Are the evaluation criteria used in preclinical endodontic training courses relevant? a preliminary study

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Abstract

This study aimed to evaluate the relevance of a conventional evaluation protocol (CEP) for preclinical endodontic training. Seven dental students performed root canal treatments on an extracted human molar which was then evaluated by CEP (clinical and radiographic observations, including preparing the access cavities, preparing and filling the root canal, and detecting iatrogenic errors). A reference evaluation protocol (REP) based on micro-computed tomographic images analysis was used as a control. The evaluation scores obtained by CEP and REP were compared using a non-parametric Wilcoxon's test. CEP was relevant for access cavity, irrigation, working length, and ledge detection training but was no more effective than the REP for evaluating the apical diameter and taper of the root canals, the quality of the fillings, and the presence of perforations and fractured instruments using retro-alveolar radiographs. The conventional evaluation criteria used in preclinical endodontics should be used with care to detect "unsafe" students.

Keywords: Endodontics, Evaluation, Evaluation of clinical performance, Preclinical skills, X-ray microtomography

Introduction

Preclinical endodontic training is essential to prepare under- and postgraduate dental students in the performance of adequate and predictable root canal treatments before the transition to a clinical setting (1-3). Various studies have indicated that European populations continue to receive unsatisfactory standard root canal (3,4). To ensure a minimum level of competence in endodontics before graduation, ESE has published guidelines that cover all the essential steps of root canal treatment defining better-quality endodontic work (1,3). However, to determine whether a student has successfully completed his/her training, the establishment of clear evaluation criteria to grade the student's performance and to detect potential errors that may occur are also required.

Unfortunately, no widely accepted standardized evaluation protocols or data regarding the clinical relevance of the criteria commonly used in such protocols are currently available (5,6). However, a variety of conventional evaluation protocols (CEP) based on clinical and radiographic observations are widely used worldwide to evaluate the work of dental students and dentists. For example, the global quality of a root canal treatment can be evaluated by measuring the distance between the tip of the master-cone/end of the filling material and the radiographic apex in an artificial tooth model or by evaluating individual steps such as the preparation of the access cavity or the preparation and filling of the root canal (7-10).

However, most CEPs rely on subjective evaluations, and the evaluators are aware of the lack of sufficient measurement precision or accuracy for parameters such as the appropriate root taper, the cleanliness of the prepared root canal system, or the absence of leakage of the filled root canal. The main concerns with respect to such subjective evaluations are, first, that they suffer from many amongst others systematic biases, variabilities, psychological factors, and, second, that they are difficult to aggregate and interpret because they are often expressed in ordinal scales

(11). Few studies have verified the accuracy of these subjective evaluations and none have shown whether CEP measurements are truly uncorrelated or negatively correlated with independent objective measurements related to the variable of interest.

In an attempt to increase the accuracy or precision of the evaluations, various studies have used "experimental evaluation protocols" to assess endodontic procedures. These protocols, which mainly rely on advanced techniques such as scanning electron microscopy (SEM) and quantitative radiographic analyses (e.g., micro-computed tomography, µCT), as well as various traditional histological, biological, or electrochemical methods (dye leakage), are very effective at evaluating the cleanliness, shaping, and filling of the root canal. µCT, a high-precision 3D non-destructive analytical technique, for instance, can be used to quantitatively evaluate the quality of the access cavity, the root canal preparation, and the filling without superimposition (12-14). Despite their excellent performance, not all these experimental methods can be successfully transferred to preclinical or clinical use because they are neither cost nor time-effective.

A clinically relevant, standardized, and validated CEP is thus lacking for the evaluation and self-evaluation of endodontic procedures. In this context, we propose a CEP with multiple criteria based on previous studies and the preclinical training and evaluation program at Université de Lille (8-10). The aim of the present study was to assess the relevance of the criteria in the proposed CEP to that of a reference evaluation protocol (REP) using objective measurements from µCT analyses.

The H_0 null hypothesis tested was that there is no difference between the evaluation results of the proposed CEP and the REP with respect to the parameters studied.

Materials and methods

Seven third-year dental students, who received the same level of dental education and training, were asked to perform a total of 7 root canal treatments on 3-rooted extracted human molars (local ethics committee approval DC-2008-642). Seven prepared access cavities and eighteen treated root canals were evaluated by CEP and REP.

Endodontic Procedures

The extracted human molars were embedded in a wax model and were mounted on a phantom head (Adec, Nuneaton, England), with the dental dam held in place. The students were first asked to evaluate preoperative radiographs to estimate the preoperative working length. They were then asked to perform the following classic root canal treatment on the teeth:

- Prepare the access cavities using diamond burs and Zekrya-endo and X-Gates (Dentsply Sirona, York, Pennsylvania, USA) burs.
- Instrument the root canals using progressive hand files (MMC, MicroMega, Besançon, France) up to a #15 file and determine the working length by evaluating a peri-operative radiograph with the #15 file located 0.5 mm from the apical foramina.
- Prepare the roots with the RevoS system (MicroMega) up to a #25 instrument, following the manufacturer's instructions: SC1 (#25.06) at two-thirds of the working length, SC2 (#25.04) at the working length and SU (#25.06) at the working length.
- Irrigate the access cavities and the root canals with a copious amount of 2.5% sodium hypochlorite solution though the opening of the pulp chamber, between each instrument, and after preparation.
- Maintain and check apical patency by passing a #10 K file beyond the apex.

- Calibrate a master cone of gutta-percha (taper 06) by cutting it with an endodontic gauge ruler and a scalpel blade to the dimensions of the prepared root canal and adjust it by verifying the presence of tug-back and by checking it visually and radiographically.

After the treatment, each student was asked to complete a form concerning the apical diameter, the working length, and the coronal landmark used during his/her canal treatment. All the treated teeth were then collected for evaluation as described below.

In the following practical session, the students were asked to fill the root canals with a zinc oxide-based sealer (Cortisomol SP, Acteon, Mérignac, France) using the thermomechanical technique (Gutta Condensor, Densply). A post-operative radiograph was taken, and potential difficulties were noted by the students on a form.

Evaluation

We designed a standardized CEP based on ESE guidelines, approaches described in the literature, and the practical experience of members of the dental faculty at Université de Lille. An experienced clinician from the Department of Endodontics acted as the evaluator for the study. His CEP and REP evaluations of the endodontic procedures by the students were blinded and were calibrated by evaluating five standard treatments. This approach permitted to eliminate the bias associated with the calibration by the students.

The CEP only required an operating microscope to facilitate the evaluations and to improve the detection of iatrogenic errors (15), as well as other materials commonly used to score parameters with respect to the access cavity, the root canal preparation, the root canal filling, and iatrogenic errors (Table 1). The scores of most of the items (access cavity, preparation and filling of the root canal) were assigned using a Lickert scale of agreement (from 0 to 4). Items, such as the evaluation of the apical diameter, the working length, and the filling length, were not directly scored but were first recorded as quantitative data, which were then converted into a score (0-4).

The parameters were scored to reflect whether the student's work attained the objectives of the treatment:

- Opening the access cavity: adequate shape, dimension, and position of the access cavity. Root canal inlets directly visible. No interference of a DG16 probe or a #10 K file with the walls of the access cavity.
- Pulp chamber roof elimination: absence of a pulp chamber roof evaluated visually and with a DG17 probe.
- Canal inlet preparation: access to the apical third or the first curvature evaluated visually and with a DG16 probe, no residual dentine triangles.
- Irrigation: absence of debris, clean endodontic system walls, evaluated visually.
- Taper: adequate taper of the root canal evaluated on the radiographic master cone in place.
- Working length: measured visually between the landmark given by the student and a point 0.5 mm short of the apical foramina using a #10 K file.
- Apical diameter: measured when a gently inserted gauging file reached the measured working length and was stabilized.
- Root canal filling length: evaluated as the distance between the limit of the radiographic filling and the radiographic apex.
- Root canal filling density and homogeneity: good density, with no voids within the filling material visible on the post-operative radiograph.

The presence/absence of iatrogenic errors (ledges, false canals, perforations, instrument fractures, unprepared canals) was scored using the following binary scale: 0: absence of iatrogenic error; 1: presence of iatrogenic error.

For the REP evaluation, the processed teeth were scanned after the preparation step and then after the root canal filling step using a µCT device (SkyScan 1172; Bruker, Kontich, Belgium) at 80 kVp and 100 µA, with a 450-ms integration time and a 20-µm voxel size. Data were reconstructed using NRecon software (Bruker). The access cavity, the irrigation and the iatrogenic errors were evaluated by analyzing the 3D reconstructed images using Dataviewer (Bruker) and CT-An (Bruker) software (Table 1). The high precision of the µCT analysis made it possible to conduct a quantitative evaluation of the following parameters:

- Taper: The tapers of the root canals over the last 5 mm were calculated as follows:
  Taper = ((root canal diameter at working length + 5 mm) – root canal diameter at working length)/5.
- Apical diameter: The end of the root canal preparation was determined visually on the µCT images, and the diameter of the root canal was measured as the distance of the shortest diameter of the root canal at this point with the 'measuring' instrument of the Dataviewer software (Bruker).
- Working length: The distance between the apical foramina and the apical limit of the preparation was measured at the axis of the canal in this area with the 'measuring' instrument of the Dataviewer software (Bruker).
- Root canal filling length: The distance between the apical foramina and the apical limit of the filling was measured at the axis of the canal in this area.
- Root canal filling density and homogeneity: In order to calculate the percentage of space filled with obturation material, the root canal volume was segmented and was isolated from the tooth using CT-An software (Bruker). Therefore, a threshold was selected in the binary image page to exclude the voxels corresponding to dentin. Only the voxels corresponding to voids and to the filling materials were kept. The region of interest

ranged from the apical foramina to the root canal inlets, and a fixed threshold was used to binarize the data (200/255 greyscale) and isolate the voxels corresponding to the filling material from the voxels corresponding to the canal voids. The density was calculated as follows:

Density (%) = dense voxels/radiotransparent voxels×100.

The quantitative REP data were also converted into a score to be able to compare the two evaluation methods, as shown in Table 1. The iatrogenic errors were evaluated in the same manner as for the CEP.

Statistical analysis

Data are expressed as median (Q1-Q3) for the scores of the treated teeth. The normalities of the distributions were assessed following a Kolmogorov-Smirnov test. The statistical difference in the scores obtained by the CEP and REP was analyzed with GraphPad Prism 5 software (GraphPad Software, La Jolla, CA, USA) using a non-parametric matched pairs Wilcoxon test with the level of significance set at 5%.

Results

The results of the CEP and REP evaluations are shown in tables 2 and 3. The irrigation scores obtained by the CEP were significantly lower ($P < 0.05$) than those obtained by the REP for the root canal preparation. However, the CEP scores for the root canal filling length and density were higher ($P < 0.05$) than the REP scores. There were no significant differences between the CEP and REP scores for the other parameters ($P > 0.05$).

Twelve iatrogenic errors were detected by the CEP, and eleven by the REP (Table 3). Neither evaluation protocol detected false or unprepared canals. Nine ledges were detected by the CEP, while three were detected by the REP. One perforation and two instrument fractures were detected by the CEP, whereas two other instrument failures were detected by the REP.

Discussion

The absence of a broadly agreed approach in endodontic teaching and training to evaluate a student's performance after preclinical training results in a great variability of existing practical endodontic teaching and evaluation methods (5-10, 16-17). The ESE recommendations partially overcome this problem.[1,3] However, they are only guidelines and provide no detailed evaluation criteria or protocols to follow. Traditional clinical and radiographic evaluation methods are time-tested for their ease of use and lend themselves to large-scale evaluations (fast and cost-effective), but often lack precision and vary from dental school to dental school.

In the past few decades, modern medical imaging has evolved from conventional two-dimensional imaging to advanced cross-sectional and volumetric imaging. In the field of endodontics, advanced radiological modalities such as micro-computed tomography (μCT) and cone beam CT (CBCT) have proved their worth in the determination of working length without the need for any surgical modifications of the tooth (20). CBCT has been shown to have demonstrable advantages over conventional imaging for almost all endodontic applications, with the exception of assessing the quality of root canal fillings (21). μCT has often been used as a reference method due to its high accuracy in terms of radiographically observing mineralized tissues and its non-destructive nature, which makes it possible to obtain 3D images that are ideal for evaluating the access cavity and the preparation and filling of the root canal (12-14). Despite the undisputed usefulness of these advanced techniques, radiation protection principles, availability, and costs have made them impracticable for preclinical training. As such, at the present time, standardized conventional evaluation criteria or protocols for preclinical endodontics are lacking. However, existing conventional evaluation criteria need to be compared to those of a reference (μCT) in order to determine their relevance and validate them.

Root canal treatments are step-by-step interdependent procedures, and the quality of the work performed during one step will have a direct impact on the success of the following steps. It is thus reasonable to evaluate each step individually rather than to evaluate the treatment as a whole. The proposed CEP was thus designed with multiple variables that focus on specific individual steps during the treatment. It would, however, be interesting to design a comprehensive approach in the future.

Overall, the comparison of the CEP and the μCT-based REP rejected the H_0 null hypothesis. However, for each specific step, the results were not uniform. For example, no difference was observed between the two protocols with respect to access cavities. The effectiveness of the CEP at this step might result from the use of specific instrumentations and visual aids that enabled the evaluator to obtain an acceptable degree of sensitivity. The CEP was thus better than the REP in that it provided a direct, quick, and simple evaluation of the presence of coronal interferences and residual pulp chamber roof material and made it possible to observe the root canal inlets (22). Interestingly, the CEP was also more effective than the REP in evaluating root canal irrigation. On the one hand, visual aids facilitated that direct observation of macroscopic debris on the visible walls of the root canal system. On the other, using μCT to evaluate this parameter is questionable as it cannot distinguish between dentin debris and the dentin walls of the root canal (23). Even so, μCT can be an excellent adjunct for observing radiopaque materials in the whole root canal system, especially along root canal curvatures, which is impossible with any CEP. SEM can also be superior to CEP for observing the cleanliness of root canals, but its destructive nature makes it impossible to continue the next steps in the treatment (24). The working length scores were similar for both protocols in terms of shaping the root canal, while apical diameter and taper scores were lower with the REP than with the CEP, although the differences were not statistically significant. This aspect should be confirmed in future studies using increased statistical power.

However, the present study showed the limitations of the CEP (e.g., measuring the apical diameter using a hand file and making a radiograph with a master cone in position) with respect to the µCT analysis. This can be explained by the approximate calibration of the master cone and the tip of the gauging file used in the CEP while the high accuracy of the µCT facilitated the measurement of the taper of the root canal over the last 5 mm. In fact, determining the apical taper on a conventional radiograph remains a subjective low precision measure given that it uses interpretations of 2D images to describe 3D objects (25). Moreover, the anatomical specificities of root canals in their apical portions may result in a high taper that is not generated by shaping. To reduce the impact of these limitations during our evaluation, the taper was calculated along the first 5 mm.

The evaluation of root canal obturation was clearly more stringent with the REP than with the CEP in terms of filling length, density, and homogeneity. This is not surprising given that the CEP is based on a 2D radiographic evaluation with interpretation-related biases. Although µCT allows the real radiologic density of the filled root canal volume to be precisely calculated, it cannot provide a correspondence between the calculated filling density and the attributed scores (26,27). Given this, a correspondence scale was created based on a fixed threshold due to the lack of a quantitative definition of an "acceptable" or "unacceptable" filling.

As for iatrogenic errors, more ledges were detected with the CEP than with the REP. This was likely due to the fact that a manual file was used to check root canal patency and, as such, acted as a probe along the canal walls. Ledges are often located on the external side of canal curvatures where the working length can no longer be reached and a hand file is usually blocked (28). A clinical approach to detect ledges is thus more appropriate. However, the REP was more sensitive for detecting perforations and instrument fractures than the CEP, again due to the 3D nature and high accuracy of μCT (29).

Our results only provide exploratory data due to the small sample size. As expected, we noted that the average quality score for each parameter in the treatments carried out by the students was quite low. This can be attributed to the fact that the students were still at the preliminary stage of learning. However, the amount and variety of mistakes made by the students revealed many "hidden dangers," which increased the power of our study and could be considered as an advantage.

Conclusion

The access cavity, irrigation, working length, and detection of ledges are relevant factors in the clinical and radiographic evaluation of endodontic procedures commonly used in preclinical exercises. They are very useful for detecting “unsafe” students. The evaluation of the apical diameter and of the taper of shaped root canals needs to be further investigated by large scale studies. Conventional retro-alveolar radiographs overestimate the quality of root canal fillings and make it difficult to detect root canal perforations and fractured instruments compared to μCT. This is why these criteria are not relevant and should be used with care to detect “unsafe” students. Large-scale student training and testing investigations need to be conducted to confirm these results.

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29. Guedes OA, da Costa MVC, Dorilêo MCGO *et al*. Detection of procedural errors during root canal instrumentation using cone beam computed tomography. J Int Oral Health 2015; 7:28-32.Table 1: Scores following the conventional evaluation protocol (CEP) and the reference evaluation protocol (REP) of teeth endodontically treated by third-year dental students with respect to various evaluation criteria.

Evaluation criteria		Type of evaluation	Score				
			0	1	2	3	4
Access cavity	Opening	*CEP and REP:* Qualitative; Lickert scale	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
	Pulp chamber roof elimination	*CEP and REP:* Qualitative; Lickert scale	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
	Canal inlets preparation	*CEP and REP:* Qualitative; Lickert scale	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
	Irrigation	*CEP and REP:*	Strongly disagree	Disagree	Neutral	Agree	Strongly agree

Root canal preparation		Qualitative; Lickert scale					
	Taper	*CEP:* Qualitative; Lickert scale	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
		REP: Quantitative; Taper over the last 5 mm	2 or 10%	3 or 9%	4 or 8%	5 or 7%	6%
	Working length	*CEP and REP:* Quantitative; Difference between the expected and the measured working length	≥ 2 mm or overrunning	1.5-2 mm	1-1.5 mm	0.5-1 mm	0-0.5 mm
	Apical diameter	*CEP and REP:* Quantitative	≥ 0.20 mm	0.15-0.20 mm	0.10-0.15 mm	0.05-0.10 mm	0-0.05 mm

		; Difference between the expected and the measured apical diameter					
Root canal filling	Length	*CEP and REP:* Quantitative; Distance between the end of the filling and the radiographic apex (CEP) or apical foramina (REP)	≥ 2 mm or overrunning	1.5-2 mm	1-1.5 mm	0.5-1 mm	0-0.5 mm
	Density and homogeneity	*CEP:* Lickert scale	Strongly disagree	Disagree	Neutral	Agree	Strongly agree

		REP: Quantitative; Percentage of filling material in the root canal	< 80%	81-85%	86-90%	91-95%	> 95%
Iatrogenic errors	Ledge	*CEP and REP:* Qualitative; Binary scale	Absence	Presence			
	False canal	*CEP and REP:* Qualitative; Binary scale	Absence	Presence			
	Perforation	*CEP and REP:* Qualitative; Binary scale	Absence	Presence			
	Instrumental fracture	*CEP and REP:* Qualitative; Binary scale	Absence	Presence			

Non-prepared canal	*CEP and REP:* Qualitative; Binary scale	Absence	Presence

Table 2: Median scores (Q1-Q3) of teeth endodontically treated by third-year dental students obtained using a conventional evaluation protocol (CEP) and a reference evaluation protocol (REP) with respect to various evaluation criteria.

Evaluation criteria		CEP score (/4) Median (Q1-Q3)	REP score (/4) Median (Q1-Q3)	*P*-value
Access cavity	Opening	1 (0.00-3.00)†	1 (0.00-4.00)†	0.586
	Pulp chamber roof elimination	3 (1.00-4.00)†	2 (0.00-4.00)†	0.148
	Canal inlet preparation	3 (1.00-3.00)†	2 (1.00-4.00)†	1.000
Root canal preparation	Irrigation	1 (0.00-2.00)†	2 (1.00-3.00)‡	0.003
	Taper	4 (2.50-4.00)†	3 (0.00-4.00)†	0.055
	Working length	3 (2.00-4.00)†	3 (0.00-4.00)†	0.926
	Apical diameter	2 (1.75-3.25)†	0 (0.00-4.00)†	0.102
Root canal filling	Length	3 (0.75-4.00)†	1 (0.00-2.25)‡	0.008
	Density and homogeneity	3 (0.75-3.00)†	0 (0.00-1.25)‡	0.002

† and ‡ indicate significant differences between the groups ($P < 0.05$).

Table 3: Number of iatrogenic errors detected by the conventional evaluation protocol (CEP) and the reference evaluation protocol (REP).

Evaluation criteria		CEP (nb)	REP (nb)
Iatrogenic errors	Ledges	9	3
	False canals	0	0
	Perforations	1	4
	Instrument fractures	2	4
	Unprepared canals	0	0

Title page

(i) Are the evaluation criteria used in preclinical endodontic training courses relevant? A preliminary study.

Running head: Relevance of endodontic evaluation

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