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Assessment of Treatment Quality Risk Factors Influencing the Radiographic Detection of Apical Periodontitis in Root-Filled Teeth: A Retrospective CBCT Analysis

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ABSTRACT

Objective: This study aimed to assess the treatment quality factors associated with the risk of radiographic detection of apical periodontitis (AP) in root-filled teeth (RFT) on CBCT images.

Methods: Two hundred eighty-five CBCT scans of patients (range 18-60, mean 35.1) years old were selected from a pool of CBCT scans which were taken from 2016-2022. Gender and age were recorded. The presence/absence of AP, unfilled canal, perforation, zipping and ledge and homogenous/nonhomogeneous root canal filling (RCF), adequate/inadequate coronal restoration and under/over filled RCF and those within 0-2 mm from the radiographic apex were recorded for RFTs. Kappa was used to assess intra-consensus reliability. Chi-square and Binary logistic regression were used to assess and predict risk factors related to the detection of AP. A significant difference was set at $p<0.05$.

Results: AP was present in 81.5% of RFTs. No significant difference was present in the AP prevalence in RFT between males and females, maxilla and mandible, right and left sides, RFT with adequate and inadequate coronal restoration and RFT with/without zipping and ledge and between RFT with overfilled and those with RCF end within 0-2 mm from the radiographic apex ($p>0.05$), respectively. Significantly higher AP prevalence was present in RFT with unfilled canal, perforations, non-homogenous and underfilled RCF ($p<0.05$), respectively. The odds of AP detection were 2.02, 5.5, 2 and 1.98 times higher in RFT with unfilled canal, perforations, non-homogenous and underfilled RCF, respectively. Intra-consensus reliability was (0.98, 0.95, 0.85, 0.81, 0.88, 0.85 and 0.92) for AP, unfilled canal, perforation, zipping and ledge, homogeneity of RCF, coronal restoration and length of RCF, respectively.

Conclusion: The vast majority of teeth with previous root fillings presented with AP. AP detection risk was significantly higher in root-filled teeth with perforation, non-homogeneous, and underfilled root canal filling. Other factors do not influence the radiographic detection of AP in CBCT images.

Keywords: Apical periodontitis, perforation, root canal filling, short root filling, unfilled canal

HIGHLIGHTS

- The majority of root-filled teeth showed periapical lesions on cone beam computed tomography radiographs, which may indicate the inability to prevent/treat the disease in the current treatment standards.
- The chance of detecting periapical lesions in root-filled teeth will increase when there is a perforation, gaps in the root filling, or short root filling more than 2 mm from the apex.
- Variables such as age, sex, position of the tooth, and quality of coronal restoration don't affect the chance of detecting periapical lesions in root-filled teeth.

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INTRODUCTION

Apical periodontitis (AP) is the periradicular bone resorption caused by endodontic infection. AP results from root canal infection after pulp necrosis or persistent infection after root canal treatment. The primary objective of root canal treatment is to treat or prevent apical periodontitis by elimination and/or inhibition of microbes' growth through thorough cleaning, shaping and tri-dimensional obturation of the root canal system (1). Inadequate elimination of root canal infection, because of incorrect access cavity, missed canals, improper or inadequate instrumentation, irrigation and root canal filling, or leaking of coronal restoration results in the persistence of AP (1). Optimum bacterial reduction in the cleaning phase is essential for the success of root canal treatment.

Although AP is an oral disease, many studies suggest associations between AP and cardiovascular diseases (2), gastrointestinal and inflammatory bowel diseases (3, 4), and Rheumatoid Arthritis (5). The golden standard to determine the presence of AP is histopathological examination which is unethical and impractical; therefore, radiographic assessment is an important step in diagnosing and evaluating the presence of pathology. Radiographic presentation of AP is a radiolucency related to the root apex exceeding double the thickness of adjacent healthy periodontal ligament (6). The presence/absence of AP on radiographs along with clinical signs and symptoms is considered the main determinant of the outcome of root canal treatment. Cone beam computed tomography (CBCT) has a significantly higher detection ability of AP compared to periapical radiographs, which was confirmed by histopathological examination on cadavers (7).

Development/persistence of AP indicates infection in the root canal system causing an immunological response. The etiology of persistent apical periodontitis is complex due to the heterogeneous communities of bacteria present in the area (8). The prevalence of persistent infection could be reduced and the outcome of RCT could be improved by confirming successful infection eradication using a chairside vital fluorescence staining through paper point sampling (9). To date, limited surrogate end-points are still not present to be used in clinical settings: therefore, the quality of the endodontic treatment provided is poor, and the not a lack of iatrogenic complications.

Globally, AP prevalence was assessed in many studies, and they found that normal apical periodontal condition on radiographs (periapical radiographs, panoramic radiographs and CBCT images) were present in 35–60% of root canal-treated teeth only and many of these studies found a significant association between the presence of root canal treatment and periapical pathosis (10–21). Many technical factors such as the use of rubber dam, the level of operator skill, materials and methods could affect the outcome of root canal treatment, prospective studies are required to address such associations. On the other hand, treatment quality determinants such as presence of voids in the obturation material, adequacy of coronal restoration and distance of the filling material from the radiographic apex also could affect the outcome of root canal treatment. Iatrogenic mishaps such as missed canals, sub-orifice and pulpal perforation, zips and ledges can jeopardize the success of the treatment. Assessing the presence of these factors together can predict the development or persistence of AP in root filled teeth. Also, the assessment of the prevalence of the disease helps in evaluating the performance of the profession and predicts the requirement to ameliorate the situation of a high prevalence of AP in teeth receiving root canal treatment.

The aim of this cross-sectional study was to assess the treatment quality risk factors influencing the radiographic detection of AP in root-filled teeth found on CBCT images for patients referred for radiographical examination (via CBCT) for orthodontic and surgical needs only.

MATERIALS AND METHODS

Institutional ethical approval of this cross-sectional study was acquired from the College of Dentistry/ University of Baghdad. (Ref. no. 345 on 13-06-2021). The study was carried out in compliance with the principles of the Declaration of Helsinki. Two hundred eighty-five CBCT scans were selected from a pool of archived data from the dental radiographic department of a private health clinic in Baghdad using SCANORA-3Dx CBCT device (SCANORA 3Dx, Tuusula, Finland). Technical settings were as follows, the exposure time was 4.9 sec., 90 Kvp, tube current 10 mA, 0.125–0.200 mm^3 voxel size, slice thickness (0.15 to 1 mm), 8×10 cm field of view. Scans were taken for patients referred for orthodontic and surgical requirements not related to this study in the period from 2016–2022 and only scans with at least one root filled tooth were selected.

Any type of root filled tooth was included in the analysis, A tooth with a radiopaque material in the root canals was considered root filled. exclusion criteria were non-root filled teeth, root filled teeth undergone orthodontic treatments or had more than 3 mm bone loss, C-shaped canals, presence of CBCT artifacts, root resorption and previous retrograde filling. Further 50 CBCT scans not belonging to the study were used to calibrate a consensus panel before the main study sample assessment was undertaken. Two experienced endodontists comprised the consensus panel, who reached an agreement during the assessment of CBCT scans jointly. The assessment of CBCT scans was repeated after one month to assess the reliability of the consensus panel. To avoid fatigue, only fifteen scans were analyzed daily.

The assessment of CBCT scans was conducted using a 15.6-inch DESKTOP-OGC9HJ7 laptop computer, with a 1920×1080 screen resolution in a dimmed light room. The examiners have free utilization of the scans in all planes with the ability to adjust magnification, brightness, and contrast. Images in axial, sagittal, and coronal sections of the target tooth were observed by sliding and scrolling along each section. Data were analyzed, documented and arranged in an Excel spreadsheet. To avoid fatigue, twenty examinations were performed per day.

The demographics (Age and gender) of the patients were recorded. The presence/absence of AP (defined as a radiolucency associated with the apex of the root or the lateral aspect of the tooth exceeding double the thickness of the adjacent periodontal ligament) was recorded. The presence/absence of the following technical errors was recorded for each root filled tooth included in the study, the unfilled canal (defined as a canal with no sign of filling from the orifice to the foramen), perforation (defined as the presence of communication that permit periodontal extrusion of the filling materials in the furcation area and lateral walls of the canal), stripping (defined as the elliptical transportation of the apical end of the filled canal to the outer wall), ledge (indicated by incomplete root filling shorter than the working length by 1 mm with deviation in the original root canal curvature).

Also, root filled teeth were grouped into homogenous/non-homogeneous root canal filling (non-homogeneous root canal filling included non-uniform density of root filling with clear space visible), root canal filling length (those with root canal filling length terminate 0–2 mm from the radiographic apex, overfilled canals those that had extruded filling beyond the radiographic apex, underfilled canals those that had fillings terminated shorter than 2 mm from the radiographic apex). Coronal restorations were categorized into adequate (including intact permanent restoration and crowns) and inadequate (including no coronal restoration, open margin, temporary restoration, overhang and recurrent caries). In multirooted teeth evaluation, the root with AP and/or technical error was used to categorize the tooth.

Statistical Analysis

Statistical analysis was performed using SPSS package version 26 (SPSS Inc., Chicago, IL, USA). Frequencies and percentages were reported. Kappa was used to assess intra-consensus reliability. Chi-square was used to assess the association between the prevalence of AP and sex and other treatment quality risk factors. Binary logistic regression was used to assess the odds of the predictive risk factors associated with the detection of AP. Statistical significance was set at p-value<0.05.

RESULTS

A total of 285 subjects/scans of patients aged between 18–60 (mean 35) years old contained 610 root filled teeth. Distributed as 198 and 412 teeth in the mandibular and maxillary jaws, respectively. Two hundred sixty and 350 teeth in males and females, respectively and 311 and 299 in left and right sides, respectively. AP in root filled teeth in this study was detected in 497/610 (81.5%) teeth. Figure 1 shows examples of root canal fillings associated with apical periodontitis. There were no significant differences in the percentage of teeth with AP between males and females, between maxilla and mandible, between left and right sides, between teeth with adequate and inadequate coronal restorations, or between teeth with zipping and ledges and teeth without or between teeth with overfilling and teeth with root filling end 0–2 mm from radiographic apex (p>0.05), respectively. However, there were statistically significantly higher percentages of teeth with AP in teeth with unfilled canals, non-homogeneous root fillings, perforations and underfilling compared to teeth with no unfilled canals, homogenous root filling, no perforation, overfilled and teeth with root filling end 0–2 mm from the radiographic apex (p<0.01), respectively, as shown in Table 1.

Table 2 shows the numbers and percentages of root filled teeth with and without AP according to tooth type. There was a high prevalence of AP in the first molar teeth (94.7%) followed by the second molar (89.3%). Second premolars represent the highest proportion 20.3% (124 teeth) and the canine was the lowest proportion 4.8 % (29 teeth) in the study sample.

A binary logistic regression of the associated risk factors showed that the risk of detecting AP was significantly associated with the presence of non-homogenous root filling (OR=2, CI 95% 1.26–3.16, p<0.01), presence of perforation (OR=5.5, CI 95% 1.66–18.16, p<0.01), presence of underfilled root filling (OR=1.98, CI 95% 1.22–3.22, p<0.01), as shown in Table 3.

Reliability of the consensus panel using Cohen kappa was (0.98, 0.95, 0.85, 0.81, 0.88, 0.85 and 0.92) for AP, unfilled canal, perforation, zipping and ledge, homogeneity of root filling, coronal restoration and length of root filling, respectively.

DISCUSSION

This study assessed the frequency of AP in teeth with root fillings and the treatment quality risk factors associated with its detection in CBCT images. Information about the prevalence of AP in root filled teeth may help in evaluating the quality of treatment. Evaluations of treatment quality factors and technical errors are parts of most CBCT studies. Adequacy and/or inadequacy of root canal filling quality in terms of density and length of the filling materials inside the root canal and the occurrence and/or absence of different technical or procedural errors during root canal procedure have been frequently reported to affect the prevalence of AP in root canal treated teeth (10–12, 21). In, this study, attempts have been made to include most if not all the factors that could influence the quality of the treatment of root canal filling that can be extracted from radiographic examination of CBCT images.

The population of the study involved subjects with an average of 2.14 root canal treated teeth per subject. The large field of view CBCT scans were taken for reasons not related to endodontic purposes. The cross-sectional distribution can be assumed as the imaging of CBCT scans was for reasons not related to any endodontic treatment planning.

It was found that about 81% of root filled teeth were associated with AP in this study sample compared to 59.5%, 42.5% and 38.2% in other populations (14, 19, 22), respectively. Another study reported similar findings instead (21). It seems that the treatments provided with the current standards do not treat or prevent endodontic disease thus improving the quality of the treatment provided for patients is a must. To improve the outcome of treatment, urgent investment in the development of the abilities of general dental practitioners in the treatment of teeth requiring root canal treatment is needed. By enhancing general dental practitioners' contact with postgraduate mentoring and training; expanding their practical experience; and raising their pay so that they have enough time and resources to meet clinical standards (23).

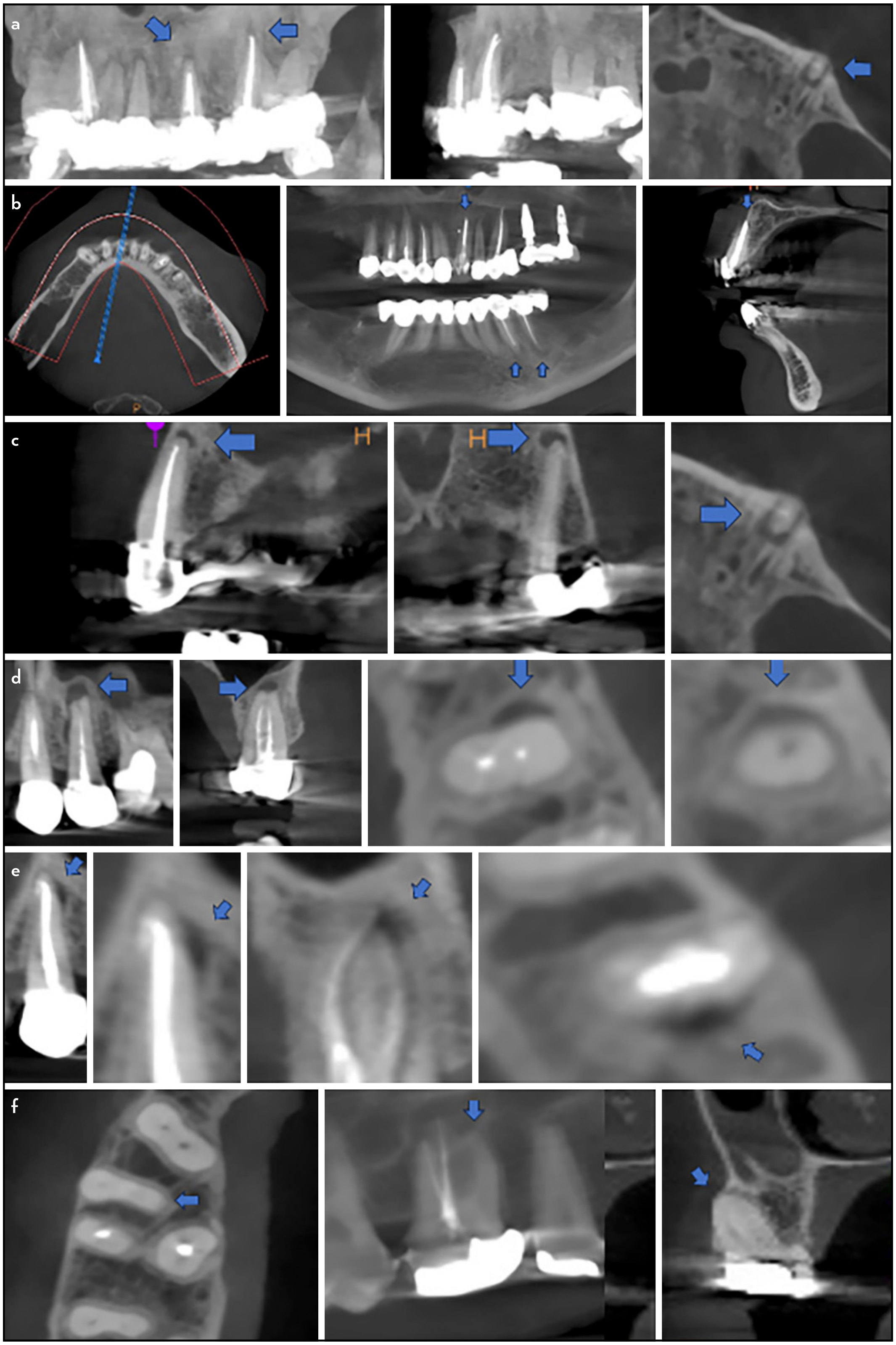

Figure 1. Sagittal, axial, and coronal cone beam computed tomography views. (a) Root canal fillings in the upper left central incisor and canine associated with apical periodontitis. (b) Over-extended root canal fillings in the upper left canine and short root canal fillings in the lower first and second premolars are associated with apical periodontitis. (c) Root canal treatment in the upper left canine is associated with the presence of apical periodontitis. (d) Short root canal treatment in the upper left second premolar with low density as well associated with the presence of apical periodontitis. (e) Root canal treatment in the upper left first premolar associated with the presence of lateral apical periodontitis. (f) Root canal treatment in the upper left first premolar associated with the presence of lateral apical periodontitis.

TABLE 1. Frequency and percentage of root filled teeth with and without apical periodontitis according to gender, jaw, sides and treatment quality factors

Factor	Category	No AP lesion		With AP lesion		p*
		n	%	n	%	
Gender	Male	48	18.5	212	81.5	0.972
	Female	65	18.6	285	81.4	
Jaw	Maxilla	70	17.0	342	83.0	0.159
	Mandible	43	21.7	155	78.3	
Side	Right	60	20.1	239	79.9	0.336
	Left	53	17	258	83	
Quality of coronal filling	Adequate	87	18.7	378	81.3	0.833
	Inadequate	26	17.9	119	82.1	
Unfilled canal	Absent	106	20.3	415	79.7	0.005
	Present	7	7.9	82	92.1	
Homogeneity of root canal filling	Homogenous	78	24.8	237	75.2	0.000
	Non-homogenous	35	11.9	260	88.1	
Perforations	Absent	110	21	413	79	0.000
	Present	3	3.4	84	96.6	
Zipping or ledge	Absent	103	18	470	82	0.170
	Present	10	27	27	73	
Root canal filling length	Within 0-2 mm from the apex	54	25.4	159	74.6	0.000
	Underfilling (shorter than 2mm from apex)	39	11.7	293	88.3	
	Overfilling (beyond apex)	20	30.8	45	69.2	

*: Chi-square. AP: Apical periodontitis.

TABLE 2. Distribution of root filled teeth with and without apical periodontitis according to the tooth type

Tooth type	Jaw	Periapical status				Frequency and percentage of tooth type		Frequency and percentage of total	
		No AP lesion		With AP lesion					
		n	%	n	%	n	%	n	%
Central incisor	Maxilla	13	18.3	58	81.7	71	77.2	92	15.1
	Mandible	7	33.3	14	66.7	21	22.8		
Lateral incisor	Maxilla	16	29.6	38	70.4	54	79.4	68	11.1
	Mandible	2	14.3	12	85.7	14	20.6		
Canine	Maxilla	7	30.4	16	69.6	23	79.3	29	4.8
	Mandible	1	16.7	5	83.3	6	20.7		
First premolar	Maxilla	10	12.0	73	88.0	83	76.9	108	17.7
	Mandible	9	36.0	16	64.0	25	23.1		
Second premolar	Maxilla	17	22.1	60	77.9	77	62.1	124	20.3
	Mandible	17	36.2	30	63.8	47	37.9		
First molar	Maxilla	3	4.5	64	95.5	67	58.8	114	18.7
	Mandible	3	6.4	44	93.6	47	41.2		
Second molar	Maxilla	4	10.8	33	89.2	37	49.3	75	12.3
	Mandible	4	10.5	34	89.5	38	50.7		
Total	Maxilla	70	17.0	342	83.0	412	67.5	610	100.0
	Mandible	43	21.7	155	78.3	198	32.5		

AP: Apical periodontitis

It was found that CBCT images significantly have higher accuracy in detecting AP than periapical and panoramic radiographs using histopathological reference as it overcomes superimposition of adjacent structures during imaging of the periapical areas (7). CBCT was used in the current study to assess the periapical status and treatment quality of root filled teeth, using a large field of view CBCT scans with low resolution which is less detailed but permits a better cross-sectional analysis thus it was used in many previous studies. Previous studies that involved panoramic and periapical radiographs

TABLE 3. Binary logistic regression of risk factors associated with the radiographic detection of apical periodontitis on CBCT scans

Factor	Category	Reference	OR	CI 95%	p
Gender	Female	Male	1.17	0.75–1.81	0.479
Jaw	Maxilla	Mandible	1.24	0.79–1.95	0.346
Side	Left	Right	1.20	0.78–1.85	0.396
Quality of coronal restoration	Inadequate coronal restoration	Adequate coronal restoration	0.95	0.57–1.58	0.854
Unfilled canal	Present	Absent	2.02	0.88–4.65	0.096
Homogeneity of root canal filling	Non-homogenous	Homogenous	2.00	1.26–3.16	0.003
Perforations	Present	Absent	5.50	1.66–18.16	0.005
Zipping or ledge	Present	Absent	0.51	0.21–1.23	0.137
Root canal filling length	Underfilling (shorter than 2mm from apex)	Within 0–2 mm from the radiographic apex	1.98	1.22–3.22	0.006
	Overfilling (beyond apex)	Within 0–2 mm from the radiographic apex	0.89	0.45–1.75	0.751

CBCT: Cone beam computed tomography, OR: Odd ratio, CI: Confidence interval

reported a lower prevalence of AP (13, 15) compared to this study. It is well established that CBCT detects periapical lesions about three and two times as much as the ones detected by panoramic and periapical radiographs, respectively (24).

Results of this study show that non-homogenous root canal filling increases the risk of radiographic detection of AP in CBCT scan by 100% (Table 3) compared to homogenous root canal filling, these findings are in agreement with other epidemiological studies (16, 25). A similar finding in a recent systematic review suggests that the homogeneity of the root canal filling without gaps significantly increases the chances of the absence of unhealed periapical lesions (26).

Also, in this study, the root canal fillings that are shorter than 2 mm from the radiographic apex were significantly associated with AP more than root canal fillings that end 0–2 mm from the radiographic apex by approximately 2 times (98% risk) as shown in Table 3. These findings incorporate findings from other studies that found a higher chance of detecting AP in teeth with root canal filling ends more than 2 mm from the radiographic apex (26, 27). On the other hand, root filled teeth with root filling ending beyond the apex have no risk of radiographic detection of AP, probably because of the elimination of the microorganisms from, and complete obturation of, the root canal system. The main objective of root canal treatment is to eliminate AP by eliminating or reducing bacterial infection and sealing the root canal system, successful treatment requires adequate cleaning and shaping, to eliminate or reduce necrotic pulp tissue and microbes, these are critical factors for success. Prevention of recontamination of the root canal can be achieved by obturation and coronal restoration to entomb the remnant microbes in the root canals.

The findings of this study disagree with findings from another study which found that root filling end beyond the apex increases the risk of detecting AP 27 times, however, that was calculated on a very limited number of teeth presented with overfilling (only 7 teeth in total) (19). In Bürklein et al. (19), sealer buff was associated with less AP, we didn't categorize that in a different category than the root filling ends beyond the apex. The advancement of endodontic materials enhanced the finding of overfilling or sealer puffs in dental radiographs, especially because some bioceramic sealers had significant resistance to dissolution compared to other sealers (28). The importance of proper determination and maintenance of working length during root canal treatment is necessary as indicated by the results of this study.

Also, it was found that perforations significantly increased the risk of detecting AP by 5.5 times compared to no perforations in the study population. Perforation may provide communication for microorganisms into the periodontal ligament causing periodontal and periapical infection. Iatrogenic errors such as perforations in root canal treatments are common findings in epidemiological studies (16, 19, 21). In this study, perforations were present in about 14.2% of root filled teeth, and 95.4% of them were associated with AP.

Other risk factors such as age, gender, jaw, side, and quality of coronal restoration did not represent significant predictors for the detection of AP in CBCT scans in this study. Previous studies showed no difference in AP prevalence between males and females in root filled teeth (16, 25), however, other studies did find a significantly higher prevalence of AP in males compared to females (19, 29). First molars showed the highest prevalence of AP compared to other teeth types (Table 2), this is probably because of the more complex anatomy of first molars, which may lead to difficulty in cleaning, shaping, and obturation procedures compared to other teeth types (30).

Persistent apical periodontitis of endodontic origin is still caused by untreated root canals because they still contain microbes and remanent of the pulp. In this study, about 14.5% of root filled teeth were associated with untreated canals, similar to that reported by Costa et al. (31) and lower than that reported by Karabucak et al. (22), which was 23%. These teeth presented with a higher prevalence of AP compared to root filled teeth with no untreated canals (92.1% vs 79.7%), respectively. This is similar to the results obtained in previous studies; the results from Ali et al. (21) demonstrated that 93.2% of root filled teeth with untreated canals showed AP compared to 78.3% of root filled teeth with no untreated canals. Similarly, Costa et al. (31) showed that AP was present in 98% of teeth with untreated canals compared to only 86% of teeth with no untreated canals.

It was found previously that the presence of an untreated canal in root filled teeth significantly increases the risk of detection of AP to 4.38 times (22). In this study, the presence of untreated canals was not a significant predictor of the risk of detecting AP in CBCT in root filled teeth (Table 3). However, loupes and dental operating microscopes now are important equipment in endodontics and can significantly improve the detection rate of additional canals (32).

Compared to prospective studies, the lack of information related to the treatment methods such as the use of rubber dam, materials, time of treatment and operators' skills in this study may play as variables that may limit the conclusions drawn from the data. For example, the time between endodontic treatment and CBCT scanning may be less than the optimum period for the healing of AP lesions, therefore it is impossible to know whether the lesion is healing or not at the moment of scanning. Also, the variation in the level of the skill of the operators may influence the outcome of the treatment, this may reduce the internal validity of the study but at the same time increase its external validity and generalizability of the findings.

However, with advancements in methods and materials used in modern endodontics, there has been almost no change in the prevalence or risk of developing AP over two decades (from 1997 to 2019) (33), Thus, the epidemiological methods are still important for conducting and interpreting of findings from clinical, observational studies in endodontology (34).

For endodontic diagnosis and treatment planning purposes, it is usual to use a small field of view CBCT scan, which can reduce the ionizing dose to the region of interest and produce high resolution (75 um3 voxel size) images compared to a large field of view CBCT scans (35), however, to ensure cross-sectional nature of the sample and prevent over-representation of endodontic pathology/technical errors, only CBCT scan of patients referred for orthodontic and surgical purposes (Large field of view) were included in the current study.

To overcome the limitations of the current study, prospective studies are required in the future to assess the endodontic treatment quality and outcome which minimize variations in the confounding factors such as time of treatment, operator skills, materials, and methods of treatment.

CONCLUSION

AP was prevalent in the majority of root filled teeth. The presence of perforations, non-homogenous root filling and underfilling more than 2 mm shorter from the radiographic apex were significant risk predictors of detecting AP in CBCT radiographs. Also, AP was significantly higher in root filled teeth with untreated canals compared to root filled teeth with no untreated canals. Age, gender, jaw, side, and quality of coronal restoration did not play as significant predictors for the detection of AP in root filled teeth.

Disclosures

Ethics Committee Approval: The study was approved by the College of Dentistry/ University of Baghdad Ethics Committee (no: 345, date: 13/06/2021).

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