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ORIGINAL ARTICLE

Quality of Root Canal Fillings Performed by Undergraduate Students and the Related Factors on the Treatment Outcome: A 2- to 5-Year Follow-Up

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ABSTRACT

Objective: To evaluate radiographically the quality of root canal fillings performed by undergraduate students between 2012 and 2015, and to investigate the impact of their quality in correlation with root type, preoperative periapical status, and type of restorative treatment on the treatment outcome.

Methods: Six hundred seventy-seven non-surgical root canal treatments were performed by undergraduate students from the Aristotle University of Thessaloniki at the endodontic department clinics between 2012 and 2015. Two hundred forty-four teeth (349 roots) fulfilled the criteria and were clinically and radiographically re-examined between 2016 and 2017, and the outcome was classified as "success" or "failure." Root canal fillings were radiographically evaluated in terms of apical extension and density. The root filling was classified as acceptable when both parameters were rated as acceptable. Statistical analysis was performed using generalized estimating equations. Pairwise comparisons were performed by the sequential Bonferroni method. Intra-examiner and inter-examiner agreements were checked by the intraclass correlation coefficient and Cohen's kappa. The statistical significance level was set at $p<0.05$.

Results: The percentage of the roots with acceptable root canal fillings was 40.4%. The molar roots demonstrated the lowest rate (30.7%) compared with the anterior (53%, $p<0.05$) and premolar teeth (43%, $p>0.05$). The results of the correlation of the quality of the root canal fillings with the root type, preoperative periapical status, type of coronal restoration, and the treatment outcome showed that the unacceptable quality of root canal filling in relation to root or presence of periapical lesion or crown revealed the lowest success rates (47.2%, 40.3%, and 52.3%, respectively). In contrast, results showed that roots with canal fillings of acceptable quality demonstrated success rates close to 90%, regardless of the other variables.

Conclusion: Within the limitations of the present study, the percentage of radiographically acceptable root canal fillings performed in the undergraduate clinic of the Department of Endodontology at Aristotle University of Thessaloniki was low (40.4%). Results showed that there was a strong association of higher success rates with root fillings of acceptable quality.

Keywords: Assessment, coronal restoration, density, outcome, periapical status, root canal fillings

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HIGHLIGHTS

- The percentage of roots with acceptable root fillings was 40.4%.
- Anterior roots revealed a statistically significant higher percentage (OR=2.5) of acceptable root canal fillings than molar roots (95% CI: 1.5–4.3; $p<0.001$).
- There was a strong association of success rates with quality of root canal fillings.

INTRODUCTION

Obturation of the root canal system is the final stage of endodontic treatment, aiming to the effective sealing of the entire root canal system with a biologically compatible material. A three-dimensional obturation of the radicular space is essential to eliminate coronal and apical leakage and to isolate and entomb any irritants remaining in inaccessible areas, such as crypts or dentinal tubules (1).

The quality of a root canal filling is radiographically assessed according to two main technical variables: the length of the filling material in relation to the radiographic apex and its density (absence of voids within the root filling material) (2). The majority of studies evaluating the technical quality of root canal fillings performed by undergraduate students have revealed a high ratio of unacceptable root fillings (3–6), and some of them have reported a great frequency of "iatrogenic

errors," such as ledges, perforations, and fractured instruments, especially in the posterior teeth (6–7). Therefore, the Undergraduate Curriculum Guidelines for Endodontology was published in an attempt to establish a broad and evidence-based undergraduate curriculum in European dental schools (8).

In the School of Dentistry at Aristotle University of Thessaloniki, Greece, the undergraduate students have to complete a pre-clinical endodontic course that is held during the 4th and the 5th semesters of the 5-year dental degree program. This course consists of 26 h of seminar lessons and 26 h of laboratory practice per semester, and aims to teach students the basic concepts and principles of the endodontic therapy, the morphology of teeth and their root canal anatomy, and the basic preparation and obturations techniques of the root canals. Moreover, during the laboratory practice, students have to perform a total of 12 endodontic treatments on extracted teeth placed in resin blocks (4 anteriors, 4 premolars, and 4 molars). The teacher to student ratio is 1:11. For the first clinical year in endodontics (7th and 8th semesters), students are required to perform five non-surgical endodontic treatments in single-rooted and multi-rooted teeth (three anteriors/premolars and two molars). Additionally, in the 5th year, students have to complete another five endodontic cases (at least two multi-rooted teeth) in order to complete their clinical practice in endodontics.

The aim of the present study was to assess the performance of undergraduate students in endodontics during their clinical practice. This was undertaken by evaluating radiographically the quality of root canal fillings performed in the undergraduate clinic of the Department of Endodontology at Aristotle University of Thessaloniki between 2012 and 2015. The impact of the quality of the root canal fillings in correlation with root type, preoperative periapical status, and type of coronal restoration on the 2- to 5-year outcome of endodontic treatments was also investigated.

MATERIALS AND METHODS

Selection of cases

The study sample consisted of 286 root-filled teeth from a total of 677 non-surgical root canal treatments performed between 2012 and 2015 in the undergraduate clinic of the Department of Endodontology at the Aristotle University of Thessaloniki, Greece. These teeth corresponded to 159 patients who were contacted via telephone calls for a follow-up examination. All of the procedures were performed after receiving approval from the Ethical Committee of the School of Dentistry, Faculty of Medicine, University of Thessaloniki, Greece (protocol no. 13/1-2-2017).

The inclusion criteria were:

I. Endodontic cases of single- and multi-rooted permanent teeth treated with a non-surgical endodontic approach,

II. Endodontic cases performed by undergraduate students under the same treatment protocol,

III. Fully detailed case history sheets accompanied by a full set of periapical radiographs of good diagnostic value (initial, working length, master cone, and post-obturation radiographs),

IV. Patients >18 years at the time of treatment.

The exclusion criteria were:

I. Patients with systemic diseases, such as diabetes (type I or II), autoimmune disease, or HIV,

II. Teeth that were not permanently restored, with severely damaged restorations or root canal filling materials exposed to the oral environment,

All of the non-surgical root canal treatments were performed by undergraduate students between 2012 and 2015 following the same treatment protocol under the supervision of a faculty member. Preoperative radiograph of the tooth in need of root canal treatment was obtained. After consideration of the medical and dental histories of each patient, local anesthesia was administered if needed. Rubber dam isolation was applied in all of the cases. After the establishment of a straight-line access, the working length was determined radiographically using a K-file in each root canal. The step-back technique was used for the instrumentation of each root canal, using stainless steel K–files of a 0.02 taper (Kerr Sybron, Romulus, MI, USA). A 25% NaOCl was used as an irrigation solution. In calcified root canals, Rc-Prep paste (Premier Dental Products Co., Norristown, Philadelphia, PA, USA) was also used. Calcium hydroxide paste (Kaloudis Mon Epe, Thessaloniki, Greece) was used as intracanal medicament between appointments. The root canals were filled with gutta-percha cones and an epoxy resin-based root canal sealer (ADSeal; Meta Biomed, Cheongju, South Korea) using the cold lateral compaction technique. Final periapical radiograph after temporary coronal filling was obtained. All of the conventional non-digital periapical radiographs were acquired using the bisecting-angle technique.

Clinical and radiographic examination

After collection of all patients' information, two postgraduate students (NP and KS) performed clinical and radiographic evaluation of the 286 endodontically treated teeth in 159 patients who accepted to attend the follow-up examination. The following features were recorded using a special form that was created for each tooth: i) presence of discomfort, pain, swelling, and sinus tract; ii) measurement of the pocket depth using a periodontal probe at 6 points around the tooth; iii) results from a palpation test; and iv) results from a percussion test (vertical and horizontal).

Follow-up radiographs performed by the parallel technique were digitally obtained by photostimulable phosphor plates using DIGORA OPTIME DXR-60 (SOREDEX, Tuusula, Finland). The conventional periapical radiographs (pre- and post-obturation) were digitalized and were categorized together with the follow-up images of each tooth in separate files.

Evaluation of the technical quality of root canal fillings

The root canal filling of each root was radiographically assessed in terms of the apical extension and density of the filling materials using the criteria suggested in a previous study (6). A root

TABLE 1. Assessment criteria used for the classification of the technical quality of root fillings

Technical variable	Apical extension		Density	
Assessment criteria	Acceptable	Unacceptable	Acceptable	Unacceptable
	Filling material ends 0–2 mm short of the radiographic apex	Filling material ends >2 mm from the radiographic apex or extruded beyond the apex	No voids present within the material or between the material and the root canal walls	Voids are present within the material or between the material and the root canal walls

canal filling was regarded as "acceptable" when both parameters were rated as acceptable (Table 1). Roots with more than one root canal were classified considering the root canal with the worst quality.

Evaluation of the periapical status

The periapical status of each root was assessed by the periapical index (PAI) (9), with scores of 1 and 2 signifying the absence of apical periodontitis and scores of 3, 4, and 5 signifying the presence of apical periodontitis. Each assessor was asked to score the periapical status at both the baseline appointment and the follow-up appointment.

Calibration and assessment procedure

Two independent examiners, NP and the co-investigator GM (an Assistant Professor of Endodontology Faculty), were asked to radiographically assess the periapical status and technical quality of root canal fillings according to the abovementioned criteria. An initial calibration was undertaken between the two assessors by discussing and evaluating some selected cases that were not included in the present study. The root of each tooth was considered the unit of evaluation. The evaluation procedure took place in a darkened room and was composed of three sessions. Each session lasted not >60 min. The digital images (the preoperative, post-obturation, and follow-up radiographs) were imported using the Scanora software (SOREDEX), which provided the option of measuring the distance between the end of the root canal filling material and the radiographic apex. Any manipulation of the images and use of the brightness or contrast tools of the program were not allowed. In cases where disagreement between the two examiners occurred (42 roots for periapical status, 40 roots for apical extension, and 33 roots for presence of voids), an appointment with a third examiner (KL) was arranged, and the radiographs were re-evaluated until a consensus was reached between the examiners.

Moreover, as part of the calibration procedure, 87 randomly selected cases included in the study were evaluated by each assessor for a second time after 1 month, and both the intra-examiner and the inter-examiner agreements were checked. The intra-examiner agreement for the preoperative PAI score variable showed an intraclass correlation coefficient (ICC)=0.805 and ICC=0.895, and the inter-examiner agreement showed an ICC=0.877. The kappa scores were 0.907 and 0.915 for the intra-examiner agreement for the apical extent variable and 0.881 for the inter-examiner agreement. The kappa scores for the intra-examiner agreement for the voids were 0.891 and 0.872, and the kappa score for the inter-examiner agreement was 0.951. Finally, the intra-examiner agreements for the follow-up PAI score variable were ICC=0.881 and ICC=0.852, and the inter-examiner agreement for this variable was ICC=0.876. Kappa scores >0.8 (10) and ICC scores between 0.75 and 0.9 (11) indicate good agreement.

Treatment outcome classification

Radiographic and clinical criteria were used to classify the outcome in two categories:

A) Success:

I. Healed, absence of radiographic signs of apical periodontitis (PAI score <3) and no clinical signs other than tenderness to percussion and no symptoms,

II. Incomplete healing (for cases with <3 years of follow-up period), reduction of the size of the periapical lesion but not completely resolved (reduction of PAI score but still >2) with no clinical signs other than tenderness to percussion and no symptoms.

B) Failure:

I. Uncertain healing, no radiographic sign of reduction of the size of the periapical lesion (follow-up PAI score remaining at pathological value similar to preoperative) with no clinical signs and symptoms,

II. Unsatisfactory healing, development of a new periapical lesion or increase in size of an existing periapical lesion (further increase of PAI score) or presence of clinical signs and symptoms.

Statistical analysis

Statistical analysis of data was performed using generalized estimating equations (12) in SPSS software (IBM SPSS Statistics for Windows, version 21.0; IBM Corp., Armonk, NY, USA). The result was given as odds ratio (OR) with 95% confidence interval (CI), and pairwise comparisons were performed using the sequential Bonferroni method. Additionally, the intra-examiner and inter-examiner agreements were studied by the ICC for numeric-ordinal data and Cohen's kappa for nominal data. The statistical significance was set at $p<0.05$ for all the tests.

RESULTS

Sample characteristics

From a total of 286 teeth that were re-examined, 42 teeth (11 teeth without permanent restoration, 7 extractions due to periodontal disease, 19 extractions for prosthetic considerations, and 5 extractions due to complications/discomfort) were excluded from the study, resulting in a final sample of 133 patients with 244 teeth (349 roots). The follow-up periods ranged

TABLE 2. Distribution of sample characteristics

Characteristic	Number of roots (%)
Gender	
female	185 (53%)
male	164 (47%)
Arch	
maxillary	212 (60.7%)
mandibular	137 (39.3%)
Root type	
anterior	98 (28%)
premolar	98 (28%)
molar	153 (44%)
Pre-operative periapical lesion	
present	122 (35%)
absent	227 (65%)
Type of restoration	
filling	190 (54.5%)
crown	62 (17.7%)
crown+post	97 (27.8%)

from 2 years to 5 years, and the mean follow-up period was 2.8 (SD=0.7) years. Of the 133 patients, 71 (53.3%) were males, and 62 (46.7%) were females with a mean age of 53.1 years. Table 2 shows the data referring to the sample characteristics.

Technical quality of root fillings

According to the evaluation criteria, 141 (40.4%) out of 349 roots appeared to have acceptable root fillings in both technical variables (apical extension and density), whereas 208 (59.6%) roots appeared to have unacceptable root fillings. Sub-analysis of each variable separately revealed that 176 (50.4%) roots had root fillings of acceptable length (0–2 mm within the apex), 149 (42.7%) were under-filled, and 24 (6.9%) were over-filled. Regarding the density of root canal fillings, 251 (71.9%) roots appeared to be without voids, whereas 98 (28.1%) appeared with voids within the root filling material or between the root filling material and the canal walls.

Table 3 shows the technical quality of root canal fillings according to the root type. Molar roots demonstrated the lowest rate of acceptable root fillings (30.7%) compared with anterior roots (53%) and premolar roots (43%). However, only anterior roots revealed a statistically significant higher chance (OR=2.5) of acceptable root fillings than molar roots (95% CI: 1.5–4.3; p<0.001).

Effect of the related factors on the treatment outcome

According to the assessment criteria, 254 (72.8%) roots presented a desirable outcome (success), whereas 95 (27.2%) roots presented an undesirable outcome (failure). Investigating the success rate in relation to the quality of root canal fillings and the root type (Table 4), molar roots with unacceptable root fillings demonstrated the lowest success rate (47.2%), whereas the other sub-groups revealed 2.36 to 22.4 times higher probability of success (p<0.05).

Correlating the quality of root canal fillings and the preoperative periapical status with the treatment outcome (Table 5), the sub-group of periapical lesion present and unacceptable root filling quality revealed the lowest success rate (40.3%), whereas the other three sub-groups showed 3.4 to 25.5 times higher chance of success (p<0.001). When the treatment outcome according to the quality of root canal fillings and type of restoration was investigated (Table 6), roots with unacceptable root canal fillings restored with crowns showed the lowest percentage of success (52.3%) in comparison with the sub-groups of unacceptable root canal filling restored with a direct filling (58%) and unacceptable root canal filling restored with a crown and post (69.2%). Nevertheless, this difference was not statistically significant (p>0.05). Furthermore, the success rate of the sub-group unacceptable root canal filling restored with crown (52.3%) differed significantly from the sub-groups of acceptable root canal fillings restored with any type of restoration that revealed success rates >90% (p<0.05).

DISCUSSION

Studies show that the healing of periapical tissues is associated with root canal fillings ending 0–2 mm from the radio-

TABLE 3. Distribution of acceptable root fillings according to root type

Factor	Number of roots	Number of roots with acceptable root fillings (%)	OR	95%CI	Wald χ^2	df	p-value
Root type							
anterior	98	52(53%)	2.5	1.5-4.3	12.219	1	<0.001
premolar	98	42(43%)	1.7	1.0-2.9	3.817	1	0.051
molar	153	47(30.7%)	1.00		.	.	

OR: odds ratio, CI: confidence interval, df: degrees of freedom

TABLE 4. Success rate according to the quality of root canal fillings and root type

Factors	Number of roots	Roots with success (%)	OR	95%CI	Wald χ^2	df	p-value
RC filling quality+root type							
acceptable+anterior	52	47(90.4%)	10.53	3.88-28.55	21.385	1	<0.001
acceptable+premolar	42	40(95.2%)	22.4	5.15-97.47	17.174	1	<0.001
acceptable+molar	47	43(91.5%)	12.04	4.04-35.93	19.901	1	<0.001
unacceptable+anterior	46	36(78.3%)	4.03	1.82-8.95	11.736	1	0.001
unacceptable+premolar	56	38(67.9%)	2.36	1.2-4.66	6.185	1	0.013
unacceptable+molar	106	50(47.2%)	1.00				

OR: odds ratio, CI: confidence interval, df: degrees of freedom

TABLE 5. Success rate according to the quality of root canal fillings and preoperative periapical status

Factors	Number of roots	Roots with success (%)	OR	95%CI	Wald χ^2	df	p-value
RC filling quality+Periapical lesion							
Acceptable+Absent	91	86(94.5%)	25.5	9.2-70.5	38.943	1	<0.001
Acceptable+Present	50	44(88%)	10.9	4.1-28.8	23.043	1	<0.001
Unacceptable+Absent	136	95(69.9%)	3.4	1.9-6.2	16.44	1	<0.001
Unacceptable+Present	72	29(40.3%)	1.00				

OR: Odds ratio, CI: Confidence interval, df: degrees of freedom

TABLE 6. Success rate according to the quality of root canal fillings and the type of restoration

Factors	Number of roots	Roots with success (%)	OR	95%CI	Wald χ^2	df	p-value
RC filling quality+Coronal restoration							
Acceptable+crown+post	45	42(93.3%)	9.69	2.83-33.21	13.069	1	<0.001
Acceptable+filling	78	71(91%)	7.02	2.96-16.67	19.526	1	<0.001
Acceptable+crown	18	17(94.4%)	11.77	1.51-91.63	5.544	1	0.019
Unacceptable+crown+post	52	36(69.2%)	1.56	0.77-3.14	1.536	1	0.215
Unacceptable+filling	112	65(58%)	0.76	0.38-1.53	0.595	1	0.44
Unacceptable+crown	44	23(52.3%)	1.00				

OR: odds ratio, CI: confidence interval, df: degrees of freedom

graphic apex and with no presence of voids within the filling materials (13–14). These radiographic criteria were used in the present study to evaluate the technical quality of root canal fillings performed by undergraduate students.

The preoperative periapical status (13) and the tooth type (15) have also been regarded as decisive prognostic factors of the treatment outcome. Furthermore, some studies have demonstrated the association of the treatment outcome with the quality (13, 16) or the type of coronal restoration (17, 18). In a previous study conducted in a Greek dental school (19), preoperative periapical status, apical extension and density of the root filling material (assessed as separate variables), and root type were regarded as significant prognostic factors, whereas the type of coronal restoration had no significant impact on the outcome of non-surgical endodontic treatments.

All endodontic treatments included in the present study were performed using the step-back technique with stainless steel hand K-files in combination with the cold lateral compaction technique. This classic treatment protocol does not appear to be inferior to more contemporary ones (instrumentation with hand and rotary nickel–titanium files) according to some studies (20–21), whereas other studies (22) have reported that significantly better results can be achieved with the use of nickel–titanium files. Moreover, the sole use of conventional radiographs for the determination of the working length in the current study instead of the combined use of radiographs and electronic apex locators could have a negative impact on the students' clinical performance (23).

Regarding the obturation technique used in the current study, the cold lateral compaction of gutta-percha is the most commonly taught technique worldwide because of its advantages of controlled placement of the root filling material and low cost (24). However, the selection of this obturation technique could negatively influence the quality of root fillings as it produces a non-uniform mass of gutta-percha, and the chances of voids creation are high, especially in minimally flared root canals (4). On the other hand, warm vertical compaction creates a homogeneous mass of gutta-percha that can flow into canal irregularities (25). One study revealed that inexperienced students obtained more homogeneous canal fillings with warm vertical obturation technique (26). Nevertheless, the incidence of overextending filling material was higher with this technique than with cold lateral compaction (24, 25).

In this retrospective survey, the recall rate (45.4%) was similar to that in previous studies (15). Although it could be characterized as low and could have a negative impact on the strength of the study, the number of patients included is a representative subset of the potentially recallable patients, and the estimation of parameters of the larger population could be done using statistical methods. Regarding the radiographic assessment of the root canal filling quality, there were some limitations due to the two-dimensional nature of periapical radiograph. Images with mesial or distal angulations have been suggested for the detection of voids, especially between root canal walls and the filling material, due to their good reliability (27). However, some of the post-obturation images of the anterior teeth in the present study were exposed without alteration in horizontal angulation, resulting in a number of voids that arguably remained undetectable. Furthermore, the apical extension of the filling material was probably not estimated correctly in all of the cases as images exposed with the bisecting-angle technique tend to be projected as shorter than images exposed with the parallel technique (28).

The principal aim of the present study was to evaluate radiographically the technical quality of root canal fillings according to two parameters: density and apical extension. The overall percentage of roots with acceptable root fillings was 40.4%. Additionally, the percentage of acceptable root fillings de-

creased significantly as the location of the root moved posteriorly. Although a comparison with the results reported in other studies is difficult due to differences in the evaluation criteria, study material, teaching methods, and techniques, the trend is similar to some of them (3) and at variance to others (4–6). Subsequently, the two previous studies evaluating the technical quality of root fillings performed by undergraduate students in Greek dental schools (4, 29) revealed higher percentages of acceptable root fillings than that of our study (54.8% and 55.3%, respectively). This difference could be explained by the fact that the unit of evaluation in the current study was each root of the teeth (evaluation unit in the other two studies was each root canal), and roots with more than one root canal were classified considering the root canal with the worst quality of root filling, resulting in an overestimation of the proportion of unacceptable root fillings.

The other goal of the current study was to investigate the effect of the quality of root canal fillings in correlation with root type, preoperative periapical status, and type of coronal restoration on the treatment outcome, in an attempt to reveal the significance of each variable as prognostic factor. First, correlating the treatment outcome with the quality of root canal fillings and the root type (Table 4), the root type was not an important prognostic factor when the quality of root fillings was acceptable. On the contrary, when the quality was unacceptable, the success rates decreased significantly as the root type moved posteriorly. In previous studies, molars were strongly associated with higher risk of post-treatment disease because of their complex anatomy and difficult accessibility (5, 14–15). However, we cannot find previous studies in which the treatment outcome is directly correlated with the quality of root fillings and root type.

Furthermore, correlating the treatment outcome with the technical quality of root fillings and the preoperative periapical status (Table 5), roots with unacceptable canal fillings and periapical lesions showed the lowest success rate (40.3%) among the other sub-groups (69.9%–94.5%, $p<0.05$). This could be explained by the fact that a root canal with an unacceptable root filling in terms of apical extension and density is not properly shaped and cleaned to its full length and is not adequately sealed in order to establish the favourable biological conditions for the healing of periapical tissues (13, 15). In contrast, when the root fillings were acceptable, the success rate increased significantly to 88% and 94.5% with or without preoperative lesion, respectively.

Finally, the restorative modality did not have a significant impact on the outcome (Table 6). This finding contradicted those of a previous study (17) in which the restorative modality was presented as an important prognostic factor. The success rate of the sub-group unacceptable root filling restored with crown differed significantly only from the sub-groups of acceptable root canal fillings. However, a limitation of the present study to be mentioned was that the actual time interval between the final root canal obturation and permanent restoration of teeth was not clarified. As a result, the treatment outcome could have been influenced negatively in cases of an extended time interval (30).

CONCLUSION

Within the limitations of the present study, the percentage of roots with acceptable root fillings was 40.4%. This percentage decreased significantly as the location of the root moved posteriorly. Moreover, roots with canal fillings of acceptable quality demonstrated success rates close to 90%, regardless of the other variables' categories. Taking into account these findings, there is a need to implement a more effective theoretical and clinical training of undergraduate students in order to improve the technical quality of root canal fillings. Increasing the teacher-to-student ratio, increasing the number of molars treated in the laboratory, and the implementation of Ni–Ti rotary files and electronic apex locators are strongly recommended.

Disclosures

Conflict of interest: The authors deny any conflict of interest.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethical Committee of the School of Dentistry, Faculty of Medicine, Aristotle University of Thessaloniki, Greece (protocol number 13/1-2-2017).

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