Detection Accuracy of Bone Defects Depending on Exposure Settings of Cone Beam Computed Tomography

Spyridon I. Vassilopoulos, DDS, MS, DrDent
Yiorgos A. Bobetsis, DDS, PhD
Michalis Mastoris, DDS, MS
Eudoxie Pepelassi, DDS, MS, DrDent
Keti Nikopoulou-Karagianni, DDS, MS, DrDent

Despite the widespread use of cone beam computed tomography (CBCT), few articles have been published to assess the accuracy in detecting alveolar bone defects using different CBCT exposure settings. A human cadaver with rounded bone defects in various locations was scanned using a CBCT scanner at different settings. Four examiners twice studied 1,500 cross-sectional digital and printed slices for defect presence, location, and size. High-resolution zoom mode achieved the highest overall accuracy. Moreover, apical location of the defects significantly affected overall accuracy. Bone defect detection depends upon exposure settings of CBCT scans. Exposure settings and field of view dimensions should be individualized per case. Int J Periodontics Restorative Dent 2020;40:e65–e72. doi: 10.11607/prd.4258

By generating cross-sectional slices and images in all planes, cone beam computed tomography (CBCT) technology overcomes the limitations of conventional two-dimensional imaging such as superimposition, distortion, and magnification, allowing for better visualization of bone defect morphology. However, both image quality and ability to depict natural and pathologic structures depend on a variety of CBCT factors such as the scanning unit, radiographic source size, field of view (FOV), voxel size, tube voltage and amperage, the examined object, examination time, and unintentional head movements. Due to the variability of these parameters, recent systematic reviews conclude that the definition of a general CBCT protocol for specific diagnostic tasks in dentistry is not yet feasible. Therefore, individualized CBCT protocols could be helpful to enhance the clinician’s diagnostic ability. The aim of this study was to assess the sensitivity, specificity and overall diagnostic accuracy in detecting various artificially prepared bone defects in multiple sites of a dry human mandible when using different exposure settings of CBCT scans and different imaging protocols.
Materials and Methods

Creation of Bone Defects

An edentulous mandible from a human cadaver provided by the Medical School of the National and Kapodistrian University of Athens was dried out and all soft tissues were removed. Round bone defects were created buccally and linguually in the areas of the central incisors, canines, second premolars, and first and second molars using round carbide burs (Hager & Meisinger) with 0.5-, 1-, and 1.6-mm diameters. Apical/intrabony defects were also created at the postextraction socket bottom using 2.1- and 2.7-mm–diameter burs (Fig 1). Each defect depth was measured twice using a digital caliper (Standard Gage) with 0.01-mm precision. The median value was considered as the actual defect depth.

Image Capturing and Processing Stage

The mandible was sunk in a plastic food container filled with distilled water to mimic soft tissue–equivalent absorption.12 Proper mandible position was verified with laser guides and was slightly adjusted according to scout views (one lateral and one frontal) prior to scanning. The mandible was stable between examinations to keep the same imaging projection geometry for all scans, and it was then scanned using the NewTom VGi CBCT scanner under the following conditions and varying FOV sizes and resolution settings: (1) zoom mode (standard...
dose), (2) zoom mode (boosted dose), (3) high-resolution zoom mode, (4) full mode (standard dose), and (5) full mode (boosted dose). Exposure settings were set automatically by the unit using a special software to achieve proper radiologic brightness and contrast in all images. Technical specifications for each imaging modality are presented in Table 1.

Slice reconstruction from the volumetric data of each examination was performed perpendicular to the mandible’s longitudinal axis in each anatomical region and to the tangent of the mandibular body’s lower edge. The image processing procedure was the same as in clinical practice for CBCT analysis, and a cross-sectional slice series was created with a constant slice interval and slice thickness of 1 mm. Films were printed out in a DRYSTAR 5300 thermal high-resolution printer (AGFA).

Radiographic Evaluation

A total of 1,500 radiographic slices (750 printed and 750 digital) were evaluated twice, with an interval of 1 month between evaluations, by each one of the four blinded examiners (two oral radiologists [M.M. and K.N.K], one periodontist [Y.B.], and one general practitioner). For each bone defect, the following parameters were evaluated: (1) Defect presence or absence (scale of 1 to 5: 1 = absent; 2 = possibly absent; 3 = unsure; 4 = possibly present; 5 = present); (2) Defect location (buccal, lingual, apical/intrabony), evaluated for “possibly present” (marked as a 4 on the scale) or “present” (marked as a 5 on the scale) defects; (3) Defect size (in mm), evaluated in the printed format only due to small (one decimal) precision in the digital format.

Table 1 Technical Specifications for Each Imaging Modality

<table>
<thead>
<tr>
<th></th>
<th>Zoom mode: standard dose</th>
<th>Zoom mode: boosted dose</th>
<th>High-resolution zoom mode</th>
<th>Full mode: standard dose</th>
<th>Full mode: boosted dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voxel size, mm</td>
<td>0.24</td>
<td>0.24</td>
<td>0.125</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Axial thickness, mm</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Peak kilovoltage, kV</td>
<td>110</td>
<td>110</td>
<td>110</td>
<td>110</td>
<td>110</td>
</tr>
<tr>
<td>Millamperes, mA</td>
<td>4.3</td>
<td>8.24</td>
<td>12.09</td>
<td>0.5</td>
<td>0.55</td>
</tr>
<tr>
<td>Exposure time, s</td>
<td>3.6</td>
<td>3.6</td>
<td>5.4</td>
<td>3.6</td>
<td>3.6</td>
</tr>
</tbody>
</table>

Statistical Analyses

Statistical analysis included the following comparisons: (1) Defect presence, location, and size for each radiographic exposure type as compared to the actual defect; (2) Defect presence and location between printed and digital radiographic format; and (3) Initial and reevaluation data (intra- and interexaminer measurements).

Because a defect could be detected in adjacent slices, the slice with the highest examiner response (from the scale of 1 to 5) was included in the analysis. Results were initially presented as frequencies and proportions in two-way tables. When cross-tabulating examiners’ responses with actual status of the area (defect presence or absence), additional statistics were reported: (1) Kendall tau rank correlation and corresponding P value, (2) proportion of “correct” responses, (3) sensitivity, and (4) specificity. Concordance of examiners’ responses in the two evaluations was assessed through a weighted version of Cohen’s kappa coefficient of agreement. Formal analysis of sensitivity, specificity, and the overall accuracy of examiners was based on logistic regression and ordinal logistic regression models. Finally, the full spectrum of possible answers by the examiners from absence (scale: 1) to presence (scale: 5) were analyzed through an ordinal regression model, which included interaction terms between covariates of interest (exposure type, defect location, printed or digital, initial and reevaluation) with an indicator variable for the presence or absence of a defect in the specific area (overall accuracy).
Results

Resolution Settings

There were significant differences in the probabilities of bone defect detection (sensitivity) depending on the type of radiographic exposure. Compared to the “full (boosted)” exposure type, “full (standard)” achieved the highest sensitivity (odds ratio [OR]: 1.03; 95% confidence interval [CI]: 0.77 to 1.39; P < .001), followed by “high-resolution” (OR: 1.97; 95% CI: 1.67 to 2.32; P < .001) and “full (standard)” (OR: 1.57; 95% CI: 1.48 to 1.66; P < .001).

There were no significant differences between “full (standard)” and “full (boosted)” (Table 2).

Next, bone defect detection specificity was studied. Compared to the “full (boosted)” exposure type, only “full (standard)” achieved higher specificity (OR: 1.90; 95% CI: 1.35 to 2.67; P < .001). “High-resolution” and “zoom (standard)” did not differ from “full (boosted),” while “zoom (boosted)” demonstrated the worst specificity (OR: 0.49; 95% CI: 0.27 to 0.89; P = .019) (Table 2).

Results from the analysis of the full spectrum of all possible examiners’ answers (from “absent” to “present”) representing the overall accuracy (better sensitivity and specificity) are summarized in Table 2. Compared to the “full (boosted)” exposure type, “high-resolution” achieved the highest relative OR (rOR) (rOR: 1.92; 95% CI: 1.32 to 2.79; P < .001), followed by the “full (standard)” (rOR: 1.80; 95% CI: 1.09 to 2.96; P = .021) and “zoom (standard)” (rOR: 1.44; 95% CI: 1.14 to 1.83; P = .002). No difference was observed with “zoom (boosted).”

Figure 2 depicts an example of cross-sectional slices of the same area of the mandible in all resolution settings. In this area, bone defects were simultaneously located apically, buccally, and lingually. There are obvious differences in detection accuracy depending on the imaging modality. Figure 3 presents the examiners’ responses of defect detection in respect to various resolution settings.
Observational Format

Sensitivity, specificity, and overall accuracy did not differ significantly between printed and digital evaluations (Table 2). Figure 4 presents the examiners’ responses regarding defect presence with respect to printed or digital format.

Bone Defect Location

The sensitivity in detecting defects located apically/intrabony was remarkably low (OR: 0.05; 95% CI: 0.01 to 0.32; P < .001). Bone defects in the buccal area were harder to be detected by all examiners compared to lingual ones (OR: 0.65; 95% CI: 0.48 to 0.87; P = .004) (Table 2). When specificity was evaluated, no differences were detected with respect to defect location (Table 2).

Defect location seemed to significantly affect the overall accuracy of examiners’ responses, with the apical/intrabony being associated with very poor performance (rOR: 0.03; 95% CI: 0.01 to 0.08; P < .001) compared to lingual locations. Buccal defects were associated with less-accurate results compared to lingual defects, but without reaching significance (rOR: 0.69; 95% CI: 0.46 to 1.05; P = .081). Figure 5 presents the examiners’ responses regarding defect presence or absence with respect to defect location.

Repeatability

Sensitivity and overall accuracy were significantly improved at reexamination, both for printed and digital formats. Specifically, there was a slight but significant increase in defect detection rates at reevaluation compared to initial evaluation (OR: 1.15; 95% CI: 1.02 to 1.29; P = .023), and reevaluation results tended to be slightly more accurate (rOR: 1.20; 95% CI: 1.00 to 1.42; P = .044). No differences were detected in specificity (Table 2). Figure 6 presents the examiners’ responses regarding defect presence or absence with respect to initial examination and reevaluation.

Defect Size

Defect size assessment was closer to the actual size in “high-resolution” and “full (standard)” modes; however, estimation differences between resolution settings were not significant. Defect detection accuracy was stronger for lingual and larger defects. No differences in detection accuracy were observed buccally and apically/intrabony depending on defect size (data not presented).

Discussion

Based on the present results, the high-resolution setting had the best overall performance. Obviously, the reason for that was the combination of high radiation dose and higher image resolution (smaller voxel dimension). Interestingly, boosted modes did not significantly improve defect detection compared to the respective standard modes (full and zoom). Although raising the radiation dose theoretically increases the signal-to-noise ratio, this did not improve diagnostic accuracy. Hence, these results indicate that higher image resolution (smaller voxel size) may be a critical factor in detecting bone defects accurately. In addition,
full and zoom standard settings did not significantly differ and achieved the second-best results in detection accuracy. Therefore, physical FOV dimensions were not significant for the final results. From a clinical point of view, if the optimum high-resolution setting is not selected, zoom standard mode should be preferred over the full standard mode in cases where a larger FOV is not needed diagnostically (as the radiation dose is reduced by using a smaller FOV, like in zoom mode). In clinical conditions, FOV size should be carefully selected to restrict exposure to anatomic areas where the defect is suspected to be found.
Defect location was an important factor that affected the examiners’ detection effectiveness. Irrespective of resolution settings, the apical/intrabony defects were poorly detected. The small actual size of the defects in combination with the very low contrast with the surrounding tissues possibly led the examiners to confuse the defects with large medullary spaces. However, lingual and buccal defects were significantly better identified in all resolution settings. Overall detection ability did not significantly differ between buccal and lingual defects, though detection sensitivity was significantly lower for buccal than lingual defects for both initial and reevaluations. This observation was unexpected, since the mandibular buccal plate width is thicker than the lingual width, especially posteriorly, and thus a higher contrast with a present defect would be anticipated.14

Results from CBCT viewing con-

Fig 5 Examiners’ responses of defect detection (actual absence/presence of bone defect) with respect to defect location. Aggregated results included data from all examiners, all resolution settings, all observational formats (printed or digital), all defect sizes, and initial and reevaluation examinations.

Fig 6 Examiners’ responses of defect detection (actual absence/presence of bone defect) with respect to initial and reevaluation examinations. Aggregated results included data from all examiners, all locations, all resolution settings, all observational formats (printed or digital), and all defect sizes.
ditions (high-resolution computer monitor or printed hard copy) did not differ significantly. However, digital CBCT evaluations had a trend of performing better. It is possible that if the whole volume data set and all potentials of the digital image processing were utilized, a higher defect detection might have been achieved. In the present study, the advantage of using an edentulous mandible was that it excluded artifacts due to dental restorations and patient’s head movement. However, limitations include the evaluation of only spherical defects and the lack of soft tissues, although the use of the surrounding water has been described to simulate radiation absorption, secondary radiation, and scattering caused in clinical conditions by head soft tissues.

Conclusions

Within the limitations of this study, it was demonstrated that bone defect–detection sensitivity, specificity, and overall accuracy depend on exposure settings of CBCT scans. Prior to CBCT examination, exposure settings and FOV should be individually selected to reduce the radiation dose without affecting diagnostic accuracy. Further research is needed to determine the cut-off point in the size of bone defects that can be detected at different exposure settings as well as to compare CBCT to other three-dimensional imaging modalities, such as multislice computed tomography.

Acknowledgments

The authors declare no conflicts of interest. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. All applicable international, national, and/or institutional guidelines for the use of human cadavers were followed. The edentulous mandible of a human cadaver was provided by the Medical School of the National and Kapodistrian University of Athens. The study was reviewed and approved by the ethical board of the Dental School of the National and Kapodistrian University of Athens.

References