

Accuracy of Periapical Radiography and Cone-Beam Computed Tomography Scans in Diagnosing Apical Periodontitis Using Histopathological Findings as a Gold Standard

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Abstract

Introduction: The aim of this study was to evaluate the accuracy of two imaging methods in diagnosing apical periodontitis (AP) using histopathological findings as a gold standard. **Methods:** The periapex of 83 treated or untreated roots of dogs' teeth was examined using periapical radiography (PR), cone-beam computed tomography (CBCT) scans, and histology. Sensitivity, specificity, predictive values, and accuracy of PR and CBCT diagnosis were calculated. **Results:** PR detected AP in 71% of roots, a CBCT scan detected AP in 84%, and AP was histologically diagnosed in 93% ($p = 0.001$). Overall, sensitivity was 0.77 and 0.91 for PR and CBCT, respectively. Specificity was 1 for both. Negative predictive value was 0.25 and 0.46 for PR and CBCT, respectively. Positive predictive value was 1 for both. Diagnostic accuracy (true positives + true negatives) was 0.78 and 0.92 for PR and CBCT ($p = 0.028$), respectively. **Conclusion:** A CBCT scan was more sensitive in detecting AP compared with PR, which was more likely to miss AP when it was still present. (*J Endod* 2009;35:1009–1012)

Key Words

Cone-beam computed tomography scan, diagnostic accuracy, histology, periapical radiography, predictive values, sensitivity, specificity

Periapical radiographs are used clinically to diagnose apical periodontitis (AP). Successful treatment outcome is determined when symptoms and periapical radiolucency are absent after treatment. Posttreatment disease is diagnosed when periapical radiolucency is still present 4 years after the treatment (1). Although longitudinal studies have shown that persistent asymptomatic periapical radiolucencies may stay asymptomatic during a long extended follow-up (2, 3), there is no consensus whether success does not require complete and utter radiographic resolution. For a long time, the absence of periapical radiolucency diagnosed by periapical radiography (PR) has been used to diagnose a healthy periapex. The selection of treatment procedures, instruments, and materials is often determined based on evidence of a higher success rate.

However, the PR image corresponds to a two-dimensional aspect of a three-dimensional structure (4). Periapical lesions confined within the cancellous bone are usually not detected (4–9). A lesion of a certain size can be detected in a region covered by a thin cortex, whereas the same size lesion cannot be detected in a region covered by thicker cortex (10).

It has been reported that cone-beam computed tomography (CBCT) scans detected periapical lesions in many cases in which periapical radiolucency was absent in the periapical radiograph (11–15). Lofthag-Hansen et al (11) diagnosed periapical lesions in endodontically treated human molar teeth using both PR and CBCT scans. Fifty-three lesions were detected using both techniques. An additional 33 lesions were detected by CBCT scans only. Jorge et al (12) detected no AP lesion with PR on day 14 after root canal infection, whereas 47% of samples showed a lesion at day 21; CBCT evaluation detected AP in 33% and 83% of samples at days 14 and 21, respectively. Estrela et al (13) found posttreatment AP in 35% of teeth using PR, but in 63% using CBCT scans. Paula-Silva et al (14) endodontically treated 72 roots of dog teeth, and the outcome was evaluated 6 months after treatment. Periapical lesions were emerged, unchanged, or enlarged (unfavorable outcome) in 21% of roots when determined by PR but in 65% when determined by CBCT scans. All of these findings indicate that the absence of radiolucency in PR does not guarantee a healthy periapex and suggest that a CBCT scan is better suited for diagnosis (16, 17). However, it is not clear whether all CBCT scan–detected periapical lesions are true lesions.

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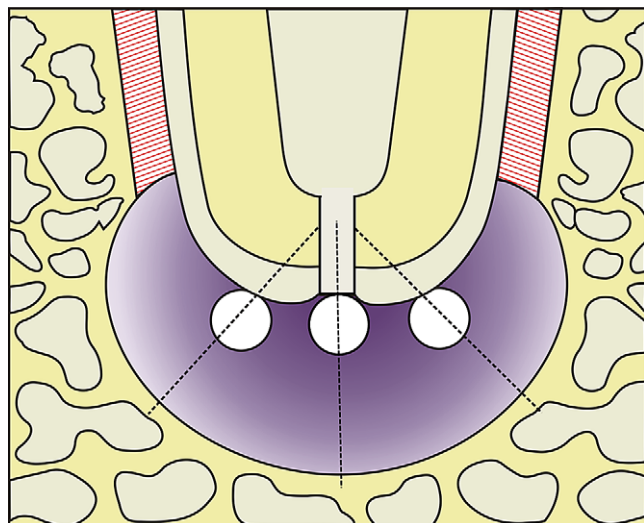


Figure 1. Three representative microscopic fields around the root apex in three orientations: the longitudinal axis through the center of the apical opening and at 45° to this long axis at each side. The number of inflammatory cells was counted in each microscopic field using a counting frame.

Scientific consensus maintains that AP is accurately identified by histologic findings (18). The purpose of this study was to evaluate the sensitivity, specificity, and predictive values of PR and CBCT scan methods in diagnosing AP using histopathological findings as a gold standard.

Material and Methods

An animal experiment with 12 dogs was performed as described previously (14). Briefly, 96 roots of dog teeth were used to form 4 groups (n = 24). In group 1, root canal treatment was performed in healthy teeth. Root canals in groups 2 through 4 were infected until AP was confirmed by PR. Roots with AP were treated by one-visit therapy in group 2, by two-visit therapy in group 3, and left untreated in group 4. The radiolucent area in PRs and the volume of CBCT-scanned periapical lesions were measured before and 6 months after treatment. Four groups were compared in order to observe whether the outcome differed after different treatment programs. The results have been reported (14).

Histological treatment outcomes from 83 roots (24 from group 1, 18 from group 2, 21 from group 3, and 20 from group 4) were examined. Thirteen roots were lost during histologic procedures. An additional 24 roots, which presented radiographically healthy periapices, served as controls (group 5).

The histopathologic procedures and analysis performed were based on those previously described by Leonardo et al (19). The

TABLE 1. Number of Roots with AP Diagnosed by PR, CBCT Scan, and Histology

Group	n	Number of roots with AP		
		PR	CBCT	Histology
1	24	9	11	18
2	18	18	18	18
3	21	12	21	21
4	20	20	20	20
Total	83	59 (71%)	70 (84%)	77 (93%)

AP, apical periodontitis; PR, periapical radiography; CBCT, cone-beam computed tomography

TABLE 2. TPs, FPs, True-Negatives (TNs) and False-Negatives (FNs) in the Diagnosis of AP

Method	Diagnosis of AP					
	Positive	Negative	TP	FP	TN	FN
PR	59	24	59	0	6	18
CBCT scan	70	13	70	0	6	7

TPs, true positives; FPs, false positives; AP, apical periodontitis; CBCT, cone beam-computed tomography

animals were euthanized with a lethal intravenous overdose of sodium pentobarbital. The mandibles were dissected and sectioned to obtain individual roots that were fixed in 10% buffered formalin for 72 hours, demineralized in EDTA, and embedded in paraffin. The specimens were serially sectioned. Longitudinal sections of 5-µm thickness were stained with hematoxylin and eosin and examined under light microscopy by a skilled observer blinded to the treatment groups.

For each specimen, the section that showed the largest periapical lesion was considered as the representative section and used for further observation and measurements. The number of inflammatory cells was counted using a counting frame centered in three representative microscopic fields around the root apex in three orientations, including the longitudinal axis through the center of the apical opening and at 45° to this long axis on each side (Fig. 1). The mean number of inflammatory cells per field of view was calculated for each specimen.

True-positives (TPs), false-positives, true-negatives (TNs), and false-negatives in PR and CBCT diagnoses were determined using histopathologic findings as the gold standard. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic accuracy (true positives + true negatives) in the diagnosis of AP were calculated.

Statistical Analysis

Data were analyzed statistically by chi-square and analysis of variance tests. The level of significance was set at α = 0.05.

Results

The results are presented in Tables 1 through 3. PR detected AP in 71% of roots, CBCT scans detected AP in 84%, and AP was histologically diagnosed in 93% (p = 0.001) (Table 1). In 15 (19.5%) of 77 roots in which periapical inflammation was histologically diagnosed, the inflammatory cells were restricted to the apical foramen (Fig. 2).

Results of TPs, false-positives, TNs, and false-negatives, sensitivity, specificity, PPV, NPV, and diagnostic accuracy for diagnosis of AP are summarized in Tables 2 and 3. CBCT scans produced more accurate diagnoses (TP + TN) than PR (p = 0.028).

Significant differences in the number of inflammatory cells were observed among the five groups (p < 0.0001). Group 4 (roots with AP, untreated) presented the highest number (71.8 ± 19.7) and group 5 (healthy controls) the lowest (5 ± 2.4). The numbers of inflammatory cells were 46.8 ± 16.4, 45.3 ± 10.0, and 42.8 ± 13.1 for groups 1 (root canal treatment in healthy teeth), 2 (roots with AP, one visit), and

TABLE 3. Sensitivity, Specificity, PPV, NPV, and Diagnostic Accuracy (TPs and TNs) for PR and CBCT scans Calculated Using Histologic Findings as the Gold Standard

Method	Sensitivity	Specificity	PPV	NPV	Accuracy
PR	0.77	1	1	0.25	0.78
CBCT	0.91	1	1	0.46	0.92

PPV, positive predictive value; NPV, negative predictive value; TPs, true positives; TNs, true negatives; PR, periapical radiography; CBCT, cone-beam computed; tomography

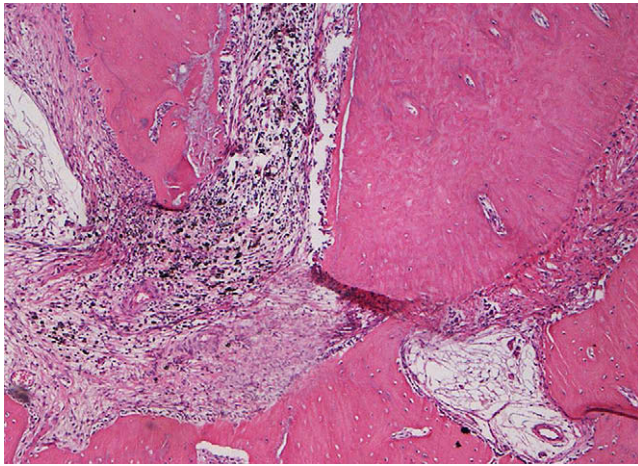


Figure 2. A specimen in group 3 showing a small periapical lesion (magnification 10 \times) measured as 1.2 mm² in PR and 2.8 mm³ in a CBCT scan. Inflammatory cells were restricted to the apical foramina surrounding extruded material particles.

3 (roots with AP, two visit), respectively. There were no significant differences between groups 1, 2 and 3 ($p > 0.05$).

Discussion

The NPV for PR diagnosis was 0.25 in this study; thus, when an intact periradicular region was diagnosed by PR, 75% of the cases actually had AP. It is not a new finding that PR diagnoses have a low NPV. The NPV was reported to be 0.74 by Green et al (20), 0.53 by Brynolf (21), 0.55 by Rowe and Binnie (22), 0.35 by Stavropoulos and Wenzel (23), and 0.67 by Barthel et al (24). In an *in vivo* histologic study by Ricucci and Langeland (25), the root apex and periapical tissues were examined histologically after root canal treatment. Twenty cases were clinically and radiographically classified as successful; only four (20%) were free of inflammatory cells within the surrounding bone or fragments of periodontal ligament attached to the extracted roots. Our observations, in conjunction with previous studies, make it clear that the value of PR is limited for diagnosing the absence of AP.

Computed tomography scans have been widely used in medicine since the 1970s (26) and first appeared in endodontic research in the late 80's (27, 28). Cone-beam technology has existed since the 1980s. The effective dose of radiation for CBCT scans is much lower than for traditional computed tomography scans (29). The predictive values and diagnostic accuracy of CBCT for diagnosing AP are essential to the current practice of dentistry. In a study by Velvart et al (30), 78 CBCT-scanned AP lesions were considered to be true lesions during periapical surgery. However, biopsies of periapical materials were not evaluated. In an *ex vivo* study by Stavropoulos and Wenzel (23) in which the accuracy of CBCT diagnosis was calculated, artificial periapical lesions were cut in pig jaws using drills and the relationship between the artificially prepared lesions and CBCT diagnoses was analyzed. To our knowledge, the present study is the first *in vivo* study to investigate the predictive value of CBCT scans for diagnosing AP using histopathologic findings as a gold standard. Importantly, the conditions in our experiment (14) mimicked the clinical situation. In group 1, root canal treatment was performed in healthy teeth. Root canal infection and AP developed in groups 2 through 4 after the access openings were exposed to the oral cavity for 1 week to allow microbial contamination and then sealed. Roots with AP were endodontically treated with one- or two-visit therapy.

The NPV for CBCT was almost twice as high as that for PR (Table 3), indicating that CBCT scans more accurately diagnosed the healthy periapex. However, histology still detected seven more roots with AP when compared with CBCT scans (Table 1). Among the 77 periapical lesions detected by histology, 15 were rather small and the inflammatory cells were restricted to the apical foramen (Fig. 2). It is possible that the volumetric bone loss was low in these cases and therefore that the lesion was not detectable, even by CBCT scans, in 7 roots.

Nevertheless, the specificity and PPV were 1 for both PR and CBCT. Thus, whenever an apical lucency was detected by PR or a CBCT scan, it corresponded histologically with mild or severe inflammation. The accuracy of CBCT scans in diagnosing AP was 0.92 (Table 3). Thus, TP and TN diagnoses of AP occurred in 92% of cases. In conclusion, CBCT diagnosed healthy periapex more accurately than PR did.

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