

Evaluation of the Quality of Root Canal Treatments Performed by Dental Undergraduates: Is There a Need to Review Preclinical Endodontic Courses?

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Abstract Aim: To evaluate the quality of root canal treatment (RCT) performed by undergraduate (UG) dental students at the Jordan University Dental Hospital (JUDH) using radiographic records. **Methods:** All RCTs performed by UG students in the period between November 2013 and May 2014 were included in this study (213 teeth). 'Adequate' filling quality was defined as having adequate length, density and taper with the absence of any procedural error. Statistical analysis of the resulting data was carried out using the Chi-square test (χ^2). **Results:** 61.5% of treated teeth were adequate in length, 50.5% were adequate in density and 56.1% were adequate in taper; only 29.2% fulfilled these criteria at the same time, the relationship between the technical quality of root filling and tooth type was statistically significant ($P < 0.01$); the most adequate found in maxillary anterior teeth (47.1%), the least adequate found in maxillary molar teeth (5.9%). **Conclusions:** The technical quality of root fillings performed by undergraduate dental students using cold lateral compaction was poor. This suggests that the undergraduate endodontic training at the JUDH needs to be improved.

Keywords: root canal filling, quality, dental undergraduates

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1. Introduction

The general objectives of root canal preparation were defined as follows: "Root canal system must be cleaned and shaped: cleaned of their organic remnants and shaped to receive a three dimensional hermetic filling of the entire root canal space". The final prepared shape should be a continuously tapering funnel following the shape of the original canal; this was termed as the 'concept of flow' allowing both removal of tissue and appropriate space for filling. [1]

Methods used to determine the technical outcome of root canal treatments are based mainly on radiographical evaluation. [2,3] The European Society of Endodontology issued a consensus report in 2006 stating guidelines for radiographic evaluation of root canal fillings "the prepared root canal should be filled completely unless space is needed for a post. The prepared and filled canal should contain the original canal. No space between canal filling and canal wall should be seen. There should be no canal space visible beyond the end-point of the root canal filling." [4] Similarly, the American Association of Endodontists in its 2009 colleagues for excellence publication stated that "for radiographic evaluation of root canal fillings, the three qualities that should be observed are: length, shape and density. The length of an ideal fill should be from the canal's apical minor constriction to the

canal orifice unless a post is planned, the shape of the completed case is somewhat dependent on the instrumentation technique being used, and voids should not be visible on the radiographic image". [5]

Previous studies in the literature [2,3,6-18] show a wide range of percentage of adequate root canal treatments performed by undergraduate dental students, ranging from as high as 80%⁹ in which single-canal teeth were treated and evaluated, to as low as 13%, [6] in which multi-rooted teeth and re-treatments were carried out and assessed. A single retrospective study carried out at the faculty of Dentistry, Jordan University of Science and Technology, evaluated the performance and frequency of complications of root canal treatments performed by undergraduate dental students. It was concluded that the technical quality of 47.4% of root fillings was acceptable. [7]

The technical quality of root canal filling has a significant impact on the outcome of the procedure and the long-term retention of teeth. [19,20,21] Evidence suggests that many general practitioners lack sufficient knowledge of the factors important in determining the outcome of root canal treatment [22] and that basic endodontic principles are often disregarded. [23] Some of this may reflect the acquisition of foundational knowledge and skills during undergraduate training, where standards remain highly variable. [2,3,6-18,24,25] It is therefore important to ensure that undergraduate training is undertaken to a level that encourages deep understanding of the factors important in determining clinical outcome.

[4] In an attempt to achieve such goal, the European Society of Endodontology recently updated its undergraduate curriculum guidelines for endodontology in 2013. [26] The guidelines emphasized the importance of the acquisition of basic endodontic skills in a suitably equipped pre-clinical environment.

The faculty of dentistry at the University of Jordan was established in 1983. Its undergraduate endodontics curriculum is mainly comprised of one preclinical course at the third year level and two clinical courses at both fourth and fifth year levels. The third year preclinical course is made up of theoretical weekly lectures, and a 2-hours duration weekly preclinical endodontic lab. The preclinical course aims to provide the dental student with necessary theoretical knowledge and training in performing root canal treatments on extracted teeth, to acquire the desired skills and abilities to treat patients in a clinical setting in the following academic years.

The aims of this study were:

- To investigate the technical quality of root canal fillings performed by undergraduate students at the faculty of dentistry, University of Jordan, as a method to assess endodontic skills and abilities developed at the pre-clinical level.
- To compare the technical quality of root canal fillings performed by 4th and 5th year undergraduate students.

2. Material and Methods

This prospective study was proposed and approved by Faculty of Dentistry Academic Research Committee (FDARC). It was carried out in order to assess the technical quality of undergraduate root canal treatment compared to the international guidelines. The target sample was single- and multi-rooted teeth treated by 4th and 5th year students in the period between November 2013 and May 2014. All treatments were carried out under the direct supervision of a qualified endodontist. Canal instrumentation was carried out using the step back technique with stainless steel hand files and obturation was completed using cold lateral condensation.

An overall number of 213 teeth were treated in that period and included in the study. For each root filled tooth, at least three periapical radiographs were retrieved; preoperative, working length determination and postoperative. The radiographs were evaluated independently by two senior endodontists, using a handheld X-ray film viewer with magnifying lens. Length, density, taper of root canal fillings were investigated in addition to the presence of procedural errors. The results were compared, and a final evaluation was agreed upon. In case of disagreement, the two examiners discussed the case until a consensus is reached. Table 1 shows criteria against which filling quality was evaluated. A pro forma sheet was designed to facilitate data collection and analysis.

Table 1. Criteria used to assess the radiographic quality of root filling

Parameter	Criteria	Definition
Length of the root canal filling	Adequate	Root canal filling is 0-2 mm from radiographic apex.
	Under -filled	When it is more than 2 mm from radiographic apex.
	Over -filled	Any extrusion beyond radiographic apex.
Density	Adequate	Homogeneous with the absence of voids
	Inadequate	Not uniform homogeneity with the presence of voids.
Taper	Adequate	Consistent and uniform taper from the coronal to apical area with a reflection of the original shape of the canal.
	Inadequate	Inconsistent taper.
Procedural errors	Ledge	Root filling is at least 1 mm shorter than the working length and deviated from the original canal shape in teeth where root canal curvature occurred. [13]
	Transportation	The filling material is located on the outside curve of the canal at the apical third. [13]
	Perforation	The obturation material is detected outside the canal walls.

3. Statistical Analysis

For statistical analysis, the tooth was considered as a unit. 'Adequate' filling quality was defined as adequate length, density and taper with the absence of any procedural error. The analysis of the data was performed using SPSS 20.0 for Windows (SPSS Inc., Chicago, IL, USA). The Chi-squared statistic was used for statistical evaluation of the results. A P-value <0.05 was considered statistically significant.

4. Results

Two hundred and thirteen teeth were treated. Root canal treatments were carried out by 47 (22.1%) male students and 166 (77.9%) female students. 147 (69%) students were at the fourth year level whereas 66 (31%)

students were at the fifth year level. Percentages of tooth type included; 86 anterior teeth (40.4%), premolar teeth 87 (40.8%) and 40 molar teeth (18.8%).

1. Length

Table 2 shows adequacy of length according to tooth type. The χ^2 value was 21.99 ($P = 0.01$). A statistically significant difference in obturation length was evident based on the tooth type; the highest percentage of adequate obturation was found in maxillary anterior teeth (75.7%), while the lowest percentage was found in mandibular molar teeth (39.1%). In total, 61.5 % had adequate length; over-filling was generally more frequent than under-filling (24.4% and 14.1% respectively).

2. Density

Table 2 shows adequacy of density according to tooth type. The χ^2 yields a value of 16.76 ($p = 0.01$), a statistically significant difference in filling density is shown based on tooth type; the highest percentage of adequate fillings was found in maxillary anterior teeth

(70.0%), while the lowest percentage was found in maxillary premolar teeth (36.0%). Overall, 50% of teeth treated were considered adequate in density.

3. Taper

Table 2 shows the adequacy of taper according to tooth type. The χ^2 value was 13.94 ($p = 0.02$), a statistically

significant difference in filling taper is evident based on tooth type; the highest percentage of adequate fillings was found in upper maxillary teeth (71.4%), whereas, the lowest percentage was found in mandibular molar teeth (34.8%). 56.1% of treated teeth had an adequate taper.

Table 2. Overall Adequacy and adequacy of length, density and taper according to different tooth type

Tooth type	Length			Density		Taper		Overall treatment		Total
	Adequate	Underfill	Overfill	Adequate	Inadequate	Adequate	Inadequate	Adequate	Inadequate	
Maxillary Anterior	53 (75.7%)	7 (10%)	10 (14.3%)	49 (70%)	21 (30%)	50 (71.4%)	20 (28.6%)	33 (47.1%)	37 (52.9%)	70 (32.86%)
Mandibular Anterior	8 (50%)	1 (6.3%)	7 (43.8%)	7 (43.8%)	9 (56.3%)	10 (62.5%)	6 (37.5%)	4 (25%)	12 (75%)	16 (7.51%)
Maxillary Premolar	28 (54.9%)	10 (19.6%)	13 (25.5%)	18 (36%)	32 (64%)	23 (46%)	27 (54%)	11 (22%)	39 (78%)	51 (23.94%)
Mandibular Premolar	24 (68.6%)	6 (17.1%)	5 (14.3%)	15 (42.9%)	20 (57.1%)	20 (57.1%)	15 (42.9%)	9 (25.7%)	26 (74.3%)	36 (16.43%)
Maxillary Molar	8 (47.1%)	1 (5.9%)	8 (47.1%)	7 (41.2%)	10 (58.8%)	7 (41.2%)	10 (58.8%)	1 (5.9%)	16 (94.1%)	17 (7.98%)
Mandibular Molar	9 (39.1%)	5 (21.7%)	9 (39.1%)	10 (43.5%)	13 (56.5%)	8 (34.8%)	15 (65.2%)	4 (16.7%)	20 (83.3%)	23 (11.27%)
Total	131 (61.5%)	30 (14.1%)	52 (24.4%)	107 (50.5%)	105 (49.5%)	119 (56.1%)	93 (43.9%)	62 (29.2%)	150 (70.8%)	213 (100%)

4. Overall adequacy of treatment

Table 2 shows adequacy of treatment when the three criteria were combined together according to tooth type. The χ^2 value was 19.6 ($p < 0.01$) showing a statistically significant difference in overall adequacy of treatment and tooth type; the most adequate found in maxillary anterior teeth (47.1%), the least adequate found in maxillary molars (5.9%). In total, only 29.2% of cases were considered overall adequate.

Table 3 shows the adequacy of treatment according to student level. The χ^2 yields a value of 0.97 ($p = 0.32$). No statistically significant difference was evident in adequacy of treatment based on student level.

Table 3. Adequacy of treatment according to student level

Student level	Adequate	Inadequate	Total
Fourth year	46 (31.3%)	102 (68.7%)	148
Fifth year	16 (24.6%)	49 (75.4%)	65
Total	62 (29.2%)	151 (70.8%)	213

Table 4 shows distribution of procedural errors according to tooth type. The majority of cases were free of procedural errors (85.3%). The χ^2 value was 32.08 ($p=0.01$). A statistically significant difference in procedural errors among teeth type was evident; 30.4% of mandibular molars had transportation errors, whereas, 94.3% of mandibular premolar had no procedural errors.

Table 4. Procedural errors according to tooth type

Tooth type	Procedural Errors				Total
	Perforation	Ledge	Canal Transportation	No Errors	
Maxillary Anterior	0 (0%)	3 (4.3%)	3 (4.3%)	64 (91.4%)	70 (32.86%)
Mandibular Anterior	0 (0%)	1 (6.2%)	0 (0%)	15 (93.8%)	16 (7.51%)
Maxillary Premolar	1 (2%)	2 (4%)	2 (4%)	46 (90%)	51 (23.94%)
Mandibular Premolar	0 (0%)	1 (2.9%)	1 (2.9%)	34 (94.2%)	36 (16.43%)
Maxillary Molar	2 (11.8%)	2 (11.8%)	3 (17.6%)	10 (58.8%)	17 (7.98%)
Mandibular Molar	1 (4.3%)	2 (8.7%)	7 (30.4%)	13 (56.5%)	23 (11.27%)
Total	4 (1.9%)	11 (5.2%)	16 (7.6%)	180 (85.3%)	213 (100%)

5. Discussion

In any endodontic clinical setting, dental radiographs are the means to assess the status of root canal fillings. Similar to previous studies, [2,3,6-18] dental radiographs were utilized in this study to assess the quality of root canal obturation. A pro forma was formulated, filled and at least three radiographs were obtained for each tooth treated. The criteria used to assess the quality of root canal treatment followed the guidelines published by the European Society of Endodontology and the American Association of Endodontists. [4,5] In addition, procedural errors were recognized and registered.

This study showed that 29.2 % of teeth had adequate root canal filling. This was similar to the (23%) in Saudi Arabia, [13] (24.2%) in Sudan, [14] (30.3%) in France, [10] (32.5%) in Iran, [11] (33%) in Turkey [3] and the (34.8%) in Taiwan, [18] higher than the (13%) in Cardiff, [6] and lower than the (45%) in Iran, [17] (47.4%) in Jordan, [7] (55%) in Greece, [12] (55.3%) in Greece, [2] (63%) in Cork, [8] (79.47%) in Turkey, [15] and the (80%) in Glasgow. [9] Differences in results among studies may be attributed to different study designs; prospective [6,16] or retrospective, [3] type of teeth treated; single-canal teeth [8,9] or both single-canal and multiple-canal teeth [7,14,13,16], level of students; fourth-year only, [27] fifth-year only [14] or fourth-year and fifth-year students [3,7,16], and criteria used to evaluate quality of treatment;

length and density only [10,11,16] or length, density and taper. [3,7,13,14]

This study showed that quality of root canal fillings was better in anterior single-canal teeth when compared to posterior multi-canal teeth. Such result was in agreement with other studies that reported that technical quality was acceptable more often in anterior teeth. [3,11,12,13,16,17] This may be explained by the more complex anatomy of posterior teeth and more posterior location that may render the endodontic treatment more difficult.

The quality of root canal filling provided by fourth year dental students was similar to that provided by fifth year dental students. This was in agreement with some studies. [12,13,15] Although it is logical to assume that fifth year students have more experience and clinical training hours than fourth year students, hence, they should provide better quality root canal treatments, fifth year students undertake more difficult and further posteriorly located root canal treatments of molar teeth, compared to the less difficult and anteriorly located teeth that the fourth year carry out root canal treatments on. Some studies in the literature showed no gender difference in quality of root canal treatment provided. [15] This aspect was not investigated in this current study.

The most common procedural error encountered in this study was canal transportation, followed by perforations, and then ledges. About 41.2 % of upper molar teeth and 41.7% of lower molar teeth treated suffered procedural errors, whereas approximately 90% anterior and premolar teeth had none of these errors. This was in agreement with many studies. [2,11,12,13] This may be attributed to the nature of the anatomy of the canals as canals in posterior teeth tend to be more curved and narrow, and also to the location of the tooth; being more posterior would tend to be more difficult which makes endodontic treatment more challenging.

As shown earlier, most of published studies that evaluated the technical quality of root canal obturation provided by undergraduate students at dental schools were generally of poor quality. It is assumed that both quantity and quality of endodontic teaching might have an impact on treatment outcomes. [6,8] In addition, it was assumed that both the academic infrastructure and the priority which was given for endodontic teaching were limited in some countries which may have some impact on the quality of root canal treatment provided. [28] Differences between dental schools regarding the structure of undergraduate endodontic courses exist. [24,25,29,30] At the preclinical endodontic course at the University of Jordan students receive 14-hrs of lectures, and gain 56-hrs of laboratory endodontic training. The amount of pre-clinical laboratory teaching at Jordan is greater than the amount of preclinical training in Cork (48 h), Eastern Europe (16 h), the UK (24 h), Western Continental Europe (38 h), and North America (41 h). [29] However, in Scandinavia, undergraduate students receive 66 h of pre-clinical laboratory training in endodontics. [29] However, The staff to student ratio for the pre-clinical laboratory course in Jordan is 1:15 which is much lower than that in Cork is 1:8, UK (1:12), and the Scandinavian average (1:9).

The clinical endodontic teaching program at the Jordan University Dental School and hospital takes place over the final 2 years (fourth and fifth) of the undergraduate degree

program. During which student receive 28-h lectures in endodontics and 112 h of clinical endodontic training. Unlike some dental schools in UK and Europe where it is extremely difficult to provide specialist endodontists for both pre-clinical and clinical endodontic courses, [29] pre-clinical and clinical endodontic treatments are performed under the direct supervision of full-time academic staff specialist endodontists. Unfortunately, the ratio of clinical staff to students is 1:12 which is also lower than other countries.

A recent study showed that pre-clinical endodontic training had an influence on the technical quality of root canal treatment performed at the clinical level.²⁵ In addition, studies associate the curriculum of pre-clinical endodontic course with the low technical quality of root canal treatments. [8,14,27,28] In the last few years, many new topics have been added to our curriculum such as training on the use of apex locators on models and the placement of rubber dam isolation on teeth on the phantom head, in order to increasingly simulate the true clinical environment that student will face when working on a patient. Nevertheless, many students express their anxiety and restlessness when treating a patient endodontically for the first time as it does not simulate their training at the pre-clinical course. This might be attributed to many clinical factors such as patient cooperation, need to achieve adequate anesthesia, interference of saliva and the tongue. All these factors are not simulated at the pre-clinical course.

It is recommended to review the curriculum of the pre-clinical endodontic courses and provide a more-simulating environment to the clinical setting. Also, an increase in direct supervision and training time would be desirable. The introduction of rotary endodontic files might have an impact on the quality of root canal treatment provided. In addition, third year students should be allowed access to the clinical environment by assisting a fourth or fifth year student performing root canal treatment on a patient. This will assist in the overall comprehension of root canal treatment and the ability to evaluate the clinical situation and factors that may play a role in quality of endodontic treatments.

6. Conclusions

The technical quality of root canal obturation performed by undergraduate dental students using cold lateral compaction was found to be poor with only 29.2% having adequate quality, regardless of student level. This low percentage suggests that the training course in endodontics has to be improved at both preclinical and clinical levels. It is recommended that new techniques and instruments incorporated into the curriculum to enhance the quality of endodontic work.

Abbreviations

FDARC: Faculty of Dentistry Academic Research Committee; JUDH: Jordan University Dental Hospital; RCT: root canal treatment; UG: undergraduate.

Competing Interests

The authors declare that they have no competing interests.

References

- [1] Schilder H (1967) Filling root canals in three dimensions. *Dental Clinics of North America* 11, 723-44.
- [2] Eleftheriadis GI, Lambrianidis TP. Technical quality of root canal treatment and detection of iatrogenic errors in an undergraduate dental clinic. *Int Endod J*. 2005 Oct; 38(10):725-34.
- [3] 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 Nov; 39(11):867-72.
- [4] European Society of Endodontology. Quality guidelines for endodontic treatment consensus report of the European Society of Endodontology. *Int Endod J* 2006; 39: 921-30.
- [5] AAE Colleagues for Excellence Newsletter, 2009, www.aae.org/colleagues.
- [6] Hayes SJ, Gibson M, Hammond M, Bryant ST, Dummer PM. An audit of root canal treatment performed by undergraduate students. *Int Endod J*. 2001 Oct; 34(7):501-5.
- [7] Barrieshi-Nusair KM, Al-Omari MA, Al-Hiyasat AS. Radiographic technical quality of root canal treatment performed by dental students at the Dental Teaching Center in Jordan. *J Dent*. 2004 May; 32(4):301-7.
- [8] Lynch CD, Burke FM. Quality of root canal fillings performed by undergraduate dental students on single-rooted teeth. *Eur J Dent Educ*. 2006 May; 10(2):67-72.
- [9] Pettigrew LK, Jauhar S, Lynch CD, Savarrio L, Carrotte P, Hannigan A. An audit of the quality of root canal treatments performed by undergraduate dental students on single-rooted teeth in Glasgow dental hospital and school. *Eur J Prosthodont Restor Dent*. 2007 Jun; 15(2):72-6.
- [10] 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 Aug; 41(8):679-84.
- [11] Dadresanfar B, Mohammadzadeh Akhlaghi N, Vatanpour M, Atef Yekta H, Baradaran Mohajeri L. Technical quality of root canal treatment performed by undergraduate dental students. *Iran Endod J*. 2008 summer; 3(3):73-8.
- [12] Khabbaz MG, Protogerou E, Douka E. Radiographic quality of root fillings performed by undergraduate students. *Int Endod J*. 2010 Jun; 43(6):499-508.
- [13] Balto H, Al Khalifah Sh, 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 Apr; 43(4):292-300.
- [14] Elsayed RO, Abu-Bakr NH, Ibrahim YE. Quality of root canal treatment performed by undergraduate dental students at the University Of Khartoum, Sudan. *Aust Endod J*. 2011 Aug; 37(2):56-60.
- [15] Unal GC, Kececi AD, Kaya BU, Tac AG. Quality of root canal fillings performed by undergraduate dental students. *Eur J Dent*. 2011 Jul; 5(3):324-30.
- [16] Kumar M, Duncan HF. Radiographic evaluation of the technical quality of undergraduate endodontic 'competence' cases in the Dublin Dental University Hospital: an audit. *J Ir Dent Assoc*. 2012 Jun-Jul; 58(3):162-6.
- [17] Moradi S, Gharechahi M. Quality of root canal obturation performed by senior undergraduate dental students. *Iran Endod J*. 2014 winter; 9(1):66-70.
- [18] Chueh LH, Chen SC, Lee CM (2003) Technical quality of root canal treatment in Taiwan. *International Endodontic Journal* 36, 416-22.
- [19] Kerekes K, Tronstad L. Long-term results of endodontic treatment performed with a standardized technique. *J Endod*. 1979 Mar; 5(3):83-90.
- [20] Ray HA, Trope M. Periapical status of endodontically treated teeth in relation to the technical quality of the root filling and the coronal restoration. *Int Endod J*. 1995 Jan; 28(1):12-8.
- [21] Saunders WP, Saunders EM, Sadiq J, Cruickshank E. Technical standard of root canal treatment in an adult Scottish sub-population. *Br Dent J*. 1997 May 24; 182(10):382-6.
- [22] Bjørndal L, Laustsen MH, Reit C. Danish practitioners' assessment of factors influencing the outcome of endodontic treatment. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2007 Apr; 103(4):570-5.
- [23] Peculiene V, Maneliene R, Drukteinis S, Rimkuviene J. Attitudes of general dental practitioners towards endodontic standards and adoption of new technology: literature review. *Stomatologija*. 2009; 11(1):11-4.
- [24] Sonntag D, Bärwald R, Hülsmann M, Stachniss V. Pre-clinical endodontics: a survey amongst German dental schools. *Int Endod J*. 2008 Oct; 41(10):863-8.
- [25] Tchorz JP, Ganter PA, Woelber JP, Stampf S, Hellwig E, Altenburger MJ. Evaluation of an improved endodontic teaching model: do preclinical exercises have an influence on the technical quality of root canal treatments? *Int Endod J*. 2013 Jul 6. [Epub ahead of print]
- [26] De Moor R, Hülsmann M, Kirkevang L, Tanalp J, Whitworth J. European Society Of Endodontology: Undergraduate Curriculum Guidelines for Endodontology. *International Endodontic Journal*, 46, 1105-1114, 2013
- [27] Alkahtani A. Radiographic technical quality of root canal treatment performed by undergraduate students at college of dentistry, King Saud University. *J Pak dent assoc*. 2009; 18(4):162-166.
- [28] Qualtrough AJ, Dummer PM. Undergraduate endodontic teaching in the United Kingdom: an update *Int Endod J*. 1997 Jul; 30(4):234-9.
- [29] Qualtrough AJE, Whitworth JM, Dummer PMH. Preclinical endodontology: an international comparison. *Int Endod J* 1999; 32: 406-414.
- [30] Dummer PM. Comparison of undergraduate endodontic teaching programmes in the United Kingdom and in some dental schools in Europe and the United States. *Int Endod J*. 1991 Jul; 24(4):169-77.