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CLINICAL RESEARCH:

Relationship of Periapical Radiolucencies with the Quality of Root Canal Treatment: A CBCT Study on an Iranian Population

Relación de las radiolucidez periapicales con la calidad del tratamiento del conducto radicular: un estudio CBCT en una población iraní

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ABSTRACT: This study aimed to assess the relationship of periapical (PA) radiolucencies with the quality of root canal treatment (RCT) using cone-beam computed tomography (CBCT) scans of an Iranian population. This cross-sectional study was conducted on 200 endodontically-treated teeth on CBCT scans retrieved from a radiology clinic in Qazvin, Iran. The sagittal, coronal, and axial views were evaluated by an endodontist and a trained senior dental student for root canal procedural errors and presence/absence of PA radiolucency in the respective teeth. The association of PA lesions with age, gender, jaw, tooth type, presence/absence of coronal restoration, and RCT quality was analyzed by the logistic regression model (alpha=0.05). The frequency of poor-quality RCT was 75.3% in teeth with a PA radiolucency, and 15.5% in teeth without it. A significant association was found between the quality of RCT and PA radiolucencies (P<0.001). Absence of coronal restoration also had a significant association with the presence of PA radiolucencies (P<0.001). Of the procedural errors, perforation, under- and over-obturation, low obturation density (voids), and canal transportation were significantly associated with the presence of PA radiolucencies (P<0.05). The RCT quality had a significant association with development of PA radiolucencies, such that procedural errors and absence of coronal restoration were associated with a significantly higher frequency of PA lesions.

KEYWORDS: Cone-beam computed tomography; Root canal therapy; Periapical periodontitis; Periapical granuloma.

RESUMEN: Este estudio tuvo como objetivo evaluar la relación de las radiolucidez periapicales (PA) con la calidad del tratamiento del conducto radicular (RCT) mediante tomografías computarizadas de haz cónico (CBCT) de una población iraní. Este estudio transversal se realizó en 200 dientes tratados endodónticamente en exploraciones CBCT recuperadas de una clínica de radiología en Qazvin, Irán. Las vistas sagitales, coronales y axiales fueron evaluadas por un endodoncista y un estudiante de odontología de último año capacitado para detectar errores en el procedimiento del conducto radicular y la presencia/ausencia de radiolucidez PA en los respectivos dientes. La asociación de las lesiones PA con la edad, el sexo, la mandíbula, el tipo de diente, la presencia/ausencia de restauración coronal y la calidad del RCT se analizó mediante el modelo de regresión logística (alfa=0,05). La frecuencia de RCT de mala calidad fue del 75,3 % en los dientes con radiolucidez PA y del 15,5 % en los dientes sin ella. Se encontró una asociación significativa entre la calidad de la tomografía computarizada de haz cónico y las radiolucencias de la PA (P<0,001). La ausencia de restauración coronal también tuvo una asociación significativa con la presencia de radiolucencias de la PA (P<0,001). De los errores de procedimiento, la perforación, la obturación insuficiente y excesiva, la baja densidad de obturación (huecos) y el transporte del conducto se asociaron significativamente con la presencia de radiolucencias de la PA (P<0,05). La calidad de la tomografía computarizada de haz cónico tuvo una asociación significativa con el desarrollo de radiolucencias de la PA, de modo que los errores de procedimiento y la ausencia de restauración coronal se asociaron con una frecuencia significativamente mayor de lesiones de la PA.

PALABRAS CLAVE: Tomografía computarizada de haz cónico; Terapia del conducto radicular; Periodontitis periapical; Granuloma periapical.

INTRODUCTION

Periapical (PA) radiolucencies develop in the alveolar bone surrounding the apex in response to necrosis or inflammation of the pulp tissue, or periodontal tissue destruction (1). They most commonly occur in non-vital teeth following pulp necrosis due to extensive caries (1). Mild occlusal trauma, bruxism, and force application in orthodontic treatment are among the factors that can lead to PA periodontitis in vital teeth (2). Post-endodontic treatment infection or reinfection due to coronal leakage are among other factors that can lead to development of PA radiolucencies (3). Root canal infection can clinically cause PA bone resorption and development of PA periodontitis (4). Poor-quality root canal treatment (RCT) is among the most important parameters associated with PA periodontitis (5).

RCT includes pulp chamber removal, mechanical and chemical debridement of the root canals, and obturation (6). Poor quality in any step of the treatment can increase the risk of RCT failure and development, persistence, or progression of PA inflammation (6). A previous study reported the prevalence of PA periodontitis to be over 90% in teeth with a poor-quality RCT (7).

In RCT, root canal obturation is performed to seal the main canal(s) and all portals of exit to prevent communication between the endodontium and periodontium; in this process, no empty space should remain. Evidence shows that many cases of endodontic treatment failure are due to impaired obturation of the root canal system. It has been demonstrated that the prevalence of PA lesions is significantly lower in teeth with optimal length of root canal filling compared to under-filled teeth (8).

The majority of PA lesions remain limited in size for years and are not enlarged. Nonetheless, they can increase microbial virulence. Also, compromised immunity and some systemic diseases such as diabetes mellitus, AIDS, and leukemia may lead to progression of PA lesions and their transformation to osteomyelitis (9). Furthermore, if left untreated, PA lesions may be transformed into acute form of disease such as soft tissue abscess and cellulitis (10,11).

Clinical assessment of PA lesions has several limitations since their signs and symptoms such as pain, swelling, and sinus tract are not exclusive to PA lesions, and may be seen in other conditions as well. Thus, radiography is imperative for detection and subsequent management of PA lesions (12,13). PA and panoramic radiographic modalities have high sensitivity and specificity for detection of PA lesions (13). However, cone-beam computed tomography (CBCT) as an advanced imaging modality has a higher sensitivity for detection of PA lesions, and can provide more details about the quality of RCT and prevalence of PA lesions compared with PA and panoramic radiographic modalities (14-17). To the best of the authors' knowledge, studies using CBCT for detection of PA lesions and assessment of their association with the quality of RCT in the Iranian population are not many. Thus, the purpose of this study was to assess the relationship of PA radiolucencies with the quality of RCT using CBCT scans of an Iranian population.

MATERIALS AND METHODS

This cross-sectional study was conducted on 200 endodontically-treated teeth on CBCT scans retrieved from a radiology clinic in Qazvin, Iran during 2020-2022. The study protocol was approved by the ethics committee of the university (R.QUMS.REC.1401.374). This research followed a cross-sectional design, as all data were obtained from CBCT scans and patient records at a single point in time. The study did not include follow-up or longitudinal assessment; therefore, temporal changes in periapical status or healing progression were not evaluated. This design allowed for the assessment of the association between current clinical and radiographic findings but does not provide information about their evolution over time or since the initial endodontic treatment.

ELIGIBILITY CRITERIA

The inclusion criteria were optimal-quality CBCT scans with no motion artifact, presence of at least one endodontically treated maxillary or mandibular tooth, and availability of demographic information of patients. Also, the respective tooth had to have a mature apex, no visible root fracture, and no internal/external root resorption.

The exclusion criteria were PA lesions with undetectable borders and pathological lesions with other than pulpal or PA origin.

SAMPLE SIZE

The sample size was calculated to be 200 according to a previous study (16) assuming alpha=0.05, beta=0.2 (study power of 80%), and mean values of 0.228 in the group with PA radiolucency, and 0.41 in the group without PA radiolucency using the following sample size calculation formula:

$$N= (Z1-\alpha/2+Z1-\beta)^2 *P1(1-P1)+P2(1-P2)^2 /(P1-P2)^2$$

DATA COLLECTION

All CBCT scans had been taken with ProMax 3D CBCT scanner (Planmeca, Helsinki, Finland) with a 0.15 x 0.15 mm voxel size, and 8 x 8 cm field of view. Eligible CBCT scans were evaluated by an endodontist and a trained senior dental student. Prior to the main study, 10 randomly selected images were evaluated by the two examiners, and re-evaluated again by them after a 2-week period. The intra- and inter-observer agreements were then calculated by using the kappa coefficient of agreement. In cases of disagreement, an oral radiologist was consulted.

PA radiolucencies were classified according to the PA index presented by Orstavik *et al*. (18). Accordingly, the PA status around each root can be assigned to one of the following five categories (Figure 1):

- Normal PA structures
- Small changes in bone structure
- Changes in bone structure with little mineral loss
- Periodontitis with a well-defined radiolucent area
- Severe periodontitis with exacerbating features

In multi-rooted teeth, this classification was separately performed for each root.

Regarding the quality of root filling in terms of working length, the teeth were assigned to two groups:

- Appropriate: Root canal obturation 0-2 mm shorter than the radiographic apex
- Inappropriate: Root canal obturation by more than 2 mm shorter than the radiographic apex (under-obturation), root canal obturation beyond the radiographic apex (over-obturation), or obturation of the pulp chamber alone.

Obturation density was also evaluated. Radiographic density of the root filling had to be homogenous. Presence of voids indicated low obturation density (Figure 2). Also, presence of a small amount of radiopaque material at the PA region limited to the PDL width and following the semilunar contour of the root apex was defined as sealer puff (19). Other procedural errors such as strip-perforation, ledge formation, and canal transportation were also recorded (Figure 3).

All images were evaluated in a semi-dark room on a 19-inch monitor (Samsung, Seol, Korea) using Romexis software (R version 3.8.3 Planmeca Helsinki, Finland). The sagittal, coronal, and axial views were all evaluated. The age and gender of patients were also extracted from the patient records.

STATISTICAL ANALYSIS

Logistic regression was applied to analyze the association of quality of RCT and obturation with PA radiolucency. All statistical analyses were conducted using R version LP/2/3 software at 0.05 level of significance.

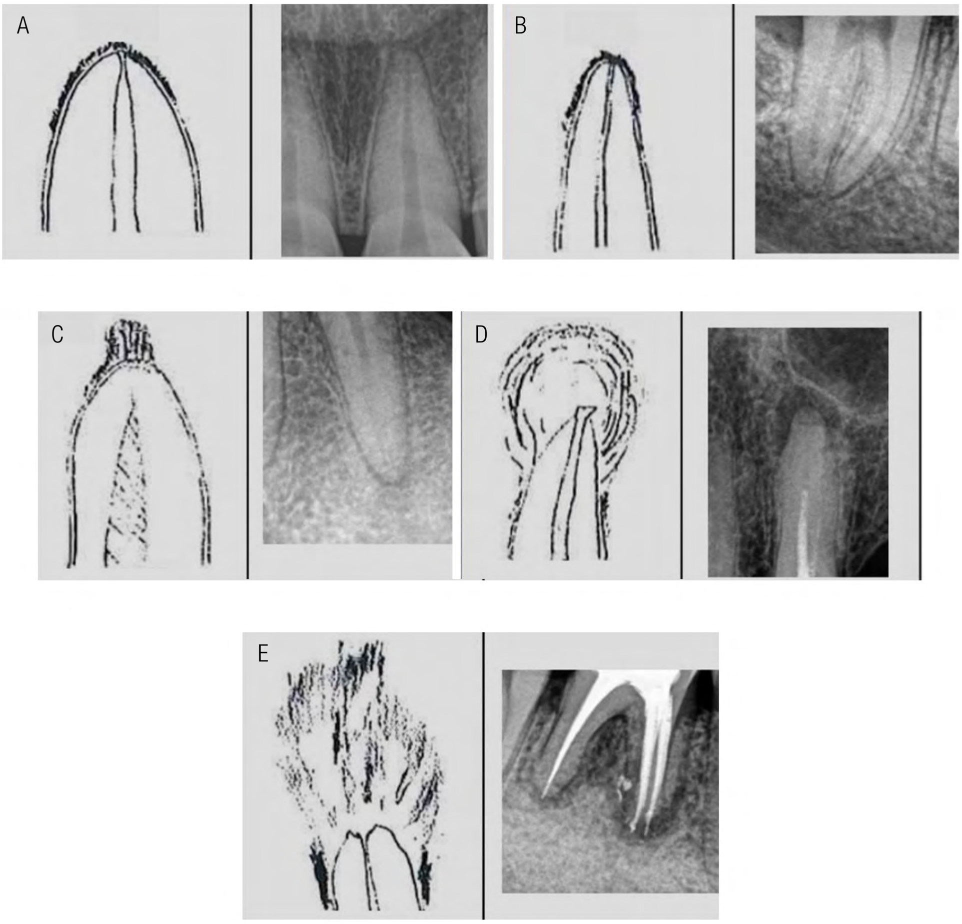

Figure 1. Orstavik's PA index: (A) normal PA structures; (B) small changes in bone structure, (C) changes in bone structure with little mineral loss, (D) periodontitis with a well-defined radiolucent area, (E) severe periodontitis with exacerbating features (18).

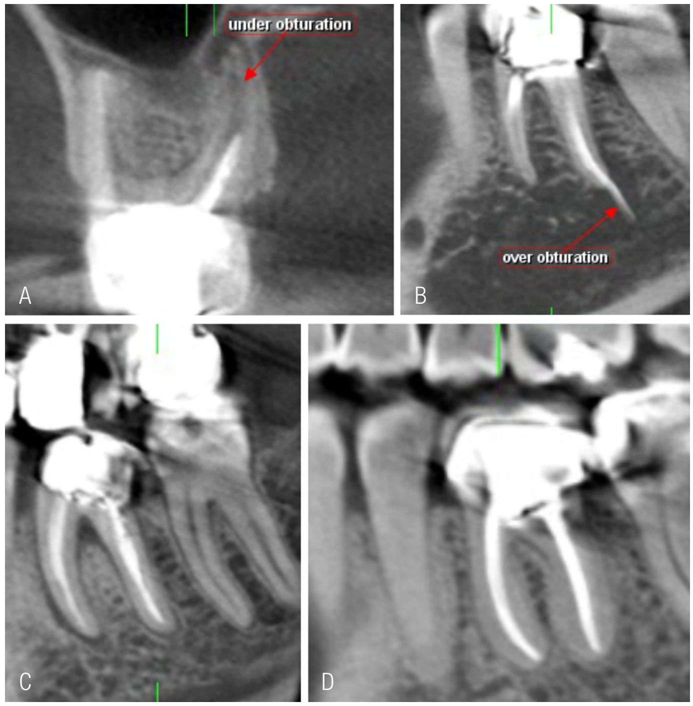

Figure 2. CBCT scans showing procedural errors:
(A) under-obturation; (B) over-obturation; (C) poor density; (D) optimal length and density of obturation.

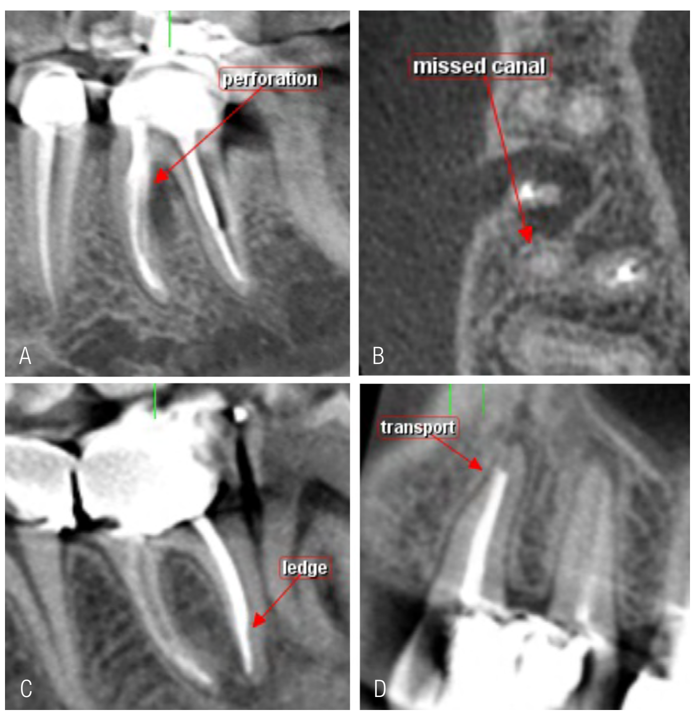

Figure 3. CBCT scans showing (A) strip-perforation in the mesial canal, (B) axial view of a missed unobturated canal, C) ledge formation in the distal canal, (D) canal transportation in a maxillary premolar.

RESULTS

A total of 200 teeth were evaluated; out of which, 103 (51.5%) did not have a PA radiolucency while 97 (48.5%) had a PA radiolucency. Of all, 64.5% of the lesions were in females, and 35.5% were in males. Demographic information of the study population is presented in Table 1. The mean age of the patients was 42.44±11.36 years. Also, 52.5% of the lesions were in the mandible and 47.5% were in the maxilla. The majority of the PA lesions were in molar teeth (57.5%).

Table 2 presents the quality of RCT in teeth with/without PA lesions. As shown, 44.5% had a poor-quality RCT, and 16% did not have a coronal restoration.

Table 3 shows the odds ratios (ORs) and P values for development of PA radiolucency based on each variable. As shown, according to the multivariate model, poor quality of obturation (P<0.001), absence of coronal restoration (P<0.001), and molar tooth type (P=0.001) had significant associations with development of PA radiolucencies. The results of univariate model were similar to those of multivariate model, except for the effect of jaw, which was significant in univariate model (P=0.011). According to the best model, poor obturation quality, absence of coronal restoration, and molar tooth type were the best predictors for development of PA radiolucency (P<0.05). According to the ORs, poor quality of obturation would increase the risk of development of PA radiolucency by 40 times. Molar tooth type compared with premolar would increase the risk of development of PA radiolucency by 6 times. Presence of coronal restoration would decrease the risk of development of PA radiolucency by 0.03 times.

Table 4 shows the ORs and P values for development of PA radiolucency based on procedural errors. The multivariate model showed significant association of perforation (P=0.012), over-obturation (P<0.001), transportation (P=0.004), under-obturation (P<0.001), and voids (P<0.001) with development of PA radiolucencies. Over-obturation increased the risk of development of PA radiolucencies by 18 times. This increase was 11 times by under-obturation, 7 times by presence of voids, 13 times by transportation, and 58 times by perforation. The same results were obtained by using the univariate model. The best model also showed that over- and under-obturation and voids were the best predictors for development of PA radiolucency (P<0.05).

Table 1. Demographic information of the study population.

Category	Presence of PA lesion	Absence of PA lesion	Total
Mean age	42.23±12.56	42.25±10.18	42.75±11.37
Females	60 (61.9)	69 (67)	129 (64.5)
Males	37 (38.1)	34 (33.0)	71 (35.5)
Maxilla	37 (38.1)	58 (56.3)	95 (47.5)
Mandible	60 (61.9)	45 (43.7)	105 (52.5)
Molars	71 (73.2)	44 (42.7)	115 (57.5)
Premolars	24 (24.7)	49 (47.6)	73 (36.5)
Anterior teeth	2 (2.1)	10 (9.7)	12 (6)

Table 2. Quality of RCT in teeth with/without PA lesions.

RCT quality	Presence of PA lesion Number (percentage)	Absence of PA lesion Number (percentage)	Total Number (percentage)
Poor	73 (75.3)	16 (15.5)	89 (44.5)
Optimal	24 (24.7)	87 (84.5)	111 (55.5)
Presence of coronal restoration	71 (73.2)	97 (94.2)	168 (84)
Absence of coronal restoration	26 (26.8)	6 (5.8)	32 (16)
Under-obturation	31 (32.0)	8 (7.8)	39(19.5)
Over-obturation	14 (14.4)	2 (1.9)	16 (8)
Transportation	8 (8.2)	1 (1.0)	9 (4.5)
Missed canal	2 (2.1)	0	2 (1)
Perforation	7 (7.2)	0	7 (3.5)
Poor density (voids)	14 (14.4)	5 (4.9)	19 (9.5)
Ledge formation	1 (1.0)	0	1(0.5)

Table 3. ORs and P values for development of PA radiolucency based on each variable.

Variable	Multivariate model		Univariate model		Best model	
	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value
Age	0.98 (0.95,1.02)	0.389	1 (0.97,1.02)	0.712	-	-
Gender	0.56 (0.22,1.35)	0.205	1.25 (0.7,2.24)	0.449	-	-
Jaw	0.77 (0.31,1.89)	0.561	0.48 (0.27,0.84)	0.011	-	-
Obturation quality	40.17 (15.43,122.76)	0.001>	16.54 (8.37,34.45)	0.001>	27.22 (11.83,69.34)	0.001>
Coronal restoration	0.03 (0.01,0.1)	0.001>	0.17 (0.06,0.41)	0.001>	0.04 (0.01,0.14)	0.001>
Molar tooth	6.09 (2.31,18.16)	0.001	3.29 (1.8,6.18)	0.001>	4.85 (2.06,12.26)	0.001>
Anterior tooth	0.97 (0.05,9.76)	0.983	0.41 (0.06,1.71)	0.271	0.9 (0.05,7.76)	0.936
Premolar tooth	1	-	1	-	1	-

Table 4. ORs and P values for development of PA radiolucency based on procedural errors.

Procedural error	Multivariate model		Univariate model		Best model	
	OR	P value	OR	P value	OR	P value
Ledge formation	1.89 (0.06,57.57)	0.718	3.37 (0.13,85.32)	0.451	-	-
Missed canal	16.31 (0.77,331.88)	0.08	6.15 (0.31,126.22)	0.242	16.14 (0.72,394.42)	0.08
Perforation	58.29 (2.35,1373.94)	0.012	21.91 (1.07,428.25)	0.042	59.38 (2.4,1422.4)	0.012
Over-obturation	18.48 (4.61,74.97)	0.001>	8.52 (2.29,55.24)	0.005	18.53 (4.55,74.18)	0.001>
Transportation	13.9 (2.34,77.41)	0.004	9.17 (1.64,171.75)	0.038	13.61 (2.4,77.16)	0.004
Under-obturation	11.38 (4.95,26.85)	0.001>	5.58 (2.52,13.73)	0.001>	11.54 (4.87,27.24)	0.001>
Poor density (voids)	7.16 (2.44,20.85)	0.001>	3.31 (1.21,10.58)	0.027	7.16 (2.46,20.92)	0.001>

DISCUSSION

This study assessed the relationship of PA radiolucencies with the quality of RCT using CBCT scans of an Iranian population. The prevalence of PA radiolucencies was found to be 48.5% in the present study population, which was close to the rate (50.7%) reported by Alaidarous *et al.*, (20) in their systematic review. This rate was 75.4% in a study by Mesgarani *et al.*, (19) in Iran and 10.4% in a study by Meirinhos *et al.* (21). Variations in the reported results in this respect may be due to differences in the type of radiographic modality used, method of assessment, and eligibility criteria (21).

The present results found no significant association between age and development of PA lesions. Lesions with a PA index between II-V were evaluated in the current study. However, Kazemipoor *et al.* (22) found significant differences in size of lesions in vertical and mesiodistal dimensions in 15-44-year-olds, and mesiodistal and buccolingual dimensions in 45-54-year-olds. In the present study, any deviation from the normal structure was considered as a PA lesion, and size of lesions was not evaluated.

The present study failed to find an association between gender and presence of PA radiolucencies, which was in contrast to some other studies that reported a significantly higher prevalence in males than females (7,8) and attributed it to higher level of dental care in females (23,24). However, another study reported a higher prevalence of PA lesions in females (25). Controversy in this regard may be due to differences in social patterns, public knowledge, and level of health literacy of the study population.

The current study found no significant difference in the frequency of PA lesions between the maxilla and mandible after adjusting for the confounders. However, some previous studies reported higher prevalence of PA lesions in the maxilla (19,21). This difference may be due to variations in sample size and eligibility criteria.

The present results showed that poor quality of RCT was the main risk factor for development of PA lesions, which was in agreement with previous findings (19,21,26,27) showing that poor-quality RCTs and under- and over-obturation increase the risk of development of PA lesions. Consistent with the present results, Bürklein *et al.* (12) reported that under-obturation increased the risk of PA radiolucencies by 4.4 times. However, they also reported missed canals as a significant risk factor for development of PA lesions while this association was not significant in the current study. This association may become significant in a larger sample size. Also, missed canals may not cause PA radiolucency due to calcification or type II canal configuration. In line with the present results, de Sousa Gomide *et al*. (28) showed that under-obturation or over-obturation by more than 2 mm can increase the risk of development of PA radiolucencies. Several others also showed that poor quality of RCT can increase the risk of PA lesions (29), and is the main predictor of their occurrence (13).

The current findings indicated that absence of coronal restoration was significantly associated with development of PA radiolucency, which was in agreement with the results of Kielbassa *et al*., (29) and Cakici *et al*., (27) who pointed to the significant role of poor quality of coronal restoration in development of PA lesions. Also, Meirinhos *et al*. (21) demonstrated significantly higher prevalence of PA lesions in crowned teeth compared with directly restored teeth, probably due to the greater loss of tooth structure in the former group.

Poor quality of RCT can lead to development of PA radiolucencies due to several reasons. Incomplete cleaning is one such reason. The residual necrotic tissues and infective bacteria in the root canal system can lead to PA infection and inflammation (30). Canal complexities, isthmi, and ramifications can further complicate efficient root canal cleaning, and increase the risk of development of PA lesions (30). Inadequate shaping of the root canal system is another important reason since it can result in remaining of some intact uncleaned areas in the root canal system, which can serve as a bacterial reservoir and lead to subsequent reinfection and development of PA lesions (31-33). This parameter was not evaluated in the present study. Inadequate density of root canal obturation and presence of voids can also lead to bacterial proliferation and development of PA lesions (28,29,34). Missed unfilled canals also serve as a bacterial reservoir and can lead to development of PA lesions (7,8,12,35,36); although this association did not reach statistical significance in the present study. Over-obturation is another important procedural error that can lead to development of PA lesions by stimulation of the PA tissue and causing inflammation (28). This parameter has been mentioned as an important cause of PA lesions by several previous investigations (12,37,38). Poor quality of coronal restoration also allows bacterial reentry and recurrence of infection, leading to development of PA radiolucencies (36,39). Finally, follow-up care after RCT is imperative, and failure to do so can also increase the risk of development of PA lesions (12).

The cross-sectional nature of this study limits the interpretation of causal relationships between the quality of root canal treatment and the presence of periapical radiolucencies. Information regarding the time elapsed since the initial endodontic treatment or the temporal evolution of the cases was not available, which restricts the ability to determine whether the lesions were healing, stable, or progressive. Future longitudinal studies including defined follow-up intervals and clinical assessments are recommended to better understand the dynamics of periapical healing and treatment outcomes.The clinical information of patients was not available either. Therefore, the exact reason for development of PA lesions could not be identified. Also, this study was a single-center study, which limits the generalizability of the findings. Additionally, the quality of root canal cleaning could not be evaluated. Future multi-center studies with a larger sample size and different designs (such as longitudinal design) are required to consider both clinical and radiographic information of patients.

CONCLUSION

The RCT quality had a significant association with development of PA radiolucencies, such that procedural errors and absence of coronal restoration were associated with a significantly higher frequency of PA lesions. Given the cross-sectional design, the observed associations reflect relationships at a single time point and should be interpreted with caution regarding causality.

AUTHOR CONTRIBUTIONS STATEMENT: Conceptualization and design: M.B.; Data analysis and interpretation: A.A.; Writing-original draft preparation: M.A.; P.R., Z.K., R.R., L.T.; Supervision: M.B.; M.T.

ETHICS COMMITTEE APPROVAL: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board of Qazvin University of Medical Sciences (IR. QUMS.REC. 1401.374).

INFORMED CONSENT STATEMENT: Informed consent was obtained from all subjects involved in the study.

CONFLICTS OF INTEREST: The authors declare no conflict of interest.

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