

Comparison of Periapical Radiography and Limited Cone-Beam Tomography in Posterior Maxillary Teeth Referred for Apical Surgery

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Abstract

This study compared periapical (PA) radiography and cone-beam tomography (CBT) for preoperative diagnosis in posterior maxillary teeth of consecutive patients referred for possible apical surgery. Images were concurrently analyzed by an oral radiologist and an endodontist to reach consensus in interpretation of the radiographic findings. The final material included 37 premolars and 37 molars with a total of 156 roots. CBT showed significantly more lesions (34%, $p < 0.001$) than PA radiography. Detecting lesions with PA radiography alone was most difficult in second molars or in roots in close proximity to the maxillary sinus floor. Additional findings were seen significantly more frequently in CBT compared with PA radiography including expansion of lesions into the maxillary sinus ($p < 0.001$), sinus membrane thickening ($p < 0.001$), and missed canals ($p < 0.05$). The present study highlights the advantages of using CBT for preoperative treatment planning in maxillary posterior teeth with apical pathology. (*J Endod* 2008;34:557–562)

Key Words

Apical lesion, apical surgery, cone-beam tomography, periapical radiography, posterior maxillary teeth

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A thorough history, clinical examination, and good quality periapical (PA) radiographs are essential (1) for preoperative diagnosis of teeth scheduled to undergo apical surgery. However, PA radiography is limited by the fact that information is rendered in only two dimensions. Interpretation is more difficult when the background pattern is complex (2). This often occurs in the posterior maxillary region, where roots of teeth overlap and anatomic structures such as the maxillary sinus and the zygomatic buttress are present (3). The presence of radio-opaque root canal fillings and posts may also add to the complex background pattern.

The use of computed tomography (CT) scans has enabled evaluation of the true extent of lesions and their spatial relationship to important anatomic landmarks (4). The improved detection rate of a periapical lesion over PA radiography was shown experimentally by Fuhrmann et al (5). Artificial bone defects in the antral floor ranging from 1 to 2 mm in diameter to entire denudation of the antral surface were not detected with PA radiography. In comparison, CT scans were able to detect 62.5% of the bone defects. The in vivo detection of periapical lesions by CT scans has also been shown to be more effective (6, 7). Similarly, because of overlapping roots, only 1 out of 14 furcation defects in upper molars were seen on PA radiography, whereas CT scans were able to identify all furcal defects (8). With regards to apical surgery, Velvart et al (6) found that CT scans aided in determining the relationship of lesions to the mandibular canal before apical surgery. In the maxilla, Huumonen et al (7) examined 39 root-filled maxillary molars and concluded that CT scans may provide information important for retreatment decisions, especially in the case of apical surgery. Moreover, the spread of infection originating from maxillary teeth was also clearly recorded by CT scans as erosion of the alveolar cortical plates, soft tissue changes, and sinus membrane thickening (9). However, a CT scan is expensive and produces a much higher radiation dosage than PA radiography. Currently, no clear indications for the use of CT scans in diagnosis before apical surgery have been identified.

Recently, limited cone-beam tomography (CBT) proved useful in detecting periapical lesions in the upper maxillary region in a case report (10). Further advantages were described by Lofthag-Hansen et al (11), who discovered additional lesions with CBT and reported that in 70% of the cases CBT provided clinically relevant information not found on PA radiography. This machine was found to deliver a lower radiation dose and to have a higher resolution than conventional CT scans and was designed for use in dentistry (12, 13).

The relationship of periapical lesions of the roots of posterior maxillary teeth to the maxillary sinus has yet to be evaluated using this modality. Knowledge of such a relationship may be useful in treatment planning, in the prevention of oroantral communication (OAC), and in the prevention of complications in an expected OAC during apical surgery. The use of CT scans in this situation has mainly been limited to the study of bone thicknesses between a normal root apex and the maxillary sinus (14). Others have evaluated the usefulness of conventional PA radiography in determining the risk of creating an OAC during apical surgery (15).

The purpose of this study was to evaluate the detectability of lesions, their relationship with the maxillary sinus, and the overall amount of information using CBT and PA of posterior maxillary teeth. Moreover, the relationship of the maxillary sinus and the roots of these teeth were examined using CBT.

TABLE 1. Types of Evaluated Teeth (*n* = 74)

Tooth	<i>n</i>
First premolars	17
Second premolars	20
First molars	29
Second molars	8

Material and Methods

Patients

Fifty-three consecutive patients were enrolled in the study. The patients were referred to the Department of Oral Surgery and Stomatology at the University of Bern, Bern, Switzerland, for possible apical surgery. They visited the clinic from June 2005 to August 2006 and were selected according to the following criteria: (1) there were clinical signs or symptoms and/or radiographic findings of apical periodontitis of one tooth in the posterior maxilla, (2) teeth had been previously endodontically treated, and (3) teeth involved were examined with PA and CBT.

The final study population consisted of 45 patients (19 women/26 men) with a mean age of 51 years (range, 31–80 years). Hence, 74 teeth yielding 156 roots were evaluated. The distribution of the teeth is listed in Table 1. Eight cases were rejected because images (six PA radiographs/two CBT) were of poor quality.

Radiographic Techniques

The PA radiographs were obtained with a paralleling technique using a film holder (Rinn XCP; Dentsply, Elgin, IL). A dental x-ray machine (HDX; Dental Ez, Lancaster, PA) operating at 65 kV and 7 mA was used, and the exposure time was 0.12 seconds. F Speed films (Kodak Insight, Eastman Kodak, Rochester, NY) were used and processed in an automatic processor (XR 24PRO; Dürr Dental, Bietigheim, Germany). The radiographs were evaluated by using a light box with the aid of an x-ray viewer with 2× magnification.

The CBT images were obtained with a 3 DX Accuitomo XYZ Tomograph (Morita, Kyoto, Japan). Operating parameters were set at 3.0 mA and 80 kV, and exposure time was 17.5 seconds. The 1-mm reconstructed “sagittal” slices were placed parallel to the horizontal axis of the alveolar process, and the teeth to be examined were placed in the center of the volume. For each root, the slices were reformatted to align the root axis with the vertical plane in the “sagittal” and “coronal” views. Images were analyzed by using a Dell 380 Precision workstation and an 18-inch LCD Dell monitor with resolution of 1,024 × 768 pixels (Dell Computer Corporation, Round Rock, TX).

Evaluation of the Images

The images were analyzed concurrently by an oral radiologist and an endodontist. Radiographs were analyzed first, followed by the CBT images at least 2 weeks later. Any disagreement in interpretation was resolved by consensus. Each CBT scan produced three image views: “axial,” “coronal,” and “sagittal.” Each image view was evaluated with respect to the recorded parameters.

A periapical lesion was defined as PA radiolucency in connection with the apical part of the root if the width of the radiolucency exceeded at least twice the width of the periodontal ligament space. For CBT images, the same criteria were applied, and the lesion had to be visible

TABLE 3. The Detection of Lesions in Relation to Apex Classification (*n* = 109)

Detection method	Apex classification (%)			<i>n</i> lesions (%)
	Apex class 1	Apex class 2	Apex class 3	
PA radiography and CBT	38 (83)	9 (35)	25 (68)	72 (66)
CBT only	8 (17)	17 (65)	12 (32)	37 (34)
<i>n</i> lesions	46 (100)	26 (100)	37 (100)	109 (100)

Statistics: apex class 1 versus apex class 2: *p* = 0.001, apex class 2 versus apex class 3: *p* = 0.010, and apex class 1 versus apex class 3: *p* = 0.111.

in two image planes. The relationship of the maxillary sinus to the examined roots and the lesions, respectively, in PA radiographs were classified according to criteria described by Oberli et al (15) (Table 2).

From CBT images, the distances between the lesions and the maxillary sinus were classified into three groups: bone thickness > 1 mm, bone thickness ≤ 1 mm, and the absence of bone. Bone thickness was measured using the measurement tool provided by the software for all three views. The minimum distance from any of the three views was recorded.

The relationships between the maxillary sinus and the roots were evaluated by using images from the “coronal” view. For premolars, the roots were defined as away from, touching, or overlapping the sinus floor. For molars, the roots were defined as away from the sinus floor, overlapping the sinus floor, or having the sinus floor being interposed between the roots. This occurred when the sinus floor overlapped a line joining the tips of the palatal and mesiobuccal roots.

Other recorded parameters included the expansion of lesion into the maxillary sinus, localized thickening of the sinus membrane, a missed canal, and an apicomarginal communication. Thickening of the sinus membrane in response to periapical infection was defined as a sinus membrane exceeding 4 mm on any of the three views with CBT. A missed canal was considered present when a definite canal space was visible and there was no root canal filling material throughout the length of the canal; presence on all three CBT views was required. An apicomarginal communication was considered present when the periodontal ligament space from the marginal bone crest to the apex or to the periapical lesion was twice its normal width.

Statistics

The lesions were classified as being present in either PA radiography, in CBT, or in both of them. A Fisher exact Test (SAS Version 8.2; SAS Inc, Cary, NC) was used to classify their presence in the corresponding subgroups. Bonferroni-Holm adjustment was done where applicable.

Results

The Detection of Lesions (PA Radiography and CBT)

Forty-seven roots had no discernible lesions when evaluated with both PA radiography and CBT. Seventy-two roots had lesions detected by both modalities, whereas 37 roots had lesions discernible only by CBT and missed by PA radiography (Table 3). Overall results showed that 34% of lesions were missed by PA radiography (*p* < 0.001).

TABLE 2. The Classification of Apex and Lesion on PA Radiograph According to Oberli et al (15)

Classification of apex		Classification of lesion	
Class 1	Distinct distance between root tip and sinus floor	Class 1	Distinct distance between lesion and sinus floor
Class 2	Root tip touches sinus floor	Class 2	Lesion touches sinus floor
Class 3	Root tip overlaps sinus floor	Class 3	Lesion overlaps sinus floor

TABLE 4. The Detection of Lesions in Relation to Tooth Type (*n* = 109)

Detection method	Type of tooth (%)				<i>n</i> lesions (%)
	1st premolar	2nd premolar	1st molar	2nd molar	
PA radiography and CBT	13 (72)	13 (81)	40 (65)	6 (46)	72 (66)
CBT only	5 (28)	3 (19)	22 (35)	7 (54)	37 (34)
<i>n</i> lesions	18 (100)	16 (100)	62 (100)	13 (100)	109 (100)

Statistics: 1st premolar versus 2nd premolar: *p* = 0.69, 1st premolar versus 1st molar: *p* = 0.78, 1st premolar versus 2nd molar: *p* = 0.26, 2nd premolar versus 1st molar: *p* = 0.24, 2nd premolar versus 2nd molar: *p* = 0.06, 1st molar versus 2nd molar: *p* = 0.23, and premolar pooled versus molar pooled: *p* = 0.13.

PA, periapical; CBT, cone-beam tomography.

The detection of lesions was influenced by apex location (in relation to the maxillary sinus) and by tooth type (Tables 3 and 4). There were significant differences for lesion detection when comparing apex class 2 to apex classes 1 (*p* < 0.001) and 3 (*p* < 0.010); there was no difference when comparing apex class 1 with class 3 (*p* = 0.111) (Table 3). Hence, the detection of lesions associated with roots located in close proximity to the maxillary sinus was significantly worse when PA radiography alone was used. With regard to tooth type, second molars proved to be the most difficult for detecting lesions with PA radiography alone. The smallest number of lesions was missed in second premolars when comparing PA radiography and CBT (Table 4). The percentages of detection of lesions in relation to bone thickness measured with CBT are summarized in Table 5. The lowest probability of detecting lesions with PA radiographs compared with CBT was seen in lesions with a bone thickness ≤ 1 mm; however, the table shows no significance.

Bone Thickness between the Lesion and Sinus (CBT) Related to Lesion Classification (PA)

All lesions classified as class 1 with PA radiography (= away from the maxillary sinus) had bone > 1 mm between the lesion and the maxillary sinus as measured on CBT images. However, lesions classified as class 2 (= in contact with maxillary sinus floor) or as class 3 (= overlapping maxillary sinus floor) with PA radiography still had some bone between the lesions and the maxillary sinus on CBT images (Table 6). All lesion classes showed significant differences (*p* < 0.001) in homogeneity of bone thickness.

The Expansion of Lesions into the Maxillary Sinus (PA Radiography and CBT)

With regard to the ability of PA radiography and CBT to detect expansion of the lesion into the maxillary sinus, CBT evaluation was significantly more informative (*p* < 0.001). Twenty-three teeth with lesions expanding into the maxillary sinus were detected by CBT, of which only two teeth were seen with PA radiography.

TABLE 5. The Detection of Lesions in Relation to Bone Thickness between Lesion and Sinus Floor (*n* = 109)

Detection method	Bone thickness measured with CBT (%)			<i>n</i> lesions (%)
	>1 mm	≤1 mm	No bone	
PA radiography and CBT	31 (76)	19 (58)	22 (63)	72 (64)
CBT only	10 (24)	14 (42)	13 (37)	37 (34)
<i>n</i> lesions	41 (100)	33 (100)	35 (100)	109 (100)

Statistics: > 1 mm versus ≤ 1 mm: *p* = 0.135, > 1 mm versus no bone: *p* = 0.316, and ≤ 1 mm versus no bone: *p* = 0.805.

PA, periapical; CBT, cone-beam tomography.

Sinus Membrane Thickening (PA Radiography and CBT)

When the sinus lining was studied, 35 teeth with membrane thickening were identified with CBT, of which 16 teeth were also detected with PA radiography (*p* < 0.001).

Missed Canal, Apicomarginal Communication (PA Radiography and CBT)

A total of 15 teeth with missed canals was detected with CBT, of which only four teeth were identified with PA radiography (*p* < 0.05). With regard to apicomarginal communications, six teeth were found with CBT compared with only one with PA radiography (*p* = 0.12).

Distances Measured between Lesions and the Maxillary Sinus (CBT Only)

Maxillary root lesions were frequently found near the sinus, with 32% of lesions perforating the maxillary sinus (no bone detected between lesion and maxillary sinus). Another 30% of lesions only were separated from the maxillary sinus by 1 mm or less of bone. The remaining 38% of lesions were separated from the sinus by a bone thickness greater than 1 mm.

Relationship of Sinus Floor and Roots (CBT Only)

When the relationship between the sinus floor and premolar roots was evaluated, first premolars were generally fairly distant, with only one tooth (5.9%) approaching the sinus floor. For second premolars, 50% of roots overlapped the sinus floor, and in 90% of these, the maxillary sinus was found more palatally. An additional 30% of second premolar roots were approaching the sinus floor. In 76% of first molars and 50% of second molars, the sinus floor was found to be intertwined with the roots.

Discussion

The present study compared the efficacy of PA radiography and CBT in detecting periapical lesions in maxillary premolars and molars referred for apical surgery. The study showed that of 109 lesions detected with CBT, 34% were not detected with PA radiography. This

TABLE 6. Bone Thickness Between Lesion and Sinus Floor Measured with CBT in Relation to Lesion Classification with PA Radiography (*n* = 72)

Bone thickness	Lesion classification (%)			<i>n</i> lesions (%)
	Lesion class 1	Lesion class 2	Lesion class 3	
>1 mm	20 (100)	9 (47)	2 (6)	31 (43)
≤1 mm	—	7 (37)	12 (36)	19 (26)
No bone	—	3 (16)	19 (58)	22 (31)
<i>n</i> lesions	20 (100)	19 (100)	33 (100)	72 (100)

Statistics: lesion class 1 versus class 2 versus class 3: *p* < 0.001, lesion class 1 versus class 2: *p* < 0.001, lesion class 1 versus class 3: *p* < 0.001, lesion class 2 versus class 3: *p* < 0.001.

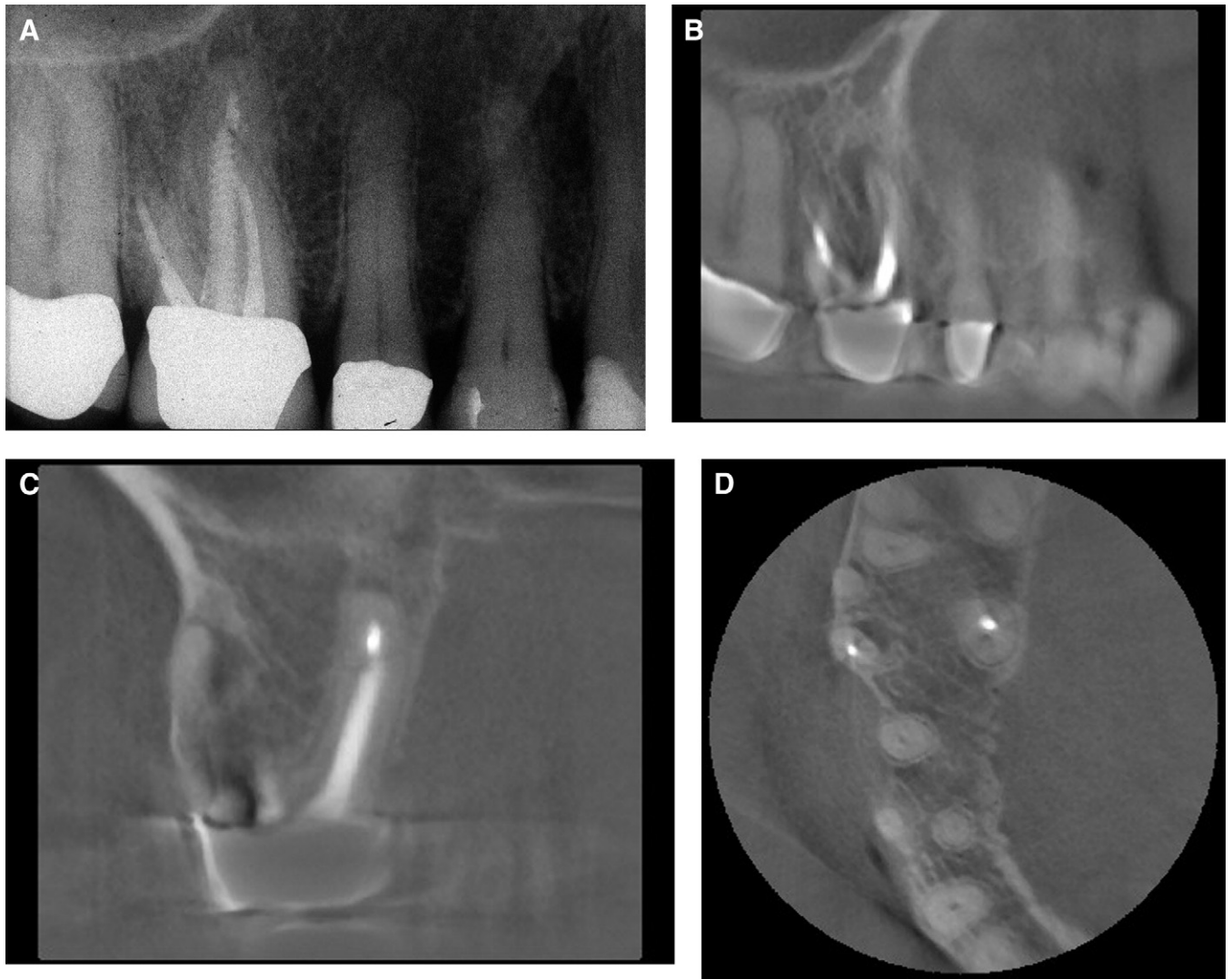


Figure 1. (A) Periapical radiograph showing a small apical lesion associated with the palatal root of the right maxillary first molar. The patient was complaining about pain on the buccal aspect of this tooth. (B) The sagittal CBT image shows a distinct lesion at the distal aspect of the mesiobuccal root of the right maxillary first molar. (C) The coronal CBT image shows a lesion at the palatal aspect of the mesiobuccal root and small apical lesion of the palatal root of the right maxillary first molar. (D) The axial CBT confirms the distinct lesion at the distopalatal aspect of the mesiobuccal root of the right maxillary first molar.

difference was statistically highly significant ($p < 0.001$). Lofthag-Hansen et al (11) showed that 38% of lesions that were undetected by PA radiography despite the fact that an additional PA radiograph (angled view of 10°) was taken.

The present study also showed that lesions associated with apices near the sinus floor had a higher probability of being missed with PA than lesions associated with apices located away from or overlapping the sinus floor. Similarly, lesions associated with molars (Figures 1 and 2), in particular second molars, were more likely to be missed with PA than lesions associated with premolars. Additional findings, such as expansion of the lesion into the maxillary sinus, thickening of the sinus membrane, missed canals, and presence of apicomarginal communications, were more frequently detected with CBT than with PA radiography. In Lofthag-Hansen's study (11), sinus membrane thickening was seen four times as often with CBT (30 cases) compared with PA radiography (7 cases). The lower occurrence in the present study can possibly be explained by the defined criteria where a membrane thickening was deemed to have occurred only when the thickness exceeded 4 mm. In the present study, 83% of apicomarginal communications were not seen

with PA radiography compared with 56% in Lofthag-Hansen's study. A possible explanation could be the fact that in Lofthag-Hansen's study, two PA radiographs were taken with a horizontal angle difference of 10° , thus increasing the probability of detecting an apicomarginal communication with PA radiography.

The detection of apicomarginal communications was found to be an important predictor for the success rate of apical surgery (16, 17). Such communications may be associated with undetected vertical root fractures, which may necessitate extraction. Or, additional measures such as the use of guided tissue regeneration may be required, and, if so, CBT may allow the clinician to study the topography of the bony defect and assess whether the use of membranes would be beneficial (18, 19).

In understanding the relationship of lesions to the maxillary sinus, we can see that no bone existed between the lesion and the sinus only if the roots or the lesion overlapped the maxillary sinus. Hence, our findings agree with those of Oberli et al (15) who found that if the radiograph shows a distinct distance between the periapical lesion and the sinus floor, there is a high probability that an OAC will not occur. A

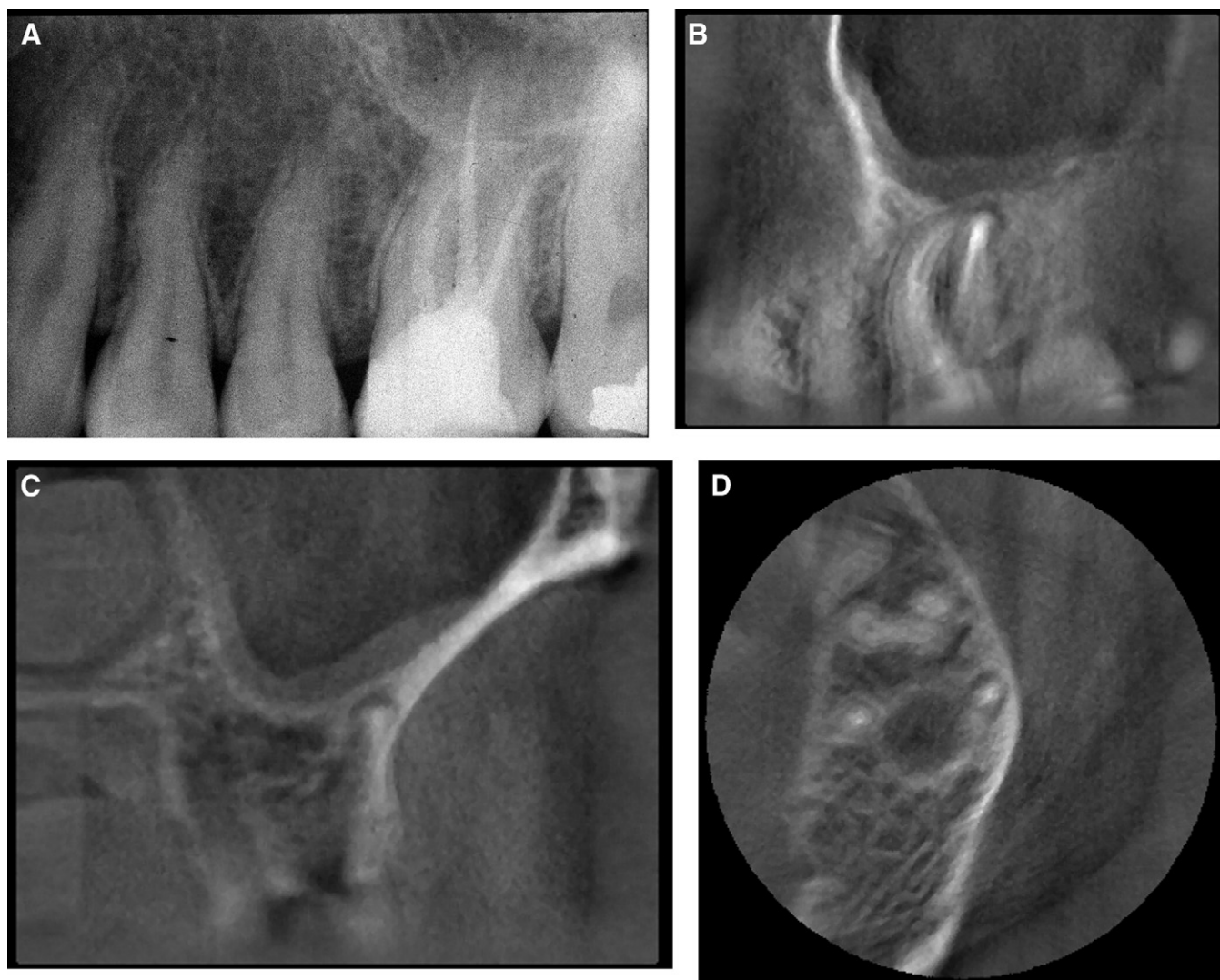


Figure 2. (A) The patient is complaining about a painful sensation in her left maxillary first molar. No periapical lesion can be detected on the periapical radiograph. (B) A small apical lesion was diagnosed with the sagittal CBT image at the distobuccal root of the left maxillary first molar. In addition, a slight thickening of the sinus membrane can be seen. (C) The coronal CBT image confirms the presence of the apical lesion at the distobuccal root of the left maxillary first molar. (D) Similarly, the lesion can be seen on the axial CBT image.

similar situation exists when the bony wall is thin, and one has to be careful to avoid iatrogenic accidents during apical surgery. Whereas precise morphometric assessment of osseous relationships is inadequate with periapical radiography, both situations were easily identified by CBT, which overcomes the diagnostic limitations of PA (14).

The value of CBT in treatment planning for apical surgery may be shown in that in 70% of the cases this revealed clinically relevant information not found in PA radiography (11). Rigolone et al (20) found CBT to optimize anatomic information for the feasibility of vestibular access to palatine roots of maxillary molars. Other researchers have reported that CBT, which can be used to measure the grayscale values of lesions, may provide a better, more accurate, and faster method to differentially diagnose a solid from a fluid filled lesion or cavity. This may allow the clinician to decide whether or not surgery is necessary without waiting a recall period to see if healing has occurred (21). For a comprehensive understanding on advanced imaging and its usefulness in endodontics, the reader is encouraged to read the recently published reviews (22–24).

Conclusions

The present study showed that 34% of lesions detected with cone-beam tomography were missed with periapical radiography in maxillary premolars and molars. The probability of detecting lesions with PA alone was limited for teeth with apices in close contact with the floor of the maxillary sinus, for molars (in particular second molars), and when bone thickness between lesion and sinus (measured with CBT) was ≤ 1 mm. Additional findings such as lesion expansion into the sinus, sinus membrane thickening, missed canals, and presence of apicomarginal defects were also more frequently seen with CBT than PA.

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