Dental Research Journal

Original Article

Technical quality of root canal therapies performed by novice dental students in preclinical practice

Mahmood Reza Kalantar Motamedi[1], Seyed Hamid Reza Davoodi[1], Alireza Saeidi[1], Behnaz Barekatain[2], Hamid Noormohammadi[3], Hamid Razavian[3]

[1]Dental Students Research Center, [2]Torabinejad Dental Research Center and Department of Endodontics, [3]Dental Materials Research Center and Department of Endodontics, School of Dentistry, Isfahan University of Medical Sciences, Isfahan, Iran

ABSTRACT

Background: For improving the quality of endodontic performance of practitioners in clinical practice, their basic, preclinical performance and knowledge must be taken into consideration. This study aimed to radiographically evaluate the technical quality of preclinical molar root canal treatments (RCTs) performed by undergraduate dental students at a dental school in Iran. Further, the effect of using Gates-Glidden (GG) drills on the final quality of RCTs was evaluated.

Materials and Methods: In this retrospective cross-sectional study, 315 roots of 105 endodontically treated teeth in preclinical practice were evaluated radiographically. The analyzed quality parameters included length, taper and density of fillings, which were scored as S2 (adequate standard), the S1 (slight deviation), or S0 (considerable deviation). For all the parameters, acceptable, moderate and poor fillings received total scores of 6, 3-5 and 0-2, respectively. There were two groups of students: One group had used only K-files, and the other had used K-files along with GG drills. The quality of RCTs between these groups was evaluated using the aforementioned scoring protocol. The results were analyzed using Chi-square, Mann–Whitney and Fisher's exact tests ($\alpha = 0.05$).

Results: Under-fillings ($P = 0.001$) and under-shapings ($P = 0.007$) occurred mostly in mandibular root fillings. A lower density was found in maxillary fillings ($P < 0.001$). No relationship was observed between the technique used (irrespective of GG drills usage) and length ($P = 0.499$) and taper of fillings ($P = 0.238$). The roots instrumented with GG drills had a higher filling density ($P = 0.004$). The quality mean score of RCTs was improved when GG drills were used ($P = 0.008$).

Conclusion: The technical quality of preclinical molar RCTs performed by undergraduate dental students was considered acceptable in 35.6% of the cases. When GG drills were used along with K-files, the technical quality of RCTs was enhanced.

Key Words: Dental, dental student, education, endodontics, root canal therapy

Recieved: March 2014
Accepted: August 2014

Address for correspondence:
Dr. Hamid Razavian, Department of Endodontics, Dental Materials Research Center, School of Dentistry, Hezar-Jarib Ave, Isfahan University of Medical Sciences, Isfahan 8174673461, Iran.
E-mail: hamidrazavian@yahoo.com

INTRODUCTION

Root canal therapy plays an important role in dental health care.[1,2] An important parameter necessary to achieve a proper endodontic treatment is the quality of root canal filling.[3]

Access this article online

Website: www.drj.ir
www.drjjournal.net
www.ncbi.nlm.nih.gov/pmc/journals/1480

The success rate of root canal treatments (RCTs) is reported to be >90%.[4,5] The success of this treatment depends on many factors, and the technical quality of RCT is one of the most important.[3,6,7] On the other hand, numerous studies have been reported in several countries on the high prevalence of poor fillings in association with periapical radiolucency,[1,3,7,8] leading to increasing number of public health problems. Amongst the several risk factors corresponding to progressive periapical radiolucency, the quality of root filling was one of the most important factors.[3,7,8] Therefore, efforts are needed for improving the quality of RCTs. To improve the quality of clinical performance,

some factors such as knowledge, training, ability and utilization of technology are necessary.[9-11] Of these, technology involves the use of rotary instruments in endodontics. Gates-Glidden (GG) drills are low-speed rotary instruments that have been used for over one hundred years without major changes in design.[12] Some advantages of such instruments include safety, ease of use, reduction in working time and low cost. In spite of the advantages of rotary instruments, some studies reported that GG drills increase the risk of endodontic mishaps.[13] However, they must be used, where necessary, with caution.[14] Therefore, whether undergraduate students should use GG drills is still under debate. The decision as to whether new techniques and materials should be incorporated into the undergraduate curriculum can pose problems for teachers of endodontology.

The study of quality of RCTs and prevalence of endodontic procedural accidents can help improve educational programs, thus leading to improvement in oral health-related quality of life in society.

The quality of an operation can be improved by gaining more knowledge about it. Therefore, for improving the quality of endodontic performance of practitioners in clinical practice, their basic, preclinical performance and knowledge must be taken into consideration. Until date, very few studies have focused on the preclinical abilities of students.[15-17]

The aim of this study was to evaluate the technical quality of molar RCTs performed by undergraduate practitioners at a dental teaching school during the preclinical course. In addition, the effect of GG drills use on the final quality of the performed RCTs was evaluated.

MATERIALS AND METHODS

Tooth preparation

In this retrospective cross-sectional study, 315 roots of 105 endodontically treated molar teeth in preclinical practice in 2010 were obtained from the undergraduate program in endodontics of the School of Dentistry, Isfahan University of Medical Sciences, Isfahan, Iran. All the undergraduate students underwent extensive laboratory training on the instruments and filling techniques on all groups of teeth. The obtained teeth consisted of 64 maxillary and 41 mandibular permanent molar teeth. For mounting the teeth, the students had used different materials with different concentrations; therefore prior to evaluation, the teeth were removed from the mounts and then assessed.

There were two equal groups of endodontically treated teeth: one group had been prepared using K-files along with GG drills (GG Group) and the other using only hand instruments (K-files) (No GG Group). All the RCTs were performed by fourth grade undergraduate dental students, who possessed the same level of knowledge and practical experience of RCT, using the step-back technique. They were taught by the instructors to use at least files number 15 for initial length determining via conventional radiographs. After determination of working length, the master apical file was set at minimum of number 30. In the GG group, GG drills number 1-3 were used after the root canals were instrumented by files number 20-25. Passive step-back technique was carried out when using GG drills. Using patency file (#10 or 15) and copious canal lavage was recommended to the students. The canals were irrigated by 1% sodium hypochlorite during RCT. All the teeth were obturated using the cold lateral condensation filling technique using the gutta-percha (AriaDent, Tehran, Iran) and AH-26 sealer (Dentsply, DeTrey, Konstanz, Germany).

Radiographic procedure

Although the students had taken conventional radiographs of completely treated teeth to pass their educational course, the radiation environments were different. Therefore, to calibrate the images and prevent bias, new digital images were obtained. In addition, all the teeth were held in a plaster block containing a very thin layer of wax to ensure immobility. The distances from the X-ray tube to the teeth and the teeth to the receptor were 2 and 0.5 cm, respectively.

The radiographs of maxillary and mandibular molar teeth were obtained in the buccolingual direction using paralleling technique. Moreover, as recommended,[18] a 20° horizontal mesial angulation of X-ray tube was used for the mandibular molars to prevent the superimposition of roots. The receptor, X-ray tube and tooth position were kept constant. The radiographic procedure was performed using a dental X-ray unit (Planmeca Intra Planmeca Oy, Helsinki, Finland) at 50 kVp, 8 mA and 0.01 s exposure time, and digital sensor (MPS, Progeny Dental, Buffalo Grove, USA). The selected exposure environments (i.e. kVp, mA and exposure time) were based on a pilot exposure prior to the final imaging confirmation of an endodontist and a maxillofacial radiologist.

Radiographic assessment

In the present study, a total of 146 images including 64 of maxillary molars and 82 of mandibular molars (from two directions) were evaluated.

The images were interpreted by three endodontists acting as observers. Initially, the images were independently evaluated by two observers. The results were then compared, and a final consensus was reached. In the case of disagreement, a third observer with more experience was asked to interpret the images for final agreement. The observers used the same monitor (LG Flatron L1755S 17-inch, manufactured by Madiran, Iran, under license of LG Electronics Inc.).

The digital software used was SygnusMedia (Version 3.0.1.391; USA). The observers were free to use and perform all the options in the software, such as brightness, contrast adjustment and magnification. No time limit was set for viewing the images.

The observers were asked to evaluate the radiographic quality of the fillings according to a criteria defined in Table 1. As in other similar studies,[2,17,19,20] the filling quality was assessed on the basis of three parameters: Filling length, density (homogeneity) of filling and taper of root canals [Table 1]. Apart from the above characteristics, overextension and coke bottle shaped root canals were detected. Root filling beyond the apex and also the canal that has not been filled adequately within its confines was diagnosed as overextension.[21] The coke bottle shape was diagnosed when a bottle-like widening produced by the over action of GG drills was observed in the root canals.[21]

As shown in Table 1, a specific score was assigned to each parameter, which was similar to that in the study of Santos *et al*.[22] The root canal was considered as a sampling unit, and the quality of the root filling was evaluated according to the following parameters:

1. Length,
2. density and
3. taper, which were scored (S) as S0, S1 and S2.

S2 corresponded to an adequate standard whereas S1 and S0 referred to slight and considerable deviation from the adequate standard, respectively [Table 1].[22] A root canal filling was considered acceptable (total score: 6) only when the length, density and tapering of the filling were adequate (three scores of 2). Fillings with total scores of 0-2 and 3-5 were considered to be poor and moderate, respectively.

Statistical analysis

Data were analyzed using SPSS software, version 20.0 (SPSS Inc., Chicago, USA). Descriptive analysis was performed separately for each type of root canal, and the sum of all endodontic errors was calculated. Strength of agreement was measured using Kappa value. Chi-square test was used to compare the GG drill (GG Group) with hand instrument (No GG Group) with respect to taper of root canal (adequate, under-shaped and over-shaped), length of fillings (adequate, under-fill, over-fill and tip-to-tip) and scoring (poor, moderate and acceptable). To compare the coke bottle shaped errors between the groups, Fisher's exact test was used. Mann-Whitney test was used for comparison of frequency of voids within each root canal and the scores of the two groups were obtained. All the aforementioned analyses used for comparing the GG and No GG groups were also used to compare maxillary and mandibular root canals. The *P* value was set to be 0.05.

RESULTS

The calculated Kappa value for inter-examiner agreement was 0.80.

The distributions of the evaluated parameters, that is, length, density and taper of RCTs are shown in Table 2. A significant relationship was found between

Table 1: Criteria followed for evaluation of root fillings

Parameter	Definition	Score
Length of root canal filling	Root filling ending >1.5 mm short of the radiographic apex (under-filling)	0
	Root filling ending beyond the radiographic apex (over-filling)	0
	Root filling ending at the radiographic apex (tip-to-tip)	1
	Root filling ending 0.5-1.5 mm short of the radiographic apex (adequate)	2
Density of root canal filling	Inhomogeneous root filling with several visible voids	0
	Root filling with only one visible void	1
	No void present in the root filling (adequate)	2
Taper of root canal filling	Not consistently tapered from the apex to the coronal part (over-shaped or under-shaped)	0
	Consistently tapered from the apex to the coronal part (adequate)	2

the type of teeth (maxillary or mandibular) and the length of fillings, with more number of under-fillings in mandibular root canals ($P = 0.001$). A significant more number of voids (lower density) were seen in maxillary root canals ($P < 0.001$). The Chi-square test showed a significant number of under-shapings in mandibular root canals ($P = 0.007$). Only one (0.3%) palatal root of the maxillary molar was over-shaped [Table 2].

Fisher's exact test did not reveal a significant relation between coke bottle shape mishap and type of the teeth ($P = 0.212$). The exact distribution of this mishap is demonstrated in Table 2.

Table 3 shows the length, density and taper of RCTs based on the type of instrument used (whether GG drills were used). No relationship was found between the type of instrument used and the length ($P = 0.499$) and taper of fillings ($P = 0.238$). On the other hand, the Mann–Whitney test showed that the root instrumented with GG drills had a significantly higher density when compared with those for which GG drills were not used ($P = 0.004$). Moreover, GG drills did not increase the rate of the coke bottle shaped canals ($P = 0.467$).

Table 4 shows the technical quality scores of RCTs performed in different root canals. A root canal filling was considered acceptable only when the length, density and tapering of the filling were adequate. The percentages of RCTs with acceptable, moderate and poor quality were 35.6, 39 and 24.1%, respectively. Mandibular root canals had significantly better quality mean score ($P = 0.024$) when compared with maxillary root canals.

The number of poor, moderate and acceptable fillings with GG drills were 27 (17.3%), 64 (41%) and 65 (41.7%), respectively. On the other hand, the distributions of poor, moderate and acceptable fillings performed using only K-files were 49 (31.4%), 59 (37.8%) and 47 (30.1%), respectively. The Mann-Whitney test showed that the mean score of root fillings quality was significantly higher for the GG Group (4.15 ± 0.12) than the No GG Group (3.61 ± 0.14) ($P = 0.008$).

DISCUSSION

In the present study, the technical quality of root fillings in a preclinical course as well as the influence

Table 2: Length, density and taper of RCTs in different root canals

Root canal group	Length				Density			Taper		
	Adequate (%)	Under (%)	Tip-to-tip (%)	Over (%)	Adequate (no void) (%)	1 void (%)	≥2 voids (%)	Adequate (%)	Under (%)	Over (%)
Maxilla										
Mesiobuccal	29 (45.3)	10 (15.6)	14 (21.9)	11 (17.2)	34 (53.1)	15 (23.4)	15 (23.4)	32 (50)	32 (50)	0
Distobuccal	38 (59.4)	7 (10.9)	12 (18.8)	7 (10.9)	43 (67.2)	13 (20.3)	8 (21.5)	31 (48.4)	33 (51.6)	0
Palatal	39 (60.9)	6 (9.4)	7 (10.9)	11 (17.2)	32 (50)	18 (28.1)	13 (20.3)	35 (54.7)	27 (42.2)	1 (1.6)
Total	106 (55.2)	23 (12)	33 (17.2)	29 (15.1)	109 (56.8)	46 (24)	36 (18.8)	98 (51)	92 (47.9)	1 (0.5)
Mandible										
Mesiolingual	14 (35)	16 (40)	6 (15)	4 (10)	31 (77.5)	8 (20)	1 (2.5)	32 (80)	8 (20)	0
Mesiobuccal	21 (52.5)	13 (32.5)	0	6 (15)	34 (85)	4 (10)	2 (5)	23 (57.5)	17 (42.5)	0
Distal	23 (57.5)	7 (17.5)	6 (15)	4 (10)	29 (72.5)	9 (22.5)	2 (5)	28 (70)	12 (30)	0
Total	58 (47.2)	36 (29.3)	12 (9.8)	14 (11.4)	94 (76.4)	21 (17.1)	5 (4.1)	83 (67.5)	37 (30.1)	0
Maxilla and mandible										
Total	164 (52.1)	59 (18.7)	45 (14.3)	43 (13.7)	203 (64.4)	67 (21.3)	41 (13.1)	181 (57.5)	129 (41)	1 (0.3)

RCTs: Root canal treatments

Table 3: Length, density and taper of RCTs based on the types of instruments used by students

Group	Length				Density			Taper		
	Adequate (%)	Under (%)	Tip-to-tip (%)	Over (%)	Adequate (no void) (%)	1 void (%)	≥2 voids (%)	Adequate (%)	Under (%)	Over (%)
GG	87 (55.8)	27 (17.3)	24 (15.4)	18 (11.5)	113 (72.4)	30 (19.2)	13 (8.4)	97 (62.2)	59 (37.8)	0
No GG	77 (49.4)	32 (20.5)	21 (13.5)	25 (16)	90 (57.7)	37 (23.7)	28 (18)	84 (53.8)	70 (44.9)	1 (0.6)
P	0.001*				<0.001**			0.007*		

In the GG group, GG drills and K-files were used whereas in the no GG group, only K-files were used. *Pearson Chi-square test; **Mann–Whitney test.
RCTs: Root canal treatments; GG: Gates-Glidden

Table 4: Technical quality scores of performed RCTs in different root canals

Root canal group	Poor (score: 0-2) (%)	Moderate (score: 3-5) (%)	Acceptable (score: 6) (%)	Mean score ± SE
Maxilla				
Mesiobuccal	25 (39.1)	19 (29.7)	20 (31.3)	3.42±0.22
Distobuccal	17 (26.6)	23 (35.9)	24 (37.5)	3.89±0.2
Palatal	16 (25)	23 (35.9)	24 (37.5)	3.76±0.23
Total	58 (30.2)	65 (33.9)	68 (35.4)	3.69±0.12
Mandible				
Mesiolingual	4 (10)	23 (57.5)	13 (32.5)	4.2±0.19
Mesiobuccal	7 (17.5)	23 (57.5)	10 (25)	4.00±0.23
Distal	7 (17.5)	12 (30)	21 (52.5)	4.37±0.26
Total	18 (14.6)	58 (47.2)	44 (35.8)	4.19±0.13
Maxilla and mandible				
Total	76 (24.1)	123 (39)	112 (35.6)	3.88±0.09

SE: Standard error; RCTs: Root canal treatments

of using GG on occurrence of endodontic mishaps was evaluated. It should be noted that although the radiographic technical quality of fillings was evaluated in several studies,[19,23,24] only in a few studies[15,16] the quality of preclinical course was considered and that was via questionnaires filled by students. Recently, one study radiographically assessed the quality of RCTs performed in preclinical setting.[17]

Although it is difficult to compare the results of the present work with other studies because of the differences in the design of the studies, other similar works looked into the quality of RCTs performed by undergraduate dental students.

In most of the studies, over-filling was considered to be equal to tip-to-tip filling. However, similar to the study of Santos *et al*., we considered them to be different and assigned a better score to tip-to-tip filling.[22] In this study, the root fillings that were adequate, short, tip-to-tip and over-filled were 52.1, 18.7, 14.3 and 13.7%, respectively. The number of fillings with adequate length was more than those of the Lupi-Pegurier *et al*. study (38.7%).[25] In a dental school in Jordan, the percentages of teeth with adequate, short and over-fillings were reported to be 61.3, 34.5 and 4.2%, respectively.[19] Peak *et al*. evaluated the technical quality of fillings performed by Royal Air Force dental students and found the percentages of adequate, short and over-filled root canals to be 50, 32 and 18%, respectively.[6] These aberrations can be due to several reasons, the most important being the radiographic technique used. In real clinical practice, the radiographs are commonly obtained using bisecting-angle technique,[23] whereas the paralleling technique was used in the current study. In addition, different techniques were used for RCTs in the studies.

The results of the present study showed that there was a significant under-filling in mandibular molars. It is reported that most of the under-filled root canals are observed in mandibular molars.[19,23,26] This can be explained by the anatomy of multi-canalled curved roots in these teeth.[23]

In the current study, 57.5% of root fillings had adequate tapering whereas 41.3% had poor tapers. Contrarily, in the Tarim Ertas *et al*. study, adequate and poorly tapered canals were 31.2 and 68.8%, respectively.[24] A significant percentage of adequately tapered root canals (85.3%) were reported in Barrieshi-Nusair *et al*. study.[19] As shown in Table 2, most of the poorly tapered root canals were, in fact, under-shaped (41%), and only a few were over-shaped (0.3%). This may be due to the inadequate consideration of undergraduate students to completely clean and shape the canals. Further, 64.4% of root fillings had an adequate density, and 35.6% had at least one visible void. The number of root fillings with adequate density was somewhat less than those reported in the studies of Barrieshi-Nusair *et al*. (72.6%)[19] and Dadresanfar *et al*. (70.7%).[23] Barrieshi-Nusair *et al*. did not find a significant difference between the density of maxillary and mandibular root fillings.[19] In contrast, in our study, most of the fillings with poor density were observed in maxillary molars when compared with the mandibular molars. Our findings were similar to other previous studies.[2,23]

In this retrospective study, preclinical students were divided into two groups: GG Group (used K-files along with GG drills) and No GG Group (used only K-files). No significant difference was observed

between the two groups with respect to length of fillings and taper of root canals; however, usage of GG drills significantly increased the final density of fillings. In addition, the technical quality scores of root canals were significantly higher in the GG Group. This may be attributed to the fact that GG drills provide a better coronal enlargement and shaping of the root canals, leading to a straight-line access to the root apex. The better straight-line access in the properly shaped teeth may lead to a further depth of insertion of spreaders during gutta-percha administration, thus resulting in a better homogeneity of the filling. Coronal enlargement, adequate shaping and straight-line access are the factors responsible for the greater number of acceptable fillings in the GG Group in this study.

Unexpectedly, coke bottle shape incidence was not significantly related to usage of GG drill and only occurred in 18 (5.7%) of the root canals. This may be because the students, who were taught by preclinical instructors, did not apply too much force when using GG drills.

As can be clearly observed from the results, GG drills not only reduced practitioners' errors but also significantly increased the quality mean score of RCTs when compared with the No GG Group. However, Wu *et al*.[13] concluded that GG drills can increase the risk of perforation; therefore, they must be used with caution.[14]

In this study, the technical quality of fillings was evaluated. Acceptable, moderate and poor RCTs were 35.6, 39 and 24.1%, respectively. The percentage of acceptable root fillings reported in this study was nearly in accordance with the studies of Er *et al*. (33%)[2] and Dadresanfar *et al*. (32.5%).[23] This percentage is much higher than those of the studies of Hayes *et al*.[27] and Tarim Ertas *et al*.[24] (approximately 13%). A remarkably high rate of acceptable RCTs was reported elsewhere.[5,28] The low percentage of acceptable root fillings found in the current study could be attributed to several reasons, including the design of the study, criteria followed, RCT techniques used and most importantly, the endodontic curriculum of the school. According to the European Society of Endodontology, an important criterion is the time allocated to the subject matter; however, in this faculty, 55 h are devoted to preclinical endodontic teaching, which seems to be insufficient. This period was reported much higher in some other dental schools.[17,19] Moreover, the staff to student ratio was 1:15, which should be improved when compared with some other studies.[17,19]

In summary, to improve the technical quality of RCTs performed by the undergraduate dental students, the endodontics curriculum can be revised in some aspects. The training time of students in preclinical practice can be extended. Furthermore, students must be taught new techniques and instruments to ensure that they are up-to-date. The clinical training course must be designed in such a way that the students are provided with proper skills in endodontics, starting with the basic principles of real clinical endodontics.

Each study has its strengths and limitations. In this study, the teeth radiographs taken by students were not used because of the different radiation angles used, and image recapturing was performed by one examiner in order to calibrate the data. Digital radiographs were used to develop the images and to ensure that small endodontic errors were not missed.

Of the limitations of this study were the observers that were not blinded. In addition, other accurate tools such as scanning electron microscopy, stereomicroscopy, cone beam computed tomography, etc. could be used instead of digital imaging. However, these instruments are expensive. Another limitation of this study was that the survey was done in a preclinical setting, and some procedural accidents such as strip perforation was not assessed because the students do not deliver these cases to their evaluators. This fact can lead to a study bias when evaluating the role of GG drills in the final quality of fillings. Therefore, more accurate studies with restriction of such confounding variables are needed.

CONCLUSION

The technical quality of preclinical molar RCTs performed by undergraduate dental students using step-back technique and cold lateral condensation was considered to be acceptable in 35.6% of the cases. When GG drills were used along with K-files, the technical quality of RCTs was enhanced.

ACKNOWLEDGMENTS

This study was supported by a grant (291297) from the Isfahan University of Medical Sciences. The authors would also like to thank Dr. Mehrdad Abdinian for consulting and participating in some practical parts of this work.

REFERENCES

1. Chueh LH, Chen SC, Lee CM, Hsu YY, Pai SF, Kuo ML, *et al.* Technical quality of root canal treatment in Taiwan. Int Endod J 2003;36:416-22.
2. Er O, Sagsen B, Maden M, Cinar S, Kahraman Y. Radiographic technical quality of root fillings performed by dental students in Turkey. Int Endod J 2006;39:867-72.
3. Friedman S. Expected outcomes in the prevention and treatment of apical periodontitis. Essential Endodontology. In: Örstavik D, Pitt Ford T, editors. 2nd ed. Oxford, UK: Blackwell Munksgaard Ltd.; 2008. p. 408-69.
4. Lazarski MP, Walker WA 3rd, Flores CM, Schindler WG, Hargreaves KM Epidemiological evaluation of the outcomes of nonsurgical root canal treatment in a large cohort of insured dental patients. J Endod 2001;27:791-6.
5. Sjogren U, Hagglund B, Sundqvist G, Wing K. Factors affecting the long-term results of endodontic treatment. J Endod 1990;16:498-504.
6. Peak JD, Hayes SJ, Bryant ST, Dummer PM. The outcome of root canal treatment. A retrospective study within the armed forces (Royal Air Force). Br Dent J 2001;190:140-4.
7. Ricucci D, Gröndahl K, Bergenholtz G. Periapical status of root-filled teeth exposed to the oral environment by loss of restoration or caries. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2000;90:354-9.
8. Estrela C, Leles CR, Hollanda AC, Moura MS, Pécora JD. Prevalence and risk factors of apical periodontitis in endodontically treated teeth in a selected population of Brazilian adults. Braz Dent J 2008;19:34-9.
9. Lynch CD, Burke FM. Quality of root canal fillings performed by undergraduate dental students on single-rooted teeth. Eur J Dent Educ 2006;10:67-72.
10. Molander A, Caplan D, Bergenholtz G, Reit C. Improved quality of root fillings provided by general dental practitioners educated in nickel-titanium rotary instrumentation. Int Endod J 2007;40:254-60.
11. Tu MG, Chen SY, Huang HL, Tsai CC. Endodontic shaping performance using nickel-titanium hand and motor ProTaper systems by novice dental students. J Formos Med Assoc 2008;107:381-8.
12. Hargreaves KM. Cohen's Pathways of the Pulp Expert Consult. Maryland Heights, USA: Mosby Elsevier; 2010.
13. Wu MK, van der Sluis LW, Wesselink PR. The risk of furcal perforation in mandibular molars using Gates-Glidden drills with anticurvature pressure. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2005;99:378-82.
14. Duarte MA, Bernardes RA, Ordinola-Zapata R, Vasconcelos BC, Bramante CM, Moraes IG. Effects of Gates-Glidden, LA Axxess and orifice shaper burs on the cervical dentin thickness and root canal area of mandibular molars. Braz Dent J 2011;22:28-31.
15. Qualtrough AJ, Whitworth JM, Dummer PM. Preclinical endodontology: An international comparison. Int Endod J 1999;32:406-14.
16. Qualtrough AJ, Dummer PM. Undergraduate endodontic teaching in the United Kingdom: An update. Int Endod J 1997;30:234-9.
17. Román-Richon S, Faus-Matoses V, Alegre-Domingo T, Faus-Llácer VJ. Radiographic technical quality of root canal treatment performed ex vivo by dental students at Valencia University Medical and Dental School, Spain. Med Oral Patol Oral Cir Bucal 2014;19:e93-7.
18. Walton RE. Endodontic radiographic technics. Dent Radiogr Photogr 1973;46:51-9.
19. Barrieshi-Nusair KM, Al-Omari MA, Al-Hiyasat AS. Radiographic technical quality of root canal treatment performed by dental students at the Dental Teaching Center in Jordan. J Dent 2004;32:301-7.
20. Moussa-Badran S, Roy B, Bessart du Parc AS, Bruyant M, Lefevre B, Maurin JC. Technical quality of root fillings performed by dental students at the dental teaching centre in Reims, France. Int Endod J 2008;41:679-84.
21. Ingle JI, Bakland LK. Endodontics. Hamilton, London, UK: Pmph Bc Decker; 2002.
22. Santos SM, Soares JA, César CA, Brito-Júnior M, Moreira AN, Magalhães CS. Radiographic quality of root canal fillings performed in a postgraduate program in endodontics. Braz Dent J 2010;21:315-21.
23. Dadresanfar B, Mohammadzadeh Akhlaghi N, Vatanpour M, Atef Yekta H, Baradaran Mohajeri L. Technical quality of root canal treatment performed by undergraduate dental students. Iran Endod J 2008;3:73-8.
24. Tarim Ertas E, Ertas H, Sisman Y, Sagsen B, Er O. Radiographic assessment of the technical quality and periapical health of root-filled teeth performed by general practitioners in a Turkish subpopulation. ScientificWorldJournal 2013;2013:514841.
25. Lupi-Pegurier L, Bertrand MF, Muller-Bolla M, Rocca JP, Bolla M. Periapical status, prevalence and quality of endodontic treatment in an adult French population. Int Endod J 2002;35:690-7.
26. Smith CS, Setchell DJ, Harty FJ. Factors influencing the success of conventional root canal therapy – A five-year retrospective study. Int Endod J 1993;26:321-33.
27. Hayes SJ, Gibson M, Hammond M, Bryant ST, Dummer PM. An audit of root canal treatment performed by undergraduate students. Int Endod J 2001;34:501-5.
28. Kerekes K, Tronstad L. Long-term results of endodontic treatment performed with a standardized technique. J Endod 1979;5:83-90.

How to cite this article: Kalantar Motamedi MR, Davoodi SH, Saeidi A, Barekatain B, Noormohammadi H, Razavian H. Technical quality of root canal therapies performed by novice dental students in preclinical practice. Dent Res J 2015;12:365-71.

Source of Support: Nil. **Conflicts of Interest:** The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.