Original Article

Retrospective Evaluation of Endodontic Procedural Errors by Under-and Post-Graduate Dental Students Using Two Radiographic Systems

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Abstract

Background and Aim: Recognition of factors that cause procedural errors in dental practiceand their prevention increase the success rate of endodontic treatment. This study aimed to evaluate the rate of procedural errors in a clinical training setting using conventional and digital radiography systems.

Materials and Methods: In this study, digital and conventional radiographs available in the archives of the Department of Endodontics, Shahed School of Dentistry were used, including 684 conventional radiographs of 171 patients (treated by the 5th and 6th year under-graduate dental students and the 1st and 2nd year post-graduate students) and 852 digital radiographs of 213 patients (treated by the 5th and 6th year under-graduate dental students and the 1st, 2nd, and 3rd year post-graduate students).

Radiographs were examined by 3 observers in terms of type of error during endodontic treatment.

Results: In the under-graduate student group, the most frequent errors found in conventional radiographs were poor obturation and under-filling with 8.13% prevalence rate. The most frequent error in post-graduate student group was poor obturation as well with10.58% frequency. In digital radiographs, in both under-graduate and post-graduate groups, the most frequent error was poor obturation, as well (11.86% in undergraduate and 9.47% in post-graduate groups).

Conclusion: It appears that the educational system in the Department of Endodontics at Shahed School of Dentistry must place a stronger emphasis on the internal anatomy and principles of root canal treatment of the posterior teeth, as well as on the final stage of endodontic treatment (canal filling) for all teeth.

Key Words: Procedural errors, Conventional radiography, Digital radiography

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Introduction

Endodontic treatment, like other complex dental procedures, is associated with the risk of occurrence of unexpected complications affecting the treatment prognosis. Such unwanted events in endodontics are known as procedural errors [1]. Correction of such errors is difficult, if not impossible. For instance, some cases may require retreatment or apicoectomy. Some errors may necessitate tooth extraction, which contradicts the clinicians' main goal regarding tooth preservation. Clinical skills of clinicians play an important role in treatment outcome. Dental students do not have proficiency when take the endodontic course for the first time and must acquire the necessary skills by exercising over time. However, they can compensate for this lack of skills by paying utmost care when treating patients. Obviously, there is a big difference between the performance of dental students and endodontists. But, dental students

must practice root canal therapy (RCT) on actual patients to eventually learn the necessary skills. Thus, clearly, procedural errors have a higher frequency among dental students due to their lack of skills and low self-confidence. It is necessary to prevent such procedural errors as much as possible and in order to do so, factors related to the occurrence of procedural errors must be recognized and eliminated or controlled.

A successful RCT is the result of complete cleaning, shaping and filling of the root canal system (RCS) at the determined working length while maintaining the natural canal shape. Thus, adequate knowledge about the anatomy of the RCS is necessary for the clinicians. Such knowledge may be acquired via the followings:

1. Information available regarding the anatomy of the RCS for each group of teeth
2. Radiography [2]

Radiography is the commonly used method to assess the outcome of endodontic treatment [3]. A pre-operative radiograph can provide clinicians with comprehensive information regarding the internal anatomy of the RCS, risk of possible complications, and treatment prognosis. Also, radiography can be used to assess the quality of work at each phase during the procedure [4].

Conventional radiography is the commonly used imaging technique. However, with the advances in computer science, digital radiography has gained increasing popularity. Digital radiography has been widely used since its introduction in 1970. This system has several advantages that clearly distinguish it from conventional radiography. Such advantages justify the use of digital radiography in dentistry [2]. However, it must be noted that in general, radiographs have some limitations and are not completely reliable in all cases [5].

The superiority of digital over conventional radiography especially in terms of immediate image display with high resolution [6] and the ability to enhance image quality [2], raises a theory that use of digital radiography may help prevent some procedural errors. Digital radiography is much more costly than conventional radiography. Thus, it is important to find out whether this imaging modality can actually decrease the occurrence of procedural errors or not. This issue is especially important in the educational curriculum of the department of endodontics in dental universities. The current study can serve as a preliminary study for future investigations to confirm or reject the efficacy of digital radiography for decreasing the frequency of endodontic procedural errors. Moreover, endodontic treatment plays a main role in preservation of teeth and success of future periodontal, restorative and prosthodontic treatments. Thus, recognizing factors that play a role in occurrence of endodontic procedural errors is particularly important.

This study aimed to assess the prevalence of endodontic procedural errors made by dental students and detected via digital and conventional radiography.

Materials and Methods

In this retrospective observational study, endodontic treatments performed by undergraduate and postgraduate dental students in Endodontics Department of Shahed University, School of Dentistry were evaluated using conventional and digital radiography in the first semesters of 2011 and 2012 academic years.

Understudy subjects were:

Undergraduate dental students: In this group, all root canals are filed with stainless steel hand K files with 0.02 taper using the step back technique. The canals are filled with gutta percha and AH26 sealer using cold lateral condensation technique.

Dental students evaluated in this group were fifth and sixth year dental students.

Postgraduate dental students: In this group, canals are prepared using hybrid technique. Stainless steel hand K files with 0.02 taper, nickel-titanium files and rotary instruments are all used for canal preparation. Digital radiographs obtained by first, second and third year postgraduate students and conventional radiographs obtained by first and second year postgraduate students were evaluated (conventional radiographs obtained by third year postgraduate students were not available). It should be noted that cases treated by postgraduate students were more complex than those treated by undergraduate dental students.

In the current study, a total of 684 conventional radiographs of 171 patients (46 patients treated by fifth year and 40 patients treated by sixth year

undergraduate dental students and nine patients treated by first year and 76 patients treated by the second year postgraduate students) treated in the first semester of 2011 academic year were evaluated. At the mentioned time interval, all endodontic treatments had been conducted with the use of conventional radiography. Also, 852 digital radiographs of 213 patients (86 patients treated by fifth and 32 patients treated by sixth year undergraduate dental students and 46 patients treated by first year, 22 patients treated by the second year and 57 patients treated by the third year postgraduate students) treated in the first semester of 2012 were evaluated. At the mentioned time interval, all endodontic treatments had been conducted with the use of digital radiography.

Cases treated with other dental students (foreign graduates and oral hygienists who had experience in endodontic treatment) were excluded from the study. Re-treatment cases were also excluded. Moreover, those with insufficient number of radiographs or radiographs with no diagnostic value were classified as "inadequate radiographs". Understudy variables and their definitions are demonstrated in Table 1.

All radiographs were evaluated by two endodontists and one oral and maxillofacial radiologist. In other words, the quality of each treatment was assessed three times. Prior to assessment, definitions of each error were explained by an endodontist to the radiologist observer in order for all observers to use the same definitions for the assessment of procedural errors.

Initial, master file length determination, master cone length determination and final radiographs were evaluated for each patient. Conventional radiographs were placed on a negatoscope and evaluated using a magnifier with 2X magnification. For digital radiographs, enhancement filters were used whenever required.

Statistical analysis: After initial evaluation, controversial radiographs (in terms of the procedural error diagnosed by the observers) were re-evaluated by the same observers. Radiographs that were agreed upon by all three or two of the three observers were qualified for statistical analysis. Data were analyzed using SPSS 16. Frequency and percentage values were described for data and Chi Square and Fisher's exact tests were applied for data analysis.

Results

Prevalence of procedural errors on conventional radiographs: Among undergraduate dental students, poor obturation and under-filling (8.13%) were the most common procedural errors; however, the frequency of these errors was not significantly different from that of other errors. Among postgraduate dental students, poor obturation (10.58%) was the most common procedural error; with no significant difference in terms of frequency with other errors.

The prevalence of procedural errors by fifth and sixth year undergraduate dental students and first and second year postgraduate dental students detected on conventional radiographs is shown in Table 2.

Prevalence of procedural errors on digital radiographs: The difference in frequency of error-free treatments done by fifth year (83.72%) and sixth year (53.12%) undergraduate dental students was statistically significant (p=0.001) (Table 3).

In both undergraduate and postgraduate dental student groups, poor obturation was the most commonly performed procedural error (11.86% in undergraduate and 9.47% in postgraduate group); this frequency was not significantly different from that of other errors in each group.

On both digital and conventional radiographs, the prevalence of poor obturation, over-filling and under-filling errors was higher than that of other procedural errors (Table 5). Poor obturation had the highest prevalence in both groups of undergraduate and postgraduate students on both types of radiographs (Tables 2, 3 and 5). However, the difference between the frequency of this error and other errors was not significant.

In this study, the frequency percentage of error-free anterior teeth was higher than that of posterior teeth (82.05% versus 65.29%) and this difference was statistically significant (p=0.0001). Also, 11.96% of anterior teeth were defective in terms of the length and quality of root canal filling, while this rate was 23.5% in posterior teeth and

Table 1. Understudy variables and their definitions

Type of error	Definition
Missed canal	Canals missed or not found during endodontic treatment [21]
Ledge	On the final radiograph, gutta percha at the apical third does not follow the curvature of the main canal path compared to the working length determination radiograph [8]
Transportation	Any deviation from the main canal path [5] visible on the radiograph
Apical perforation	Perforation at the apical foramen or farther apically on the root surface [21]
Furcal perforation	Detected by the protrusion of filling material from the furcation area in multi-rooted teeth [21], or file deviation from the main path and entering into the inter-radicular space on the radiograph [5]
Strip perforation	Perforation of the internal canal wall at the root curvature during preparation with hand file or rotary instruments [21]
Over-filling	Filling material exceeding the radiographic apex by more than one millimeter
Under-filling	Filling material shorter than the radiographic apex by more than one millimeter
Poor obturation	Presence of void within the filling material or at the material-canal wall interface in apical one-third of the root [9]
Broken instrument	Detected on the final radiograph due to the difference in the opacity of broken instrument and that of filling material [8]
Inadequate quality of radiograph	-Insufficient number of radiographs (each tooth must have at least three radiographs: pre-treatment, peri-operative and final) -Poor quality of radiographs due to student errors when taking the radiograph [8]

Table 2. Frequency of procedural errors done by undergraduate and postgraduate dental students on conventional radiographs

Type of procedural error	Fifth year undergraduate	Sixth year undergraduate	First year post-graduate	Second year post-graduate
Missed canal	(%0) n=0	(%0) n=0	(%0) n=0	(%0) n=0
Ledge	(%0) n=0	(%2/5)n=1	(%0) n=0	(%0) n=0
Transportation	(%0) n=0	(%7/5)n=3	(%0) n=0	(%1/31)n=1
Apical perforation	(%0) n=0	(%0) n=0	(%0) n=0	(%1/31)n=1
Furcal perforation	(%0) n=0	(%0) n=0	(%0) n=0	(%0) n=0
Strip perforation	(%0) n=0	(%0) n=0	(%0) n=0	(%0) n=0
Over-filling	(%0) n=0	(%2/5)n=1	(%0) n=0	(%7/89)n=6
Under-filling	(%6/52)n=3	(%10)n=4	(%0) n=0	(%3/94)n=3
Poor obturation	(%4/37)n=2	(%12/5)n=5	(%0) n=0	(%11/48)n=9
Fracture of instrument	(%0) n=0	(%0) n=0	(%0) n=0	(%0) n=0
Inadequate radiographs	(%10/86)n=5	(%0) n=0	(%0) n=0	(%2/63)n=2
Error-free cases	(%80/43)n=37	(%65)n=26	(%100) n=9	(%73/68)n=56

Table 3. Prevalence of procedural errors done by undergraduate and postgraduate dental students on digital radiographs

Procedural error	Fifth year undergraduate	Sixth year undergraduate	First year post-graduate	Second year post-graduate	Third year post-graduate
Missed canal	(%3.84)n=3	(%0) n=0	(%0) n=0	(%0) n=0	(%0) n=0
Ledge	(%1.16)n=1	(%3.12)n=1	(%0) n=0	(%0) n=0	(%0) n=0
Transportation	(%1.16)n=1	(%3.12)n=1	(%12.5) n=2	(%4.54) n=1	(%0) n=0
Apical perforation	(%0) n=0	(%0) n=0	(%0) n=0	(%0) n=0	(%0) n=0
Furcal perforation	(%0) n=0	(%6.25)n=2	(%0) n=0	(%0) n=0	(%1.75) n=1
Strip perforation	(%0) n=0	(%3.12)n=1	(%0) n=0	(%0) n=0	(%1.75) n=1
Over-filling	(%1.16)n=1	(%3.12)n=1	(%12.5) n=2	(%4.54) n=1	(%1.75) n=1
Under-filling	(%9.3)n=8	(%3.12)n=1	(%6.25) n=1	(%18.18) n=4	(%1.75) n=1
Poor obturation	(%5.81)n=5	(%28.12)n=9	(%0) n=0	(%18.18) n=4	(%8.77) n=5
Fracture of instrument	(%1.16)n=1	(%0) n=0	(%0) n=0	(%0) n=0	(%5.25) n=3
Inadequate radiographs	(%0) n=0	(%6.25)n=2	(%6.25) n=1	(%9.09) n=2	(%0) n=0
Error-free cases	(%83.72) n=72	(%53.12)n=17	(%68.75) n=11	(%72.72) n=16	(%89.47) n=51

this difference was statistically significant as well (p=0.003).

Based on the assessments made, the frequency percentage of error-free cases in the maxilla (74.77%) was significantly higher than that in the mandible (64.67%) (p=0.037). Of a total of 384 teeth, mandibular first molar had the highest (n=79) and maxillary and mandibular third molars had the lowest frequency (n=1) (Table 4).

Discussion

As stated earlier, retreatment cases were excluded and not evaluated in this study. However, in a study by Eleftheriadis et al, [5] such cases were not excluded; which can affect the results because procedural errors have occurred in the initial treatment of these cases and increase the risk of subsequent errors during retreatment. But, this issue was controlled for in the current study.

Another inclusion criterion in the current study was that only undergraduate and postgraduate dental students were included and foreign graduates and oral hygienists who had experience in RCT were not included. By doing so, we ensured that dental students in our study had the same level of clinical expertise. Based on the results, number of error-free treatments made by fifth year dental students on both types of radiographs was higher than that by sixth year dental students and this difference based on digital radiographs was statistically significant (p=0.001).

Increased number of errors by students of higher educational level is probably attributed to treatment of more complex cases by higher level students (sixth year dental students must treat multi-rooted and molar teeth in addition to single-rooted teeth).

In the current study, radiographically appropriate length of root canal filling was defined as root canal filling terminated within zero to one millimeter distance from the radiographic apex. Root canal fillings terminated more than one millimeter short or long of the radiographic apex were considered as under- or over-filling, respectively according to the definition by Ardosabir [7] and Ilguy et al [8]. However, in studies by Eleftheriadias and Lambrianidis [5], Er et al, [3], Khabbaz et al, [9] and Lynch and Burke [10], adequate length of root canal filling was defined as termination of root canal filling within zero to two millimeters of the radiographic apex. All the afore-mentioned studies reported lower percentage of error-free cases compared to our reported value. However, accurate comparison of results is difficult due to the variability of radiographic and clinical assessment criteria. For instance, Lynch and Burke [10] only evaluated single-rooted teeth in terms of the quality of root canal filling and reported that only 63% were error-free; whereas, in the current study, percentage of error-free anterior teeth was 82.05%. In a study by Lynch and Burke [10] skills of students could not be assessed because in expertise assessment multi-rooted teeth must be included as well [11, 12].

Another reason making the comparison of results almost impossible is simultaneous education of undergraduate and postgraduate dental students in Shahed University, School of Dentistry. As the result, teeth requiring simple treatments are assigned to undergraduates while complex cases are assigned to post-graduate students of endodontics.

Since on both types of radiographs, prevalence of procedural errors in the root canal filling phase (poor obturation, over-filling, under-filling) was higher than that of other errors, it appears that this phase of RCT requires further attention in the process of instruction. However, it must be noted that errors in obturation are mostly secondary to errors in canal preparation.

The most common procedural error was poor obturation in both undergraduate and postgraduate students on both conventional and digital radiographs. It must be noted that presence of void in root canal filling is very important because according to a study by Helminen et al, the success and favorable prognosis of RCT depend on the quality of root canal filling [13]. In this study, a poor obturation was defined as radiographically inadequate seal at the apical one-third. This is similar to the definition by Weine [14]. In a study by Aghdasi et al, presence of void in apical one-third was considered as poor quality of root canal filling [15].

In general, presence of void in the root canal filling affects the treatment outcome. Moreover, detection

Table 4. Comparison of the prevalence of procedural errors for each tooth irrespective of the type of radiography (frequency of errors in the respective tooth/total number of the respective tooth)

Error \ Tooth	Maxillary central incisor	Mandibular central incisor	Maxillary lateral incisor	Mandibular lateral incisor	Maxillary canine	Mandibular canine	Maxillary first premolar	Mandibular first premolar	Maxillary second premolar	Mandibular second premolar	Maxillary first molar	Mandibular first molar	Maxillary second molar	Mandibular second molar	Mandibular third molar	Maxillary third molar	Total errors
Missed canal	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	3
Ledge	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	3
Transportation	0	0	1	0	0	0	0	0	1	1	0	4	0	1	0	0	8
Apical perforation	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Furcal perforation	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	3
Strip perforation	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2
Over filling	0	1	0	0	0	0	1	0	1	0	2	5	2	0	0	0	11
Under filling	3	0	4	0	0	0	2	1	4	2	2	8	0	0	0	0	26
Poor obturation	2	0	2	1	0	1	1	1	2	0	9	13	3	2	1	0	39
Fracture of instrument	1	0	0	0	0	0	1	0	0	0	0	2	0	0	0	0	4
Inadequate radiographs	0	0	1	0	1	1	2	1	0	1	0	4	1	0	0	0	12
Error-free cases	34	4	29	6	15	8	16	15	34	26	22	38	13	10	0	0	270
Total	41	5	37	8	16	10	24	19	44	30	36	79	19	14	1	1	384

Table 5. Prevalence of procedural errors on conventional and digital radiographs (regardless of the educational level of dental students)

Type of procedural error	Conventional radiography	Digital radiography
Missed canal	(%0)n=0	(%1.4)n=3
Ledge	(%0.58)n=1	(%0.93)n=2
Transportation	(%2.33)n=4	(%1.87)n=4
Apical perforation	(%0.58)n=1	(%0)n=0
Furcal perforation	(%0)n=0	(%1.4)n=3
Strip perforation	(%0)n=0	(%0.93)n=2
Over-filling	(%4.09)n=7	(%2.81)n=6
Under-filling	(%5.88)n=10	(%7.04)n=15
Poor obturation	(%9.35)n=16	(%10.79)n=23
Fracture of instrument	(%0)n=0	(%1.87)n=4
Inadequate radiographs	(%4.09)n=7	(%2.34)n=5
Error-free cases	(%74.85)n=128	(%78.4)n=167

of void is difficult and the final radiograph is the only paraclinical tool to assess the density of filling and detect voids. Also, presence of void in the apical and middle one-third has a poorer prognosis than a void in coronal one-third of the root canal filling [15].

According to a study conducted by Ebrahimi in Shahed University, School of Dentistry, the most common procedural error during 1997-2000 was poor quality of root canal filling (29%). However, all radiographs evaluated in their study were conventional. According to a study conducted by Mozayeni et al, in Shahid Beheshti University, School of Dentistry in 2000, the most common procedural error was void in root canal filling (27.3%) [1].

The frequency percentage of broken instrument in our study was very low (1.04%); while this rate was 2.5% in a study by Ilguy et al, [8]. In a study by Rafeek et al, [16] 10.9% of canals had overall acceptability in terms of having adequate length and taper, no voids and no broken instrument.

In our study, RCT was performed using the step back technique. According to Greene and Krell [17], Gambarin [18] and Kfir et al, [19] this technique is associated with the risk of ledge formation and transportation when attempted by inexperienced clinicians; these errors lead to inefficient cleaning and shaping of the root canal. Also, files used by dental students in our study were made of stainless steel. As described by Cheung and Liu [20], using these files increases the risk of errors and consequently decreases treatment prognosis.

Moreover, in the current study, root canals were filled using cold lateral condensation technique; this technique increases the risk of void formation in under-prepared canals that do not have a conical shape [9].

In our study, number of error-free anterior teeth (82.05%) was higher than that of posterior teeth (65.29%); this difference was statistically significant. Also, 11.96% of anterior teeth had problems in terms of length and quality of the root canal filling; while, this rate was 23.5% in posterior teeth and this difference was statistically significant. In studies by Gulcelikunal et al, [21], Khabbaz et al, [9] and Eleftheriadis and Lambrianidis [5], number of anterior teeth with acceptable root canal filling in terms of length and quality was higher than that of posterior teeth. These findings indicate the need for some modifications in educational curricula and call for emphasis on the differences in treatment of anterior and posterior teeth to achieve clinical expertise.

Based on the assessments made, number of error-free treatments in the maxilla (74.77%) was significantly higher than that in the mandible (64.67%); which is in accord with the results of Er et al, [3] and Khabbaz et al, [9]. The reason may be less complexity of root canals in the maxilla.

Moreover, in the current study, the lowest number of procedural errors belonged to the maxillary canines (93.75% error-free); which is similar to the results of Er et al, [3] (51.5% error-free maxillary canines) (Table 4).

The highest number of missed canals occurred in

mandibular lateral incisors (12.5%) (Table 4).

Based on the literature, mandibular incisors have second canals in 40% of cases. Also, the RCS of mandibular central and lateral incisors has been the subject of investigation of many previous studies and it has been revealed that the RCS of these teeth is not as simple as it seems on periapical radiographs [22].

In our study, furcal perforation only occurred in the mandibular first molar; which is in accord with the statement made by Cohen and Burnes, who believe that mandibular teeth are at a higher risk of furcal perforation compared to maxillary teeth [23].

Due to the dissimilarity of operators in the current study, the two radiographic systems cannot be compared. But, in general, number of error-free treatments on digital radiographs (78.4%) was higher than that on conventional radiographs (74.85%); which may be due to one or more of the followings:

1. Superior performance and clinical skills of students who performed treatments using digital radiography
2. Simpler anatomy of teeth treated by students using digital radiography
3. Improved educational quality of the endodontics department of the university
4. Students were allowed to enhance the quality of digital radiographs; thus, students could better evaluate the anatomy of the respective tooth and do a more accurate treatment resulting in lower percentage of procedural errors.

After evaluation of radiographs, in 4.09% of patient records with conventional and 2.34% with digital radiographs, the radiographs did not have optimal quality for detection of errors. Poor quality of conventional radiographs was probably due to the processing errors.

Most dental students in department of endodontics do not have the necessary skills to do a quick treatment and the time allocated for the procedures is usually not enough for them. As the result, they are in a rush when processing the films.

Carelessness in this step results in low quality of images and increases the risk of procedural errors. In digital radiography, film-processing phase is skipped and thus, this system seems to have a superior performance in educational departments particularly endodontics since dental students can immediately view the obtained image on the monitor.

It is highly likely that dental students make mistakes in department of endodontics due to lack of skills. Thus, other factors that can increase the risk of procedural errors (like poor quality of radiographs due to film processing errors) must be eliminated as much as possible to decrease the overall possibility of procedural errors by dental students.

Conclusion

1. Poor obturation was the most common procedural error made by both undergraduate and postgraduate dental students detected on both digital and conventional radiographs.
2. Number of error-free anterior teeth was significantly higher than that of posterior teeth.

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