	29 (13)	.418
Periapical outcome at follow-up	($n = 207$)	($n = 205$)	
Healthy	146 (71)	127 (62)	.066
Healing	158 (76)	150 (73)	.461
PAI 1 + 2 at start	($n = 113$)	($n = 110$)	
Healthy	93 (82)	90 (82)	.925
PAI 3 + 4 + 5 at start	($n = 94$)	($n = 95$)	
Healthy	**53 (56)**	**37 (39)**	**.016**
Healing	65 (69)	60 (63)	.384

Note: 445 teeth (224 pre-course + 221 post-course) included for evaluation of technical quality. 412 teeth (207 pre-course + 205 post-course) included for evaluation of periapical outcome. Results significant at 5% level marked in bold. Adequate quality: satisfactory length and density; Healthy: PAI 1 or 2 at follow-up; Healing: PAI 1 or 2 at follow-up plus PAI 4 or 5 at start scored as PAI 3 at follow-up.

Other factors associated with technical quality and treatment outcome

For assessment of factors associated with technical quality and periapical outcome, 16 and 15 teeth, respectively, were excluded due to the nonresponse of 3 dentists to the background questionnaire (Table 4). Analyses of all root filled teeth (pre- and post-course) in relation to background characteristics of dentists indicated that teeth treated by female dentists had more often adequate root filling quality and good periapical health at follow-up (Table 4), and teeth treated by dentists educated in Norway and dentist who claimed to always use rubber dam were more often scored as healthy at follow-up.

Mixed-effect logistic regression analyses

The mixed-effect logistic regression analysis of teeth-treated pre- and post-course with root filling quality and periapical outcome as dependent variables is presented in Table 5. Only teeth treated by the 35 dentists who contributed to both periods were included to avoid data clustering on dentist level. In the unadjusted model, the course had a significant inverse association with the overall technical quality and the periapical outcome of the root canal treatment. The results on technical quality remained significant after adjusting for dentists' gender, years of experience and education place, but there was no significant effect of the course on periapical health in the adjusted model. Further, the sensitivity analyses using less strict definition for periapical outcome revealed that the results did not vary from the main analyses.

When assessing effect modification on the outcome variables (root filling quality and periapical outcome) by selected modifiers presented in Table 6, the p-value for interaction on 'patient age ≤18' was significant ($p_{\text{interaction}} = .0023$) and indicated that this group healed relatively better post-course compared to the peer group (>18 years).

TABLE 3 Distribution of teeth according to PAI score between teeth-treated pre- and post-course

	Follow-up PAI 1 + 2	Follow-up PAI 3	Follow-up PAI 4 + 5	Total
	n (%)	*n* (%)	*n* (%)	*n*
Pre-course				
Start PAI 1 + 2	93 (82)	12 (11)	8 (7)	113
Start PAI 3	31 (60)	11 (21)	10 (19)	52
Start PAI 4 + 5	22 (52)	12 (29)	8 (19)	42
Post-course				
Start PAI 1 + 2	90 (82)	15 (14)	5 (5)	110
Start PAI 3	21 (62)	6 (18)	7 (21)	34
Start PAI 4 + 5	16 (26)	23 (38)	22 (36)	61

Abbreviation: PAI, periapical index.

TABLE 4 Technical quality and periapical outcome of root-filled teeth related to background characteristics of dentists

	Technical quality			Periapical outcome		
	Adequate	Inadequate		PAI1 + 2	PAI3 + 4 + 5	
	n (%)	*n* (%)	*p*-Value	*n* (%)	*n* (%)	*p*-Value
Dentist's gender						
Female	130 (48)	146 (52)	**.004**	191 (74)	67 (26)	**<.001**
Male	56 (33)	113 (67)		82 (53)	72 (47)	
Educated in Norway						
Yes	120 (43)	156 (57)	.415[a]	178 (70)	76 (30)	**.027**[b]
No	60 (40)	93 (60)		84 (59)	59 (41)	
Always use rubber dam						
Yes	44 (41)	63 (59)	.910[a]	74 (76)	23 (24)	**.019**[b]
No	136 (42)	186 (58)		188 (63)	112 (37)	
Dentist experience <12 years						
Yes	70 (48)	75 (52)	.063[a]	92 (69)	42 (31)	.436[b]
No	110 (39)	174 (61)		170 (65)	93 (35)	

Note: 445 teeth (224 pre-course + 221 post-course) included for evaluation of technical quality. 412 teeth (207 pre-course + 205 post-course) included for evaluation of periapical outcome. The analysis was performed by Pearson's chi-squared test. Results significant at 5% level marked in bold. Adequate quality: satisfactory length and density.

[a]16 teeth were excluded due to 3 dentists' nonresponse of the questionnaire.

[b]15 teeth were excluded due to 3 dentists' nonresponse of the questionnaire.

DISCUSSION

The PDS in Møre and Romsdal is responsible for dental care of children and adolescents 0–20 years, the intellectually disabled, elderly and physically disabled in institutions or granted home nursing, and other groups that the county municipality has decided to prioritize. The PDS has a uniform digital patient record system, and this made it feasible to collect information from a large number of dental records. The background characteristics of course participants appeared to be similar to those of practitioners in the PDS in other parts of Norway (Bletsa et al., 2019; Uhlen et al., 2019) and thus potentially represent a wider population of dental providers in PDS.

Scoring of root filling quality was performed in the ImageJ extension. As the anatomical areas were described and no interpretation was required, calibration or use of two examiners was not considered necessary. Root fillings were categorized as 'adequate' or 'inadequate' with regard to length and density. Root fillings ending ≤2 mm from radiographic apex were considered of adequate length, as in the study by (Koch et al., 2015), but slightly different from (Molander et al., 2007) and (Dahlström et al., 2015) who used a limit of ≤2.5 mm, and from (Kirkevang et al., 2000) who used ≤3 mm from

TABLE 5 Mixed-effect logistic regression analyses to assess the association of CE course on technical quality and periapical outcome

	Model 1			Model 2		
	OR	**95% CI**	***p*-Value**	**aOR**	**95% CI**	***p*-Value**
Adequate quality[a]						
Pre-course (reference)	1.00		**<.001**	1.00		**<.001**
Post-course	0.51	(0.35–0.73)		0.52	(0.36–0.75)	
Level 1: teeth		$n = 374$			$n = 362$	
Level 2: dentists		$n = 35$			$n = 33$	
Periapical outcome: healthy[b]						
Pre-course (reference)	1.00		**.037**	1.00		.082
Post-course	0.60	(0.37–0.97)		0.67	(0.43–1.05)	
Level 1: teeth		$n = 347$			$n = 336$	
Level 2: dentists		$n = 35$			$n = 33$	

Note: Model 1 is unadjusted, and Model 2 adjusted for dentists' gender, dentists' years of experience and dentists' place of education. Results' significant at 5% level marked in bold; Adequate quality: satisfactory length and density; Periapical outcome: healthy: PAI 1 + 2 at follow-up.

Abbreviations: aOR, adjusted Odds ratio; CI, confidence interval; OR, Odds ratio.

[a]Missing values: 71 teeth treated by dentists only producing root fillings either before or after CE course were excluded. *N* in Model 2 is further reduced as 12 teeth were excluded due to 2 dentists' nonresponse to dentists' years of experience or dentists' place of education in the questionnaire.

[b]Missing values: 65 teeth treated by dentists only producing root fillings before or after CE course were excluded. *N* in Model 2 is further reduced as 11 teeth were excluded due to 2 dentists' nonresponse to dentists' years of experience or dentists' place of education in the questionnaire.

the radiographic apex. As there were no aim to set a standard for adequate root fillings, but rather compare two groups of teeth, ≤2 mm was optimal for statistical calculations with the data.

For each of the included teeth, periapical status was assessed using the PAI index. The index is well established in endodontic epidemiology and follow-up studies and provides reproducible assessment of periapical status. The interobserver agreement on PAI scores was high, thus the scores should be deemed reliable.

Randomly including one tooth per patient to study periapical outcome was done to ensure the independence of the data and to avoid data clustering. The individual dentist´s contribution of root-filled teeth was unevenly distributed and could have been a possible source of bias. Therefore, cases from dentists who did not perform root canal treatments both before and after the course were excluded. Due to some dentists' lack of routines of taking post-operative or follow-up radiographs, only 45% of the root filled teeth in the pre-course group and 41% in the post-course group were included in the final analyses. The large drop-out rate may limit the validity of the outcomes.

The findings of the present study indicate that no improvements in the technical quality of root fillings occurred after the course. On the contrary, a decrease in a proportion of adequate root fillings was found, particularly regarding root filling length. One feasible explanation for this could be that one focus in the educational course was that extruded root fillings negatively affect treatment outcome in infected teeth, which may have resulted in dentists trying to avoid producing long root fillings after the course and instead making them too short.

The increase in the proportion of inadequate root fillings post-course is in contrast to similar studies showing improvement in technical quality after introduction of rotary files (Dahlström et al., 2015; Koch et al., 2015; Molander et al., 2007). In some of these studies a different method for quality scores was used, which in addition to measuring length and density included taper and transportation (Dahlström et al., 2015; Molander et al., 2007). Rotary techniques provide greater taper and less transportation than conventional techniques (Del Fabbro et al., 2018; Taşdemir et al., 2005), which may improve that aspect of the score for optimal technical quality.

The present study and similar studies performed in Sweden (Dahlström et al., 2015; Koch et al., 2015; Molander et al., 2007) are based on teeth treated by dentists working in the PDS. However, the PDS in Sweden (Folktandvården) has a slightly different patient profile compared to the Norwegian PDS. In addition to the priority groups, Swedish PDS treat almost half of all adults (https://folktandvarden.se). The present material consisted of 31% molars pre-course and 40% post-course. (Koch et al., 2015) did not describe the proportions of molars in their study while (Molander et al., 2007) and (Dahlström et al., 2015) studied exclusively molars. In the Swedish studies (Dahlström et al., 2015; Koch et al., 2015; Molander et al., 2007), the predominant pre-course technique was conventional hand file canal instrumentation (79%–96%) compared to only 62% in the present material. Therefore, the dentists in Møre and Romsdal may

TABLE 6 Impact of possible effect modifiers on technical quality and periapical outcome – a mixed-effect logistic regression analysis

	n pre	*n* post	aOR	95% CI	*p*-Value of interaction
Adequate quality[1]					
Molars	60	59	0.46	(0.21–1.01)	.57
Nonmolars	136	107	0.63	(0.40–0.98)	
S angle ≥25	40	35	0.36	(0.13–1.01)	.59
S angle <25	156	131	0.57	(0.39–0.84)	
Patient age >18	157	123	0.54	(0.36–0.80)	.82
Patient age ≤18	39	43	0.45	(0.16–1.32)	
Dentist experience ≥12 years	133	100	0.66	(0.39–1.09)	.17
Dentist experience <12 years	63	66	0.36	(0.21–0.63)	
Periapical outcome: healthy[2]					
Molars	57	57	0.79	(0.40–1.57)	.82
Nonmolars	126	96	0.71	(0.38–1.32)	
1–2 years follow-up	72	91	0.81	(0.41–1.60)	.33
>2 years follow-up	111	62	0.49	(0.25–0.95)	
Adequate quality	101	80	0.54	(0.28–1.02)	.43
Inadequate quality	82	73	0.86	(0.47–1.57)	
Patient age >18	141	112	0.45	(0.29–0.68)	**.0023**
Patient age ≤18	42	41	2.85	(0.75–10.81)	
Dentist experience ≥12 years	120	97	0.55	(0.32–0.96)	.28
Dentist experience <12 years	63	56	0.91	(0.40–2.09)	

Note: Exposure was pre/post-CE course (pre as reference). Adjusted for dentists' gender, dentists' years of experience and dentists' education in Norway. Missing values: on technical quality and periapical outcome, 71 and 65 teeth, respectively, were treated by dentists only producing root fillings before or after courses and 12 and 11 teeth due to 2 dentists' nonresponse of the questionnaire, were excluded. Adequate quality: satisfactory length and density; Periapical outcome: healthy: PAI 1 + 2 at follow-up. Effect modifiers marked in bold.

Abbreviations: aOR, adjusted Odds ratio; CI, confidence interval; *n* post, number, post-course; *n* pre, number, pre-course.

have started at a baseline with potentially better technical quality than their Swedish counterparts.

No significant change in the overall periapical status was found after the course and this finding is in accordance with previous studies. Despite improved technical quality of root fillings, (Koch et al., 2015) also did not show improved treatment outcome. However, when teeth with pre-operative apical periodontitis were analysed separately, there was a decrease in teeth scored as healthy at follow-up after the course. Short and overextended root fillings are associated with significantly lower success rates (Ng et al., 2011; Sjögren et al., 1990); therefore, the lack of improvement in outcome post-course in this study could be due to the increased proportion of short root fillings.

It is also conceivable that the dentists decided to treat more difficult teeth after the course. These may be associated with a poorer prognosis and thus influence the outcome. Pre-operative apical periodontitis, molars, and retreatments are considered to influence the outcome (Frisk et al., 2008; Kirkevang & Hørsted-Bindslev, 2002; Kirkevang et al., 2007; Ng et al., 2008; Torabinejad et al., 2009). There was higher proportion of teeth with pre-operative definite apical periodontitis (PAI 4 + 5) post-course (Table 1). There was a tendency of higher number of molar teeth-treated post-course; however, the difference did not reach statistical significance. This indicates that there were only minor differences in treatment difficulty after the course. Retreatments may be associated with poorer prognosis, but the proportion of retreatments was low and similar for both the pre- and post-course group. The proportion was also similar to those reported in a study based on GDPs working in the PDS in Sweden (Wigsten et al., 2019).

There were significantly longer follow-up times for teeth in the pre-course group, with an average of 30 months, in contrast to 21 months post-course. Some teeth need more time to heal, thus a better outcome could be expected with longer follow-up (Ng et al., 2007; Ørstavik, 1996). However, the multivariate analysis of outcome in the data revealed that the length of follow-up had no significant impact on healing. Although the importance of follow-up radiographs was emphasized repeatedly during the course, less than half of the root canal treatments included a follow-up radiograph, before and after the course.

The background questionnaire revealed that several generally accepted procedures in clinical root canal treatment were not routinely applied by a large proportion of the dentists (Jordal et al., 2021). Twenty two per cent reported not always taking post-operative radiographs and only 37% reported always using rubber dam. Information from the questionnaire on gender, place of education and years of experience, made it possible to assess differences in technical quality and outcome of root canal treatment between subgroups of practitioners. Root canals treated by female dentists had a better outcome in both root filling quality and periapical health. A better periapical outcome was observed for teeth treated by dentists educated in Norway versus abroad, whilst years of experience did not seem to have much impact. Lack of rubber-dam use has been associated with significant reduced survival rate of root filled teeth (Kwak et al., 2019; Lin et al., 2014). Teeth root filled by dentists claiming always to use rubber dam (Jordal et al., 2021) had better results in terms of healing (Table 4). However, the results are based on a small sample of dentists and conclusions should be drawn with caution.

There was evidence that the effect of CE course on root filling quality and periapical outcome was modified by patient's age ($p_{\text{interaction}} = .0023$) suggesting that the younger patients' teeth (≤18 years) healed relatively better post-course compared to the peer group (>18 years). Post-course, a larger proportion of the younger teeth were treated by dentists with <12 years' experience, dentists claiming to 'always use' rubber dam, and teeth with a visible rubber-dam clamp on working length radiographs (data are not shown). Usage of rubber dam did indeed have a positive impact on periapical outcome (Table 4).

The finding that a two-day education course in root canal treatment did not have positive impact on treatment outcome is not unique. A Cochrane study from 2009 based on 30 randomized controlled trials (RCTs) concluded that educational meetings on professional practice and health care did not appear to be effective for complex behaviours (Forsetlund et al., 2009). The behaviour was categorized as complex when a number of behaviours were required, or complex judgements or skills were necessary. Root canal treatment is considered a complex and particularly technically demanding field of dentistry and thus could be categorized as such.

A high prevalence of apical periodontitis in root filled teeth reported in epidemiological studies suggests that there is a need for quality improvement for root canal treatments performed in general practice. However, it is a complex educational problem to improve treatment quality and outcomes. Dentists may not change established clinical routines easily. Efforts were made to prepare and plan a CE course to be of the best possible benefit to the participants (Jordal et al., 2021). Most dentists participating in the course (78%) reported that they performed root canal treatment less than once in a regular week (Jordal et al., 2021). The lack of reinforcement by root canal treatment in daily practice could be one possible explanation for the lack of improvement in quality and outcome. It is also possible that a two-day course may be too limited to effectively change clinical routines incorporated through a professional career. It might also be that a closer follow-up of the participants in between the course sessions, for example with clinic visits by the course holders, would have increased the effect of the course. However, with many clinics involved, this approach was considered too resource intensive.

CONCLUSION

A two-day continuing education course in root canal treatment for the dentists in PDS in Norway did not improve the technical quality of root fillings or outcome of root canal treatments. Findings from the present study suggest that postgraduate training of dentists is challenging, and more knowledge is needed on implementation of new knowledge and means of changing established daily procedures amongst dentists.

CONFLICT OF INTEREST

The authors have stated explicitly that there are no conflicts of interests in connection with this article.

AUTHORS CONTRIBUTION

Kristin Jordal - main author, the conception and design of the study, drafting the article, acquisition of data and interpretation of data. Rasa Skudutyte-Rysstad - epidemiology, the conception and design of the study, analysis and interpretation of data, revising the article critically, final approval of the version to be submitted. Abhijit Sen - statistics, analysis and interpretation of data, revising the article critically, final approval of the version to be submitted. Gerald Torgersen - digital tools, analysis and interpretation of data, revising the article critically, final approval

of the version to be submitted. Dag Ørstavik - experience and overview, drafting the article, the conception and design of the study, analysis and interpretation of data, revising the article critically, final approval of the version to be submitted. Pia Titterud Sunde - close follow-up and main responsibility, drafting the article, the conception and design of the study, interpretation of data, revising the article critically, final approval of the version to be submitted.

ORCID

Kristin Jordal https://orcid.org/0000-0002-8340-2544

REFERENCES

Bletsa, A., Iden, O., Sulo, G. & Berggreen, E. (2019) Work experience influences treatment approaches in endodontics: a questionnaire survey among dentists in Western Norway. *Acta Odontologica Scandinavica*, 77, 617–623.

Bołtacz-Rzepkowska, E. & Pawlicka, H. (2003) Radiographic features and outcome of root canal treatment carried out in the Łódź region of Poland. *International Endodontic Journal*, 36, 27–32.

Boucher, Y., Matossian, L., Rilliard, F. & Machtou, P. (2002) Radiographic evaluation of the prevalence and technical quality of root canal treatment in a French subpopulation. *International Endodontic Journal*, 35, 229–238.

Dahlström, L., Lindwall, O., Rystedt, H. & Reit, C. (2018) 'It's good enough': Swedish general dental practitioners on reasons for accepting substandard root filling quality. *International Endodontic Journal*, 51(Suppl. 3), e168–e177.

Dahlström, L., Molander, A. & Reit, C. (2015) The impact of a continuing education programme on the adoption of nickel-titanium rotary instrumentation and root-filling quality amongst a group of Swedish general dental practitioners. *European Journal of Dental Education*, 19, 23–30.

Del Fabbro, M., Afrashtehfar, K.I., Corbella, S., El-Kabbaney, A., Perondi, I. & Taschieri, S. (2018) In vivo and in vitro effectiveness of rotary nickel-titanium vs manual stainless steel instruments for root canal therapy: systematic review and meta-analysis. *Journal of Evidence Based Dental Practice*, 18, 59–69.

Dugas, N.N., Lawrence, H.P., Teplitsky, P.E., Pharoah, M.J. & Friedman, S. (2003) Periapical health and treatment quality assessment of root-filled teeth in two Canadian populations. *International Endodontic Journal*, 36, 181–192.

Eriksen, H.M., Kirkevang, L.-L. & Petersson, K. (2002) Endodontic epidemiology and treatment outcome: general considerations. *Endodontic Topics*, 2, 1–9.

ESE. (2006) Quality guidelines for endodontic treatment: consensus report of the European Society of Endodontology. *International Endodontic Journal*, 39, 921–930.

Forsetlund, L., Bjørndal, A., Rashidian, A., Jamtvedt, G., O'Brien, M.A., Wolf, F.M. et al. (2009) Continuing education meetings and workshops: effects on professional practice and health care outcomes. *Cochrane Database of Systematic Reviews*. 2009, CD003030. https://doi.org/10.1002/14651858.CD003030.pub2

Fransson, H., Dawson, V.S., Frisk, F., Bjørndal, L., Kvist, T., Bjørndal, L. et al. (2016) Survival of root-filled teeth in the Swedish adult population. *Journal of Endodontics*, 42, 216–220.

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

Jordal, K., Sen, A., Skudutyte-Rysstad, R., Ørstavik, D. & Sunde, P.T. (2021) Effects of an individualised training course in endodontics on the knowledge and insights of dentists in Public Dental Service in Norway. *Acta Odontologica Scandinavica*, 79, 426–435.

Jordal, K., Valen, A. & Ørstavik, D. (2014) Periapical status of root-filled teeth in Norwegian children and adolescents. *Acta Odontologica Scandinavica*, 72, 801–805.

Kirkevang, L.-L. & Hørsted-Bindslev, P. (2002) Technical aspects of treatment in relation to treatment outcome. *Endodontic Topics*, 2, 89–102.

Kirkevang, L.L., Ørstavik, D., Hörsted-Bindslev, P. & Wenzel, A. (2000) Periapical status and quality of root fillings and coronal restorations in a Danish population. *International Endodontic Journal*, 33, 509–515.

Kirkevang, L.L., Vaeth, M., Hörsted-Bindslev, P., Bahrami, G. & Wenzel, A. (2007) Risk factors for developing apical periodontitis in a general population. *International Endodontic Journal*, 40, 290–299.

Kirkevang, L.L., Vaeth, M. & Wenzel, A. (2014) Ten-year follow-up of root filled teeth: a radiographic study of a Danish population. *International Endodontic Journal*, 47, 980–988.

Koch, M., Eriksson, H.G., Axelsson, S. & Tegelberg, Å. (2009) Effect of educational intervention on adoption of new endodontic technology by general dental practitioners: a questionnaire survey. *International Endodontic Journal*, 42, 313–321.

Koch, M., Wolf, E., Tegelberg, Å. & Petersson, K. (2015) Effect of education intervention on the quality and long-term outcomes of root canal treatment in general practice. *International Endodontic Journal*, 48, 680–689.

Kwak, Y., Choi, J., Kim, K., Shin, S.-J., Kim, S. & Kim, E. (2019) The 5-year survival rate of nonsurgical endodontic treatment: a population-based cohort study in Korea. *Journal of Endodontics*, 45, 1192–1199.

Lin, P.-Y., Huang, S.-H., Chang, H.-J. & Chi, L.-Y. (2014) The effect of rubber dam usage on the survival rate of teeth receiving initial root canal treatment: a nationwide population-based study. *Journal of Endodontics*, 40, 1733–1737.

Llena, C., Nicolescu, T., Perez, S., Gonzalez de Pereda, S., Gonzalez, A., Alarcon, I. et al. (2020) Outcome of root canal treatments provided by endodontic postgraduate students. A retrospective study. *Journal of Clinical Medicine*, 9, 1994.

Lupi-Pegurier, L., Bertrand, M.F., Muller-Bolla, M., Rocca, J.P. & Bolla, M. (2002) Periapical status, prevalence and quality of endodontic treatment in an adult French population. *International Endodontic Journal*, 35, 690–697.

Malmberg, L., Sturestam, A., Fagring, A. & Björkner, A.E. (2020) Endodontic follow-up practices, sources of knowledge, and self-assessed treatment outcome among general dental practitioners in Sweden and Norway. *Acta Odontologica Scandinavica*, 78, 547–552.

Markvart, M., Fransson, H. & Bjørndal, L. (2018) Ten-year follow-up on adoption of endodontic technology and clinical guidelines amongst Danish general dental practitioners. *Acta Odontologica Scandinavica*, 76, 515–519.

Meirinhos, J., Martins, J.N.R., Pereira, B., Baruwa, A., Gouveia, J., Quaresma, S.A. et al. (2020) Prevalence of apical periodontitis

and its association with previous root canal treatment, root canal filling length and type of coronal restoration—a cross-sectional study. *International Endodontic Journal*, 53, 573–584.

Molander, A., Caplan, D., Bergenholtz, G. & Reit, C. (2007) Improved quality of root fillings provided by general dental practitioners educated in nickel-titanium rotary instrumentation. *International Endodontic Journal*, 40, 254–260.

Neukermans, M., Vanobbergen, J., De Bruyne, M., Meire, M. & De Moor, R.J. (2015) Endodontic performance by Flemish dentists: have they evolved? *International Endodontic Journal*, 48, 1112–1121.

Ng, Y.L., Mann, V., Rahbaran, S., Lewsey, J. & Gulabivala, K. (2007) Outcome of primary root canal treatment: systematic review of the literature – part 1. Effects of study characteristics on probability of success. *International Endodontic Journal*, 40, 921–939.

Ng, Y.L., Mann, V. & Gulabivala, K. (2008) Outcome of secondary root canal treatment: a systematic review of the literature. *International Endodontic Journal*, 41, 1026–1046.

Ng, Y.L., Mann, V. & Gulabivala, K. (2011) A prospective study of the factors affecting outcomes of nonsurgical root canal treatment: part 1: periapical health. *International Endodontic Journal*, 44, 583–609.

Ørstavik, D. (1996) Time-course and risk analyses of the development and healing of chronic apical periodontitis in man. *International Endodontic Journal*, 29, 150–155.

Ørstavik, D., Kerekes, K. & Eriksen, H. (1986) The periapical index: a scoring system for radiographic assessment of apical periodontitis. *Endodontics & Dental Traumatology*, 2, 20–34.

Peciuliene, V., Maneliene, R., Drukteinis, S. & Rimkuviene, J. (2009) Attitudes of general dental practitioners towards endodontic standards and adoption of new technology: literature review. *Stomatologija, Baltic Dental and Maxillofacial Journal*, 11, 11–14.

Peters, L.B., Lindeboom, J.A., Elst, M.E. & Wesselink, P.R. (2011) Prevalence of apical periodontitis relative to endodontic treatment in an adult Dutch population: a repeated cross-sectional study. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology*, 111, 523–528.

Rasband, W.S. (1997–2018) *ImageJ*.

Reit, C., Bergenholtz, G., Caplan, D. & Molander, A. (2007) The effect of educational intervention on the adoption of nickel-titanium rotary instrumentation in a Public Dental Service. *International Endodontic Journal*, 40, 268–274.

Ricucci, D., Russo, J., Rutberg, M., Burleson, J.A. & Spångberg, L.S. (2011) A prospective cohort study of endodontic treatments of 1,369 root canals: results after 5 years. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology*, 112, 825–842.

Ridell, K., Petersson, A., Matsson, L. & Mejàre, I. (2006) Periapical status and technical quality of root-filled teeth in Swedish adolescents and young adults. A retrospective study. *Acta Odontologica Scandinavica*, 64, 104–110.

Schneider, C.A., Rasband, W.S. & Eliceiri, K.W. (2012) NIH Image to ImageJ: 25 years of image analysis. *Nature Methods*, 9, 671–675.

Schneider, S.W. (1971) A comparison of canal preparations in straight and curved root canals. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology*, 32, 271–275.

Siqueira, J.F. Jr., Rôças, I.N., Alves, F.R. & Campos, L.C. (2005) Periradicular status related to the quality of coronal restorations and root canal fillings in a Brazilian population. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology*, 100, 369–374.

Sjögren, U., Hagglund, B., Sundqvist, G. & Wing, K. (1990) Factors affecting the long-term results of endodontic treatment. *Journal of Endodontics*, 16, 498–504.

Skudutyte-Rysstad, R. & Eriksen, H.M. (2006) Endodontic status amongst 35-year-old Oslo citizens and changes over a 30-year period. *International Endodontic Journal*, 39, 637–642.

Taşdemir, T., Aydemir, H., Inan, U. & Unal, O. (2005) Canal preparation with Hero 642 rotary Ni-Ti instruments compared with stainless steel hand K-file assessed using computed tomography. *International Endodontic Journal*, 38, 402–408.

Torabinejad, M., Corr, R., Handysides, R. & Shabahang, S. (2009) Outcomes of nonsurgical retreatment and endodontic surgery: a systematic review. *Journal of Endodontics*, 35, 930–937.

Tsuneishi, M., Yamamoto, T., Yamanaka, R., Tamaki, N., Sakamoto, T., Tsuji, K. et al. (2005) Radiographic evaluation of periapical status and prevalence of endodontic treatment in an adult Japanese population. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology*, 100, 631–635.

Uhlen, M.M., Valen, H., Karlsen, L.S., Skaare, A.B., Bletsa, A., Ansteinsson, V. et al. (2019) Treatment decisions regarding caries and dental developmental defects in children—a questionnaire-based study among Norwegian dentists. *BMC Oral Health*, 19, 1–8.

Wigsten, E., Jonasson, P. & Kvist, T. (2019) Indications for root canal treatment in a Swedish county dental service: patient- and tooth-specific characteristics. *International Endodontic Journal*, 52, 158–168.

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

How to cite this article: Jordal, K., Skudutyte-Rysstad, R., Sen, A., Torgersen, G., Ørstavik, D. & Sunde, P.T. (2021) Effects of an individualized training course on technical quality and periapical status of teeth treated endodontically by dentists in the Public Dental Service in Norway: An observational intervention study. *International Endodontic Journal*, 00, 1–12. Available from: https://doi.org/10.1111/iej.13669