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Evaluation of buccal bone coverage in the anterior region by cone-beam computed tomography

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Introduction: The purpose of this study was to compare the sensitivity of diagnoses of buccal bone coverage in anterior teeth between axial and sagittal reconstructions using cone-beam computed tomography. **Methods:** Five dry skulls were clinically evaluated to detect bone defects in the anterior maxilla and mandible to establish a gold standard. The skulls were prepared and placed on a Kodak 9000 3-dimensional scanner (Trophy, Marne La Vallée, France) for image acquisition. The images were processed and reconstructed using Kodak Dental Imaging software 3-dimensional module (version 2.4; Kodak Dental Systems, Atlanta, Ga). All bone defects were identified and recorded. **Results:** In the sagittal and axial reconstructions, regions without bone coverage were diagnosed in 91.03% of cases as "cortex not seen" or "minimum thickness, fine, without marrow bone." **Conclusions:** Cone-beam computed tomography can help in the diagnosis of lack of bone coverage on the buccal surfaces of anterior teeth. There was no difference in the performance of the axial and sagittal reconstructions. (Am J Orthod Dentofacial Orthop 2013;144:698-704)

Fenestration and dehiscence are bone defects characterized by the absence of alveolar bone coverage, where the root is covered by the periodontal ligament and mucosal lining. They occur in approximately 20% of teeth bilaterally, with greater frequency in the anterior buccal bone.[1,2]

Diagnosis of the absence of bone coverage is relevant to many areas of dentistry, such as periodontics, prosthetics, surgery, and orthodontics. Exploring the alveolar architecture, the bone support of each tooth, before starting treatment is important for safe planning for each patient. During orthodontic treatment, for example, projection and retraction of the anterior teeth are common. However, the thickness of the alveolar bone on the anterior teeth is a factor that should be considered and measured before and during treatment because the amount of bone in the region can limit tooth movement and the maintenance of periodontal health.[3-6]

Cone-beam computed tomography (CBCT) imaging has revolutionized maxillofacial diagnostics.[7,8] CBCT allows micrometric slices to be viewed from selected areas for study. Moreover, improvements in software and workstations have allowed creation of reconstructions from images acquired on various planes, even reconstructions of soft tissues; this facilitates the final diagnosis and explanation to the patient.[7]

In search of knowledge about the contribution of CBCT to bone coverage evaluation and to minimize the deleterious effects of orthodontic therapy, we aimed to detect the absence of bone coverage in the anterior region through axial and sagittal reconstructions by CBCT.

MATERIAL AND METHODS

Five dry skulls were selected from the collection of the Department of Orthodontics and Facial Orthopedics at the Professor Édimo Jose Soares Martins Centre at the School of Dentistry of the Federal University of Bahia in Brazil. All skulls were from men between 18 and 25 years of age; they were intact and free of fractures and metallic

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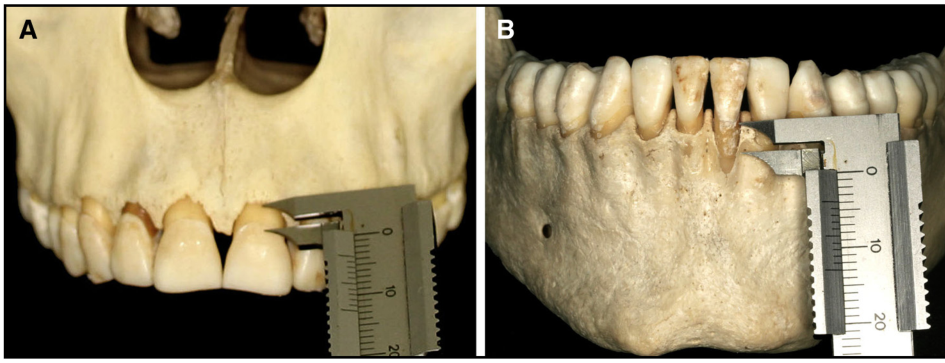

Fig 1. Measurements of buccal bone defects (dehiscence) in **A,** the maxilla and **B,** the mandible.

Fig 2. The maxilla and mandible coated with colorless wax.

restorations, with complete dentitions; the teeth had no anomalies.

Before image acquisition, the skulls were evaluated by dentists from the orthodontics postgraduate program of Federal University of Bahia to detect any bone defects in the anterior regions of the maxilla and the mandible (Fig 1). With an Odin caliper (Ortho-Pli, Philadelphia, Pa), a lack of bone coverage up to 4 mm was recorded as dehiscence, and a lack of bone marrow along the root of the tooth was classified as bone fenestration. These defects, as well as their locations, were recorded. This clinical evaluation created the gold standard.

To simulate x-ray attenuation caused by a patient's soft tissues, the jaws were coated with Wilson utility wax (Polidental, Cotia, Brazil) and then soaked in water for 24 hours before image acquisition (Fig 2).

The skulls and jaws were positioned on a Kodak 9000 3-dimensional unit (Trophy, Marne La Vallée, France) with the median sagittal plane perpendicular to the horizontal plane, and the occlusal plane parallel to the horizontal plane (Figs 3 and 4). For the maxilla, the following image acquisition parameters were used: 60 kV, 8 mA, and 0.2 voxel. For the mandible, the parameters were 60 kV, 6.3 mA, and 0.2 voxel.

The sagittal images were reconstructed and manipulated using the Kodak Dental Imaging software 3-dimensional module (version 2.4; Kodak Dental Systems, Atlanta, Ga), providing average brightness and contrast. (Fig 5). For each tooth, 3 sagittal reconstructions (Fig 6) and 6 axial reconstructions, 3 from the middle third and 3 from the apical third (Fig 7), were used. The axial reconstructions were prepared in the same

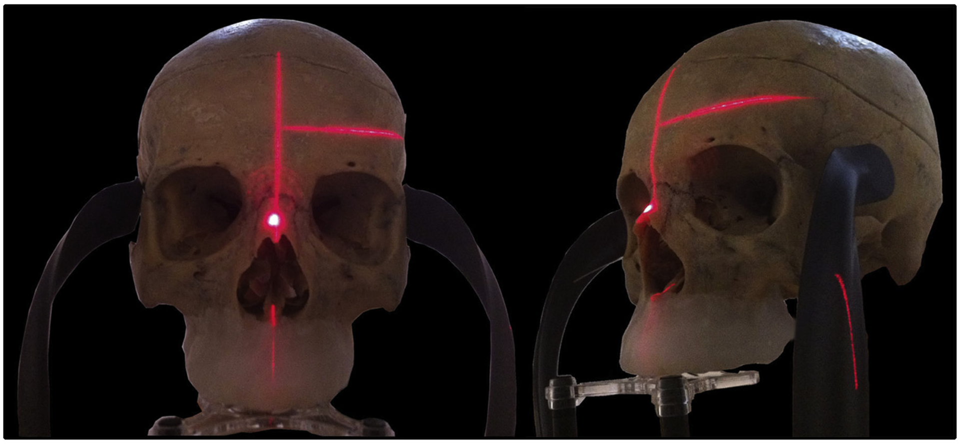

Fig 3. Skull positioned for image acquisition of the maxilla. Note that light beams assist in positioning with the median sagittal plane and for marking the height of acquisition.

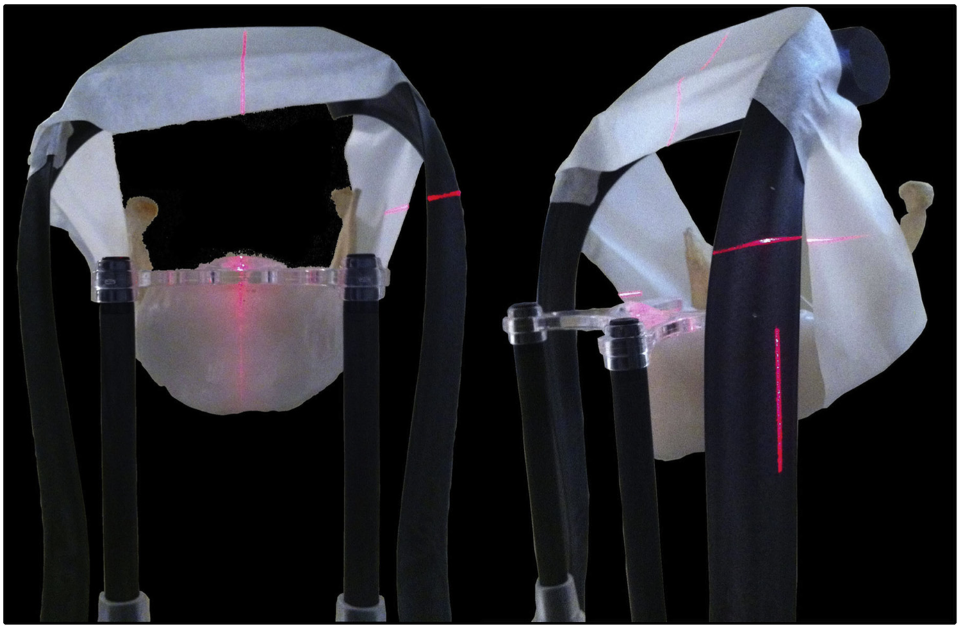

Fig 4. Jaw positioned for image acquisition.

way as the sagittal reconstructions, with a thickness of approximately 1.0 mm (Fig 8). All reconstructions were evaluated by 2 radiologists (M.T. and another), with at least 5 years of experience, without knowledge of the study protocol. The examiners evaluated and classified the bone in each third of the tooth using the following criteria: (1) critical: cortex not seen (nonexistent); (2) slender: cortical bone of minimum thickness, thin, without bone marrow; (3) regular: cortical bone and bone marrow visible; and (4) thick: significant amounts of cortical bone and bone marrow.

A week after the first evaluation, 20% of the sample was reassessed to study intraexaminer error.

RESULTS

From the 5 skulls that were clinically evaluated, there were 39 thirds (apical and middle thirds) without bone coverage. From the 60 tooth images, 120 thirds and 240 reconstructions (120 axial and 120 sagittal) were obtained. Of the 39 thirds without bone coverage, 19 were identified as having critical coverage by sagittal

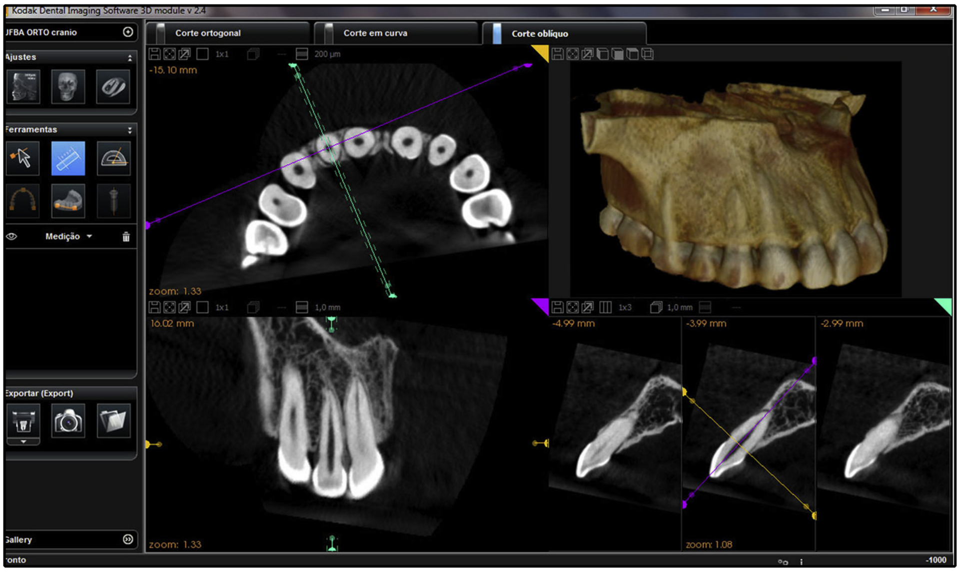

Fig 5. Screen during construction of the sagittal image by applying an oblique cutting tool. Detail for sagittal reconstruction is shown (*lower left corner*).

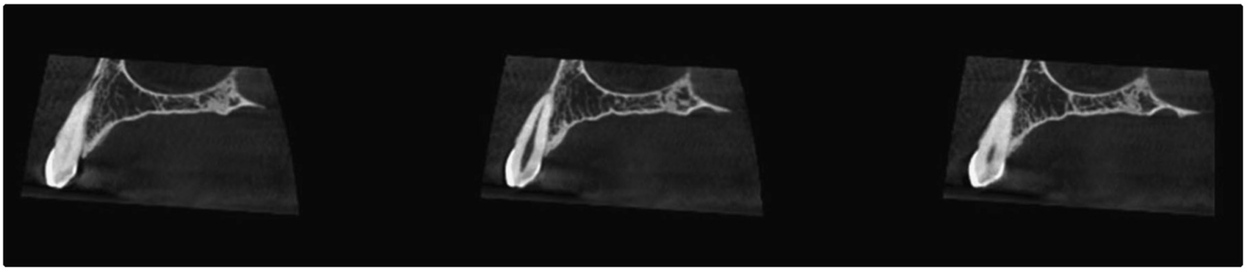

Fig 6. Sagittal reconstructions assessed by the examiners.

reconstructions and 15 by axial reconstructions. The remaining thirds were classified as having slender coverage.

The kappa test was performed to evaluate interexaminer agreement, resulting in moderate agreement ($\kappa = 0.4698$). The same test was used to evaluate intraexaminer agreement; the 2 examiners achieved substantial agreement ($\kappa = 0.6522$ and $\kappa = 0.76$, respectively). In this context, the level of agreement proved that the examiners' experience and training in advanced diagnostic techniques allowed diagnosis of subtle differences. Both examiners were instructed about the definition of each criterion assessed, so the correlation results reflect that the absence of bone coverage is a recognized condition when using CBCT. Therefore, from the images recorded here, if the professional is trained, the assessments do reflect reality.

Using the chi-square test on the sagittal and axial reconstructions, regions with a lack of bone coverage were diagnosed in 91.03% of the cases as "cortex not viewed" (critical) or "minimum thickness, thin, without bone marrow" (slender); 28.21% were classified as critical and 62.82% as slender.

According to the descriptive analysis, when separating the evaluations by thirds, we observed that in the absence of bone coverage, the middle third had a higher percentage of agreement with the clinical gold standard than did the apical third (Fig 9).

When separated by type of reconstruction, the CBCT images showed that the sagittal reconstructions had 78.43% agreement with the clinical gold standard; this represents moderate agreement ($\kappa = 0.4509$), whereas the axial reconstructions had 73.33% agreement ($\kappa = 0.3131$).

The sagittal reconstructions with CBCT had a sensitivity of 51.35%, a specificity of 90.36%, and an accuracy of 78.33% for the assessment of alveolar bone covering the anterior teeth; the sagittal reconstructions

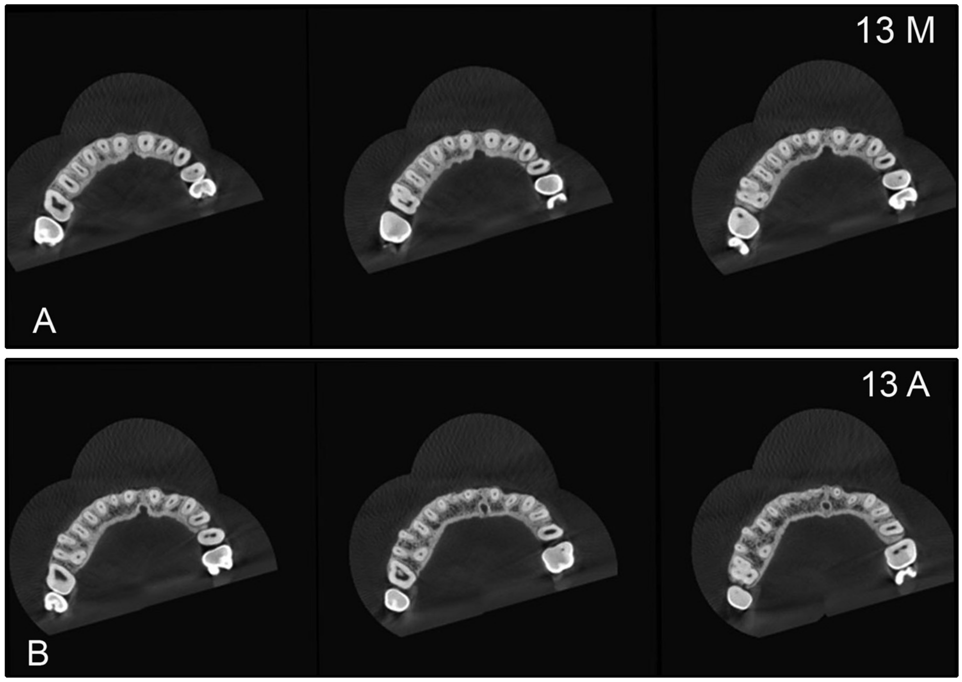

Fig 7. Axial reconstructions of the middle **(A)** and apical **(B)** thirds assessed by the examiners.

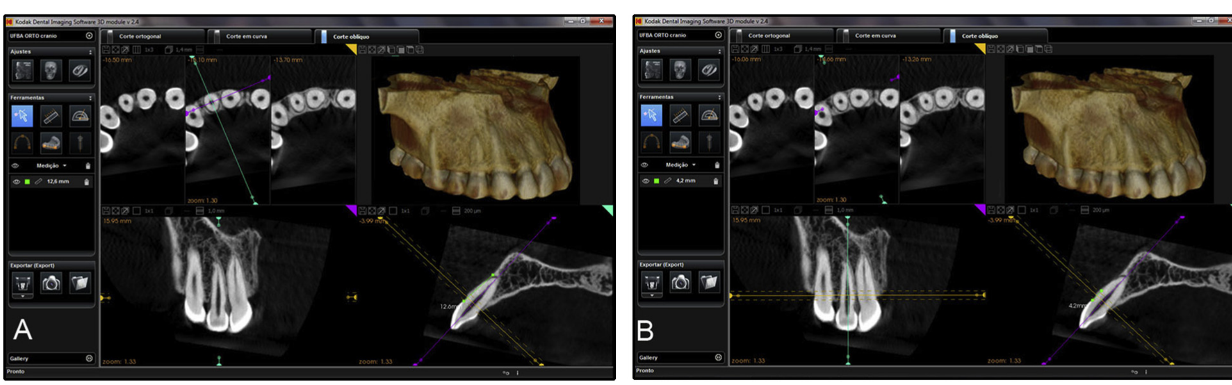

Fig 8. Screen during construction of an axial image by applying an oblique cutting tool. Detail for axial slices is shown (*upper right corner*). **A,** Measuring root size; **B,** sharing thirds.

performed better for diagnosing bone coverage compared with the axial reconstructions.

DISCUSSION

CBCT, a recent technology, requires an advanced level of computational and anatomic knowledge to diagnose subtle differences in bone thickness, as found in bone dehiscences and fenestrations.

Most thirds without bone coverage (62.82%) were identified in the CBCT reconstructions as slender thickness (cortical bone of minimum thickness, thin, no bone marrow); therefore, greater caution is recommended before working on these dental units because there might be no bone at the site.

In comparison with a study by Leung et al,[9] who found that the number of fenestrations observed in CBCT was 3 times the number in the skulls, and that the number of dehiscences was smaller than the clinical diagnoses indicated, the outcome of this study showed lower general recognition by CBCT than by a clinician. However, the differences in methodology must be considered. Leung et al used 3-dimensional reconstructions to detect bone defects, and only when a defect was flagged could the examiner observe the bone coverage in other cuts. Furthermore, they used a voxel size of 0.38 mm; we used a voxel size of 0.2 mm as determined in a previous study to detect bone defects.[10] Panzarella et al[11] reported that voxel size can affect the accuracy of diagnoses in CBCT in some areas, such as implantodontics, endodontics, and periodontics; in these cases, it is better to use a low voxel size. These authors suggested a protocol using a voxel size of 0.25 mm to evaluate details higher than used in our study. Patcas et al[12] observed that voxel size can affect the precision of bone defect measurements. These factors, as well as the acquisition of images with different devices, greatly influenced the outcomes.[13] The sagittal results were slightly higher than the axial results because of the method's high success rate in diagnosing lesions in the middle third (81.82%). Apparently, interpretation of sagittal reconstruction requires less complex evaluation compared with axial reconstruction. When they are categorized into thirds, it was observed that the results for the sagittal third were lower than for the apical third; only 35.29% of cases of absence of bone coverage in the sagittal region were classified correctly, and bone coverage in 72.73% of the remainder was considered slender. It is possible that the anatomic curvature in dental apices influenced this result because during the making of a sagittal section, the long axis of the tooth was the reference for the creation of the sagittal plane, so the apical curvature cannot be considered. For the diagnosis in the middle third, the sagittal reconstructions showed good agreement with the clinical gold standard; among those not classified as critical, 100% were in the slender category.

Ferreira et al[5] developed a specific method to measure the buccal bone plate and lingual bone in the maxillary area from axial reconstructions using CBCT and concluded that based on this methodology, it is possible to evaluate cortical bone and the risk of tooth movement as well as its limits during orthodontic treatment. They stated that to evaluate buccal and palatal bone coverage, a visual analysis of the axial and sagittal sections is sufficient to expose areas with critical bone coverage. However, a full sweep of the area under study by CBCT is interesting for the final diagnosis of any tomographic study. In this study, the data were satisfactory in the sagittal and axial planes, but the dynamic evaluation of all planes based on unique perspectives is essential for accurate diagnosis.

According to Evangelista et al[14] in a study of Class I and Class II patients, bone defects were diagnosed by CBCT in 51.09% of the teeth before orthodontic treatment. In this study, 45% of the teeth had at least 1region with no bone coverage. Therefore, supporting the work of these authors, CBCT is indicated to diagnose defects to preserve periodontal health before and after treatment, especially in patients with buccal tooth movement and arch expansion, and when the patient has an adverse gum biotype.

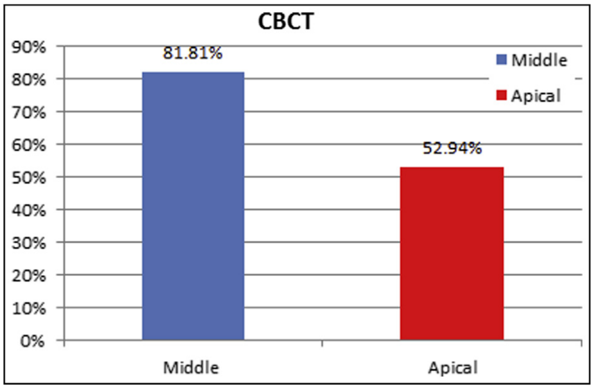

Fig 9. Agreement in the diagnosis of absence of bone coverage in the middle and apical thirds by CBCT.

CBCT allows evaluation of the images in 3 spatial planes; this enables a more accurate diagnosis. When the results are expressed together in the axial and sagittal planes, performance is better (69.23%) than with a single plane (43.59% for the axial plane, 61.53% for the sagittal plane). Therefore, there is an urgent need for multiplanar scanning of each tooth, and for careful and thorough study with the available software tools provided by CBCT. Grauer et al[15] suggested that reconstructions should be evaluated in digital imaging and communications in medicine (DICOM) format because systems are still not clear or precise. The accuracy of the diagnostic method should be evaluated before it is set as the default. However, DICOM reconstructions contribute to diagnostic socialization, enabling discussion with professionals from different specialties. Sharing knowledge is undoubtedly important. However, all reconstructions acquired must be carefully inspected before making the final diagnosis.

CONCLUSIONS

CBCT can identify a lack of bone coverage on the labial surfaces of anterior teeth. The sagittal section is more reliable than the axial section, mainly in the middle third.

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