

Technical quality of root fillings performed by undergraduate students in Saudi Arabia

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Abstract

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Aim To evaluate the technical quality of root fillings performed in the undergraduate clinic of the Dental College, King Saud University, Saudi Arabia and to compare the technical quality of root canal treatment between the 4th- and 5th-year students.

Methodology A random sample of 710 records of patients who had received dental treatment by undergraduate students at the College of Dentistry (Malaz University Campus), between the years of 2005–2008, was investigated. The final sample consisted of 550 root filled teeth in 459 patients. For each root filled tooth, at least three periapical radiographs were examined: preoperative, working length determination and post-operative. The length, density and taper of root fillings, as well as the presence of procedural errors, were recorded. 'Acceptable' filling quality was defined as having adequate length, density and taper with the absence of any procedural error. Results were evaluated statistically using chi-square test.

Results One hundred and twenty-five of 550 root filled teeth (23%) had a root filling that was classified as 'acceptable'. There was no statistical significant association between the 4th- and 5th-year students in terms of length ($P = 0.134$), density ($P = 0.081$) and taper ($P = 0.590$). Seventy-five (14%) treated teeth had ledges, 40 (7%) had apical transportation and 37 (7%) had apical root perforation. Ledges had significant association with the level of student ($P < 0.0001$) and were greater in the cases of 4th-year students (18%) compared to the 5th-year students (8%), whilst root perforations had also significant association with level of students ($P = 0.016$) and were more in the 5th-year cases (3%) compared to the 4th-year cases (0.3%).

Conclusions The technical quality of root fillings placed by undergraduate dental students was classified as 'acceptable' in 23% of cases. There was little difference between 4th- and 5th-year students in the overall quality of root fillings.

Keywords: procedural errors, radiographic records, technical quality, undergraduate clinic.

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Introduction

The prognosis of root canal treatment (RCT) depends on many variables; amongst them is the technical quality of the root filling. (Saunders *et al.* 1997, Boucher *et al.* 2002).

Several variables affect the technical quality of root fillings, such as the length of the filling material in relation to the radiographic apex, the density of the root filling material (presence of voids), the taper of the canal and the incidence of procedural errors. Methods used to evaluate the technical outcome of RCT have been based mostly on radiographic evaluation (Buckley & Spångberg 1995, Saunders *et al.* 1997).

Root fillings placed within 0–2 mm of the radiographic apex are associated with less post-treatment disease than those that are filled with a distance more

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than 2 mm from the radiographic apex (Saunders *et al.* 1997, Boltacz-Rzepkowska & Pawlicka 2003). Sjögren *et al.* (1990) and Smith *et al.* (1993) have reported that the length of the root filling, relative to the radiographic apex, significantly affected the outcome of RCT with 87–94% healing rates associated with root filling ending 0–2 mm from the radiographic apex. Lower healing rates were associated with ‘short’ root fillings ending more than 2 mm from the radiographic apex (68–77.6%) and with long fillings extruding beyond the apex (75–76%).

The correlation between density of the root filling and prognosis is not as clear as the proximity of the root filling to the radiographic apex. Several studies (Sjögren *et al.* 1990, Marques *et al.* 1998) have reported no difference in prognosis between adequately and inadequately compacted root fillings. Whilst others (Strindberg 1956, Kerekes & Tronstad 1979, Chugal *et al.* 2003, Stoll *et al.* 2005) have found that a root filling that is less dense and non-homogenous will have a negative impact on the outcome. Chugal *et al.* (2003) demonstrated that root fillings with homogenous mass of filling material and with no voids are strongly correlated with a lower risk of post-treatment disease.

Canal preparation must flow and progressively narrow in an apical direction (Coffae & Brilliant 1975). Starting at the orifice and moving apically, every cross-sectional diameter of the filling material should decrease with the smallest cross-sectional diameter at the apical terminus of the canal (Coffae & Brilliant 1975). A continuous taper in the apical third of the shaped canal creates a resistance form for gutta-percha and reduces the potential for overextensions (Schilder 1974).

Procedural errors compromise canal cleaning and shaping and result in incomplete root filling, which jeopardizes the outcome of the treatment (Lambrianidis 2001). Canal transportation can result in inadequately cleaned canals with the possible outcome of persistent apical pathosis (Peters 2004). Moreover, it has been shown that canal transportation is correlated with leakage along the root filling (Wu *et al.* 2000). Perforations are associated with infection of the periodontal ligament and the alveolar bone and consequently impair the healing process (Seltzer *et al.* 1970).

Endodontic epidemiological studies had been carried out in different population groups. The percentage of adequate root fillings performed by undergraduate students in a Turkish population was 33% (Er *et al.* 2006). Whilst in Taiwan, approximately 70% of the teeth had inadequate root fillings, inadequate length or

poor sealing density (Chueh *et al.* 2003). The technical quality of root fillings performed by undergraduate dental students in Jordan using step-back preparation and lateral condensation was found to be acceptable in less than 50% of cases (Barrieshi-Nusair *et al.* 2004). On the other hand, the quality of RCT performed by undergraduate students in Greece was classified as acceptable in more than 50% of cases (Eleftheriadis & Lambrianidis 2005). More recently, Bierenkrant *et al.* (2008) reported that the technical quality of root fillings performed by endodontists in Australia complied with current guidelines in 77.4–91.0% of roots. All variables were examined and confirmed high levels of technical proficiency. There were very few instances of canal transportation and/or procedural errors.

In King Saud University, College of Dentistry (KSU-CD), Saudia Arabia students are taught endodontics in three levels. A preclinical course is given in the 3rd year, where students are trained to perform root fillings on extracted teeth. They are expected to complete RCT of at least three anteriors, two bicusps and three molar teeth. The other two courses are clinical, where students are expected in their 4th and 5th years to perform non-surgical RCT on a variety of teeth.

Only one study (Al-Yahya 1990) evaluated the performance and the frequency of complications of RCT performed by undergraduate dental students at KSU-CD. The results showed that the most common treatment complications encountered were short root fillings, ledging and voids. Therefore, the aims of the present study were as follows:

- To evaluate the technical quality of root fillings performed in the undergraduate clinic of KSU-CD using radiographic records (namely ledges, apical transportation, apical perforation, gouging (overextension of access cavity), root perforation or missed canal).
- To compare the 4th- and 5th-year undergraduate students in terms of technical quality of root fillings.

Materials and methods

Cases selection

A random sample of 710 records of female patients who had received dental treatment by undergraduate students at the College of Dentistry, Malaz University Campus (MUC), King Saud University between the years of 2005–2008 was selected and investigated.

Evaluation of the technical quality of root fillings and detection of procedural errors were based on preoperative, working length and postoperative periapical

Table 1 The distribution of teeth in the sample

Student level	Incisors	Canines	Premolars	Molars	Total
4th year	65	21	95	119	300 (54.5)
5th year	48	45	96	61	250 (45.5)
Total	113 (20.6)	66 (12)	191 (34.7)	180 (32.7)	550 (100)

Values in parentheses are in percentage.

radiographs. Records missing one or more of these radiographs were excluded, as well as records with poor quality radiographs. As a result, 459 records were evaluated. These records consisted of 550 root filled teeth with the distribution shown in Table 1.

All RCTs were carried out by 4th- and 5th-year undergraduate students under the supervision of senior endodontists and Saudi Board in Advanced Restorative Dentistry (SBARD) residents with an average staff to student ratio of 1 : 7 for the 4th year and 1 : 12 for the 5th year. An aseptic technique with rubber dam isolation was applied in all cases. To facilitate straight-line access, Gates-Glidden drills number 2, 3 and 4 were used in most cases (Premier Dental, Norristown, PA, USA). Working lengths were determined with the use of radiographs and/or apex locators (Root ZX 'J. Morita USA, Inc.'). All teeth were instrumented with step-back technique using stainless steel K-files (Dentsply, Tulsa, Okla, USA) of 0.02 taper and irrigation with 1% sodium hypochlorite solution using a syringe. Root fillings were carried out with gutta-percha and AH-26 sealer (Dentsply) using a cold lateral condensation technique. The teeth were restored with temporary filling materials. Postoperative radiographs were then exposed using a paralleling technique.

Evaluation of the technical quality of root fillings and detection of procedural errors

Evaluating the technical quality of root fillings and detecting the procedural errors were based on the

preoperative, working length determination and post-operative radiographs (mesial and distal angulated radiographs were included for multi-rooted teeth). The radiographs were evaluated independently by two senior endodontists (with minimum experience of 8 years). Films were examined using handheld X-ray film viewer with magnifying lens that could be moved in different angulations for varying magnification (Meta Biomed Co., LTD, Cheongju City, Korea). The results were compared, and a final evaluation was agreed. In case of disagreement, the two examiners discussed the case to reach a consensus.

The quality of the root fillings was evaluated according to the distance between the end of the filling and the radiographic apex, the density of the filling and the taper of the root filling using the criteria of Barrieshi-Nusair *et al.* (2004) with modification (Table 2).

In addition, the presence of ledge, apical transportation, apical perforation, gouging, root perforation, strip perforation, missed canal, fractured instrument, lack of straight-line access, zipping and furcation perforation was examined.

The criteria for the detection of procedural errors were as follows:

- 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 (Eleftheriadis & Lambrianidis 2005).
- Apical transportation was diagnosed when the filling material was located on the outside curve of the canal at the apical third.
- 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.
- Gouging was diagnosed when there was overextension of the access cavity undermining the enamel walls, as apparent by the radiographs.

Parameter	Criteria	Definition
Length of root canal filling	Adequate	Root filling ending ≤ 2 mm from radiographic apex
	Over-filling	Root filling beyond the radiographic apex
	Short-filling	Root filling > 2 mm from radiographic apex
	Flush	Root filling at the radiographic apex
Density of root canal filling	Adequate	No voids present in the root filling or between root filling and root canal walls
	Inadequate	Voids present in the root filling or between root filling and root canal walls
Taper of root canal filling	Adequate	Consistent taper from the orifice to the apex
	Inadequate	No consistent taper from the orifice to the apex

Table 2 The criteria used to assess radiographic quality of the root fillings

- Root perforation was diagnosed when extrusion of filling material was detected in any other area of a root except the furcation area and the inner wall of the root (Eleftheriadis & Lambrianidis 2005).
- Strip perforation was diagnosed when extrusion of filling material was detected in the lateral (inner) wall of the root canal (Eleftheriadis & Lambrianidis 2005).
- Missed canal was diagnosed (with mesial and distal angulated radiographs) when the canal filling was not centred in the root and there was a radiolucent space indicating presence of another canal.
- Presence of fractured instrument was diagnosed when a fractured instrument was detected inside a root canal or with its tip extending into the periapical area (Eleftheriadis & Lambrianidis 2005).
- Lack of straight-line access was diagnosed when the coronal third of the filling was not in an immediate direct line under the access cavity.
- Zipping was diagnosed when the apical termination of the filled canal appeared as an elliptical shape transported to the outer wall.
- Furcation perforation was diagnosed when extrusion of filling material through the furcation area was detected in multi-rooted teeth (Eleftheriadis & Lambrianidis 2005).

Statistical analysis

For statistical analysis, the tooth was considered as a unit with the highest score of all roots contributing the score. 'Acceptable' filling quality was defined as adequate length, density and taper with the absence of any procedural error. Inter-examiner agreement was measured by Cohen's kappa (k) values. The analysis of the data was performed using SPSS 14.0 for Windows (SPSS Inc., Chicago, IL, USA). Sample means and their standard errors were used to describe every item listed on the evaluation form. The chi-squared statistic was used for statistical evaluation of the results. A P -value <0.05 was considered statistically significant.

Results

The k -value for inter-examiner reliability was 0.95 for length of root filling, 0.96 for density, 1.00 for taper and 0.85 for procedural errors. One hundred and twenty-five of 550 root canals (23%) had a root filling that was classified as 'acceptable'. There was no significant difference between 4th- and 5th-year students in the overall quality of root canal filling (Table 3). The frequency of root canals with an 'acceptable' filling was significantly greater in the anterior teeth (incisors and canines) (74%) than in premolars (25%) ($P = 0.001$) or in molars (6%) ($P = 0.001$) (Table 4). There was no significant difference between the 4th- and 5th-year students in terms of length ($P = 0.134$), density ($P = 0.081$) and taper ($P = 0.590$) (Table 5). In relation to tooth type, a significant difference was observed between molars and the remaining tooth types. Molars were worst in terms

Table 3: Overall quality of root fillings in relation to the student year of study

Student's level	Number of teeth	Quality	
		Acceptable	Unacceptable
4th year	300 (54.5)	64 (21.3)	236 (78.7)
5th year	250 (45.5)	61 (24.4)	189 (75.6)
Total	550 (100)	125 (22.7)	425 (77.3)

Values in parentheses are in percentage.

Table 4 Overall quality of root fillings in relation to tooth type

Tooth type	Number of teeth	Quality	
		Acceptable	Unacceptable
Incisors	113 (20.6)	44 (38.9)	69 (61.1)
Canines	66 (12)	23 (34.8)	43 (65.2)
Premolars	191 (34.7)	47 (24.6)	144 (75.4)
Molars	180 (32.7)	11 (6.1)	169 (93.9)
Total	550 (100)	125 (22.7)	425 (77.3)

Values in parentheses are in percentage.

Table 5 The length, density and taper of root fillings in 4th- and 5th-year students

Student's level	Number of teeth	Length				Density		Taper	
		Adequate	Short-filling	Flush	Over-filling	Adequate	Inadequate	Adequate	Inadequate
4th year	300 (54.5)	190 (63.3)	40 (13.3)	41 (13.7)	29 (9.7)	95 (31.7)	205 (68.3)	182 (60.7)	118 (39.3)
5th year	250 (45.5)	181 (72.4)	22 (8.8)	26 (10.4)	21 (8.4)	97 (38.8)	153 (61.2)	146 (58.4)	104 (41.6)
Total	550 (100)	371 (67.4)	62 (11.3)	67 (12.2)	50 (9.1)	192 (34.9)	358 (65.1)	328 (59.6)	222 (40.4)

Values in parentheses are in percentage.

Table 6 The length, density and taper in relation to tooth type

Tooth type	Number of teeth	Length				Density		Taper	
		Adequate	Short-filling	Flush	Over-filling	Adequate	Inadequate	Adequate	Inadequate
Incisors	113 (20.6)	91 (80.5)	3 (2.7)	14 (12.4)	5 (4.4)	54 (47.8)	59 (52.2)	84 (74.3)	29 (25.7)
Canines	66 (12)	53 (80.3)	6 (9.1)	5 (7.6)	2 (3.0)	34 (51.5)	32 (48.5)	51 (77.3)	15 (22.7)
Premolars	191 (34.7)	151 (79.1)	15 (7.9)	11 (5.8)	14 (7.3)	79 (41.4)	112 (58.6)	127 (66.5)	64 (33.5)
Molars	180 (32.7)	76 (42.2)	38 (21.1)	37 (20.6)	29 (16.1)	25 (13.9)	155 (86.1)	66 (36.7)	114 (63.3)
Total	550 (110)	371 (67.5)	62 (11.3)	67 (12.2)	50 (9.1)	192 (34.9)	358 (65.1)	328 (59.6)	222 (40.4)

Values in parentheses are in percentage.

of length, density and taper (Table 6). Amongst the procedural errors, 75 (14%) teeth had ledges, 40 (7%) had apical transportation and 37 (7%) had apical perforations. Ledges ($P < 0.0001$) and root perforations ($P = 0.016$) had a significant association with the level of students. Ledges were more prevalent in cases of the 4th-year students (18%) compared to the 5th-year students (8%), and root perforations were more prevalent in the 5th-year cases (3%) compared to the 4th-year cases (0.3%) (Table 7). Posterior teeth (premolars and molars) had significantly more ledges, apical transportation, apical perforation, root perforation and strip perforation, than anterior teeth (Table 8).

Discussion

The k-values of 0.95, 0.96, 1.00 and 0.85 in the ratings of root filling length, density, taper and procedural errors, respectively, indicate excellent agreement between the examiners because of well-defined criteria used. The data used in this study consisted of a sample

Table 7 The incidence of the procedural errors among 4th- and 5th-year students

Procedural errors	4th year	5th year	Total	P-value
Ledge*	55 (18.3)	20 (8)	75 (13.6)	0.000
Apical transportation	19 (6.3)	21 (8.4)	40 (7.3)	0.353
Apical perforation	25 (8.3)	12 (4.8)	37 (6.7)	0.100
Gouging	2 (0.7)	7 (2.8)	9 (1.6)	0.050
Root perforation*	1 (0.3)	7 (2.8)	8 (1.5)	0.016
Strip perforation	3 (1)	5 (2)	8 (1.5)	0.329
Missed canal	3 (1)	5 (2)	8 (1.5)	0.329
Fractured instrument	1 (0.3)	2 (0.8)	3 (0.5)	0.459
Lack of straight-line access	0	2 (0.8)	2 (0.4)	0.121
Zippering	0	1 (0.4)	1 (0.2)	0.273
Furcation perforation	0	0	0	0

Values in parentheses are in percentage.

*Significantly different relation.

of periapical radiographs of patients who received RCT at College of Dentistry, MUC, King Saud University. All periapical radiographs were taken during routine RCT

Procedural errors	Incisors	Canines	Premolars	Molars	Total	P-value
Ledge*	2 (1.8)	2 (3)	11 (5.8)	60 (33.3)	75 (13.6)	0.000
Apical transportation*	1 (0.9)	2 (3)	22 (11.5)	15 (8.3)	40 (7.3)	0.003
Apical perforation*	2 (1.8)	4 (6.1)	12 (6.3)	19 (10.6)	37 (6.7)	0.033
Gouging	2 (1.8)	1 (1.5)	6 (3.1)	0	9 (1.6)	0.127
Root perforation*	0	3 (4.5)	1 (0.5)	4 (2.2)	8 (1.5)	0.047
Strip perforation*	0	1 (1.5)	0	7 (3.9)	8 (1.5)	0.008
Missed canal	0	0	3 (1.6)	5 (2.8)	8 (1.5)	0.182
Fractured instrument	0	1 (1.5)	1 (0.5)	1 (0.6)	3 (0.5)	0.622
Lack of straight-line access	0	0	0	2 (1.1)	2 (0.4)	0.248
Zippering	0	0	0	1 (0.6)	1 (0.2)	0.560
Furcation perforation	0	0	0	0	0	0

Values in parentheses are in percentage.

*Significantly different relation.

Table 8 The incidence of procedural errors in relation to tooth type

procedures within a dental student practice and were not taken specifically for this study. An effort was made to exclude most of the radiographs with superimposed canal fillings or over-projection of anatomical structures, to eliminate the possibility of radiographic misinterpretation.

KSU-CD is housed in two separate buildings, one for the male students and the other for the female students. This study was conducted in the female building (Malaz University Campus-MUC) that it is dedicated to the treatment of women and children and that would not have any bearing on the results, as it is known that outcome is not affected by gender (Kerekes & Tronstad 1979, Sjögren *et al.* 1990).

Although each root was scored individually, the tooth was considered as a unit, and the highest score of all roots (in multi-rooted teeth) was assigned. Ultimately, failure of one root will lead to failure of the tooth as a whole, so it seemed logical to consider them as one unit.

The current study analysed the technical quality of root fillings achieved by 4th- and 5th-year dental students and showed that 23% of the teeth fulfilled the criteria of an acceptable root canal filling. This frequency was lower than the 76% reported by Al-Yahya (1990), 39% reported by Dugas *et al.* (2003), 47% reported by Barrieshi-Nusair *et al.* (2004) and 55% reported by Eleftheriadis & Lambrianidis (2005). On the contrary, it was higher than the 13% reported by Hayes *et al.* (2001), who evaluated treatment performed by undergraduate students. Nevertheless, it is difficult to compare these studies because of the different criteria that were used.

The frequency of teeth with an 'acceptable' root filling was significantly greater in the anterior teeth (74%) than in premolars (25%) ($P = 0.001$) or in molars (6%) ($P = 0.001$). Such results are consistent with the findings of Boucher *et al.* (2002) and Eleftheriadis & Lambrianidis (2005) who reported that the technical quality was 'acceptable' more often in anterior teeth. This may be explained partly by the anatomy of such teeth.

In the present study, the percentage of root fillings with adequate length was 67%. This frequency was close to those reported by Er *et al.* (2006) (70%) and superior to others; Lupi-Pegurier *et al.* (2002) (39%), Chueh *et al.* (2003) (62%) and Eleftheriadis & Lambrianidis (2005) (63%). These differences may be the result of the fact that dental students take several radiographs during RCT until they obtain correct working lengths. Additionally, some students used the

electronic apex locator to estimate the working length before exposing any radiographs.

Studies that addressed the lateral adaptation of the root filling as a criterion generally agreed that if void was present between the filling and the canal walls, the filling should be categorized as inadequate. Kirkevang *et al.* (2001) reported that inadequate density may lead to failure of RCT because of microleakage along the root filling. Similarly, Eriksen & Bjertness (1991) stated that the prevalence of apical periodontitis was higher in root filled teeth with poor densities. The result of the present study indicated that adequate density was achieved in 35% of teeth; such frequency was lower than the 64% reported by Yoldas *et al.* (2004) and 53% reported by Sagsen *et al.* (2006). However, it is difficult to compare the studies as a result of differences in the sample size.

Studies evaluating the radiographic quality of RCT were mostly based on the evaluation of both the length and the density of the root filling (Helminen *et al.* 2000, Kirkevang *et al.* 2001, Lupi-Pegurier *et al.* 2002 and Dugas *et al.* 2003). However, according to the European Society of Endodontology (2006), the prepared root canal should be uniformly tapered from crown to apex. The frequency of teeth with adequate taper of root filling in the present study (60%) was lower than the results of previous studies (Barrieshi-Nusair *et al.* 2004, Er *et al.* 2006, and Sagsen *et al.* 2006). This could be attributed to the highly subjective assessment of this variable radiographically.

Indistinguishably, the overall acceptable quality of RCT was similar between the 4th- and 5th-year students, showing that the improvement in the outcome with more senior students is not high enough to obtain statistically significant difference.

All procedural errors cannot be depicted on radiographs. Over-instrumentation, for example, which may push pulp remnants and microorganisms beyond the apex causing acute apical periodontitis, can be detected by the use of radiographs only when it is followed by extrusion of filling material but not during previous stages of RCT (Lambrianidis 2001).

The most common procedural errors encountered in this study were ledges (14%), apical transportations (7%) and apical perforations (7%). The incidences of all procedural errors that were identified in this study were similar in occurrence between the 4th- and 5th-year students. With the exception of ledges, which were found more in teeth that had been treated by 4th year students (18%). This might be because of the fact that 4th- year students are less familiar with the cases that

have curved canals when compared to the 5th-year students and had treated less number of teeth (i.e. less experience). Root perforations in the 5th-year students' treatments were higher (3%) compared to the 4th year (0.3%). This could be partly because 5th-year students may be more confident whilst working and take fewer radiographs during the treatment, which could increase the risk of procedural errors, or it could be that their clinical supervision is less. (Ratio was 1 : 12).

Anterior and premolar teeth were ledged less frequently than molars. Molars have a higher prevalence of narrow and curved canals, which make RCT more challenging. In molars, a ledge occurred in 33% of teeth. This percentage is lower than that reported by Greene & Krell (1990) (46%), Kapalas & Lambrianidis (2000) (52%) and Eleftheriadis & Lambrianidis (2005) (39%). The use of the Gates-Glidden to straighten the coronal portion of the canal may lead to the low percentage of ledges in the present study. The relatively high percentage of apical transportation (7%) and apical perforation (7%) could be partly because of the use of stainless steel files. Several investigators reported that nickel–titanium files cause less transportation than stainless steel files (Gambill *et al.* 1996, Schafer & Lau 1999). Weine *et al.* (1976) observed that the instrument tip had an important effect on the cutting control during root canal preparation. More specifically, if stainless steel files with active tips were used, the inherent stiffness enhanced the cutting of dentine on the concave side of the curvature, resulting in some straightening and ledging (Miserendino *et al.* 1985).

The low percentage of adequate root canals assessed in this study could be attributable to many reasons. These may include factors such as the design of the study, the criteria followed, the techniques used for RCT and the clinical requirements. Furthermore, some of the supervision for undergraduate students was undertaken by non-specialists and not totally by endodontists. The student to staff ratio at the clinic also fluctuated during the academic year.

Step-back preparation and cold lateral condensation are the standard techniques that have been taught to the undergraduate dental student. Cailleteau & Mullaney (1997) reported that this technique is the most widely taught and used technique in the United States Dental Schools. Qualtrough *et al.* (1999) found that a number of schools in North America, Scandinavia and Western Europe had incorporated usage of nickel–titanium hand instruments into their routine preclinical teaching. Some have even incorporated the usage of rotary nickel–titanium instrumentation in

their undergraduate teaching courses. Moreover, many studies (Pettiette *et al.* 1999, Park 2001, Pettiette *et al.* 2001, and Gluskin *et al.* 2001) reported that when dental students used either hand or rotary nickel–titanium instruments, canals were prepared with less procedural errors and more successful treatment occurred compared to using conventional stainless steel instruments.

Whilst the technical quality of root fillings, as portrayed by radiographs, is important for the outcome of the treatment, it may not reflect the quality of the treatment in general. The antiseptic and aseptic efforts during treatment, quality of canal preparation, materials used and treatment routines including antibacterial regimen are amongst many prognostic factors that remain inconclusive from epidemiological studies (Eriksen *et al.* 2002).

Conclusion

The technical quality of RCT performed by undergraduate dental students was classified as 'acceptable' in 23% of cases. The frequency of root canals with an 'acceptable' filling was significantly greater in the anterior than in the posterior teeth. There was no difference between 4th- and 5th-year students in the overall quality of RCT.

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