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The "Plan" phase of a Deming cycle: Measurement of quality and outcome of root canal treatments in a university hospital

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Abstract

Introduction: In many countries, dental students are taught in private or university hospitals where they treat patients under the supervision of teachers. Assessing the quality of root canal treatments (RCT) would provide information about the quality of care patients receive when treated by students.

Methods: This study describes the six-step "Plan" phase of a Plan-Do-Check-Act (PDCA) cycle that identifies and analyses clinical practices in endodontics in a university dental hospital service.

Results: Step 3 reported that the proportion of RCTs of adequate quality reached 57.1% and this proportion was significantly decreased when specific indicators for treatment difficulties were present. The proportion of successful RCTs after 1 year was 65.6%, and its variation was influenced by the preoperative periapical status rather than the quality of RCTs. The consensual meeting in Step 6 proposed to introduce three new procedures for the further Do, Check and Act phases of the PDCA cycle.

Conclusion: This study encourages systematic evaluation of RCTs and provides the first step of the methodology that can be reproduced in private and hospital practices where students are asked to treat patients.

KEYWORDS
Deming cycle, endodontics, methodology, Plan phase, professional practices evaluation, quality assessment

1 | INTRODUCTION

Professional practice evaluation allows practitioners to improve quality of care, firstly by raising questions about improving professional practice through an evidence-based approach, secondly by looking at differences between what is actually applied and the standards of practice, and finally by implementing improvement actions to reduce these differences. Quality improvement initiatives have been shown to improve outcomes, effectiveness of care in many institutions and in various domains such as paediatric anaesthesia,[1] diabetes care,[2] feeding assistance care practices[3] or post-acute stroke services.[4] Dentistry is increasingly challenged by private and public institutions to demonstrate quality of care measurement activities.[5] Every dental service, private or public, may be concerned by an evaluation of this kind. A systematic review of cross-sectional studies including 300 861 root-treated teeth indicated that on average each person had about two root canal treatments.[6]

Endodontic procedures are technically difficult, time-consuming and expensive when realised according to the current standard. The percentage of root canal treatments (RCTs) satisfying the criteria for good quality would vary between 13% to 40%,[7,8] and it was reported that the presence of a periapical radiolucency is related to the treatment quality.[19,21,22] Root canal treatments failures increased the risk for edentulousness or expensive prosthetic rehabilitations.

Thus, morbidity of RCTs is a reality and the evaluation of the quality of RCTs is important given public health consequences. Moreover, in many countries, dental students are taught in private or university hospitals where they treat patients under the supervision of teachers. Health and educational authorities could be interested in encouraging an evaluation process in dental schools for two reasons. Firstly, assessing the quality of root canal treatments (RCTs) would provide information about the quality of care that patients receive when treated by students. Secondly, exposing the students to an evaluation process during their studies would promote the development of this process through the dental professional network. However, examples of methodologies for quality measurement were poorly described in dentistry.

The Deming cycle or Plan-Do-Check-Act cycle (PDCA) is a popular approach to problem solving and implementing solutions.[24,25] The method originates from within the industry from Walter Shewhart and Edward Deming's articulation of iterative processes which is characterised by four consecutive phases: (i) Plan: identifying and analysing the problem; (ii) Do: developing and testing a potential solution; (iii) Check: measuring how effective the test solution was and analysing whether it could be improved in any way and (iv) Act: implementing the improved solution fully. In healthcare, different applications of PDCA methodology demonstrated improvements in the safety of critically ill patients transportations,[27] in modifying practitioner's prescribing behaviour,[28,29] in operating room management,[30,31] in reducing perianal infection rate of haematological malignancies,[32] in post-operative neonatal nutritional practices,[33] etc

As with all scientific methods, documentation of each stage of the PDCA cycle is important to support scientific quality, local learning and reflection and to ensure knowledge is captured to support organizational memory and transferability of learning. In particular, the "Plan" phase is the key of the success for PDCA as it defines indicators and methods to be used during the "Do," "Check" and "Act" phases. This study reports the methodology of the "Plan" phase of a Deming cycle developed in a dental department of a French university hospital.

2 | MATERIAL AND METHODS

This action was declared to the Commission for the Improvement of Professional Practices of the University hospital of Clermont-Ferrand (number A62). The "Plan" phase of a Deming cycle has its own methodology that can be divided into six steps[25] and characterised for endodontic purposes as shown in Table 1. Steps 1-5 were conducted by three PDCA managers (two teachers in endodontics and one in prosthodontics), and the endodontics and restorative dentistry faculty was enrolled for consensual decisions in Step 6.

2.1 | Step 1: Revisiting the current standard in Endodontics

This phase identified the quality and the outcome of root canal treatment (RCT) as the targeted procedure for PDCA referring to academic guidelines. The current standard in endodontics was established by internationally recognised authors in textbooks[34,35] and in the international quality guidelines report by the European Society of Endodontology.[36] In France, the National Authority for Health (HAS) edited recommendations for good clinical practice in endodontics based on a systematic literature review[37] and experts' opinions.

2.2 | Step 2: Choice of indicators

This step will provide evidence-based indicators to be used subsequently in Step 3 of the "Plan" phase of PDCA. All types of study reporting the evaluation of the quality or the outcome of RCT were subsequently searched. Keywords used on PubMed and on the Cochrane Database of Systematic Reviews were [[quality] or [[outcome] and [follow-up]] and [[endodontic treatments] or [root canal treatment] or [root canal filling]]. In addition, ascendant searches were undertaken in the review of Ng et al.[22] Criteria for study exclusion were absence of collected data on quality or outcomes of RCTs, study groups including fewer than 100 teeth, results expressed for treated roots rather than for treated teeth, studies using Cone Beam Computer Tomography, insufficiently detailed results or manuscript not written in English. Among 49 selected articles, the methodology for evaluation was based on radiographic examinations, 37 studies aimed to measure the quality of RCTs,[7,8,10-13] nine measured the outcome of RCTs,[63,64] and three had both goals.[72,73] Consequently, the results section for Step 2 will be structured in three consecutive paragraphs: types of radiographic examination, technical quality of RCT and outcome of RCT.

2.3 | Step 3: Evaluation of the targeted procedure

This step was conducted as an observational study based on clinical data from therapeutic procedures conducted in the dental service between September 2010 and July 2013. It was approved by the local ethical committee (CE-CIC-GREN-11/17).

2.3.1 | Data collection

All data were collected on paper for any patient aged 18 years or over who had received at least one root canal treatment in a permanent tooth during the study period. Each RCT performed by the fourth-, fifth- and sixth-year students was assessed using clinical and radiographic monitoring post-operatively (T0). After 1 year, patients were free to make an appointment. During this visit, clinical and radiographic evaluation of any registered treated tooth was done by a single calibrated investigator (follow-up evaluation: T1). Three cohorts of patients were created during the three consecutive academic years 2010-2013, and their data were pooled to form a single group of RCTs (Table 2).

2.3.2 | Endodontic procedures

Root canal treatments were performed by fourth-, fifth- or sixth-year dental students under supervision of a senior hospital practitioner (ratio senior/student: 1/8) according to the French recommendations

for good clinical practice. After rubber dam placement, the working length was estimated using retro-alveolar radiography or an electronic apex locator. Canal cleaning and shaping were performed according to crown down technique with Gates 3 or 2 and manual instrumentation, using sodium hypochlorite (2.5%) followed by thermomechanical compaction (Gutta Condensor, Denstply Maillefer) with a zinc oxide and eugenol sealer (Sealite™ Regular, Acteon Pharma, Mérignac, France).

2.3.3 | Study criteria

The type of radiographic examination and the criteria for technical quality of RCT and outcome of RCT were selected from the literature review of Step 2.

2.3.4 | Statistical analysis

Statistical analyses were undertaken using IBM SPSS 20.5© software (IBM France, Bois Colombes, France).

All radiographs were evaluated under optimal condition for the best possible radiographic contrast. One observer (PYC) was calibrated to evaluate the study criteria using a set of 100 radiographs randomly selected from the 501 radiographs taken during a previous study.[56] The images were scored twice at a 1-month interval. For length, density and PAI score, the intra-examiner agreement gave Kappa values of 0.65, 0.47 and 0.70. For the criterion "obturation of the whole canal system," the examiner was in full agreement for test and retest evaluations.

To test whether the follow-up group was representative of the T0 group, the distribution of all RCTs performed at T0 was compared with the distributions of RCTs using a chi-square test ($\alpha = 0.05$) according to patient's age and sex, type of tooth, initial pulp status, periapical index, quality of the treatment, student's year of study and the difficulty level of the endodontic cases, using the grid of the American Association of Endodontists.[75]

2.4 | Step 4: Comparisons between observed data, the literature data and the current standard

To measure the gap between the evaluated procedure and the literature data, two tables were constructed drawing together similar studies that evaluated proportions of good quality RCTs and proportions of effective RCTs with a favourable outcome.

2.5 | Step 5: Analysis of factors affecting the variability of the observed results

This step aimed to investigate which factors could be controlled in order to increase the LSD score and the proportion of RCTs with a favourable outcome. Factors affecting the LSD score were recorded at T0. These factors included the type of tooth, the treatment difficulty, the factors affecting difficulty, the pulpal status, the student's year of study and the preoperative PAI score using a chi-square test ($\alpha = 0.05$). Factors affecting the proportion of effective RCTs after a 1-year period (T1) were noted. These included type of tooth, treatment difficulty, the factors of difficulty, treatment quality, preoperative PAI score and the students' year of study using a chi-square test ($\alpha = 0.05$).

2.6 | Step 6: Proposal for actions

The endodontic teaching staff was invited by the managers' group of PDCA to participate at a consensus meeting. An evidence-based

TABLE 1 Description of the steps and actors of the Plan phase of a Plan-Do-Check-Act cycles for application in endodontics

Steps	Generic definitions[4]	Declination for endodontic purposes	Actors
1	Analysis of the scientific references used to define what should be the targeted procedure: the ideal situation	Reference to academic guidelines stated on the definition of the quality and the outcome of endodontic treatments	
2	Choice of pertinent clinical indicators to evaluate the targeted procedure	Using literature search for choices of indicators of (a) good quality of RCTs and (b) a favourable outcome of RCTs	
3	Evaluation of the targeted procedure on the spot: what is the real situation	Measures of (a) the proportions of RCTs reaching the conditions of good quality; and (b) the proportions of RCTs with a favourable outcome	PDCA managers': Two teachers in endodontics (MH, PYC) and one in prosthodontics (EN)
4	Measurement of the distortions between both ideal and real situations	Comparisons with the literature data (a) of the proportions of good quality RCTs; and (b) of the proportions of RCTs with a favourable outcome	
5	Identification of the potential factors that could explain the observed differences between both ideal and real situations	Analysis of factors affecting (a) the proportions of RCTs with good quality; and (b) the proportions of RCTs with favourable outcome	
6	Proposal for actions to improve the real situation, tending to the ideal situation	Using literature evidence to propose actions that could impact the effect of those factors affecting (a) the proportions of RCTs with good quality; and (b) the proportions of RCTs with a favourable outcome	PDCA managers, endodontics teachers and staff

TABLE 2 Constitution of the study group in step 3 of the Plan phase

	Cohort 1	Cohort 2	Cohort 3	Overall (Cohorts 1 + 2 + 3)
Academic year	2010-2011	2011-2012	2012-2013	2010-2013
Number of treatments achieved	1013	1022	1095	3130
Immediate postoperative evaluation				
Number of treatments (number of patients)	876 (617)	978 (666)	847 (538)	2701 (1821)
Non re-evaluated[a]				
Number of treatments (number of patients)	731 (509)	855 (569)	716 (475)	2302 (1553)
Follow-up re-evaluation				
Number of treatments (number of patients)	140 (108)	118 (97)	126 (63)	384 (268)
Duration of the follow-up period				
Mean ± SD months	18.6 ± 3.1	13.5 ± 1.2	17.9 ± 8.8	16.9 ± 5.7

Post-operative and follow-up data were collected from three cohorts of patients that were pooled to constitute a single cohort. Data from immediate postoperative evaluation were used for RCTs quality evaluation, while data from follow-up re-evaluation served for RCTs outcome evaluation.
[a]Due to non-distribution of recalls, recall avoidance or failed appointments

approach was required to propose which procedures could be introduced in order to improve the quality and outcome scores for RCTs.

3 | RESULTS

3.1 | Step 1: The current standard in endodontics

Root canal treatments aim to prevent, decrease or eliminate periapical infection, by achieving a complete apical and coronal seal of the root canal system to prevent bacterial leakage. Good clinical practice in endodontics is characterised by two criteria: the technical quality of the treatment and the outcome of this treatment. In the literature, a periapical radiograph is used to assess endodontic treatment quality. A root canal treatment is technically successful if: (i) the root filling is within 2 mm of the radiographic apex; (ii) the root filling is compact and (iii) all radicular canals are filled.[36] The biological healing process makes the follow-up period very important for the long-term assessment of the RCT outcome. The duration of the follow-up period is still debated, depending on different visions of the outcome of RCTs. Two opposing trends exist. On the one hand, some authors consider that the outcome of RCT is reached when the periapical bone is healthy or fully healed and they estimate that the follow-up period should be around 4 years.[63] On the other hand, there are authors who consider that the outcome of RCT is reached when there are no visible periapical lesions, or none have increased post-operatively; they limit the follow-up period to 1 year.[64,76]

3.2 | Step 2: Choice of indicators

In all studies, the indicators to measure the quality and the outcome of RCTs were the proportions of RCTs that met the conditions for adequate quality treatment and the proportions of RCTs meeting the criteria for the outcome of RCTs. However, the criteria for adequate RCT quality and outcome differed among studies.

3.2.1 | Type of radiographic examination

Thirty-five studies were based on periapical radiography[8,11-13,15,17-19,38-43] and fourteen on orthopantomograms.[7,10,14,16,45-49] The periapical radiograph was chosen to evaluate quality and outcomes of RCTs for Step 3 of the present project.

3.2.2 | Technical quality of RCT

Among the 40 studies that reported data on RCT quality, four criteria were used to characterise the quality of the RCTs: the root canal should be filled with material in all its length (Length criterion: L); the entire canal system must be treated (System criterion: S); the root filling density must be homogeneous and without any void (Density criterion: D); the taper of the root filling should be sufficiently conical to allow the irrigation solution to reach the apical part of the canal (Taper criterion: T). The categorisation of the "Length" criterion varied among studies. The end of the root filling had to be within 2 mm of the apex in 34 studies,[7,8,10,12-19,38-41] within 3 mm of the apex in five studies[11,57,61,73,77] and within 2 mm of the apex or 1 mm beyond the radiographic apex for one author.[46] Eight studies were based on the use of the single "Length" criterion,[7,41,42,49-51,60] twenty studies used the criteria "Length" and "Density,"[8,10-16,39,40,45,52,53] three studies associated the criteria "Length," "Density" and "Taper,"[17,38,44] and nine studies associated the criteria "Length," "System" and "Density."[18,19,43,46,48,56,59,62,74] A group of seventeen studies used the criteria LD, LDT or LSD measured on periapical

radiographs.[8,12,13,15,17-19,39,40,43,44,52,56,58,62,72] Obviously, evaluations of S and T criteria on 2D periapical radiograph are difficult and have poor sensitivity and specificity, particularly for multi-canal roots. However, LSD score corresponds to the definition of a good quality treatment, as defined in Step 1. Consequently, we choose to use both LD and LSD scores for Step 3. In case of multi-rooted teeth, the treatment was considered "unsuccessful" if one canal did not meet the three criteria.

3.2.3 | Outcome of RCT

All studies reporting data on RCT outcomes referred to the use of the periapical index (PAI) which characterises the periapical state on the basis of its radiological appearance.[78] It is divided into five stages. A tooth in stages 1 or 2 is considered healthy. Stages 3, 4 and 5 indicate the presence of a periapical infection. For multi-rooted teeth, the highest PAI scored among the roots is the PAI score for the tooth. PAI scores measured on periapical radiographs taken at the end of treatment (T0) and after a follow-up period (T1) were compared to check any potential periapical changes. Depending on the study, the radiographic evaluation of the PAI score is associated with a clinical assessment that was conducted to search for sensitivity to apical palpation, percussion and the presence or absence of a sinus tract, at T0 and T1.

Among the eleven studies that reported data on RCT outcomes, the terminology used to categorise RCT outcomes and the observed conditions for a favourable outcome varied greatly. Each study used its own terminology with two or three categories. Moreover, the conditions for a favourable outcome can have five different definitions. In 2011, considering that treated teeth with healthy, healed or healing periapical status were considered as effective treatments after a follow-up period, Wu et al[76] proposed new terms for categorising the outcome of RCTs. These terminology and categorisation were chosen to be used in Step 3. The criteria were as follows: (i) effective treatment: absence of symptoms and complete or partial resolution of the preoperatively existing periapical radiolucency 1 year following treatment. In cases where no preoperative lesion was present, "effective" would mean that no signs, symptoms or lesions developed after one year; (ii) ineffective treatment: emergence of symptoms and signs or development or enlargement of a radiolucency one year following treatment and (iii) uncertain treatment: asymptomatic teeth, where the size of the radiolucency does not noticeably change 1 year following treatment.

3.3 | Step 3: Evaluation of the targeted procedure

Overall, 2701 RCTs from 1821 patients (925 men and 896 women; mean age: 44.4 ± 17.5 years) were assessed at T0 and 384 RCTs from 268 patients (129 men and 139 women; mean age: 57.8 ± 15.2 years) were assessed at T1. The mean follow-up period was 16.9 ± 5.7 months.

The distributions of RCTs at T0 and T1 according to the type of tooth, treatment difficulty, initial pulp status, periapical index, the student's experience and the treatment quality criteria are presented in Table 3. It can be noted that: (i) the majority of RCTs were performed by fifth year students; (ii) more multi-rooted teeth than incisors and canines were treated; (iii) more than half of the treatments were highly difficult and (iv) one-third of the teeth were vital, and there were more vital molars and premolars than incisors and canines ($P < 0.001$).

The recall rate is rather low, at just 14% of treated teeth. However, T0 and T1 groups were similar by distribution of the type of tooth, pulp status and treatment quality, but in the distribution of the number of RCTs performed, they differed by the students' academic year, endodontic treatment difficulty and PAI scores at T0.

3.3.1 | Quality of RCTs

Post-operatively, the proportion of RCTs satisfying the criteria for good quality reached 58.1% and 55.5% for LD and LSD scores, respectively ($P < 0.001$). Neither score varied in T1 groups.

3.3.2 | Outcome of RCTs

Overall, in T1 group, 65.6% of RCTs were scored as effective, 13.7% were uncertain, and 20.7% were ineffective. The PAI score at T0 has a positive effect on the outcome of RCT. Among the treatments that were evaluated as ineffective, 26 had associated clinical signs (seventeen showed percussion sensitivity and nine had palpable apical swellings) without any enlargement of a radiolucency 1 year after treatment.

3.4 | Step 4: Comparisons between observed data, the literature data and the current standard

3.4.1 | Quality of RCTs

Table 4 shows that the quality of RCTs in the present study was within the range of similar studies, excluding Craveiro et al,[62] in which the operator was a specialist in endodontics. However, compared with good clinical practice, LD and LSD scores from previous similar studies and in the present evaluation were low, as about half the treatments did not satisfy the quality criteria.

3.4.2 | Outcome of RCTs

Table 5 shows that the proportion of effective RCTs was lower in the present evaluation than in other studies, where it varied between 76% and 96% when the same conditions for a favourable outcome were applied ("E" condition in Table 5). Moreover, the recall rate was particularly weak in the present evaluation.

Step 4 demonstrated that no study reported the completion of 100% of the cases either for the quality of RCTs or for the outcome, despite the fact that most of them had been done in accordance with "academic" standards.

TABLE 3 Comparison of the distribution of endodontic treatments at T0 and T1 for the initial group and the follow-up group, according to the type of tooth, the treatment difficulty, the initial pulp status, the periapical index and treatment quality criteria

	T0 group n = 2701 (%)	T1 group, n = 384 (%)	Chi-square test
Type of tooth			
Incisors and canines	740 (27.4)	123 (32)	
Premolars	911 (33.7)	125 (32.6)	ns
Molars	1050 (38.9)	131(34.1)	
Data not available	0 (0)	5 (1.3)	
Endodontic treatment difficulty			
Minimal	437 (16.2)	50 (13)	
Moderate	776 (28.7)	88 (22.9)	$P < 0.05$
High	1429 (52.9)	227 (59.1)	
Data not available	59 (2.2)	19 (4.9)	
Pulpal status			
Vital pulp	935 (34.6)	136 (35)	
Others	1739 (64.4)	234 (61)	ns
Data not available	27 (1)	14 (4)	
Periapical index (PAI)			
PAI ≤2	1405 (52)	225 (58.6)	
PAI >2	1269 (47)	150 (39.1)	$P < 0.01$
Data not available	27 (1)	9 (2.3)	
Quality of endodontic treatment			
L criterion = 0[a]	1612 (59.7)	224 (58.3)	ns
S criterion = 0[a]	2563 (94.9)	358 (93.2)	ns
D criterion = 0[a]	2454 (90.9)	344 (89.6)	ns
LD score[b]	1524 (58.1)	206 (57.4)	ns
LSD score[c]	1498 (55.5)	207 (53.9)	ns
Student's year of study			
4th year	676 (25)	169 (44)	$P < 0.001$
5th year	1562 (57.8)	203 (52.9)	
6th year	463 (17.1)	12 (3.1)	

[a]Data not available for T0 assessment = 76 (2.8%) for the L criterion (end of root filling within 2 mm of the apex), 78 (2.9%) for the S criterion (the entire canal system must be filled) and 76 (2.8%) for the D criterion (root filling density must be homogeneous and without any void).
[b]Data not available for at least one criterion L or D = 76 (2.8%)
[c]Data not available for at least one criterion L, S or D = 78 (2.9%).

3.5 | Step 5: Analysis of factors affecting the variability of the observed results

3.5.1 | Factors affecting RCT quality

The proportion of RCTs with good quality LSD scores was significantly lower for posterior teeth compared with anterior ones, for non-visible canals compared with visible canals, for vital teeth compared with non-vital and re-treated teeth and for curved canals compared with straight canals ($P < 0.001$). Neither the students' year of study nor the global score of the treatment difficulty was associated with the LSD score variations.

3.5.2 | Factors associated with RCTs outcome

The preoperative periapical status and the level of treatment difficulty seemed to be associated with the outcome of RCTs, the highest PAI scores and the highest level of difficulty associated with ineffective treatments ($P < 0.0001$). The quality of RCTs had no effect on the variation of the proportion of effective RCTs.

3.6 | Step 6: Proposal for actions

There was a consensus to develop a decisional tree for preoperative use based on the Endodontic Case Difficulty Assessment Form and the pulpal status. For the "Do" phase of the cycle, the introduction of three new procedures was proposed: (i) rotary nickel-titanium (NiTi) files should be used for any tooth where at least one canal presented moderate or high difficulty for RCT. There was good evidence that root canal preparation with NiTi rotary instruments compared with manual stainless-steel files results in a significant increase of mean LD score, from 38% to 51%[72] and of a favourable outcome from 60% to 77%[79,80]; (ii) Pulpotomy was indicated as an endodontic therapy in permanent vital molars or premolars in which the canals were anticipated to present anatomical or radiological difficulties for RCT. It has been reported that the proportion of teeth successfully treated by pulpotomy after 6 months was 97%[74] and 89.7% after 27 months,[81] while the survival rate after 24 months was 82%.[82] However, pulpotomy treatment required immediate sealing and should be limited to the teeth which could be treated and restored in a single session and (iii) other specific cases of RCT difficulty that could not be resolved using one of the previous procedures should be referred to a supervisor in endodontics.

4 | DISCUSSION

This study describes the "Plan" phase of a Deming cycle as the first step of an ongoing effort to improve practices in endodontics in a university dental hospital. The goals of a "Plan" phase are to identify and analyse the endodontic practices which can be improved. In Steps 1 and 2, endodontic standards were researched in literature reviews along with which criteria have to be used to evaluate the quality and the outcome of RCTs. The evaluation of the quality and the outcome of RCTs performed in the targeted university dental service were done in Step 3, reporting 55.5% of RCTs with good quality and 65.6% of RCTs being effective. The comparison between literature data and academic standards made in Step 4 demonstrated that these values were rather low. The factors affecting the variability for quality and outcomes of RCTs were analysed in Step 5. That allowed the proposal of the implementation of three

actions in the "Do" phase of the PDCA cycle in Step 6. The effectiveness of these actions will have to be measured during the "Check" phase, using the criteria of quality and outcome of RCTs treatment justified by the "Plan" phase described in this paper. Finally, during the "Act" phase, and depending on the results of the "Check" phase, the successful action(s) tested during the "Do" phase would then be adopted. After that, depending on the results of this first Deming cycle, a new cycle will follow.

Several points could be discussed regarding limitations of the study. First, the choice of the use of rotary nickel-titanium (NiTi) files for any tooth where at least one canal presented moderate or high difficulty for RCT was not recognised with comparable criteria for treatment quality in the student population but in general practitioners after a postgraduate course,[72] and it could be hypothesised that rotary instrumentation in the hands of undergraduate students could be more aggressive than manual instrumentation. However, it was reported that the use of rotary instrumentation by under- and postgraduate students led to a lower incidence rate of procedural errors and a higher success rate compared of the use of stainless-steel files.[79,80] An ex vivo study reported that the use of endodontic treatment systems with machine-driven files manipulated by undergraduate dental students led to a higher quality lateral seal compared to the manual system.[83]

Second, the low recall rate reported during Step 3 could depreciate the results of the RCT outcomes, despite the fact that T1 group is representative of T0 group based on the criteria for treatment quality. This representativity led us to consider that the results for the quality of RCTs founded for T1 group would not change with an increased recall rate. However, as the representativity could not be tested for the RCTs outcome, the value of 65.6% of effective RCTs is relative. Consequently, improving the recall rate could be the goal of a further PDCA cycle.

Third, it was noted that the quality of RCTs had no effect on the variation of the proportion of effective RCTs. That could be explained by the obligation for students to observe a rigorous protocol controlling asepsis and disinfection, particularly including rubber dam isolation and abundant sodium hypochlorite irrigation.

Fourth, Step 5 demonstrated that neither the students' year nor the global score for treatment difficulty was associated with the quality of RCTs. Such results could be explained by the low competencies of undergraduates, either in fourth, fifth or sixth year. In France, the dental curriculum is based on a 6-year period, the first year being basic medical, physiotherapy and maieutic studies. From the second year on, the content devoted to endodontics can vary among dental faculties. In the considered university hospital, the preclinical curriculum in endodontics included 20 hours of lectures and 20 hours of practices on dental simulators. Clinical training began at the beginning of the fourth year, the students working for 6 hours/wk as an operator assistant during the first semester and as an operator during the second semester. Hospital clinical training was pursued

TABLE 4 Operator's experience, number of treated teeth, indicators used to evaluate the quality of root canal treatments (RCTs) on postoperative periapical radiographs and proportions of RCTs of good quality

Studies	Operators	n teeth	Indicators for RCTs quality	% RCTs of good quality
Hommez et al[12]	ND	745	L & D	34.4
Dugas et al[8]	ND	383	L & D	38.9
Segura-Egea et al[13]	ND	93	L & D	34.4
Stassen et al[15]	ND	272	L & D	34
Dadresanfar et al[39]	Students	400	L & D	32.5
Moussa-Badran et al[40]	Students	304	L & D	30.3
Koch et al[72]	General practitioners	238	L & D	38
		306	L & D	51
Moradi et al[58]	Students	200	L & D	38
Er et al[38]	Students	1893	L, D & T	33
Balto et al[44]	Students	550	L, D & T	23
Tarim et al[17]	General practitioners	831	L, D & T	12.8
Tavares et al[43]	ND	1035	L, S & D	19
Alsaleh et al[56]	Students	246	L, S & D	63
Moreno et al[18]	ND	1086	L, S & D	33
Song et al[19]	ND	1030	L, S & D	35.6
Cousson et al[74]	Hospital practitioners	527	L, S & D	55
Craveiro et al[62]	Endodontist	523	L, S & D	82.9
Present evaluation	Students	2701	L & D	55.5
			L, S & D	58.1

D, density of the obturation; L, length of the obturation; S, canal system; T, taper of the canal preparation; ND, no data.

TABLE 5 Composition of the whole cohort, operators' level of experience, follow-up duration, re-evaluation rates, terminology used by the authors to categorise favourable and unfavourable outcomes, conditions for a favourable outcome, proportions of RCTs reaching the favourable outcome and calculated % reaching the condition "E" in studies reporting proportions of RCTs satisfying the criteria for a favourable outcome

Reference	Initial group	Operators	Terminology for RCTs outcome	Conditions for a favourable outcome	Follow-up durations	Numbers of re-examined teeth, (rate)	% of RCTs reaching a favourable outcome	% of RCTs satisfying the "E" condition
[65]	486 teeth	Three operators	Success/incomplete healing/failure	D	6 mo	100, (21%)	66	88
					7-12 mo	255, (52%)	82	96
					>12 mo	23, (5%)	96	96
[66]	ND	Army dental practitioners	Successful/probably successful/failure	A	<3 y	139, (ND)	82	82
					≥3 y	205, (ND)	86	86
[67]	397 patients	One single endodontist	Complete healing/ incomplete healing/ uncertain healing/ failure	A	4-5 y	200, (ND)	77	91
[63]	450 teeth	Graduate students	Healing/healed/disease	B	4-6 y	120, (27%)	81	95
[68]	579 teeth	Final year students	Success/in repair/ failure	A	1 y	178, (31%)	77.4	93.5
					3 y	49, (9%)	76	76
[69]	2000 teeth	One single endodontist	Success/failure	A	18-24 mo	1376, (69%)	94	ND
[70]	582 teeth	Graduate students	Healed/disease	A	4-6 y	137, (23%)	88	91
[71]	780 patients	One single endodontist	Successful/doubtful/ unsuccessful	A	5 y	816, (ND)	88.6	89.1
[74]	193 teeth	Hospital practitioners	Failure/success/ uncertain	C	1-6 mo	52, (12%)	75	ND
					6-24 mo	64, (13%)	88	
					>24 mo	77, (13%)	90	
[73]	240 teeth	Two endodontists	Healed/uncertain healing/disease	E	10-19 y	209, (ND)	79	79
[64]	ND	Pregraduate students	Healed/healing/not healing	E	6 mo-8 y	291, (ND)	78	78
Present evaluation	2701 teeth	Pregraduate students	Effective/uncertain/ ineffective	E	1 y	384, (14.2%)	65.6	65.6

ND, no data.

Depending on the study, five descriptions were given for the conditions for a favourable outcome of RCT: "A": no signs nor symptoms present on follow-up examination and the image of a complete lamina dura and a normally appearing periodontal membrane; "B": absence of radiographic signs of apical periodontitis (PAI <3) and absence of clinical signs and symptoms other than tenderness to percussion; "C": absence of radiographic signs of apical periodontitis (PAI <2) or decrease of the PAI score; "D": proportion of surviving teeth with normal periapical status (PAI ≤2); "E": absence of a periapical lesion with no pain, swelling or discomfort or reduction in the size of the periapical lesion but not completely resolved with no pain, swelling or discomfort.

by operators during the fifth year and the first semester of the sixth year for 6 hours/wk. Patients were referred to students regardless of the difficulties of the clinical situation or the students' experience. Moreover, these contents were not totally devoted to endodontics. It was recognised that undergraduate training can only achieve a minimum level of competence and experience.[84,85] This argument is widely debated throughout Europe in support of accreditation of postgraduate speciality training programmes in endodontology (ESE, 2010, Accreditation of postgraduate speciality training programmes in Endodontology. Minimum criteria for training Specialists in Endodontology within Europe). The list of specific aims and objectives of a specialist training programme in endodontology should include the ability to conduct a professional practice evaluation with PDCA cycle.

5 | CONCLUSION

Professional practice evaluation allows practitioners to improve quality of care, firstly by raising questions about improving professional practice through an evidence-based approach, secondly by observing differences between what is actually applied and the standards of practice, and finally by implementing improvement actions to reduce these differences.

This study describes the "Plan" phase of a Deming cycle and provides data that are necessary for further "Do," "Check" and "Act" phases of the first Deming cycle. The present methodology could be repeated in every dental practice or service, either public or private.

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CONFLICT OF INTEREST

The authors deny any conflicts of interest.

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REFERENCES

1. Hagerman NS, Varughese AM, Kurth CD. Quality and safety in pediatric anesthesia: how can guidelines, checklists, and initiatives improve the outcome? *Curr Opin Anaesthesiol*. 2014;27:323-329.
2. Rossi MC, Candido R, Ceriello A, et al. Trends over 8 years in quality of diabetes care: results of the AMD annals continuous quality improvement initiative. *Acta Diabetol*. 2015;52:557-571.
3. Simmons SF, Sims N, Durkin DW, et al. The quality of feeding assistance care practices for long-term care veterans: implications for quality improvement efforts. *J Appl Gerontol*. 2013;32:669-686.
4. Duncan PW, Bushnell CD, Rosamond WD, et al. The Comprehensive Post-Acute Stroke Services (COMPASS) study: design and methods for a cluster-randomized pragmatic trial. *BMC Neurol*. 2017;17:133.
5. Alrqiq HM, Edelstein BL. Use of quality measurement across US dental delivery systems: a qualitative analysis. *J Public Health Dent*. 2016;76:98-104.
6. Pak JG, Fayazi S, White SN. Prevalence of periapical radiolucency and root canal treatment: a systematic review of cross-sectional studies. *J Endod*. 2012;38:1170-1176.
7. De Moor R, Hommez G, De Boever JG, Delme KIM, Martens GEI. Periapical health related to the quality of root canal treatment in a Belgian population. *Int Endod J*. 2000;33:113-120.
8. Dugas NN, Lawrence HP, Teplitsky PE, Pharoah MJ, Friedman S. Periapical health and treatment quality assessment of root-filled teeth in two Canadian populations. *Int Endod J*. 2003;36:181-192.
9. Boucher Y, Matossian L, Rilliard F, Machtou P. Radiographic evaluation of the prevalence and technical quality of root canal treatment in a French subpopulation. *Int Endod J*. 2002;35:229-238.
10. Lupi-Pegurier L, Bertrand M-F, Muller-Bolla M, Rocca JP, Bolla M. Periapical status, prevalence and quality of endodontic treatment in an adult French population. *Int Endod J*. 2002;35:690-697.
11. Kirkevang LL, Ørstavik D, Hörsted-Bindslev P, Wenzel A. Periapical status and quality of root fillings and coronal restorations in a Danish population. *Int Endod J*. 2000;33:509-515.
12. Hommez G, Coppens C, De Moor R. Periapical health related to the quality of coronal restorations and root fillings. *Int Endod J*. 2002;35:680-689.
13. Segura-Egea JJ, Jiménez-Pinzón A, Poyato-Ferrera M, Velasco-Ortega E, Rios-Santos JV. Periapical status and quality of root fillings and coronal restorations in an adult Spanish population. *Int Endod J*. 2004;37:525-530.
14. Loftus JJ, Keating AP, McCartan BE. Periapical status and quality of endodontic treatment in an adult Irish population. *Int Endod J*. 2005;38:81-86.
15. Stassen I, Hommez G, De Bruyn H, De Moor RJG. The relation between apical periodontitis and root-filled teeth in patients with periodontal treatment need. *Int Endod J*. 2006;39:299-308.
16. Kayahan MB, Malkondu Ö, Canpolat C, Kaptan F, Bayırlı G, Kazazoglu E. Periapical health related to the type of coronal restorations and quality of root canal fillings in a Turkish subpopulation. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2008;105:e58-e62.
17. Tarim EE, Ertas H, Sisman Y, Sagsen B, Er O. Radiographic assessment of the technical quality and periapical health of root-filled teeth performed by general practitioners in a Turkish subpopulation. *Sci World J*. 2013;2013:514841.
18. Moreno JO, Alves F, Gonçalves LS, Martinez AM, Rôças IN, Siqueira JF. Periradicular status and quality of root canal fillings and coronal restorations in an urban Colombian population. *J Endod*. 2013;39:600-604.
19. Song M, Park M, Lee C-Y, Kim E. Periapical status related to the quality of coronal restorations and root fillings in a Korean population. *J Endod*. 2014;40(2):182-186.

20. Touboul V, Germa A, Lasfargues J-J, Bonte E. Outcome of endodontic treatments made by postgraduate students in the dental clinic of Bretonneau hospital. *Int J Dent*. 2014;2014:e684979.
21. Schaeffer MA, White RR, Walton RE. Determining the optimal obturation length: a meta-analysis of literature. *J Endod*. 2005;31:271-274.
22. Ng Y-L, Mann V, Rahbaran S, Lewsey J, Gulabivala K. Outcome of primary root canal treatment: systematic review of the literature – Part 2. Influence of clinical factors. *Int Endod J*. 2008;41:6-31.
23. Liang Y-H, Li G, Shemesh H, Wesselink PR, Wu M-K. The association between complete absence of post-treatment periapical lesion and quality of root canal filling. *Clin Oral Investig*. 2012;16:1619-1626.
24. Best M, Neuhauser D. W Edwards Deming: father of quality management, patient and composer. *Qual Saf Health Care*. 2005;14:310-312.
25. Wang L-R, Wang Y, Lou Y, Li Y, Zhang X-G. The role of quality control circles in sustained improvement of medical quality. *Springerplus*. 2013;2:141.
26. Taylor MJ, McNicholas C, Nicolay C, Darzi A, Bell D, Reed JE. Systematic review of the application of the plan-do-study-act method to improve quality in healthcare. *BMJ Qual Saf*. 2014;23:290-298.
27. Chang Y-N, Lin L-H, Chen W-H, et al. Quality control work group focusing on practical guidelines for improving safety of critically ill patient transportation in the emergency department. *J Emerg Nurs*. 2010;36:140-145.
28. Spiegel W, Mlczoch-Czerny M-T, Jens R, Dowrick C. Quality circles for pharmacotherapy to modify general practitioners' prescribing behaviour for generic drugs. *J Eval Clin Pract*. 2012;18:828-834.
29. Wensing M, Baker R, Szecsenyi J, Grol R. Impact of national health care systems on patient evaluations of general practice in Europe. *Health Policy*. 2004;68:353-357.
30. de Korne DF, van Wijngaarden J, van Rooij J, Wauben LSGL, Hiddema UF, Klazinga NS. Safety by design: effects of operating room floor marking on the position of surgical devices to promote clean air flow compliance and minimise infection risks. *BMJ Qual Saf*. 2012;21:746-752.
31. Zhang H, Wang L, Cai Y, Ye R, Lin J, Jiang D. Application of a quality control circle to reduce the wait times between continuous surgeries. *Eye Sci*. 2015;30:60-62.
32. Jiang Q, Zhang D, Majaw J, et al. Minimization of the perianal infection rate of hematological malignancies with agranulocytosis by quality control circle activity and patient-hospital-student win-win concept. *J Int Med Res*. 2018;46:2338-2345.
33. Newcombe J, Fry-Bowers E. Improving postoperative neonatal nutritional practices in an intensive care unit using the PDSA Cycle. *J Pediatr Health Care*. 2018;32(5):426-434.
34. Hargreaves K, Berman L. *Cohen's Pathways of the Pulp Expert Consult*, 10th edn. St. Louis, Mo: Mosby; 2010.
35. Torabinejad M, Endodontics WRE. *Principles and Practice*. St. Louis, Mo: Elsevier Health Sciences; 2009.
36. European Society of Endodontology. Quality guidelines for endodontic treatment: consensus report of the European Society of Endodontology. *Int Endod J*. 2006;39:921-930.
37. Haute Autorité de Santé. Traitement endodontique, rapport d'évaluation technologique. 2008.
38. Er O, Sagsen B, Maden M, Cinar S, Kahraman Y. Radiographic technical quality of root fillings performed by dental students in Turkey. *Int Endod J*. 2006;39:867-872.
39. Dadresanfar B, Mohammadzadeh AN, Vatanpour M, Atef YektaH, Baradaran MohajeriL. Technical quality of root canal treatment performed by undergraduate dental students. *Iran Endod J*. 2008;3:73-78.
40. Moussa-Badran S, Roy B, Bessart du Parc AS, Bruyant M, Lefevre B, Maurin JC. Technical quality of root fillings performed by dental students at the dental teaching centre in Reims, France. *Int Endod J*. 2008;41:679-684.
41. Estrela C, Leles CR, Hollanda A, Moura MS, Pécora JD. Prevalence and risk factors of apical periodontitis in endodontically treated teeth in a selected population of Brazilian adults. *Braz Dent J*. 2008;19:34-39.
42. Burke FM, Lynch CD, Ní Ríordáin R, Hannigan A. Technical quality of root canal fillings performed in a dental school and the associated retention of root-filled teeth: a clinical follow-up study over a 5-year period. *J Oral Rehabil*. 2009;36:508-515.
43. Tavares P, Bonte E, Boukpessi T, Siqueira JF, Lasfargues J-J. Prevalence of apical periodontitis in root canal-treated teeth from an urban French population: influence of the quality of root canal fillings and coronal restorations. *J Endod*. 2009;35:810-813.
44. Balto H, Al Khalifah S, Al Mugairin S, Al Deeb M, Al-Madi E. Technical quality of root fillings performed by undergraduate students in Saudi Arabia. *Int Endod J*. 2010;43:292-300.
45. Covello F, Franco V, Schiavetti R, et al. Prevalence of apical periodontitis and quality of endodontic treatment in an Italian adult population. *Oral Implantol*. 2010;3:9-14.
46. Ozkurt Z, Kayahan MB, Sunay H, Kazazoğlu E, Bayırlı G. The effect of the gap between the post restoration and the remaining root canal filling on the periradicular status in a Turkish subpopulation. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2010;110:131-135.
47. Asgary S, Shadman B, Ghalamkarpour Z, et al. Periapical status and quality of root canal fillings and coronal restorations in Iranian population. *Iran Endod J*. 2010;5:74-82.
48. Kamberi B, Hoxha V, Stavileci M, Dragusha E, Kuçi A, Kqiku L. Prevalence of apical periodontitis and endodontic treatment in a Kosovar adult population. *BMC Oral Health*. 2011;11:32.
49. Peters LB, Lindeboom JA, Elst ME, Wesselink PR. Prevalence of apical periodontitis relative to endodontic treatment in an adult Dutch population: a repeated cross-sectional study. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2011;111:523-528.
50. Al-Omari MA, Hazaa A, Haddad F. Frequency and distribution of root filled teeth and apical periodontitis in a Jordanian subpopulation. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2011;111:e59-e65.
51. Mukhaimer R, Hussein E, Orafi I. Prevalence of apical periodontitis and quality of root canal treatment in an adult Palestinian sub-population. *Saudi Dent J*. 2012;24:149-155.
52. İlgüy D, İlgüy M, Fişekçioğlu E, ErsanN, TanalpJ, DölekogluS. Assessment of root canal treatment outcomes performed by Turkish dental students: results after two years. *J Dent Educ*. 2013;77:502-509.
53. Jersa I, Kundzina R. Periapical status and quality of root fillings in a selected adult Riga population. *Stomatologija*. 2013;15:73-77.
54. Adebayo ET, Ahaji LE, Nnachetta RN, et al. Technical quality of root canal fillings done in a Nigerian general dental clinic. *BMC Oral Health*. 2012;12:42.
55. Huumonen S, Ørstavik D. Radiographic follow-up of periapical status after endodontic treatment of teeth with and without apical periodontitis. *Clin Oral Investig*. 2013;17:2099-2104.
56. Alsaleh I, Cousson P-Y, Nicolas E, Hennequin M. Is endodontic treatment performed under general anaesthesia technically acceptable? *Clin Oral Investig*. 2012;16:1599-1606.
57. Vukadinov T, Blažić L, Kantardžić I, Lainović T. Technical quality of root fillings performed by undergraduate students: a radiographic study. *Sci World J*. 2014;2014:e751274.
58. Moradi S, Gharechahi M. Radiographic quality of root canal treatment performed by 6th year undergraduate students in Mashhad, Iran. *Dent Res J*. 2014;11:364-369.
59. Alafif H. Impact of the quality of coronal restoration and root canal filling on the periapical health in adult Syrian subpopulation. *Indian J Dent*. 2014;5:75-80.

60. Tchorz JP, Brandl M, Ganter PA, et al. Pre-clinical endodontic training with artificial instead of extracted human teeth: does the type of exercise have an influence on clinical endodontic outcomes? *Int Endod J*. 2015;48:888-893.
61. Kirkevang LL, Væth M, Wenzel A. Ten-year follow-up observations of periapical and endodontic status in a Danish population. *Int Endod J*. 2012;45:829-839.
62. Craveiro MA, Fontana CE, de Martin AS, Bueno CE. Influence of coronal restoration and root canal filling quality on periapical status: clinical and radiographic evaluation. *J Endod*. 2015;41:836-840.
63. Friedman S, Abitbol S, Lawrence HP. Treatment outcome in endodontics: the Toronto study. Phase 1: initial treatment. *J Endod*. 2003;29:787-793.
64. Azim AA, Griggs JA, Huang G. The Tennessee study: factors affecting treatment outcome and healing time following nonsurgical root canal treatment. *Int Endod J*. 2016;49:6-16.
65. Friedman S, Löst C, Zarrabian M, Trope M. Evaluation of success and failure after endodontic therapy using a glass ionomer cement sealer. *J Endod*. 1995;21:384-390.
66. Peak JD, Hayes SJ, Bryant ST, Dummer PM. The outcome of root canal treatment. A retrospective study within the armed forces (Royal Air Force). *Br Dent J*. 2001;190:140-144.
67. Hoskinson SE, Ng YL, Hoskinson AE, Moles DR, Gulabivala K. A retrospective comparison of outcome of root canal treatment using two different protocols. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2002;93:705-715.
68. Quadros ID, Gomes Brenda P, Zaia AA, FerrazCC, Souza-FilhoFJ. Evaluation of endodontic treatments performed by students in a Brazilian dental school. *J Dent Educ*. 2005;69:1161-1170.
69. Imura N, Pinheiro ET, Gomes B, Zaia AA, Ferraz CCR, Souza-Filho FJ. The outcome of endodontic treatment: a retrospective study of 2000 cases performed by a specialist. *J Endod*. 2007;33:1278-1282.
70. de Chevigny C, Dao TT, Basrani BR, et al. Treatment outcome in endodontics: the Toronto study-phase 4: initial treatment. *J Endod*. 2008;34:258-263.
71. Ricucci D, Russo J, Rutberg M, Burleson JA, Spångberg LSW. A prospective cohort study of endodontic treatments of 1,369 root canals: results after 5 years. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2011;112:825-842.
72. Koch M, Wolf E, Tegelberg Å, Petersson K. Effect of education intervention on the quality and long-term outcomes of root canal treatment in general practice. *Int Endod J*. 2015;48:680-689.
73. Pirani C, Chersoni S, Montebugnoli L, Prati C. Long-term outcome of non-surgical root canal treatment: a retrospective analysis. *Odontology*. 2015;103:185-193.
74. Cousson PY, Nicolas E, Hennequin M. A follow-up study of pulpotomies and root canal treatments performed under general anaesthesia. *Clin Oral Investig*. 2014;18:1155-1163.
75. Simon DS. Endodontic case difficulty assessment: the team approach. *Gen Dent*. 1999;47:340-344.
76. Wu MK, Wesselink P, Shemesh H. New terms for categorizing the outcome of root canal treatment. *Int Endod J*. 2011;44:1079-1080.
77. Huumonen S, Vehkalahti MM, Nordblad A. Radiographic assessments on prevalence and technical quality of endodontically-treated teeth in the Finnish population, aged 30 years and older. *Acta Odontol Scand*. 2012;70:234-240.
78. Orstavik D, Kerekes K, Eriksen HM. The periapical index: a scoring system for radiographic assessment of apical periodontitis. *Endod Dent Traumatol*. 1986;2:20-34.
79. Schäfer E, Bürklein S. Impact of nickel–titanium instrumentation of the root canal on clinical outcomes: a focused review. *Odontology*. 2012;100:130-136.
80. Cheung G, Liu C. A retrospective study of endodontic treatment outcome between nickel-titanium rotary and stainless steel hand filing techniques. *J Endod*. 2009;35:938-943.
81. Asgary S, Eghbal MJ, Ghoddusi J. Two-year results of vital pulp therapy in permanent molars with irreversible pulpitis: an ongoing multicenter randomized clinical trial. *Clin Oral Investig*. 2014;18:635-641.
82. Simon S, Perard M, Zanini M, et al. Should pulp chamber pulpotomy be seen as a permanent treatment? Some preliminary thoughts. *Int Endod J*. 2013;46:79-87.
83. Jungnickel L, Kruse C, Vaeth M, Kirkevang LL. Quality aspects of ex vivo root canal treatments done by undergraduate dental students using four different endodontic treatment systems. *Acta Odontol Scand*. 2018;76:169-174.
84. Hayes SJ, Gibson M, Hammond M, Bryant ST, Dummer PMH. An audit of root canal treatment performed by undergraduate students. *Int Endod J*. 2001;34:501-505.
85. Jenkins SM, Hayes SJ, Dummer PM. A study of endodontic treatment carried out in dental practice within the UK. *Int Endod J*. 2001;34:16-22.

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