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

H. Balto, Sh. Al Khalifah, S. Al Mugairin, M. Al Deeb & E. Al-Madi
Department of Restorative Dental Sciences, Dental College, King Saud University, Riyadh, Saudi Arabia

Abstract

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 postoperative. 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.

Received 27 August 2009; accepted 23 November 2009

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 & Spängberg 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...
than 2 mm from the radiographic apex (Saunders et al. 1997, Boltucz-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 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 bicuspids 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, Mulaz 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...
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 in 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.

### Table 1 The distribution of teeth in the sample

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

Values in parentheses are in percentage.

### 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 postoperative 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.

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Criteria</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of root filling</td>
<td>Adequate</td>
<td>Root filling ending ≤2 mm from radiographic apex</td>
</tr>
<tr>
<td></td>
<td>Over-filling</td>
<td>Root filling beyond the radiographic apex</td>
</tr>
<tr>
<td></td>
<td>Short-filling</td>
<td>Root filling &gt;2 mm from radiographic apex</td>
</tr>
<tr>
<td></td>
<td>Flush</td>
<td>Root filling at the radiographic apex</td>
</tr>
<tr>
<td>Density of root filling</td>
<td>Adequate</td>
<td>No voids present in the root filling or between root filling and root canal walls</td>
</tr>
<tr>
<td></td>
<td>Inadequate</td>
<td>Voids present in the root filling or between root filling and root canal walls</td>
</tr>
<tr>
<td>Taper of root filling</td>
<td>Adequate</td>
<td>Consistent taper from the orifice to the apex</td>
</tr>
<tr>
<td></td>
<td>Inadequate</td>
<td>No consistent taper from the orifice to the apex</td>
</tr>
</tbody>
</table>

© 2010 International Endodontic Journal
• 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.

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

<table>
<thead>
<tr>
<th>Student’s level</th>
<th>Number of teeth</th>
<th>Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Acceptable</td>
<td>Unacceptable</td>
</tr>
<tr>
<td>4th year</td>
<td>300 (54.5)</td>
<td>64 (21.3)</td>
</tr>
<tr>
<td>5th year</td>
<td>250 (45.5)</td>
<td>61 (24.4)</td>
</tr>
<tr>
<td>Total</td>
<td>550 (100)</td>
<td>125 (22.7)</td>
</tr>
</tbody>
</table>

Values in parentheses are in percentage.

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

<table>
<thead>
<tr>
<th>Tooth type</th>
<th>Number of teeth</th>
<th>Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Acceptable</td>
<td>Unacceptable</td>
</tr>
<tr>
<td>Incisors</td>
<td>113 (20.6)</td>
<td>44 (38.9)</td>
</tr>
<tr>
<td>Canines</td>
<td>66 (12)</td>
<td>23 (34.8)</td>
</tr>
<tr>
<td>Premolars</td>
<td>191 (34.7)</td>
<td>47 (24.6)</td>
</tr>
<tr>
<td>Molars</td>
<td>180 (32.7)</td>
<td>11 (6.1)</td>
</tr>
<tr>
<td>Total</td>
<td>550 (100)</td>
<td>125 (22.7)</td>
</tr>
</tbody>
</table>

Values in parentheses are in percentage.

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

<table>
<thead>
<tr>
<th>Student’s level</th>
<th>Number of teeth</th>
<th>Length</th>
<th>Density</th>
<th>Taper</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Adequate</td>
<td>Short-filling</td>
<td>Flush</td>
<td>Over-filling</td>
</tr>
<tr>
<td>4th year</td>
<td>300</td>
<td>190</td>
<td>40</td>
<td>41</td>
</tr>
<tr>
<td>(54.5)</td>
<td>(63.3)</td>
<td>(13.3)</td>
<td>(13.7)</td>
<td>(9.7)</td>
</tr>
<tr>
<td>5th year</td>
<td>250</td>
<td>181</td>
<td>22</td>
<td>26</td>
</tr>
<tr>
<td>(45.5)</td>
<td>(72.4)</td>
<td>(8.8)</td>
<td>(10.4)</td>
<td>(8.4)</td>
</tr>
<tr>
<td>Total</td>
<td>550</td>
<td>371</td>
<td>62</td>
<td>67</td>
</tr>
<tr>
<td>(100)</td>
<td>(67.4)</td>
<td>(11.3)</td>
<td>(12.2)</td>
<td>(9.1)</td>
</tr>
</tbody>
</table>

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 of periapical radiographs of patients who received RCT at College of Dentistry, MUC, King Saud University. All periapical radiographs were taken during routine RCT...
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 Endodontontology (2006), the prepared root canal should be uniformly tapered from crown to apex. The frequency of teeth with adequate taper of root canal should be uniformly tapered from crown to apex. The frequency of teeth with adequate taper of root canal filling was significantly greater in the anterior teeth (76%) 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
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.

Acknowledgements
This work was supported by the College of Dentistry Research Center (F # 1199), King Saud University. The authors express their appreciation to Dr Zakariya Al Salam for his statistical contribution.

References


