Assessing a training programme for primary care dental practitioners in endodontics of moderate complexity: Pilot data on skills enhancement and treatment outcomes

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Key points

- This is one of the first longitudinal studies to explore the change in skills of dentists working in general practice whilst enrolled in additional training.
- This study illustrated that clinical skills can be improved by additional training running side by side with working in general practice
- Positive patient outcome were seen in relation to their perceived oral health and satisfaction with the care they received, for those treated within this initiative

Aims To explore the impact of dedicated training to extend the skills of primary care practitioners on the quality of endodontic care, using clinical, radiographic and patient-related outcomes. **Methods** The quality of endodontic treatment performed at the beginning and end of training to become dentists with extended skills (DES) in endodontics was assessed *in vitro* and *in vivo* from endo-training blocks and self-reported logbooks containing clinical notes and radiographs respectively. The quality of endodontic care delivered by DES post-training was measured using clinical and radiographic outcomes. Patient-related outcomes were assessed using a self-report questionnaire, including the Oral Health Impact Profile – Endodontic Outcome Measure (OHIP-EOM). **Results** Data on eight dentists were examined pre-and post-training, five of whom participated in further follow-up investigations on the quality of endodontic care delivered to their patients. Significant improvements in skills were seen for all domains *in vitro* ($p < 0.05$), and for all domains of the clinical treatment process, and achieving the correct working length of the root filling as seen by radiography *in vivo* ($p < 0.05$). The quality of the clinical process was maintained following training. Positive patient outcome (OHIP-EOM) scores were recorded (mean score of 34.72, SD = 10.74, n = 120 pre-treatment and 25.85, SD = 7.74, n = 47 representing reduced impact at follow-up). The majority of patients reported being satisfied, or very satisfied, with the service they received (72.5%, n = 98); would use the service again (68.1%, n = 92); and would recommend the service to friends and family (74.8%, n = 101). **Conclusions** Findings suggest that training for dentists working in practice can be successful in enhancing skills and changing practice, with evidence of high patient satisfaction and good clinical and patient-related outcomes. Pilot results must be interpreted with caution and further research is required.

Introduction

Dentistry is mostly provided in 'primary care' with a small proportion of complex treatment provided in 'secondary care' (NHS hospitals).

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Refereed Paper. Accepted 14 May 2018
DOI: 10.1038/sj.bdj.2018.807

There is a move to shift more services to primary care settings[1] where possible so that care is close to patients. Historically, significant proportions of teeth were being endodontically treated in primary care, for example, in the year 2002–2003 (in England and Wales), there were 63,519 endodontic treatments carried out in children or young people, costing £3,516,889 (1.4% of the children's budget), and 1,040,565 endodontic treatments were carried out among adults costing £50,204,951 (4.8% of the budget for adults).[2,3] Following the introduction of the 2006 dental contract for primary care, there was a reported reduction in the number of root canal treatments provided and an increase in the number of extractions provided.[4–6] In 2014–2015, the number of claims for remuneration for root canal treatment is not insignificant at 566,900–611,500,[7] however, the outcomes of treatment are unknown.

Teaching and learning in dentistry has, and still does, involve the trainee being given instruction from a more experienced trainer. While in the past these techniques were often those that have 'worked' for the trainer, now there is a move for research informed care. Since the acceptance of evidence-based dentistry, attention has turned to quality.[1,8–12] In medicine, surgeons are requested to publish their outcomes with the evidence

Table 1 Survival rates in for root canal treated teeth

Study	Number of teeth included	Years data collected	Survival rates	Country and type of service evaluated
Lazarski *et al.* 2001[95]	109,542	1993–1998	94.4% at 3.5 years	USA Private practice of generalists & specialists
Salehrabi & Rotstein 2004[96]	1,462,936	1995– 2002	97% at 8 years	USA Private practice of generalists & specialists
Chen 2007[97]	1,557,547	1998	91.1% - 95.4% at 5 years	Taiwan Private practice
Lumley *et al.* 2008[98]	30,843	1991–2001	74% at 10 years	UK (NHS) General dental practice
Tickle *et al.* 2008[99]	174	1998– 2003	90.8% at 5 years	UK (NHS) General dental practice
Ng *et al.* 2010 [100]	(Meta-analysis of 14 studies)		86% (95%CI:75%,98%) at 2–3 years 93% (95%CI:92%,94%) at 4–5 years 87% (95%CI:82%,92%) at 8–10 years	Mix of countries and settings (Review – pooled success)

Table 2 Summary of factors affecting outcome of non-surgical root canal treatment

Study	Success rates	Conditions found to improve periapical healing	Simple measures of treatment process
Success rate of primary root canal treatment (Ng *et al.*, 2011)	83% (95% CI: 81%, 85%)	1. The pre-operative absence of periapical lesion	
		2. Presence of periapical lesion, the smaller its size	
		3. The absence of a pre-operative sinus tract	
		4. Achievement of patency at the canal terminus	Use of apex locator
Success rate of secondary root canal treatment (Ng *et al.*, 2011)	80% (95% CI: 78%, 82%)	**5. Extension of canal cleaning as close as possible to its apical terminus**	Patency filing
		6. The use of EDTA solution as a penultimate wash followed by a final rinse of NaOCl in secondary root treatment cases	Use of rubber dam
		7. Abstaining from using 2%CHX as an adjunct irrigant to NaOCl solution	Use of correct irrigants
		8. Absence of tooth/root perforation	Presence of procedural errors
		9. Absence of root filling extrusion	Correct length of root filling
		10. Absence of inter-appointment flare-up (pain /swelling)	
		11. Presence of satisfactory coronal restoration	Satisfactory coronal seal

Bold: aspects of the quality of the clinical process being scored in the current study
Italics: aspects of the quality of the root filling being scored in the current study

informing future learning needs and use of National Health Service (NHS) resources.[13] Dentistry lags behind, with little analysis of clinical and patient outcomes other than through research. In relation to endodontics, the success of root canal treatments has been reported to be somewhere between 61.1% and 89.6%, depending on the definitions of success used,[14] and survival rates are shown in Table 1. Highly experienced dental practitioners may be investigating the outcome of their treatment and publishing positive results, but this raises the question as to whether other dental practitioners are achieving the same high standards and are they auditing the same measures of outcomes? The European Society of Endodontology (2006) and American Association of Endodontics (2004), have been publishing gold standards for root canal treatment since 1994.[15–17] Endodontics is taught as part of the undergraduate curriculum[18] and there are numerous factors affecting outcomes,[19] as presented in Table 2. If factors under the control of the endodontist such as the use of rubber dam for isolation, sodium hypochlorite as an irrigant and electronic apex locators to establish working length are assessed, important treatment processes relevant to the outcome of root canal treatment can be measured.

Numerous studies have assessed adherence to endodontic guidelines around the world. While there is strong evidence that use of rubber dam significantly increases the survival rate of root filled teeth,[20] rubber dam was only used by between 0.9% and 47% of dentists.[21–33] One study in Taiwan, where radiographs taken during treatment were analysed to assess compliance with rubber dam use, revealed its use in only 16.5% of patients, with hospitals being 10% higher than private practice.[34] Electronic apex locators have been reported to be used in endodontics by between 2.7% and 52% of dentists surveyed.[23,27–29,32,35] In the United States, the reported use of rubber dam and electronic apex locators was high, with more than 60% of respondents reporting that they always used rubber dam, and 70% reporting that they use electronic apex locators.[36,37] Reported rates of sodium hypochlorite use for irrigation is between 33% and 95% of responding dentists.[21–25,27,28,31,32] In Germany, Australia, Belgium and Turkey, the use of sodium hypochlorite (NaOCl) as an irrigant was high, with variation

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in the concentrations used and the adjunctive irrigants used depending on their undergraduate education.[21,27,28,31,38,39]

In England and Wales, there is evidence that only 10% of cases in general dental practice fulfilled the European Society of Endodontology defined technical criteria for standards of care.[40] Questionnaire surveys of dentists suggest that 60% of dentists never used rubber dam for root canal treatment within the NHS, the reasons cited as being time, remuneration, training and the view that patients may not like it. There may be a clustering of good process, whereby use of rubber dam was linked to irrigant use with 70% of sodium hypochlorite users also using rubber dam. There is evidence that young graduates are more likely to use rubber dam than older graduates.[41] In Wales, less than 19% use rubber dam routinely for endodontics, 89% of respondents stated that working length was established using radiographs and 19% used sodium hypochlorite.[42] In Northern Ireland, rubber dam was never used during root canal treatment by 39%, citing difficulty of use as a reason.[43] More than half of final year dental students questioned, stated they are likely to use rubber dam less in independent practice.[44] More recent surveys have suggested some improvement to adherences of recommendation, with 30% using rubber dam, 35% using electronic apex locators and 75% using sodium hypochlorite.[45] Higher rates of the use of apex locators in root canal treatment have been reported since in the UK.[46] These findings are in keeping with other reports in healthcare that 30–40% of patients do not receive care that is in accordance with current scientific literature.[47]

It is assumed that clinical practice is a form of human behaviour and therefore it is generalised that behaviour can be modified.[48] Behavioural change among healthcare professionals has been explored,[49–50] levels of compliance with recommendations being associated with the type of health problem, the quality of evidence supporting the recommendations, compatibility of the recommendations with existing values, the description of the desired performance, the complexity of the decision-making required, and the level of new skills and organisational change needed to follow the recommendations. Therefore, even if healthcare professionals are aware and willing to embrace changes in clinical practice, there is a need for environments conducive to change in order to achieve change, and change may be more difficult where complex changes in clinical practice are considered.[47] It has been suggested that the use of twelve domains (knowledge, skills, social/professional role and identity, beliefs about capabilities, beliefs about consequences, motivation and goals, memory, attention and decision processes, environmental context and resources, social influences, emotion regulation, behavioural regulation, and nature of the behaviour) for behavioural change processes in implementing evidence-based practice will enhance understanding of behaviour change.[49–51]

There is a deficiency in the literature regarding the effect of structured, long-term, post-graduate training on the adoption (change in behaviour of dentists) of recommended protocols for root canal treatment (treatment process) and the outcomes of root canal treatment (appearance of the root filling as seen radiographically, healing and patient-related outcomes), especially in NHS primary care in England.[52–58] A novel teaching pilot for endodontics in primary care offered the opportunity to test the ability to assess these measures of treatment process in relation to treatment outcomes, and use this to assess the improvement and benefits from dedicated additional training in endodontics for primary care practitioners. This study aims to report the pilot findings of measuring the process and outcome of root canal treatment before and after behaviour change is attempted via a 24-month training programme involving formal teaching and experience within primary care. The development and testing of measurement instruments for evaluating the outcomes of post-graduate training in endodontics have been previously published.[59] Wider learning from this study and the feasibility of carrying out such research in primary care have been reported elsewhere.[60–63]

Methodology

Participant selection for the training programme, ethical approval (Ref No. 10/H0718/69) and consent processes have been previously reported.[63] Learning outcomes for the training were adopted from draft documents that later developed into the Restorative Commissioning Guide in England as Level II competencies.[64] Course 'teaching days' composed of seminar/didactic teaching sessions in the morning and practical hands-on sessions in a skills-laboratory in the afternoon, once a month, for 24 months. Between teaching days, the eight potential dentists with enhanced skills (DES) continued to treat patients in general dental practice, with the agreement that approximately one hundred patients per delegate would receive endodontic treatment of moderate complexity[61] (not complicated enough to be treated in a hospital setting, but too complicated to access treatment within primary care) as part of the practical training to gain clinical experience. These cases were recorded in a detailed clinical practice logbook or portfolio and discussed with the teachers as a part of seminars and formed the summative end of Year 1 and Year 2 course assessments.[65] The quality of the treatment performed by these dentists was measured by scoring the treatment process, the appearance of the root filling as seen radiographically, healing and patient-related outcomes.[59,63,66]

The first part of the study was carried out during the training programme.[63] The second part of the study measured the maintenance of the quality of the treatment post completion of the training.[63] Participating patients' views were collected following completion of the training initiative, by means of a written, self-completed, free text anonymised questionnaire, which also collated demographic data and patient views of the service they received as part of being referred to a specific service for receiving root canal treatment. Participating dentists' views were collected using an anonymous questionnaire and previously reported.[62,63]

Data were coded, randomised and blinded during assessment and analysis, ensuring anonymity of the dentists and patients, as well as reducing examiner bias during scoring of the radiographs.[59,63,67] A black card with a window was used to ensure consistent magnification was used for all radiographic scoring and to eliminate the background light emitted by the screen.[46] Descriptive analysis was undertaken and data were tested for normality before statistical analysis.

Assessment of academic knowledge of participant dentists

Academic knowledge of individual dentists was ascertained from the training course assessments at the end of Year 1 and then again at the end of Year 2 (end of course), by *viva voce* (knowledge, ethics and attitude). Descriptive statistics were calculated for the academic scores with the unit of analysis being the dentist. Data were not normally distributed, therefore a non-parametric test for two related samples were used (Wilcoxon's rank test). Data for total scores and the mean score

Table 3 Summative quality assessment tool for root canal treatment and mean total scoring for all dentists who contributed data (excluding the scores for quality of coronal seal)[59]

			Year 0	Year 2	Post-training		Year 0	Year 2	Post-training
Process	**A. Quality of the clinical process of providing root canal treatment**	Rubber Dam used (Y=1, N=0)	3.67 (SD 0.85)	4.18 (SD 0.51)	4.41 (SD 0.55)	Total Process Quality Score	6.08 (SD 1.48)	6.91 (SD 1.27)	6.81 (SD 1.34)
		Irrigants (NaOCl + EDTA = 2, NaOCl=1, Anything else=0)							
		AL used (Y=1, N=0)							
		Patency filing (Y=1, N=0)							
Process	**B. Quality of the root filling as seen radiographically**	Procedural errors (Y=0, N=1)	2.36 (SD 1.15)	2.67 (SD 1.08)	2.43 (SD 1.20)				
		Within 2 mm of rad apex inside the root canal (Y=1, N=0)							
		Continuous taper and shape (Y=1, N=0)							
		Voids (Y=0, N=1)							
	Quality of coronal seal	Satisfactory coronal restoration (Y=1, N = 0)							
Outcome	**C. Healing as seen radiographically**	Apical area (reduced or no development of an apical area =2, no change in size of existing apical area =1, Increased or development of an apical area =0)			1.52 (SD 0.74)	Total Outcome Quality Score			4.44 (SD 0.78)
Outcome	**D. Healing as seen clinically**	Symptoms (Y=0, N=1)			2.81 (SD 0.68)				
		Clinical signs (Y=0, N=1)							
		Any other negative signs (Y=0, N=1)							
		Total (0=poor, 15=good)			11.11 (SD 0.36)				11.11 (SD 0.36)

for each domain were distributed normally, therefore, the paired t-test was used to compare group-level data.

Assessment of performance on endodontic training block (*in vitro*)

Assessment of preparation of a canal in an endodontic training block was used to evaluate the technical skills of the dentists enrolled, at the beginning and end of the course. Participating dentists were allowed to use any of the instrumentation techniques with which they were comfortable. Data on the technique used nor the time taken to complete the task were not collected. Performance on the task before training was compared to that following training. The proportion of endodontic training blocks receiving each score was calculated for each time point and the change from Year 0 to Year 2 was analysed with the unit of analysis being the dentist (statistical significance calculated using the McNemar test). Statistical significance of the difference in mean total scores (data were not normally distributed) from Year 0 to Year 2 was calculated using the Mann-Whitney U test. The Z-test was used to calculate the statistical significance of the difference from Year 0 to Year 2.

Assessment of dentist performance on patients (*in vivo*)

The quality of root canal treatment was assessed in terms of the clinical treatment process (A) and the appearance of the root canal filling as seen radiographically (B) at the end of treatment (Table 3). The first ten cases treated during the course and the last ten cases treated during the course were assessed using the logbooks and radiographs taken during treatment. No attempt was made to ascertain the patient perspective for these cases. Healing was not assessed. No additional radiographs were taken solely for the purpose of this study. Two examiners assessed all of the radiographs (independent to the DES course and independent to each other). Both examiners were trained and pre-calibrated using a selection of radiographs, and Kappa scored for inter- and intra-examiner reliability.[59] The proportion of teeth receiving each score was calculated for each time point and the change from Year 0 to Year 2 was analysed (unit of analysis was the tooth and secondarily the dentist). The Z-test was used to compare proportions of ideal scores and calculate the statistical significance of the difference from Year 0 to Year 2. The Mann-Whitney U test was used to calculate the statistical significance of the difference in mean total scores from Year 0 to Year 2.

Outcome of treatment

In addition to the quality of the treatment process and the radiographic quality of cases treated post completion of the training (Table 3), evidence of radiographic and clinical healing (C and D) as well as patient-related outcomes were measured. For patients studied post completion of the course, the proportion of teeth receiving each score was calculated for post-training cases and compared to that for Year 2. The unit of analysis was the patient and secondarily the dentist. The Z-test was used to calculate the statistical significance of the difference from Year 2 to post-training. The Mann-Whitney U test

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was used to calculate the statistical significance of the difference in mean total scores from Year 2 to post-training. Each tooth (not each root) was used as the unit of evaluation for scoring, as it would be difficult to localise failure of treatment in a multi-rooted tooth to any one root. The patient was used as the overall unit of measure in the analysis. If any of the patients had more than one tooth treated, only one tooth was randomly selected for inclusion in analysis. The mean total summative scores for all domains were calculated and no further statistical analysis was performed.

Change in quality of life scores (OHIP-EOM)

In order to evaluate clinical and patient-based outcome in relation to clinical skills, patient perception was investigated using a patient satisfaction/experience questionnaire.[66] Questionnaires were returned by post. Following principles outlined by Dillman,[68] efforts were made to contact patients consenting to take part in the survey up to a maximum of three times. The summative scores of OHIP-EOM for separate domains of health and overall health (all domains) were calculated from the OHIP-EOM questionnaire results. Changes in OHIP-EOM scores were descriptively analysed for each time period.

Patient view of the service

Participating patients' views were collected following completion of the training initiative, by means of a written, self-completed, free text anonymised questionnaire, which also collated demographic data and patient views of the service they received as part of being referred to a specific service for receiving root canal treatment. The questionnaire was returned by post.

Results

Part 1: Change in knowledge and skills during training

Eight dentists participated in the course and contributed to data.[63] A ninth participating dentist failed to complete the end of Year 1 examination with a satisfactory grade and therefore did not complete the course and was excluded from the following data sets.

Assessment of academic knowledge of participant dentists

The dentists were assessed across a number of domains in a *viva voce* examination at the end of Year 1 and Year 2 (Fig. 1). In individual domains, statistically significant differences in scores from Year 1 to Year 2 were observed in clinical assessment, investigations and referrals, and professionalism. Data for total scores and mean score for each domain appeared to be distributed normally, therefore, a parametric test for two related samples was used (paired T-test). The score for the ninth dentist (mean examination score = 3, SD = 0.71) was not included in the end of Year 1 scores.

Fig. 1 Mean total examination score for each of the participating dentists at Year 1 and Year 2 with 95% confidence intervals

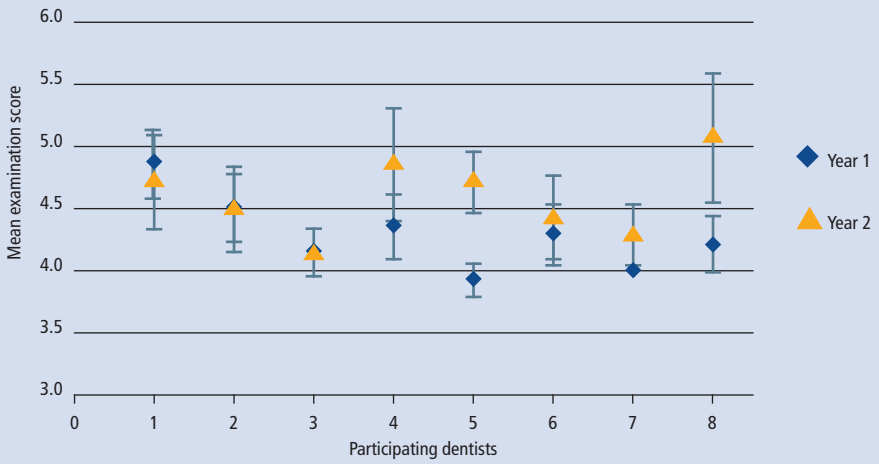
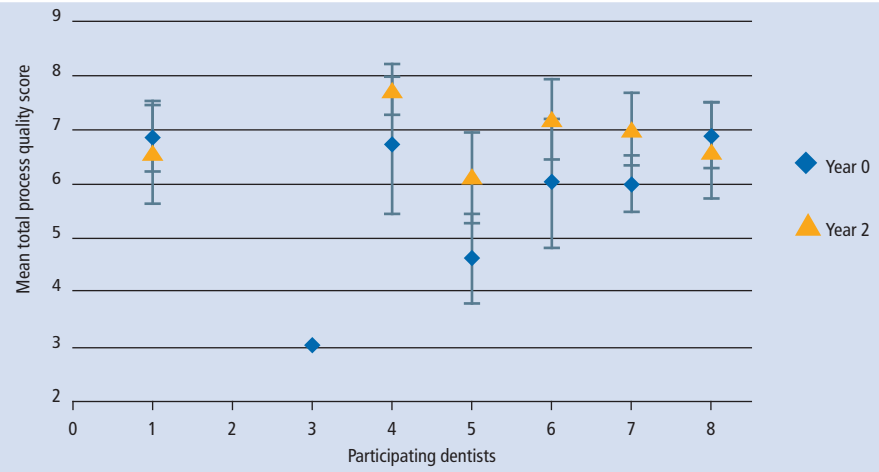


Fig. 2 Mean total process quality score for each of the participating dentists at Year 0 and Year 2



Missing data: Dentist 2 did not provide any data for this part of the research

Assessment of performance on endodontic training block (in vitro)

Technical skills acquired in endodontic training block (*in vitro*) training were assessed in three domains: 1. lack of procedural errors; 2. establishment of the correct working length (within 2mm of the apex); and 3. taper and shape achieved. Seven of the eight participants provided endodontic training blocks for all time periods (Year 0, Year 1 and Year 2). The mean total score for endodontic training blocks was 0.14 (n = 7, SD = 0.38) at Year 0, 1.43 (n = 7, SD = 1.27) at Year 1 and 2.25 (n = 8, SD = 1.04) at Year 2. There was a statistically significant difference in the mean total scores for the endodontic training blocks from Year 0 to Year 2. As the confidence intervals did not overlap and no further statistical analysis was required. The ninth dentist scored zero for all domains of the quality of endodontic training blocks at Year 0 and Year 1, and was excluded due to failure to complete the course.

Assessment of dentist performance on patients (in vivo)

The total complexity score for the first ten cases (Year 0) was 345 points (n = 60, mean = 5.75, SD = 3.08, range 0–11) and that for the last ten

Fig. 3 Mean total treatment process score (clinical quality of treatment) for Year 0 and Year 2 for each of the participating dentists with 95% confidence intervals

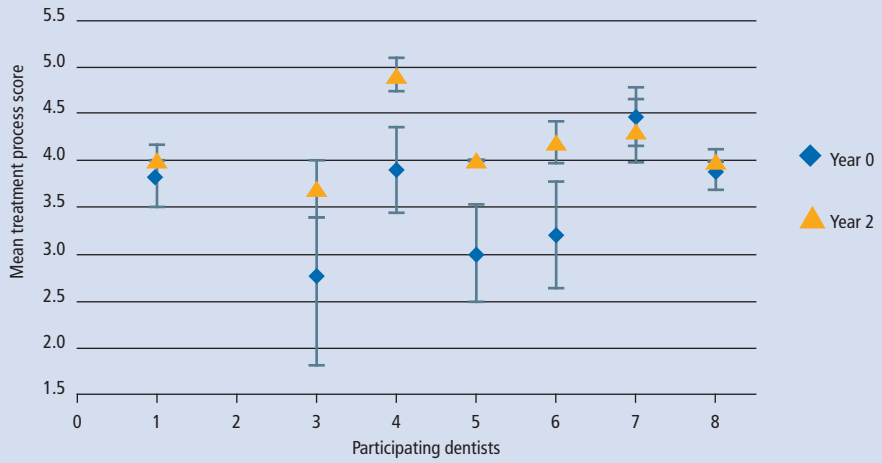


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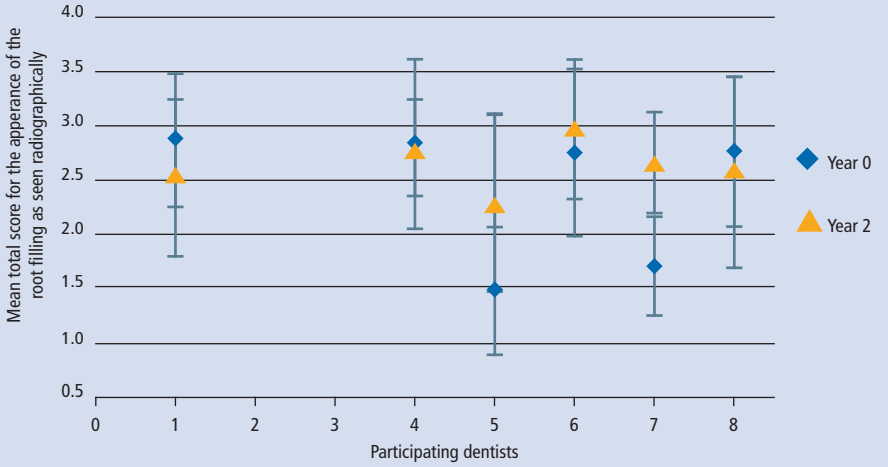
Fig. 4 Mean score for the appearance of the root filling as seen radiographically for Year 0 and Year 2 for each of the participating dentists with 95% confidence intervals



Missing data: Dentists 2 and 3 did not provide any data for this part of the research

cases (Year 2) was 411 (n = 64, mean = 6.42, SD = 2.58, range 0–10). A score of six to 15 points was considered 'moderate complexity'.[61] Complete data (radiographic and logbook data) on complexity were available for 28% of cases for Year 0 and 23% of cases for Year 2. There was no significant difference in mean complexity score from Year 0 (mean 6.29 SD = 2.54) to Year 2 (mean 7.13 SD = 2.30). There were no significant differences in the mean complexity scores for those with complete and incomplete data. This was in keeping with the triaging process for teeth of moderate complexity being referred for treatment within this service.[61]

The score for quality (process quality score) was an amalgamation of the score for the clinical process of providing treatment (A) and that for the radiological appearance (B) of the root filling (Table 3). Although there was no statistically significant difference in score from Year 0 to Year 2 when compared at a dentist level, the total process quality score (A+B) for all dentists was 6.08 (n = 50 teeth, n = 7 dentists, SD = 1.48, range 3–9) for Year 0 and 6.91 (n = 61 teeth, n = 7 dentists, SD = 1.27, range 4–9) for Year 2, out of a total possible score of nine (excluding data for the presence of a coronal seal). There was a statistically significant difference in mean total process quality score for Year 0 when compared to Year 2 for all dentists. The scores for individual dentists are shown in Figure 2. One of the dentists did not provide any data for this part of the research.

The mean total treatment process score (A) at Year 0 was 3.67 (n = 58, SD = 0.85) and at that at Year 2 were 4.18 (n = 72, SD = 0.51) and the change was statistically significant. There was a 7% increase in the reported use of rubber dam as there were less missing data in Year 2, a 29% increase in the reported use of an apex locator to establish a working length, a 22% increase in the reported use of patency filing and a 15% increase in the reported use of the two recommended irrigants for disinfection during treatment. The change from Year 0 to Year 2 was statistically significant for all domains except for the use of rubber dam where no one reported not using rubber dam, which signifies an understanding of the quality standard (root canal treatment should not be performed without the use of rubber dam). The scores for each participating dentist for Year 0 and Year 2 are presented in Figure 3. One of the dentists did not provide any data for this part of the research. All but one dentist improved from Year 0 to Year 2. It was noted that the 95% confidence interval error bars reduced in size for all participating dentists from Year 0 to Year 2. For three out of the seven dentists that contributed data, there was a significant change (improvement) in mean total treatment process scores from Year 0 to Year 2.

The post-operative radiographs (n = 133) were used to score the radiographic quality (B) of the treatment.[63] There were six unusable post-operative radiographs in total (five at Year 0 and one at Year 2). The mean total score for the appearance of the root filling as seen radiographically at Year 0 was 2.36 (n = 58, SD = 1.15) and at that at Year 2 were 2.67 (n = 64, SD = 1.08). At Year 2 there were fewer unusable radiographs. A statistically significant difference in the change in score for establishing correct working length from Year 0 to Year 2 was seen. Three dentists improved from Year 0 to Year 2. For one of the six dentists that contributed data, there was a significant change (improvement) in mean total scores for the appearance of the root filling as seen radiographically from Year 0 to Year 2 (Fig. 4). Two of the dentists did not provide any data for this part of the research.

Part 2: Outcome of treatment by DES (post training)

Five dentists, over a period of 30 months, recruited 135 patients.[63] Forty-eight of the patients were male (36%), seventy-eight (58%) was female and nine (6%) did not state their gender. The majority of the patients (56%) were aged between 25 and 44 years. Seventy percent of patients were of white ethnic background and 45% were educated to university degree

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Fig. 5 Mean total process quality score comparison with Year 0, Year 2 and post-training

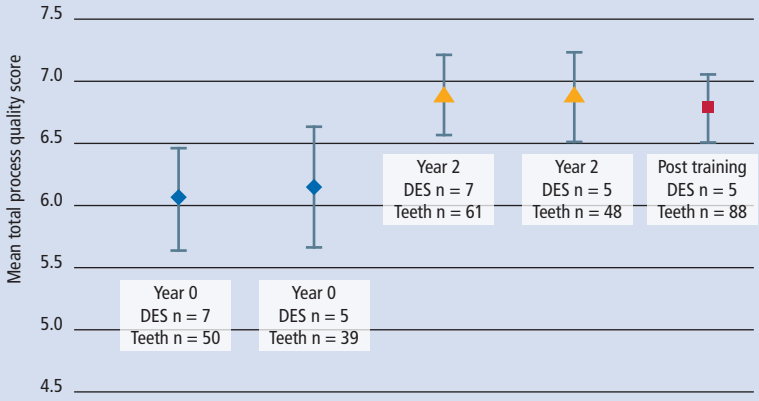
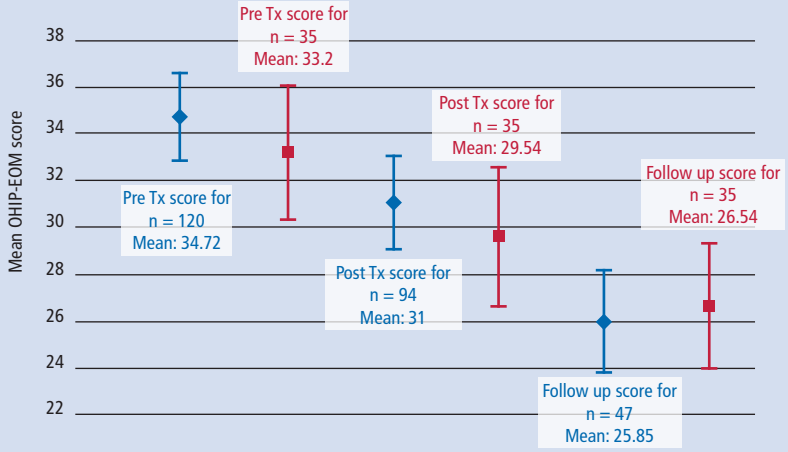


Fig. 6 Mean OHIP-EOM scores (pre-treatment, post-treatment and follow-up). Tx = treatment



level or higher. The mean complexity score was 8.42 (SD = 2.01, range 4–14). A score of between six and 15 was considered 'moderate complexity'.[61] The majority of patients (58%, n = 78) were seen for endodontic retreatment without further complicating factors.

The total process quality score (A+B, excluding the presence of a satisfactory coronal seal) post-training was 6.81 (n = 5 DES, n = 88 patients, SD = 1.34, range 3–9) out of a total possible score of nine. The mean treatment process score (A) where complete data were available (N = 99, 73%) was 4.41 (N = 5 DES, SD = 0.55, range 3–5) out of a possible score of five. Rubber dam was stated as used in 82% of patients. Apex locators were used in 82% patients, and in the remainder of patients it was not stated if apex locators were used. Patency filing was carried out in 73% of patients and its use was not stated in 25% of patients. In only 44% of the patients, a single irrigant (sodium hypochlorite) was used. In 39% of the patients, both sodium hypochlorite and EDTA were used as irrigants. The use of an irrigant was not stated in 17%. The mean score for the quality of the root filling as seen radiographically was 2.43 (N = 5 DES, SD = 1.20, range 0–4) out of a possible total score of four for the 103 patients (76%) with complete data.

To assess if skills were retained, the clinical treatment process scores at the end of Year 2 were compared to that 'post-training'. When the clinical treatment process score was compared to Year 2 scores for the same five dentists at Year 2, statistically significant improvements were seen for the use of Apex Locators (p = 0.0) and use of irrigants (p = 0.01), while quality of treatment in the other domains was maintained post-training. A statistically significant difference was not found when the score for the quality of the root filling as seen radiographically post-training for the five dentists' who recruited patients was compared to that at the end of Year 2 for the entire cohort of dentists who underwent training (n = 8). When the mean total process quality score for the five dentists that recruited patients to the second part of this study was compared to the process quality score for the entire cohort of dentists and also specifically for these five dentists, there was no statistically significant difference in the scores at the end of Year 2 compared to post-training (Fig. 5). When the mean total outcome score (excluding the presence of a satisfactory coronal seal) was analysed, the mean score was 4.44 (n = 2 DES, n = 18 patients, SD = 0.78, range 3–5) out of a possible total of five.

When the score included the presence of a satisfactory coronal seal for a measure of overall quality (A+B+C+D), the mean score was 11.72 (n = 2 DES, n = 18 patients, SD = 0.34, range 9–14) out of a total possible quality score of 15. That excluding the presence of a coronal seal was 11.11 (n = 2 DES, n = 18 patients, SD = 0.36, range 9–13) out of a total possible quality score of 14. It was not possible to compare the overall quality during the training course and after the training course as healing was not assessed during the course.

Where radiographs were available (n = 31), there was a reduction of size of lesion or no development of an apical area (healing or favourable outcome) for 19 patients (61%). No change in size of the apical area (uncertain outcome) was seen in six patients (19%). Increase in size or development of an area (failure or unfavourable outcome) was seen in four patients (13%). The mean score for healing as seen radiographically was 1.52 (N = 3 DES, SD = 0.74, range 0–2) out of a possible score of two, for the 29 patients (21%) with follow-up data. Complete data were available for 21 patients (16%) of which 11 patients received an overall score of four (good), nine patients received a score of three and one patient scored zero (poor). There were two cases with clinical signs and symptoms of non-healing. Among the 33 patients where data were available for the quality of the coronal restoration, nine patients (27.3%) were assessed as having 'unsatisfactory' coronal restorations at the follow-up. Healing as seen clinically was recorded from

Official journal of the British Dental Association.

logbook forms completed at the follow-up appointment. The mean score for healing as seen clinically (excluding data for the presence of a coronal seal) was 2.81 (n = 2 DES, n = 21 patients, SD = 0.68, range 0–3) out of a possible total score of four. The follow-up and coronal restoration were not the responsibility of the DES and not funded by the service through commissioning arrangements.

Change in quality of life scores (OHIP-EOM)

Pre-treatment questionnaires were received from 130 patients with 120 fully completed.[63] The mean summative score for all domains was 34.72 (95%CI 32.80–36.64) with scores ranging from 16–72. Post-treatment questionnaires were received from 109 patients with 94 questionnaires fully completed.[63] The mean summative score for all domains was 31.0 (95%CI 28.96–33.04) with scores ranging from 16–67. Review questionnaires were received from 56 patients, with forty-seven questionnaires fully completed.[63] The mean summative score for all domains was 25.85 (95%CI 23.64, 28.06). There was a mean change in total summative score for all domains, from pre-treatment to review of -6.14 (95%CI -8.68, -3.6). Thirty-five patients completed all three questionnaires with mean summative score for all domains being 33.2 (95%CI 30.31, 36.09) pre-treatment, 29.54 (95%CI 26.55, 32.53) post-treatment and 26.54 (95%CI 23.81, 29.27) at review. The mean change in summative score for all domains from pre-treatment to review was -6.66 (95%CI -9.76, -3.56). The mean summative scores for all domains at various time points were not significantly different for all patients who completed at least one of the questionnaires when compared with the 35 patients who completed all three questionnaires. It was observed that those who gave low scores in the pre-treatment questionnaire also gave low scores on the post treatment questionnaire and in the follow-up questionnaires. There was a statistically significant difference in OHIP-EOM scores from pre-treatment to review; with OHIP-EOM scores being significantly lower at the follow-up appointment for those that participated in this research (Fig. 6, showing in blue, the mean OHIP-EOM for all completed questionnaires returned and in red, the mean OHIP-EOM scores for the 35 patients who completed and returned questionnaires at all three time points). Time between completion of treatment and receipt of the follow-up questionnaire was 24.9months (SD = 6.35 months, range 10.1–36.4 months) as the researcher depended on the DES. There was no difference in the demographics of those that returned completed questionnaires and those that returned incomplete or partially complete questionnaires.

Part 3: Patient view of the service

Most patients (94.1%; n = 127) stated that they received a clear explanation of the service to which they were referred. Only two patients (1.5%) reported that they failed to receive a clear explanation of why they were referred to this service. Almost half of the patients (n = 65, 48.1%) stated that their own dentist was working in another practice and referred them to this root canal service, 49 patients (36.3%) reported that their own dentist was working within the same practice as this root canal service. The majority (n = 89, 65.9%) paid a fee for their NHS dental treatment. When asked how satisfied patients were about being referred to another dentist for this service, 123 patients responded, with 35.6% (n = 48) very happy, 50.4% (n = 68) happy, 3.7% (n = 5) unhappy and 1.5% (n = 2) very unhappy.

When asked to state their agreement with the phrase 'I would do anything to save a tooth, no matter how much it costs', 123 patients responded, the majority of whom agreed (n = 65, 48.1%) or strongly agreed (n = 33, 24.4%). Twenty-three patients (17%) disagreed and two patients (1.5%) strongly disagreed with the statement. No statistically significant differences were found between the OHIP-EOM scores or change in OHIP-EOM scores for those that agreed or disagreed with this statement.

The majority of patients said they were very satisfied with the service (n=87, 64.4%) and would use the service again (n=92, 68.1%), with ten patients (7.4%) stating they would probably use this service again. None reported that they would avoid this service in the future. The majority related that they would definitely recommend this service to friends and family (n = 91, 67.4%), ten patients (7.4%) conveyed that they would probably recommend this service and one (0.7%) said they would probably not recommend this service to friends and family. None stated that they would definitely not recommend this service to friends and family.

Prior to treatment, the majority of patients stated that their general health was good (n = 44, 32.6%), very good (n = 29, 21.5%) or excellent (n = 23, 17%). There were no statistical differences between the OHIP-EOM scores for those that stated their general health as excellent, very good, good, fair or poor. Prior to treatment the majority of patients stated that they did not suffer from any other problems associated with their mouth (n = 81, 60%). There were no statistical differences between the OHIP-EOM scores for those that stated the presence or absence of other conditions within the mouth. Following completion of treatment the majority of patients stated that their oral health improved a lot (n = 56, 41.5%). There was no statistically significant difference in the change in OHIP-EOM scores from pre-treatment to post-treatment for those that stated that their oral health improved or stayed the same following completion of the treatment in their post treatment questionnaire. There was no statistically significant difference in the change in OHIP-EOM scores from pre-treatment to review for those that stated that their oral health improved, stayed the same or worsened following treatment in their review questionnaire. Following completion of treatment, just over half of patients stated that their tooth improved a lot (n = 71, 52.6%), improved a little (n = 13, 9.6%) or stayed the same (n = 8, 5.9%). None of the patients stated that their tooth worsened after treatment. There was a statistically significant difference in OHIP-EOM scores or change in OHIP-EOM scores for patients that stated whether their tooth improved or stayed the same after treatment. At follow-up, a quarter of the patients stated that their tooth was still present (n = 48, 25.6%). Of the patients with a tooth present, the majority (n = 28, 20.7%) stated they had crowns or onlays placed on the tooth, twelve patients were not sure of how the tooth was restored (n = 12, 8.9%). There was no statistically significant difference in OHIP-EOM scores at any time point or change in OHIP-EOM scores for patients that stated whether their tooth was still present at follow-up.

Discussion

This study is the first to longitudinally measure outcomes at all levels of training and treatment involving dentists with enhanced skills, in the 'real world'. Preliminary findings from this study, using measurement tools,[59] suggest that a training programme combining didactic teaching in a simulated laboratory and concomitant experience working within their own practices can be successful in changing practice, although these pilot data findings should be interpreted with caution due the small sample size. Skills improved *in vitro* and *in vivo*, with those course participants who engaged in the research demonstrating adoption of techniques

Official journal of the British Dental Association.

taught, and achieved a high level of clinical and patient-related outcomes as a result of having completed dedicated training. Additionally, the course participants stated that they gained more than technical abilities alone during this course and changed practice outside of root canal treatment. There was a positive impact on professionalism of dentists and quality of life of patients.

The reported increase in the use of quality measures from the dentists' contemporaneous logbook data indicates either an actual increase in the use of the measure or at least a better understanding of the procedures to be followed during root canal treatment. Other reports of adoption of techniques in root canal treatment show low levels of adherence to guidelines and recommendations, which are not echoed in this study. Very significant improvements were seen in all areas of root canal treatment, with excess of 80% using rubber dam and an electronic apex locator, and all reporting the use of sodium hypochlorite as an irrigant. There was a statistical significant difference in their ability to establish the correct working length. The quality of treatment provided towards the end of the training course was maintained after completion of the course in those that participated in the post-training research. There were limitations on the number of patients treated by each DES and this was determined by that commissioned by the NHS. It was possible to collect OHIP-EOM data in primary care, and the results suggest improvements in oral health over time. It has been recommended that routine data collection be embedded into practice to facilitate research in some disciplines of dentistry and should be part of all dental care.[69]

The findings are not dissimilar to other studies investigating the outcomes of post-graduate education in terms of outcomes of root canal treatment.[52–58] These were all studies carried out in Sweden, where healthcare is considered a public responsibility and this includes dental care. These seven articles reported the findings from three studies, which specifically examine the ability to change practice within endodontics with additional training. All report lecture-based teaching with a hands-on component of four to six hours duration. Training was mainly in the technique of using a specific rotary instrumentation system in primary care. The studies report the adoption of the technique introduced through education, using self-reported written questionnaires, with potential for recall and reporting bias, as on-going reporting of the treatment process was not undertaken and/or clinical notes were not assessed to verify the use of the reported treatment processes. Healing as seen radiographically was assessed using the PAI scoring system[70] in accordance with convention. Although the reported use of the techniques taught increased after training, and the score for the appearance of the root filling as seen radiographically improved after training, the number of low quality root fillings did not decrease significantly and healing rates did improve change significantly.

Molander[53] assessed the uptake of Nickel-Titanium (Ni-Ti) rotary instrumentation following various methods of education to determine whether the format of the education influenced the quality of root fillings (n = 148 dentists employed in their 25 clinics). In all groups the quality of the root fillings improved with the introduction of Ni-Ti instrumentation. No statistically significant differences were found between the different educational approaches. The number of root canal treatments being performed per week influenced the adoption rate.[52] The behaviour of individuals appeared to influence the remainder of the dentists in the same practice and in 16 of the 23 clinics all dentists either accepted or rejected the new technique. At four years, the response rate to the questionnaires was 88%, with only 12% of these respondents reporting that they rejected the technique. The same group investigated the quality of root fillings four years after completion of training.[57] The number of excellent (score 1) and adequate (score 1–3) increased with training by 7% and 8% respectively. Investigations by Dahlström[58] involved general dental practitioners in public dental services in a rural part of Gothenburg, Sweden. Results showed 88% used Ni-Ti rotary instrumentation after education compared to 21% before education. Training did not appear to change dentists' confidence in treatment procedures. Excellence in root filling quality increased from 45% to 59% after education. However, 13% were non-adopters. An improvement was shown post-education. Eleven dentists from nine different clinics produced 49% of the poorest quality root fillings and 73% of these dentists stated they had adopted Ni-Ti rotary instrumentation. This study did not assess the treatment process of providing root canal treatment, healing or patient-related outcomes. Koch[54] used a self-completed questionnaire in two counties of Sweden, with similar endodontic provision in public dental clinics (general dental practice), to ascertain the use of Ni-Ti rotary instrumentation, following an educational programme in endodontics conducted over two years for one county. Two thirds of the respondents in both counties reported that they always used rubber dam isolation for root canal treatment.[55,56] There was a higher rate of adoption of Ni-Ti instrumentation in the intervention county and the treatment was completed in fewer sessions. Almost all participants in both groups established working length, used irrigation with sodium hypochlorite and used calcium hydroxide as an inter-appointment dressing. Other studies have used self-completed questionnaires to establish the uptake of rotary instrumentation.[44,52,71,72] Barbakow & Lutz[70] found that 50% of those that responded (58% of 305 dentists) reported using the techniques taught.

Reit[52] found that hands-on teaching was better than lectures; achieving 94% reported use of the technique taught with hands-on training, compared with 53% with lectures. Koch[54] demonstrated that, after training in the use of rotary instrumentation, 89% reported using these techniques frequently or routinely. Thomas[72] surveyed dentists in Wales on the use of Ni-Ti rotary instrumentation and found only 13% of primary care practitioners reported use of these instruments compared to 82% of secondary care practitioners. It has been suggested that practitioners working in isolation are slower adopters.[73–75] The advantage of the current study is that clinical logbooks were used to assess what treatment processes were used, and the dentists involved did not know which aspects of the treatment were being analysed.

In this pilot study, oral health related quality of life (OHIP-EOM) scores improved from pre-treatment to post treatment, although not as statistically significant levels, until follow-up. The difference from pre-treatment to post-treatment may not have been statistically significant because of the time required for the natural process of healing to occur after root canal treatment.[76,77] Also, post-operative pain and 'flare up' after placement of the root canal filling is possible.[19,78–82] Persistent post-operative pain even with 'successful' root canal treatments has also been reported.[83] In some patients, symptoms could have improved soon after treatment and remained stable at follow-up. Therefore it is more appropriate to only use pre-treatment and follow-up OHIP-EOM questionnaires to ascertain improvement in quality of life after root canal treatment. In other studies, subjects who had an anterior tooth root canal treated, rather than extracted, reported the peak satisfaction of 100%.[84]

Gatten compared quality of life relating to patients with endodontically treated teeth with implant treatment. Both cohorts reported similar quality of life and satisfaction, however, patients recommended preserving the natural dentition wherever possible.[85]

This study provided an insight into the experiences and views of dentists who undertook a training course to enhance their skills in endodontics in order to be able to provide higher quality endodontic treatment within their NHS practice.[62] There is limited literature in this area within the NHS in England as many of the surveys have been around new graduates and their experience of undergraduate training or vocational training.[86–88] Various techniques of teaching were embedded within the course and the perceived outcome is that knowledge, understanding, and technical skill improved for the participants within this course. The participants stated that wider change in practice occurred as a result, benefiting the participants and their patients. Log diaries kept throughout the course may have been a suitable method of validation of the questionnaire and these would be better than a one-time questionnaire which is reliant on long-term memory and summative ability of the participant. There is likely bias due to clustering of data, as a small number of (self-selected) participants with varying training and experience were enrolled in the training. These limited numbers of dentists were assessed without a control group. However, there was no scope to introduce a control group, hence the dentists were assessed longitudinally, against themselves at different time points. Further self-selection has occurred as some of the participants engaged in the research process far more than the others.

Factors that affect the learner's experiences of learning and training should be considered in the design of future training programmes. The nature of training to be provided, available infrastructure and possible remuneration are essential components to be considered. Factors identified in this study are in agreement with other published criteria.[89–91] Further research using semi-structured interviews of the stakeholders involved in this novel pilot training programme would allow a better understanding of the deeper motivations and benefits of such training in changing the skills of general dental practitioners. Intentions to change practice may be inherent in those who are always seeking to improve. In the case of the participants of this course, they were put forward for further training by their PCT as they provide sufficient endodontic services for the PCT already. Therefore, there was an element of recommendation involved. Almost all participants cited changes in practice following the course. This may be a result of the training closely mirroring principles of adult learning theory, thereby these internally motivated learners were allowed self-directed learning with the opportunity to bring their life experiences and prior knowledge to their learning experiences, with a goal in mind and didactic teaching kept relevant to practice, and with a large practical component and learners feeling respected.[92] This was achieved by providing prior reading and questions to think about, discussions in seminar format with everyone sitting in a circle, and asking for their thoughts and experiences relating to the topic/questions with opportunity for everyone to voice their view. Recommended small group teaching/learning with a mixture of didactic and interaction with an opinion leader was also implemented.[93,94]

It was possible to engage some dentists in primary care settings in research within primary care and incentives for engaging practitioners (namely structure and remuneration) were identified. Results of this study suggest that patients are willing to support service evaluations and were happy with new innovations that helped save teeth within the NHS. This proposed manner of training, combining primary care service provision as part of the training model, will be beneficial in extending skills while not hindering access to care during training. This pilot data indicates that this model of training can work and be amalgamated with research in primary care where the outcomes of treatment and by proxy, training can be measured. Even after the substantial changes to the NHS structure in recent times, although some of the DES from this initiative had struggled to secure reasonable contracts with commissioners to provide the service, many have maintained contracts to provide endodontic care. For example, two DESs in South West London and one DES in South East London are part of managed clinical networks (MCNs) for endodontics. In North London one DES has not only secured a NHS contract for this service but has also employed others to provide a similar service. Other parts of the country are looking to use this model of training to enhance skills in primary care, such as in rural parts of Aberdeen, in order to improve patient access to local services rather than travel to dental hospitals for treatment.

Future possibilities with this type of data are the exploration of relationships between process (the clinical process of providing treatment and the appearance of the root filling as seen radiographically), outcomes (healing as seen radiographically and healing as seen clinically) and patient-related outcomes (OHIP-EOM). Assessment of raw data was necessary to show the distribution of data among the various scores for each domain being correlated. This informs the validity of the correlations observed. The correlations are strongest when closer to one, even where statistical significance is shown. Spearman's Rho was used as the correlation coefficient of choice assuming non-parametric data and as many of the variables were not interval scales. Multivariate analyses of this type of data allow understanding of relationships of outcome measures at tooth, patient and dentist levels. Meaningful multivariate analysis would require a number of cases where complete sets of data were available (treatment process, radiographic quality, clinical healing, radiographic healing and change in OHIP-EOM scores). In this pilot study, limited data sets were used to test this concept. When 16 cases with complete data were analysed, the radiographic outcome/quality score, radiographic healing score and complexity score showed statistical significance in predicting the change in OHIP-EOM scores from pre-treatment to review and therefore a change in quality of life. An increase in complexity score by one point increased the change in OHIP-EOM score by one, increase in score for radiographic quality of root filling by one point increased the change in OHIP-EOM score by three points, and increase in healing score by one point reduced the change in OHIP-EOM score by four points. R-values stated a high correlation, however, these results must be treated as a demonstration of possibility and interpreted with caution, as the sample size is small.

Implications for training in primary care

This study has illustrated the potential for extended skills development during training within primary care settings to be successful. Regular hands-on training supported by seminars on a monthly basis in the provision of root canal treatment, while service delivery is maintained (and supported by NHS contracts) in primary care is sufficient to show improvement in adoption of techniques to improve care. It is recommended that this model of training be utilised to enhance skills of existing primary care practitioners to meet the needs of the population with some modifications including

Official journal of the British Dental Association.

greater levels of student-teacher contact early on in training, with prominence given to gaining practical skills, short and targeted seminars, and greater discussion of cases. Individualised feedback, especially with more clinical sessions in practice under supervision, is recommended. Further research informed by the learning from this study is recommended to confirm the findings of this pilot study.

Conclusion

This pilot study suggests that the provision of additional skills training and experience in endodontic techniques does improve the performance of dentists in primary care. In these dentists with enhanced skills, the quality of endodontic treatment provided was maintained after completion of training with favourable clinical, radiological and patient outcomes. Patients viewed the care they received from dentists with extended skills positively.

Acknowledgements
Professor Nora Donaldson and Mr Manoharan Andiappan for statistical help and advice. Professor Tim Newton for continued help with the overall project. Mr Ian Harris for his help with scoring the various components measured.

Declaration of conflict of interest
S. Eliyas taught on the DES course described above. P. Briggs was the educational lead for the London DES in Endodontics Programme, taught on the DES course and was responsible for patient triage for three of the DES participants. J. E. Gallagher was part of the Senior Dental Leadership Team in the Department of Health and a Dental Public Health representative in the working group for setting up DES in endodontics and reports grants from London Deanery (now Health Education England) during the conduct of the study. The other authors have stated explicitly that there are no conflicts of interest in connection with this article.

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