

Full Length Research Paper

Quality of root canal filling performed by undergraduate students in a Saudi Dental College

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The aim of this study was to evaluate the outcomes of teaching endodontics to undergraduate students at Riyadh Colleges. This study was undertaken by assessing the technical quality of root canal obturation and the presence of procedural errors in root canal treatment cases performed by the final year dental students in clinics. All of the root canal treatment cases performed by the final year dental students in the 2nd semester of 2012 to 2013 were examined, with a total of 450 root canals from 241 teeth. The quality of root canal obturation was examined in relation to the length of the root filling based on the radiographic apex, the density of the obturation according to the presence of voids, and the taper of root canal fillings. The overall acceptable quality of the evaluated root canals was 36%. Of these canals, acceptable length, density, and taper were reported in 76.6, 46.4, and 73.8%, respectively. Overall, 9.3% of the treated root canals had procedural errors, and majority of these errors were found in canals of posterior mandibular teeth. Apical transportation was the most encountered error; it was found in 3.1% of the treated canals. The technical quality of the root canal treatments conducted by the students in this study was comparable to other studies. However, introducing new techniques and armamentaria might improve this quality.

Key words: Technical quality of obturation, undergraduate education, evaluation, education development.

INTRODUCTION

Endodontic treatment is an essential component of comprehensive dental therapy; it acts as a foundation for other successive treatments such as post and core. Additionally, the interrelationship between pulpal and periodontal tissues is well known, and failure in endodontic therapy can lead to significant damage of the surrounding periodontal tissues (Dugas et al., 2003). The success of endodontic therapy is remarkably affected by the radiographic technical quality of the canal(s) obturation (Boucher et al., 2002).

The technical quality of root canal therapy is best assessed by radiograph (Tsuneishi et al., 2005). The European Society of Endodontology (2006) considered root canal therapy to be acceptable when it shows a root canal filling of 0 to 2 mm shorter than the radiographic apex, dense without voids, and consistently tapered. Furthermore, this society expected graduating students to be competent at doing safe root canal therapy on single and multi-rooted teeth, in addition to thoroughly understanding the iatrogenic mishaps that might happen

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and the way to manage and prevent such accidents. Yet, internationally, in "Competencies for the New General Dentist" by the American Dental Education Association (ADEA, 2011), and in "Profile and Competencies for the Graduating European Dentist: Update 2009" (Cowpe et al., 2010), and also nationally in "Learning Outcomes for Bachelor Degree Programs in Dentistry" by the National Commission for Academic Accreditation and Assessment (NCAAA, 2011), the set expectation is that dentists strive to achieve the total health of their patients through oral health management without supervision. Those skills should be taught to students during their undergraduate studies.

Learning outcomes should be evaluated to determine whether the graduates of dental institutes meet those expected competencies. Several models of evaluation have been used in the educational context to evaluate the final outcomes of learners. Among them is Stufflebeam's CIPP model, which stands for evaluations of an entity's context, inputs, processes, and products. The purpose of product evaluation is to identify and assess the outcomes, either intended or unintended (Stufflebeam and Shinkfield, 2007).

Evaluation of the technical quality of root canal obturation, which is the outcome of teaching endodontics in the undergraduate stage, has been done in several countries for both undergraduate students and general practitioners. The results in most studies have shown inadequate quality of root canal obturation (Tables 1 and 2). In Saudi Arabia, three studies were conducted to evaluate the quality of root canal treatments done by undergraduate students (Al-Yahya, 1990; Al-Kahtani, 2009; Balto et al., 2010).

At Riyadh Colleges of Dentistry and Pharmacy, Saudi Arabian undergraduate students take the pre-clinical training of endodontics in two courses through two semesters, one course in level 6 and the other in level 7. At this stage, the students are requested to complete root canal treatment on extracted teeth for two anterior teeth, two premolars, and two molars. The primary technique of root canal instrumentation is the step-back technique using hand files with Gates Glidden to provide a straight line access, and the cold lateral condensation technique for obturation. Thereafter, students start clinical practice of root canal therapy for a variety of teeth for five successive semesters.

The aim of this study was to evaluate the outcomes of teaching endodontics to the undergraduate students at Riyadh Colleges. This study was undertaken by assessing the technical quality of root canal obturation and presence of procedural errors in root canal treatment cases performed by the final year dental students (levels 11 and 12) in clinics.

MATERIALS AND METHODS

All of the root canal treatment cases performed by the final year dental students in the 2nd semester of 2012/2013 were examined,

except the following: cases with incompletely formed roots; cases with previous root canal treatment; and cases that had poor quality of treatment radiographs.

Treatment was done under rubber dam using the same instrumentation and obturation techniques of the pre-clinical training which are step-back with hand files for instrumentation and lateral condensation for obturation. Working length was determined using Apex locator (Root ZX, J. Morita USA, Inc.) and confirmed radiographically. After obturation, each tooth was temporarily restored, then a post-operative digital X-ray was taken using a paralleling approach. All cases were done under direct supervision of endodontists or Advanced Restorative Dentistry specialists with an average staff to student ratio of 1:6.

Evaluation criteria

Evaluating the technical quality of root canal obturation was based on examining the pre-operative and post-operative radiographs. The radiographs were independently evaluated by two senior endodontists; the results were compared till agreement was reached. The radiographs were taken digitally using Kodak RVG 6100 machines and were shown on 17-inch flat screens; the evaluators magnified the images as needed. The quality of root canal obturation was assessed based on the length, density, and taper of the root canal filling. This criteria was adopted from Barrieshi-Nusair et al. (2004) (Table 3). The root canal filling was considered "acceptable" when all parameters were marked as acceptable.

In addition, the presence of procedural errors was recorded. The criteria for the detection of procedural errors were as follows:

- (1) Ledge formation was diagnosed when the root filling was at least 1 mm shorter than the working length and deviated from the original canal shape in teeth where root canal curvature occurred.
- (2) Apical transportation was diagnosed when the filling material was located on the outside curve of the canal at the apical third.
- (3) Apical perforation was diagnosed when the apical termination of the filled canal was different from the original canal terminus or when the filling material was extruding through the apical foramen.
- (4) Gouging was diagnosed when there was overextension of the access cavity undermining the enamel walls, as shown by the radiographs.
- (5) Root perforation was diagnosed when extrusion of filling material was detected in any other area of a root except the furcation area, the inner wall of the root, and through the apical foramen.
- (6) Strip perforation was diagnosed when extrusion of filling material was detected in the lateral (inner) wall of the root canal.
- (7) Missed canal was diagnosed (with mesial and distal angulated radiographs) when the canal filling was not centered in the root and there was a radiolucent space indicating presence of another canal.
- (8) Presence of fractured instrument was diagnosed when a fractured instrument was detected inside a root canal or when its tip extended into the periapical area.
- (9) Zipping was diagnosed when the apical termination of the filled canal appeared as an elliptical shape transported to the outer wall.
- (10) Furcation perforation was diagnosed when extrusion of filling material through the furcation area was detected in multi-rooted teeth.

Ethical considerations

This research has been conducted in full accordance with the World Medical Association Declaration of Helsinki. Before conducting the research, an approval has been taken from the "Ethical Committee of the Research Centre at Riyadh Colleges". This was a retrospective study in which patient information was anonymized and de-identified prior to analysis.

Table 1. Quality of root canal fillings performed by undergraduate students.

Authors	Country	Sample	Acceptable fillings	
			Number	Percentage
Hayes et al. (2001)	United Kingdom	157 Teeth	27	13
Barrieshi-Nusair et al. (2004)	Jordan	912 Root canals	432	47.4
Eleftheriadis and Lambrianidis (2005)	Greece	620 Root canals	343	55.3
Er et al. (2006)	Turkey	1893 Teeth	624	33
Lynch and Burke (2006)	Ireland	100 Single rooted teeth	63	63
Moussa-Badran et al. (2008)	France	304 Teeth	92	30.3
Balto et al. (2010)	Saudi Arabia	125 Teeth	550	23
Elsayed et al. (2010)	Sudan	265 Root canals	64	24.2
Khabbaz et al. (2010)	Greece	1109 Root canals	608	54.8
Rafeek et al. (2012)	India	460 Root canals	50	10.9

Table 2. Quality of root canal fillings performed by general dental practitioners.

Authors	Country	Sample	Acceptable fillings	
			Number	Percentage
Weiger et al. (1997)	Germany	215 Teeth	30	14
De Moor et al. (2000)	Belgium	312 Teeth	135	43.3
Boucher et al. (2002)	France	1982 Root canals	412	20.8
Chueh et al. (2003)	Taiwan	1867 Root canals	650	34.8
Boltacz-Rzepakowska and Pawlicka (2003)	Poland	282 Teeth	138	48.9
Segura-Egea et al. (2004)	Spain	93 Teeth	32	34.4
Loftus et al. (2005)	Ireland	152 Teeth	72	47.4
Siqueira et al. (2005)	Brazil	2051 Teeth	1167	56.9
Ridell et al. (2006)	Sweden	153 Teeth	75	49
Sunay et al. (2007)	Turkey	470 Teeth	188	40
Chen et al. (2007)	USA	169 Teeth	44	26
Toure et al. (2008)	Senegal	344 Root canals	61	17.7

Table 3. Radiographic evaluation criteria.

Parameter	Criteria	Definition
Length of root canal filling	Acceptable	Root filling ending from 0 to 2 mm short of radiographic apex
	Overfill	Root filling ending beyond the radiographic apex
	Underfill	Root filling ending more than 2 mm short of radiographic apex
Density of root canal filling	Acceptable	Density of root filling uniform without voids and canal space not visible
	Poor	Density of root filling not uniform with clear presence of voids and canal space is visible
Taper of root canal filling	Acceptable	Consistent taper from the coronal to the apical part of the filling, with good canal shape
	Poor	Inconsistent taper from the coronal to the apical part of the filling

RESULTS

The results were analyzed using SPSS® V17.0 software. In total, this study included 450 root canals from 241 teeth. Of these, 220 (48.9%) were located in the maxillary arch and 230 (51.1%) were in the mandibular arch. Majority (85.1%) of the canals were located in posterior teeth and to a lesser extent (14.9%) in anterior teeth.

Table 4 shows the quality of the root canal fillings according to length, density, and taper. Acceptable length, density, and taper were reported in 76.6, 46.4, and 73.8% of the evaluated root canals, respectively, with an overall acceptable quality of 36%. Although the acceptable quality of individual parameters was higher when the "whole tooth" was used as the measuring unit, the overall quality of teeth with filled root canals was lower (26.1%) than that of

Table 4. Quality of root canal fillings by tooth and root canal.

Criteria	Sample	Length			Density		Taper		Overall	
		Acceptable	Underfill	Overfill	Acceptable	Poor	Acceptable	Poor	Acceptable	Unacceptable
By canal	450	349 (77.6)	53 (11.8)	48 (10.7)	209 (46.4)	241 (53.6)	332 (73.8)	118 (26.2)	162 (36.0)	288 (64.0)
By tooth	241	199 (82.6)	20 (8.3)	22 (9.1)	111(46.1)	130 (53.9)	185 (76.8)	56 (23.2)	63 (26.1)	178 (73.9)

Table 5. Quality of root canal fillings by canal location and type.

Criteria	Sample	Length			Density		Taper		Overall	
		Acceptable	Underfill	Overfill	Acceptable	Poor	Acceptable	Poor	Acceptable	Unacceptable
Canal location										
Maxillary	220	181 (82.3) ^a	17 (7.7)	22 (10)	106 (48.2)	114 (51.8)	174 (79.1) ^a	46 (20.9)	85 (38.6)	135 (61.4)
Mandibular	230	168 (73) ^b	36 (15.7)	26 (11.3)	103 (44.8)	127 (55.2)	158 (68.7) ^b	72 (31.3)	77 (33.5)	153 (66.5)
Canal type										
Anterior	67	57 (85.1)	4 (6)	6 (9)	27 (40.3)	40 (59.7)	53 (79.1)	14 (20.9)	20 (29.9)	47 (70.1)
Posterior	383	292 (76.2)	49 (12.8)	42 (11)	182 (47.5)	201 (52.5)	279 (72.8)	104 (27.2)	142 (37.1)	241 (62.9)

Figures with different symbols are statistically different.

individual root canals.

Table 5 shows the technical quality of root canal fillings by canal position and type. In general, the maxillary root canals had a better quality of individual parameters than the mandibular canals; the difference was statistically significant for the length and taper parameters ($P < 0.05$). Similarly, canals located in anterior teeth had better length and taper than their posterior counterparts, while the latter had a better density. However, no significant differences were noted for all of the three parameters ($P > 0.05$). Overall, root canals in maxillary and posterior teeth had a better quality than those in mandibular and anterior teeth without reaching a significant level.

The incidence of procedural errors by the students during treatment is shown in Table 6. Overall, 42 (9.3%) of the treated root canals had procedural errors, and the majority of these errors were found in canals of posterior mandibular teeth.

DISCUSSION

The quality of root canal treatment carried out by general practitioners has been reported to be inadequate in many countries (Table 2). Some authors attributed this inadequacy to undergraduate endodontic training. Because it has been suggested that dentists continue to use the techniques they were taught during undergraduate training, it is important to regularly evaluate the outcomes of clinical undergraduate endodontic training.

The aims of this study were to evaluate the technical quality of root canal fillings performed by final year undergraduate students at the Riyadh

Colleges of Dentistry and Pharmacy and to compare the results with the findings reported in other dental schools. To accomplish this goal, the digital periapical radiographs of 241 endodontically treated teeth containing 450 root canals were evaluated according to the guidelines suggested by international endodontic organizations. According to these guidelines, the root canal fillings should end (0 to 2 mm) from the radiographic apex, have a uniform taper from the canal end to the orifice, and have a uniform density without voids (European Endodontic Society, 2006).

This study revealed that the overall quality was acceptable in 36% of the root canals and 26.1% of teeth. Previously published studies reported that

Table 6. Incidence of procedural errors observed in the study by canal type location and type ($n=450$).

Procedural error	Overall (%)	By canal location (%)		By canal type (%)	
		Maxillary	Mandibular	Anterior	Posterior
Ledge	11 (2.4)	0 (0)	11 (100)	0 (0)	11 (100)
Transportation	14 (3.1)	3 (21.4)	11 (78.6)	1 (7.1)	13 (92.9)
Gouging	5 (1.1)	1 (20)	4 (80)	1 (20)	4 (80)
Apical perforation	5 (1.1)	1 (20)	4 (80)	2 (40)	3 (60)
Root perforation	1 (0.2)	0 (0)	1 (100)	0 (0)	1 (100)
Stripping perforation	1 (0.2)	0 (0)	1 (100)	0 (0)	1 (100)
Fractured instruments	5 (1.1)	3 (60)	2 (40)	0 (0)	5 (100)

10.1 to 63% of root canal-filled teeth (Hayes et al., 2001; Er et al., 2006; Moussa-Badran et al., 2008; Balto et al., 2010; Elsayed et al., 2011; Rafeek et al., 2012) and 10.9 to 63% of individual root canals (Barrieshi-Nusair et al., 2004; Eleftheriadis and Lambrianidis, 2005; Lynch and Burke, 2006; Khabbaz et al., 2010; Rafeek et al., 2012) had an acceptable technical quality. The differences between these studies can be attributed to the differences in the study design and the evaluation criteria. Nevertheless, majority of these studies concluded that the quality of root canal fillings performed by undergraduate students is poor and that there is a need to improve the teaching of endodontics at the pre-clinical and clinical levels.

In the current study, the quality of the root canal fillings was evaluated using three criteria: the length, density, and taper. Epidemiological studies have shown that the length of the root canal fillings had a significant influence on treatment outcome, with fillings ending (0 to 2 mm) from the radiographic apex having the best prognosis (Sjogren et al., 1990; Saunders et al., 1997; Chugal et al., 2003). In the current study, 76.6% of the individual root canals had an acceptable length. This finding is higher than the results of other studies (Barrieshi-Nusair et al., 2004; Eleftheriadis and Lambrianidis, 2005; Lynch and Burke, 2006; Khabbaz et al., 2010; Rafeek et al., 2012). At the institution (Riyadh Colleges of Dentistry and Pharmacy), the students determine the working length using electronic apex locators and confirm it radiographically, and this may account for the relatively high percentages of acceptable length canal fillings. This result is in line with the findings of a recent study (Tchorz et al., 2014) that concluded that the early introduction of electronic apex locators during pre-clinical training improves the quality of root canals performed by undergraduate students in the clinical setting.

About 73.8% of the evaluated root canals had acceptable taper. This result is generally higher than the findings of previous studies (Er et al., 2006; Al-Qahtani, 2009; Balto et al., 2010; Rafeek et al., 2012) but comparable to the findings of Barrieshi-Nusair et al. (2004). A tapered root canal is essential to facilitate the introduction

of obturation materials and instruments inside the root canal system, creates a resistance form for obturation materials, and reduces the potential for overextensions (Schilder, 1974).

Additionally, the quality of each root filling was assessed by its radiodensity and the presence of voids within the filling or between the filling and canal walls. Eriksen and Bjertness (1991) found that the incidence of apical periodontitis is higher in root-filled teeth with inadequate densities. Inadequate density of root canal obturation may lead to failure of root canal treatment because of microleakage along the root filling (Kirkevang et al., 2000). In contrast to the high percentage of acceptable length and taper of the root canal fillings noted in the current study, only 46.6% of the root canal fillings had an acceptable density. This finding is comparable to findings of previous studies (Er et al., 2006; Moussa-Badran et al., 2008; Balto et al., 2010; Rafeek et al., 2012). The high incidence of unacceptable density among undergraduate students could be in part due to the inexperience of the students in applying sufficient force when using hand or finger spreaders in non-flared or minimally-flared canals. Furthermore, the high incidence of unacceptable fill density may be due to an insufficient number of accessory gutta-percha points being used during the lateral condensation process (Khabbaz et al., 2010).

The statistical analysis demonstrated no significant differences in the overall number of acceptable root canal fillings according to canal location (maxillary versus mandibular) or type (anterior versus posterior). The findings of previous studies generally agree that although the location has little effect on the overall quality of root fillings, the posterior teeth (particularly molars) have poorer quality fillings than anterior teeth (Barrieshi-Nusair et al., 2004; Eleftheriadis and Lambrianidis, 2005; Lynch and Burke, 2006; Balto et al., 2010; Khabbaz et al., 2010; Rafeek et al., 2012). This may be in part attributed to the more complex anatomy of these teeth, which are usually associated with narrow and curved canals that require a lot of time and patience in order to properly clean, shape and obturate.

In addition to the aforementioned variables that may affect the quality of root canal fillings, the overall quality can be influenced by the type of instrumentation and the obturation technique used during root canal treatment. In majority of the previous studies (Hayes et al., 2001; Barrieshi-Nusair et al., 2004; Eleftheriadis and Lambrianidis, 2005; Er et al., 2006; Lynch and Burke, 2006; Balto et al., 2010; Elsayed et al., 2010; Khabbaz et al., 2010; Rafeek et al., 2012), the undergraduate students instrumented the root canals with stainless steel files using the step-back technique and obturated the canal spaces with cold lateral condensation. Both techniques are widely taught for undergraduate students and are indicated for canals with mild or moderate curvature. The step-back technique, when used by inexperienced students, may produce procedural errors such as ledges, blocking, and transportation of the root canal, which may lead to incomplete cleaning and underfilling (Gambarini, 1999; Kfir et al., 2004). Moreover, the use of stainless steel instruments may produce a high incidence of procedural errors, which may reduce the prognosis (Cheung and Liu, 2009). On the other hand, the cold lateral condensation technique in a non-flared or minimally flared root canal may create voids (Khabbaz et al., 2010). Recently, Silvani et al. (2013) investigated the quality of root canal fillings performed by undergraduate students using rotary nickel-titanium files (WaveOne) and preheated gutta-percha (Thermafil) in the clinical setting. The authors of that study found that 26 of the 28 (92.9%) root canal fillings had adequate length, and none of them had voids. Further studies are required to compare the quality of the root canal fillings made using conventional and contemporary techniques.

In the light of the findings of the current study, there is a need to revise the endodontic curricula in order to improve the technical quality of root canal treatment performed by undergraduate dental students. Such revision may include extending the training time in the pre-clinical and clinical sessions as well as the gradual introduction of new technology, such as nickel-titanium rotary systems and heated gutta-percha techniques, into the curricula. Finally, it will be of great interest to repeat the same research in the future to ensure the predictability of the new educational measures.

Conclusions

The technical quality of root canal fillings performed by undergraduate dental students was acceptable in 36.6% of cases. To improve the quality of treatment performed by these students, the endodontic curricula must be revised to increase the training time at the pre-clinical and clinical levels and to introduce new techniques and armamentaria into the curricula.

Conflicts of interest

The authors declare that they have no conflicts of

interest.

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