A New Periapical Index Based on Cone Beam Computed Tomography

Carlos Estrela, DDS, MSc, PbD,* Mike Reis Bueno, DDS, MSc,† Bruno Correa Azevedo, DDS, MSc,‡ José Ribamar Azevedo, DDS,§ and Jesus Djalma Pécora, DDS, MSc, PbD||

Abstract
The purpose of this study was to evaluate a new periapical index based on cone beam computed tomography (CBCT) for identification of apical periodontitis (AP). The periapical index proposed in this study (CBCT-PAI) was developed on the basis of criteria established from measurements corresponding to periapical radiolucency interpreted on CBCT scans. Radiolucent images suggestive of periapical lesions were measured by using the working tools of Planimp software on CBCT scans in 3 dimensions: buccopalatal, mesiodistal, and diagonal. The CBCTPAI was determined by the largest lesion extension. A 6-point (0–5) scoring system was used with 2 additional variables, expansion of cortical bone and destruction of cortical bone. A total of 1014 images (periapical radiographs and CBCT scans) originally taken from 596 patients were evaluated by 3 observers using the CBCTPAI criteria. AP was identified in 39.5% and 60.9% of cases by radiography and CBCT, respectively (P < .01). The CBCTPAI offers an accurate diagnostic method for use with high-resolution images, which can reduce the incidence of false-negative diagnosis, minimize observer interference, and increase the reliability of epidemiologic studies, especially those referring to AP prevalence and severity. (J Endod 2008;34:1325–1331)

Key Words
Apical periodontitis, cone beam computed tomography, diagnostic imaging, endodontic diagnosis, radiography

Periapical radiography is an essential resource in endodontic diagnosis, because it offers important evidence on the progression, regression, and persistence of apical periodontitis (AP) (1, 2). It is known that periapical radiolucencies might not be visible radiographically, although they exist clinically (3–5). Moreover, radiographs are 2-dimensional representations of 3-dimensional structures, and certain clinical and biologic features might not be reflected in radiographic changes. Clinical and radiologic criteria are frequently used to assess the status of endodontic treatment and its correlation with AP (6–14), but morphologic variations, surrounding bone density, x-ray angulations, and radiographic contrast can influence radiographic interpretation (12, 13).

With the great technological advances of recent years, new imaging modalities have been added to dental radiology as viable diagnostic tools, namely digital radiography, densitometry methods, cone beam computed tomography (CBCT), magnetic resonance imaging, ultrasound, nuclear techniques (13, 15–23), providing detailed high-resolution images of oral structures and permitting early detection of bone lesions.

CBCT has been used for several clinical and investigational purposes in endodontics (15, 16, 18–20). According to a recent study (16), the specific endodontic applications of cone beam volumetric tomography (CBVT) are being identified as this technology becomes more prevalent, but its potential indications include diagnosis of pathosis from endodontic and nonendodontic origins, assessment of root canal morphology, evaluation of root and alveolar fractures, analysis of external and internal root resorption and invasive cervical resorption, and presurgical planning in root-end surgeries. Scarfe et al. (21) have stated that important innovations of imaging systems involve the change from analog to digital imaging and advances in imaging theory and volume-acquisition data, allowing detailed 3-dimensional imaging. Investigations (22, 23) have demonstrated that a cyst could be distinguished from periapical granulomas by CBCT because it shows a marked difference in density between the content of the cyst cavity and granulomatous tissue, thus favoring a noninvasive diagnosis. At this point in time, scientific consensus has been reached to the fact that AP is correctly detected by histologic analysis (24).

Previous studies (1, 8, 10) have referred to the periapical index (PAI) as a scoring system for radiographic assessment of AP. The PAI represents an ordinal scale of 5 scores ranging from no disease to severe periodontitis with exacerbating features and is based on reference radiographs with confirmed histologic diagnosis originally published by Brynolf (8). Ørstavik et al. (1) applied the PAI to both clinical trials and epidemiologic surveys and might be transformed into success and failure criteria by defining cutoff points on the scale for a dichotomous outcome assessment (13).

Given the limitations of conventional radiography for detection of AP and the availability of new emerging 3-dimensional imaging modalities, the development of new periapical indices seems to be a necessity. The purpose of this study was to evaluate a new PAI based on CBCT for identification of AP.

Material and Methods

Cone Beam Computed Tomography Periapical Index

The Cone Beam Computed Tomography Periapical Index (CBCT-PAI) proposed in this study was developed on the basis of criteria established from measurements corresponding to periapical radiolucency interpreted on CBCT scans. The sizes of radiolu-
cent images suggestive of periapical lesions were delimited and measured by using the working tools of Planimp software (CDT Computing, Cuiabá, MT, Brazil) on CBCT scans in 3 dimensions: buccopalatal, mesiodistal, and diagonal (Fig. 1). The CBCTPAI was determined by the largest extension of the lesion.

**Figure 1.** Clinical case of mandibular molar showing the axial (A), sagittal (B), and coronal (C) planes. The CBCTPAI was determined by the largest extension of the lesion.

**TABLE 1.** Cone Beam Computed Tomography Periapical Index Scores

<table>
<thead>
<tr>
<th>Score (n)</th>
<th>Quantitative Bone Alterations in Mineral Structures</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Intact periapical bone structures</td>
</tr>
<tr>
<td>1</td>
<td>Diameter of periapical radiolucency &gt; 0.5–1 mm</td>
</tr>
<tr>
<td>2</td>
<td>Diameter of periapical radiolucency &gt; 1–2 mm</td>
</tr>
<tr>
<td>3</td>
<td>Diameter of periapical radiolucency &gt; 2–4 mm</td>
</tr>
<tr>
<td>4</td>
<td>Diameter of periapical radiolucency &gt; 4–8 mm</td>
</tr>
<tr>
<td>5</td>
<td>Diameter of periapical radiolucency &gt; 8 mm</td>
</tr>
<tr>
<td>Score (n)</td>
<td>Expansion of periapical cortical bone</td>
</tr>
<tr>
<td>+ E*</td>
<td>Expansion of periapical cortical bone</td>
</tr>
<tr>
<td>Score (n)</td>
<td>Destruction of periapical cortical bone</td>
</tr>
<tr>
<td>+ D*</td>
<td>Destruction of periapical cortical bone</td>
</tr>
</tbody>
</table>

*The variables E (expansion of cortical bone) and D (destruction of cortical bone) were added to each score, if either of these conditions was detected in the CBCT analysis.

**Figure 2.** Schematic representation of molars CBCTPAI.

**Figure 3.** Schematic representation of premolars CBCTPAI.
largest extension of the lesion. A 6-point (0–5) scoring system was used. In addition, considering that CBCT provides 3-dimensional images, with depth being added as a new plane of analysis in relation to 2-dimensional radiography, 2 variables were included in the scoring system as appropriate, expansion of cortical bone (E) and destruction of cortical bone (D) (Table 1 and Figs. 2–7).

Patients

One thousand fourteen images (periapical radiographs and CBCT scans) originally taken from 596 patients (241 men and 355 women; mean age, 54 ± 17 years) between May 2004 and August 2006 were selected from the Dental and Radiological Institute of Brasília (IORB, Brasília, DF, Brazil) database. All patients had 1 or more teeth with history of endodontic treatment. Some of the teeth in question radiographically displayed an AP. The involved teeth were mandibular molars (n = 126), maxillary molars (n = 203), mandibular premolars (n = 183), maxillary premolars (n = 226), mandibular canines (n = 11), maxillary canines (n = 99), mandibular incisors (n = 13), and maxillary incisors (n = 153).

The study design was independently reviewed and approved by the Institutional Ethics in Research Committee.

Imaging Methods and Evaluation

The periapical radiographs were taken with Max S-1 x-ray equipment (J. Morita Mfg Corp, Kyoto, Japan) with 0.8 mm × 0.8 mm tube focal spot and with Kodak Insight film-E (Eastman Kodak Co, Rochester, NY) according to the parallel radiographic technique. All films were processed in an automatic processor and developed by using standardized methods. CBCT images were obtained with 3D Accuitomo XYZ Slice View Tomograph (model MCT-1; J. Morita Mfg Corp) voxel size of 0.125 × 0.125 × 0.125 mm, 12 or 8 bits. Images were examined by using specific software (3D Tomo X version 1.0.51) in a PC workstation running under Microsoft Windows XP professional SP-1 (Microsoft Corp, Redmond, WA).

Three calibrated blinded observers evaluated all digital images by using the CBCTPAI criteria described in Table 1. The level of interobserver agreement was assessed by kappa statistics in 10% of the sample (25). Data were analyzed statistically by the $\chi^2$ test to determine significant differences among the imaging methods for detection of AP. Significance level was set at $\alpha = 1%$.

Results

Table 2 shows the prevalence of AP identified by periapical radiography and CBCT by using the CBCTPAI. AP was detected in 39.5% and 60.9% of cases by periapical radiography and CBCT, respectively ($P <$
Table 3 presents the results of the diagnostic imaging tests by using CBCTPAI kappa values for interobserver agreement, considering the CBCTPAI scores ranged from 0.86–0.96 for periapical radiographs and CBCT scans. Figs. 2–7 show the schematic representation and clinical cases of groups of mandibular and maxillary teeth corresponding to CBCTPAI.

Discussion

CBCT was more accurate than periapical radiography for AP diagnosis. AP was identified in nearly 40% of the cases by using periapical radiographs and in almost 61% of the cases by using CBCT scans (Table 2).

The accuracy of CBCT scans compared with periapical radiographic images is in accordance with the findings of previous studies (5, 16, 18, 19, 21–23, 26). Lothag-Hansen et al. (26) compared intraoral periapical radiography and a 3-dimensional imaging system (3D Accuitomo) for the diagnosis of apical pathology in 36 patients (46 teeth). When both diagnostic methods were analyzed by all observers, they agreed that the CBCT images provided clinically relevant additional information not found in the periapical films. The capacity of computed tomography to evaluate a region of interest in 3 dimensions might benefit both novice and experienced clinicians alike. The advantages include increased accuracy, higher resolution, scan-time reduction, and lower radiation dose (16).

The use of conventional radiography for detection of AP should be done with care because of the great possibility of false-negative diagnosis. The benefits of using CBCT in endodontics refer to its high accuracy in detecting periapical lesions even in its earliest stages and aiding in differential diagnosis as a noninvasive technique (5).

Simon et al. (23) compared the differential diagnosis of large periapical lesions (granuloma versus cyst) with traditional biopsy by using CBCT. Seventeen large periapical radiolucencies (equal to or greater than 1 × 1 cm) were scanned to determine densities, and a preoperative CBCT diagnosis was made. The lesions were then removed.

Figure 6. Clinical cases of maxillary incisors CBCTPAI showing all scores used and 2 additional variables (expansion of cortical bone and destruction of cortical bone).
surgically and sent for histopathologic examination. In 13 of 17 cases, the biopsy report and CBCT diagnosis coincided. In 4 of 17 cases, the CBCT read cyst, whereas the oral pathologist’s diagnosis was chronic AP. These results suggest that CBCT might provide a faster method to differentially diagnose a solid from a fluid-filled lesion or cavity, without invasive surgery and/or waiting a long time to see whether nonsurgical therapy is effective.

The CBCTPAI proposed hereby has some advantages for clinical applications. CBCTPAI scores are calculated by analysis of the lesion in 3 dimensions, with CT slices being obtained in mesiodistal, buccopalatal, and diagonal directions. The measurement of lesion depth contributes significantly to the diagnosis and consequently to improve case prognosis. The addition of the variables expansion of cortical bone and destruction of cortical bone to CBCTPAI scoring system permits the analysis of 2 possible sequels to AP that might be missed by periapical radiography. Detection of these conditions will alter the diagnostic hypothesis and the treatment plan. The goal of this new index is therefore to offer a method based on the interpretation of high-resolution images that can provide a more precise measurement of AP extension, minimizing observer interference and increasing the reliability of research results.

The PAI as indicated by Ørstavik et al. (1) ranges from health to severe periodontitis on the basis of the interpretation of 2-dimensional radiographic images, whereas CBCTPAI scores have been established according to the interpretation of 3-dimensional CBCT scans. These 2 peri-

### TABLE 2. AP Prevalence in Endodontically Treated Teeth as Determined by Periapical Radiography and CBCT, by Using CBCTPAI (n = 1014)

<table>
<thead>
<tr>
<th></th>
<th>Periapical Radiography</th>
<th>CBCT</th>
<th>P Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presence of AP</td>
<td>401 (39.5%)</td>
<td>618 (60.9%)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Absence of AP</td>
<td>613 (60.5%)</td>
<td>396 (39.1%)</td>
<td></td>
</tr>
</tbody>
</table>

AP, apical periodontitis; CBCT, cone beam computed tomography.

*χ² test.

Figure 7. Clinical cases of maxillary molars CBCTPAI showing all scores used and 2 additional variables (expansion of cortical bone and destruction of cortical bone).
apical indices thus have different scoring systems as a result of the characteristics of each target image (conventional periapical radiograph or CBCT scan). The scope of the present study is to evaluate a new PAI that is based on an imaging modality that allows detection of lesions that are not visible radiographically. Considering the clinical history, the relation between health and disease in CBCTPAI can be begun by stage 1, without detection of cortical bone expansion or destruction of the cortical bone.

The limitations of periapical radiography to identify AP support the need to review the epidemiologic studies conducted in different populations worldwide. A considerable discrepancy among the imaging methods used to diagnose AP, especially with a new baseline value, certainly might reduce the influence of radiographic interpretation and the possibility of false-negative diagnosis.

In the present study, the kappa values for CBCTPAI scores ranged from 0.86–0.96 for periapical radiographs and CBCT scans, which indicate that a very good interobserver agreement was reached. High kappa values (0.80–0.95 range) have also been observed in previous studies that examined periapical radiographs (27, 28).

In spite of the dental imaging technique, care should be taken to avoid misinterpretation. The presence of intracanal metallic posts, for example, might lead to equivocal interpretations as a result of artifact formation in CBCT images. Metallic objects can be present in either the tooth of interest or an adjacent one and hinder the analysis of CBCT images (26), although in current days the influence of this artifact has been reduced. This artifact has been found to be closely related to the type of tissue or object (ie, computed tomography value) and the x-ray energy applied (29).

Under the tested conditions and within the limitations of this study, it might be concluded that AP detection was considerably higher with CBCT than with periapical radiography. The PAI proposed in this study (CBCTPAI) offers an accurate diagnostic method for use with high-resolution images, which can reduce the incidence of false-negative diagnosis, minimize observer interference, and increase the reliability of epidemiologic studies, especially those referring to AP prevalence and severity.

References