**INTRODUCTION**

One of the most important aims of a root canal filling is to prevent the reinfection of root canals that have been biomechanically instrumented, irrigated, disinfected, and obturated (1). According to the American Association of Endodontists (AAE), there are clinical and radiographic criteria for judging the technical success of a root canal filling (2). Clinically, for a case to be considered successful, routine tests such as palpation, percussion, periodontal probing, and visual inspection of the final coronal restoration should reveal normal findings during periodical follow-up visits. The following three criteria should be radiographically assessed: length, shape, and density (2).

According to the guidelines of the European Society of Endodontontology (ESE), the radiographic criteria of an adequate root canal filling includes adequate length with no voids visible within the material or between the material and the root canal walls and consistent taper from the orifice to the apex. The amount of pre-clinical and clinical teaching in endodontics at the dental schools influences the skill and competence of practitioners or endodontists to achieve accurate root canal treatment.

**HIGHLIGHTS**

- Teaching endodontics to undergraduate students is one of the most complicated tasks for dental academics and one of the greatest challenges across all dental branches.
- The radiographic criteria of an acceptable root canal filling includes adequate length with no voids visible within the material or between the material and the root canal walls and consistent taper from the orifice to the apex.
- The amount of pre-clinical and clinical teaching in endodontics at the dental schools influences the skill and competence of practitioners or endodontists to achieve accurate root canal treatment.
The purpose of endodontics is to successfully consolidate skill and knowledge as a base for graduates to become proficient and competent in clinical work (3).

Generally, dental curricula in most dental schools worldwide comprise pre-clinical training in endodontics during inaugural classes, where students are trained to perform root canal treatment on inextracted teeth; however, during advanced classes, students clinically perform nonsurgical root canal treatment of anterior and posterior teeth (5, 6, 7, 8).

The quality of root canal fillings performed by dental students is well documented in the literature (9, 10, 11, 12, 13, 14) with different results in term of the acceptability of root canal fillings ranging from 13% reported by Hayes et al 2001 (9) to 84.1% reported by Kelbauskas et al 2009 (15).

The objective of the present study is to assess the radiographic technical quality of root canal fillings performed by senior dental students at Alfarabi college for dentistry and nursing, KSA and compare the results of our study with those of other investigations conducted in this area of endodontics.

MATERIALS AND METHODS
This study was based on pooled data from the radiographic unit of Alfarabi college for dentistry. In total, 246 records of patients who had received root canal treatment by undergraduate students during 2016–2017 were selected to evaluate the radiographic quality of the root canal fillings. The inclusion criterion for this selection was all root canal treatments performed by 6th year undergraduate dental students on adult patients with completely formed teeth.

All selected endodontics records had at least three high-quality radiographs, including the preoperative working length determination and postoperative radiographs. All selected radiographs were digital and displayed the entire length of the root and the periapical area, and the mesial and distal angulated radiographs were included for multi-rooted teeth.

The radiographic technical quality of the root canal fillings was independently evaluated by two expert endodontists, and the result was recorded when there was an agreement between the two examiners. The intra-examiner reliability was calculated by rechecking a random sample of 5% (19) of the total root canals previously examined. A 95% agreement was found, indicating that the scoring methods were reliable. The inter-examiner reproducibility was determined by calculating the kappa values, which were >0.9, indicating a high degree of inter-examiner agreement.

To assess the technical quality of root canal fillings, three criteria were evaluated as follows:

- Length of root canal filling, which includes four parameters: root filling ending ≤2 mm from the radiographic apex, root filling ending >2 mm from the radiographic apex, root filling beyond the radiographic apex (over filling), or root filling at the radiographic apex (flush).
- Density of root canal filling, which includes two parameters: the presence or absence of voids in the root filling or between the root filling and root canal walls.

Finally, the technical quality of the root canal fillings considered acceptable if the root filling ended ≤2 mm from the radiographic apex with no voids visible within the material or between the material and the root canal walls and consistent taper from the orifice to the apex (Figure 1).

In contrast, the technical quality of the root canal fillings was considered unacceptable when one or more of the aforementioned parameters were absent (Figure 2).

All root canal treatments evaluated in this study were conducted by students in an aseptic field with rubber dam isola-
of the 390 root canal treatments performed by 6th year undergraduate dental students, acceptable root canal fillings were detected in 127 (32.6%) patients, whereas unacceptable root canal fillings were detected in 263 (67.4%) patients. According to the tooth type, the number of accepted cases was distributed as follows: 15 (32.6%) in upper molars, 39 (30.2%) in lower molars, 28 (40%) in upper incisors, 13 (35.1%) in lower incisors, 18 (26.8%) in upper premolars, and 14 (34.1%) in lower premolars (Table 4). The frequency of an acceptable root canal filling in the same tooth type was significantly lesser in upper premolars, lower premolars, upper molars, and lower molars (P<0.05).

The percentage of root canal fillings with acceptable length was 59.48%, with acceptable density was 50.76%, and with consistent taper was 57.43%. The length of a root canal filling was the best criteria performed by the undergraduate students, followed by taper and density (Table 5).

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The frequency of an adequate length of a root canal filling (root filling ending ≤2 mm from the radiographic apex) was higher for lower molars (60/25.9%) than for lower incisors and lower premolars (24/10.3%). There was a significant difference in the length of the root canal filling among the types of teeth (P=0.031).

The frequency of density of the root canal filling, the presence of voids was most frequent in lower molars (60/31.2%) than in lower incisors (16/8.3%). The best result for density (no voids) was obtained for upper molars (12/6.1%). There was a significant difference in the density of the root canal filling among the types of teeth (P=0.02).

The frequency of no consistent taper from the orifice to the apex was the highest for lower molars (60/36.1%) and lowest for lower incisors (12/7.2%). There was no significant difference in the taper of the root canal filling among the types of teeth (P=0.094). The detailed results of the Kruskal–Wallis test for evaluating the association between the quality of the root canal filling criteria and tooth type are presented in Table 6.
Several studies have shown that the standard of root canal treatment performed by undergraduate students and general dental practitioners is poor (9, 6, 21, 22). Therefore, the present study was conducted to evaluate the technical quality of root canal fillings performed by senior dental students in AlFarabi colleges (KSA) and compare our results with those of previous studies.

In this study, the criteria used to evaluate the quality of root canal fillings and categorize root fillings as acceptable or unacceptable were length, density, and taper. These criteria have been used in many previous studies (6, 8, 10, 13, 14).

In our study, out of 390 root canal treatments performed by 6th year undergraduate dental students, acceptable root canal fillings were detected in 32.6% of patients. This result is similar to that of Moussa-Badran et al 2008, Er et al 2006, Chueh et al 2003 (12, 23, 24). The rate of acceptable cases in these studies was 33%, 30.3%, and 30%, respectively. However, the result of the present study was not in agreement with that of studies by Khabbaz et al 2010, Unal et al 2011, Barrieshi-Nusair et al 2004, Lynch and Burke 2006, Kelbauskas et al 2009, and Roman-Richon et al 2014 (5, 7, 10, 11, 15, 25). The rate of successful cases in these studies was higher than that obtained in our study: 54.8%, 73.7%, 47.4%, 63%, 84.1%, and 44%, respectively. However, the rate of acceptable cases was lower in studies by Balto et al 2010, Hayes et al 2001, Elsayed et al 2011: 23%, 13%, and 24.2%, respectively.

In our study, the length of root canal fillings was the best criterion performed by the undergraduate students; this result is similar to that of Moussa-Badran et al 2008, Er et al 2006, Chueh et al 2003 (12, 23, 24). The comparison of length and density of the root canal filling among all tooth types revealed that the density of the root canal filling was significantly better for upper molars than for other teeth (P<0.05); the length of the root canal filling was significantly worse for lower molars than for upper premolars and upper incisors (P<0.05). In addition, there was no significant difference in the density and length among other tooth types (P>0.05). The detailed results of the Mann–Whitney test for comparing the length and density of root canal fillings among all tooth types are presented in Table 7.

**DISCUSSION**

It has been reported that the technical quality of root canal treatment may affect the outcome of root canal treatment and the health of periapical tissues (16, 17, 18). A successful endodontic therapy is usually associated with root canal fillings that end within 2 mm of the radiographic apex and are of adequate homogeneity with no voids (19, 20).
The percentage of root canal fillings with consistent taper was 57.43%, which was lower than that reported by Balto et al 2010, Elemam et al 2015, Roman-Richon et al 2014 (6, 8, 25). The high percentage of root canal fillings with consistent taper (71%) reported by Roman-Richon et al 2014 (25) may be due to the instrumentation of root canals using rotary files.

The percentage of adequate density of root canal fillings in the current study was 50.76%, which was lower than that reported by Elemam et al 2015, Kelbauskas et al 2009, and Roman-Richon et al 2014 (8, 15, 25). The rates of adequate density in these studies were 75.8%, 79.5%, and 69%, respectively. However, our result was higher than that reported by Balto et al 2010 (6) and Moussa-Badran et al 2008 (12). In these studies, 34.9% and 42.7% of cases, respectively, had a dense root canal filling without voids.

It is well known that the anatomy and the root canal therapy of anterior teeth are less complicated than those of posterior teeth, particularly the maxilla. The frequency of an acceptable root canal filling in this study was the highest for the upper anterior teeth (40%), followed by the lower anterior teeth (35.1%); this result was consistent with that of previous studies (5, 6, 8, 12).

A wide range of results has been obtained from different studies evaluating the quality of root canal fillings performed by dental students or general practitioners. In fact, several factors may impact these outcomes. The methodology, criteria, and parameters varied among different studies. Some studies radiographically assessed only the length and density of root canal fillings but omitted the taper variable (5,7,12). However, other studies have incorporated the taper variable (6,8,13,14,25). Procedural errors have also been radiographically assessed to evaluate the quality of root canal fillings (5,6,11). There is an association between the rate of acceptable root canal fillings and the practitioners performing the root canal treatment. The percentage of acceptable root canal fillings was 91% when the root canal treatment was performed by an endodontist (27). Lower rates were obtained when the root canal treatment was performed by general practitioners (22,28) and senior (5,6) or inaugural dental students (8,14). Some studies have concluded that the percentage of technical success was highly improved with the rotary instrumentation of root canals (15,25).

This study and several previous studies has shown poor performance of undergraduate students in the root filling area; this may be due to the complications of root canal treatment and lack of basic experience, in addition to poor skill of many dental students in this branch of dentistry.

It is conceded that the skill and competence of practitioners or endodontists to achieve accurate root canal treatment may be linked to the amount of pre-clinical and clinical teaching in endodontics at dental schools. Some commissions such as AAE and ESE have formulated treatment guidelines in the area of endodontics that are intended to represent current good practices through which graduates would shortly be expected to serve the community.

CONCLUSION

The quality of root canal fillings performed by senior undergraduate dental students at Alfarabi colleges for dentistry and nursing, Riyadh (KSA) was acceptable in 32.6% of patients. This outcome enhanced the poor performance of undergraduate dental students in the area of endodontics.

Disclosures

Conflict of interest: No conflict of interest was declared by the authors.

Ethics Committee Approval: This study has been conducted in full accordance with the World Medical Association Declaration of Helsinki, with an approval from the Ethics Committee in Alfarabi colleges for dentistry and nursing, Riyadh, Saudi Arabia (Ref. 00219/2017).

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