

Technical Quality and Associated Iatrogenic Errors of Endodontic Treatments Performed in Extracted Anterior Single-Rooted Teeth by Preclinical Undergraduate Students

SUMMARY

Aim: To evaluate technical quality of root canal treatments performed in extracted anterior single-rooted teeth in an undergraduate dental clinic, and to record the associated iatrogenic errors. **Material and Method:** 287 root canal treatments performed by 114 preclinical undergraduate students in extracted anterior teeth at the Department of Endodontology were radiographically evaluated, based on the following parameters: access cavity dimensions and direction, root canal instrumentation, and root canal filling quality. **Results:** The access cavity was found of adequate dimensions in 28.9% and straight in direction in 71.1% of the material. Erroneous position, overextension of the access cavity and non-straight access were noted in 39.7 %, 21.6% and 28.9% of the cases, respectively. The frequency of ledged root canals was 10.1%, while 84.7% of the teeth had no instrumentation related iatrogenic errors. Regarding root canal filling, incomplete density apically and technical inadequacies in the middle and cervical thirds were observed in 76.3% and 82.3% of the cases. The percentage of flawless endodontic treatments was 3.1%. **Conclusions:** Most of the endodontic treatments evaluated were classified unacceptable. Inadequate root canal filling density in the middle and cervical third and ledge formation were the most common faults.

Keywords: Dental Education; Dental Students; Endodontics; Medical Errors

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Introduction

Endodontic mishaps or procedural accidents are events that happen during diagnosis, access preparation, cleaning and shaping, obturation and post-space preparation; some due to inattention to detail, while others are totally unpredictable^{4,13}. Iatrogenic errors can be classified according to the stage of endodontic treatment, and they occur as follows: (1) during access cavity preparation; (2) during root canal instrumentation (ledge, root perforation, root transportation, fractured instrument); (3) during root canal obturation (inadequate root canal filling length or density, vertical root fracture); and (4) other accidents during root canal treatment (aspiration or ingestion, extrusion of irrigant, emphysema)⁷. Iatrogenic

complications, by hindering the sequence of root canal treatment steps, thus affect its outcome².

The technical quality of root canal treatments performed in dental schools or private clinics, and the prevalence of associated iatrogenic errors have been extensively studied on the basis of radiographic criteria^{1,7}. To the best of our knowledge, the present study is the first in peer reviewed journals evaluating each stage of endodontic treatment (access cavity preparation, root canal instrumentation and filling) performed by undergraduate students at a preclinical level, although a similar study evaluated root canal filling length, density and taper only¹⁰. The influence of the preclinical teaching approach on the outcome of root canal treatment on patients was examined in another cohort study¹².

According to the “Undergraduate Curriculum Guidelines for Endodontology” of the European Society of Endodontology, a graduating European dentist is expected to be competent at performing good quality root canal treatments, and to have knowledge of prevention and management of common procedural errors⁸. The assessment of endodontic treatment during preclinical and clinical training programs is crucial in determining the level of the provided education in Endodontics. Establishing a higher level of training could lead to better qualified graduate students and more effective health services.

The purpose of this study was to evaluate technical quality of root canal treatments and to record the associated iatrogenic errors performed by preclinical undergraduate students in the extracted anterior single-rooted teeth at the Department of Endodontology, School of Dentistry, Aristotle University of Thessaloniki, Greece.

Materials and Methods

Selection of Cases

The material of this study consisted of 390 root canal treatments performed by 114 fourth semester undergraduate students in extracted anterior teeth during the academic year 2012-2013 at the Department of Endodontology, School of Dentistry, Aristotle University of Thessaloniki, Greece. The fourth semester preclinical curriculum consists of one 1-hour theoretical lecture and one 2-hour practical course per week. During these practical courses, each student has to complete at least 3 root canal fillings in the extracted anterior teeth. The 114 undergraduate students were divided into 3 groups. Supervision was carried out by academic staff, PhD candidates or postgraduate students with an overall student/staff ratio of 8:1.

The extracted tooth roots were embedded in acrylic resin (Vertex-Dental B.V., Zeist, The Netherlands). All teeth were instrumented with the step back technique using stainless steel K-files of 0.02 taper (VDW GmbH, Munich, Germany), and the canals irrigated with tap water. Root canal fillings were performed with gutta-percha (Coltène/Whaledent GmbH, Langenau, Germany) and zinc oxide-eugenol sealer (K600, Dental Corporation of Thessaloniki, Greece) using the lateral condensation technique. 4 digital radiographs (pre-operative, working length, master cone, and post-operative) for each tooth were exposed using the paralleling technique (Gendex Oralix AC, Gendex Dental Systems, Milan).

The evaluation of technical quality of root canal treatments and the detection of iatrogenic errors was based on radiographic criteria. A total of 85 cases were excluded

due to missing or poor quality radiographs and 18 cases were excluded due to pre-existing defects, such as crown fractures. As a result, a total of 287 teeth were finally evaluated.

Evaluation of Technical Quality of Root Canal Treatments

Strict radiographic criteria were defined regarding: access cavity preparation, root canal instrumentation, root canal filing and the relative iatrogenic errors. The material was evaluated by 2 members of the academic staff of the Department of Endodontology. They were calibrated by discussing some randomly selected cases separately from the main study material. Inter-examiner agreement was determined by examining 30 cases included in the main study. In cases of disagreement, the 2 groups reached a consensus by discussion.

The method of viewing the radiographs was standardized. Radiographs were interpreted on a 15.6-inch LCD monitor with a resolution of 1920 x 1080 pixels (Lenovo, Paris, France) using Windows Photo Viewer software (Microsoft, Redmond, WA, USA). Precise measurements were made where necessary by means of a 0.5 mm resolution digital ruler. The extracted evaluation data were recorded on a specially designed form. Specifically, the form included the serial number of each student, the tooth type, the dimensions and direction of the access cavity, the presence of ledge, root perforation, root transportation, fractured instrument, and the taper and density of root canal fillings.

The radiographic criteria applied were as follows:

(1) Access cavity preparation

a. Access cavity dimensions

(i) *Adequate*, when the access cavity walls and root canal walls were in a straight line.

(ii) *Incorrect*

1. *Overextended*, when the access cavity wall extension exceeded the root canal walls

2. *Inadequate*, when the root canal wall extension exceeded the access cavity wall

3. *Incorrect position*, when the access cavity was not prepared over the roof of the pulp chamber

b. Access cavity direction

(i) *Straight*, when the K file inserted into the root canal did not interfere with the access cavity walls on the working length radiograph

(ii) *Non straight*, when the K file inserted into the root canal interfered with the access cavity walls on the working length radiograph

(2) Root canal instrumentation

(i) *Ledge*, when the apical end of the master cone, or the root canal filling, deviated from the root canal

limits on the master cone or the post-operative radiograph respectively

(ii) *Root perforation*, when an iatrogenic communication between the root canal space and the extra-radicular space was detected by extrusion of the K file, the master cone or the filling material on the working length, master cone or postoperative radiographs respectively

(iii) *Root canal transportation*, when the post-instrumentation root canal walls were not the result of uniform preparation of the initial root canal walls

(iv) *Fractured instrument*, when the whole or part of a separated instrument was detected in the root canal

(3) *Root canal fillings*

a. Apical third

(i) *Adequate both in length and density*, when the filling ending was situated 0-2 mm short of the radiographic apex with uniform radiodensity and the adaptation of the filling material to the root canal walls¹¹

(ii) *Adequate in length, but inadequate in density*, when the filling ending was situated 0-2 mm short of the radiographic apex, but there were radiographically visible voids, either in the mass of the filling material or between the filling and the root canal walls

(iii) *Overextension*, when the filling ending extruded beyond the radiographic apex, and there were radiographically visible voids in either the filling material mass or between the filling and the root canal walls

(iv) *Overfilling*, when the filling material was extruded beyond the radiographic apex, but there was uniform radiodensity and adaptation of the filling material to the root canal walls

(v) *Under-extension*, when the filling material fell more than 2 mm short of the radiographic apex and there were radiographically visible voids either in the mass of the filling material or between the filling and the root canal walls

(vi) *Under-filling*, when the filling material ended more than 2 mm short from the radiographic apex, but there was uniform radiodensity and adaptation of the filling material to the root canal walls

b. Middle and cervical third

(i) *Adequate*, when there was uniform radiodensity and adaptation of the filling material to the root canal walls, and progressive taper at the middle and cervical thirds

(ii) *Inadequate*, when there were some radiographically visible voids, either in the mass of the filling material or between the filling and the root canal walls, or a lack of uniform taper at the middle and cervical thirds.

Statistical Analysis

Inter-examiner agreement was measured using Cohen's kappa (k) values^{3,14}. The k-statistic was used

to assess the intra-examiner agreement of each group by re-evaluating 30 randomly selected radiographs at least 2 months after the first examination. SPSS 17.0 for Windows software (SPSS Inc., Chicago, IL, USA) was used for data processing and statistical analysis.

Results

The k-value for inter-examiner variability was 0.73 for "access cavity direction" and 0.88 for "length of root filling". The k-values for intra-examiner reproducibility were 0.76 for "access cavity direction" and 0.85 for "length of root filling".

Technical Quality and Iatrogenic Errors

Access cavity was adequate in 83 cases, while straight line access to the root canal was observed in 204 teeth (Tab. 1). Iatrogenic errors attributed to instrumentation were observed in 44 cases (15.3%). Specifically, the prevalence of ledges, root perforations, root canal transportations, and fractured instruments was 10.1%, 1.4%, 3.1%, and 0.7% respectively (Tab. 2). Root filling length was adequate in 168 of the root canals (58.5%). Acceptable filling density in the apical third was found in 47 of the cases (16.4%). Adequate filling taper and absence of voids in the middle and the coronal thirds was observed in 51 of the root canals - 17.7% (Tab. 3). The percentage of overall "lege artis" endodontic treatments was 3.1%.

Table 1. Evaluation of technical quality and iatrogenic errors of access cavity preparation (results are shown in percentages)

Adequate access cavity preparation	28.9		
		Overextended	21.6
		Inadequate Dimensions	9.8
		Incorrect position	39.7
Direction	Straight		71.1
	Not straight		28.9

Table 2. Technical quality and iatrogenic errors of root canal instrumentation (results are shown in percentages)

Ledge	10.1
Root perforation	1.4
Root canal transportation	3.1
Fractured instrument	0.7
Total	15.3

Table 3. Technical quality and iatrogenic errors of root canal fillings (results are shown in percentages)

Apical third	Adequate both in length and density	16.4
	Adequate in length, but inadequate in density	42.5
	Overextension	0.7
	Overfilling	0.0
	Under-extension	33.8
	Under-filling	6.6
Middle and cervical thirds	Adequate	17.7
	Inadequate	82.3

Discussion

The material of this study consisted of the radiographs taken during the preclinical training of fourth semester undergraduate students. Extracted anterior single-rooted teeth were selected due to their simple anatomy and limited morphological variety compared to other groups of teeth.

To the best of our knowledge, this is the first study evaluating the technical quality of root canal treatments and recording the associated iatrogenic errors at a preclinical level. Radiographic interpretation of periapical disease is affected by the levels of inter-examiner variability and intra-examiner reproducibility^{6,9}. In our study, the high inter-examiner variability and intra-examiner reproducibility values supported a high level of reliability of the evaluation of the material.

Potential limitations of the used method should be acknowledged. The retrospective study design limits the available information to that coming from the radiographic record base. Moreover, the inherent limitations of radiographic examination and interpretation may have introduced methodological errors. In particular, the radiographs were not taken in a strictly standardized and reproducible manner. Changes in beam and sensor angulation affect the radiographic appearance of the evaluated parameters. Bucco-lingual root canal curvatures, as well as procedural errors, may not always be accurately depicted on periapical radiographs. For example, a short filling may be a result of either a ledge or apically packed dentin chips and debris. Additionally, it has been shown that there is limited correlation between the radiographic appearance of the root canal filling and its adaptation and compaction⁵. Moreover, the acrylic resin used to embed the teeth does not accurately simulate periapical tissue. This may explain the low frequency of apical foramen perforations and overfillings/overextensions in our study. Finally, the lack of phantom

heads limited the extent of the potential to simulate clinical conditions.

According to our study, the most common iatrogenic error during access cavity preparation was incorrect position (39.7%), followed by non straight access direction (28.9%), and overextension (21.6%). Regarding root canal instrumentation, the formation of ledges was the most prevalent mishap (10.1%). Finally, root canal fillings were erroneous mainly due to incomplete apical density (76.3%), and technical inadequacies in the middle and cervical thirds (82.3%).

The high frequency of endodontic mishaps assessed in this study could be attributed to several reasons: the study design, the radiographic criteria applied, the inexperience of undergraduate students, the endodontic curriculum, or the lack of proper equipment.

Conclusion

Within the limitations of this study, endodontic treatments performed by undergraduate students at a preclinical level were mostly classified as inadequate. The most common mishaps were the inadequate root canal filling density in the middle and cervical thirds and the formation of ledge. More prospective studies are needed to clarify the deficiencies of the currently applied preclinical endodontic training.

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