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Alternative cone-beam computed tomography method for the analysis of bone density around impacted maxillary canines

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Introduction: Genetic and environmental etiologic factors have been described for maxillary canine impaction, except for the trabecular bone characteristics in the impacted area. The aim of this study was to evaluate the surface area and fractal dimension of the alveolar bone on cone-beam computed tomography (CBCT) images of patients with maxillary impacted canines. **Methods:** The sample comprised preorthodontic treatment CBCT images of 49 participants with maxillary impacted canines (31 unilateral and 18 bilateral). CBCT images were acquired in portrait mode (17 × 23 cm high field of view) at 120 kV, 5 mA, 8.9-seconds exposure time, and 0.3-mm voxel size. Coronal slices (0.3 mm) were obtained from the right and left alveolar processes between the first and second maxillary premolars. We collected 64 × 64-pixel regions of interest between the premolars to assess maxillary bone area and fractal dimension using ImageJ software (National Institutes of Health, Bethesda, Md). Comparisons were made using paired *t* tests and linear regression. Repeated measurements were obtained randomly from about 20% of the sample. **Results:** In subjects with unilateral impactions, the maxillary bone area ($P = 0.0227$) was higher in the impacted side, with a mean difference of 245.5 pixels (SD, 569.2), but the fractal dimension ($P = 0.9822$) was not, −0.0003 pixels (SD, 0.082). Comparisons of unilateral and bilateral subjects using a general linear mixed model test confirmed the increased bone area in the impacted side ($P = 0.1062$). The repeated measurements showed similar results. **Conclusions:** The maxillary alveolar bone area is increased in the impacted side compared with the nonimpacted side. (Am J Orthod Dentofacial Orthop 2018;154:442-9)

Maxillary permanent canine impaction has been reported to affect 1% to 3% of the general population.[1,2] The maxillary canine is the second most frequently impacted tooth, after the third molar.[1] The impaction is more common in female patients, with some authors reporting its occurrence twice as high as in male patients.[1-3] The incidence of palatally displaced canines has been observed to be 2 to 3 times greater than buccally impacted canines.[1,4] Previous studies have suggested that palatally displaced canines are associated with increased space in the dental arch, whereas buccally shifted canines are associated with inadequate space for eruption.[5-7] Other potential etiologies for palatally impacted canines have been documented, including genetic defects[8,9] and the absence or underdevelopment of the lateral incisors.[10]

The development and increasing use of cone-beam computed tomography (CBCT) in the dental field has facilitated the study and classification of impacted canines.[11-14] CBCT has several advantages compared with traditional 2-dimensional techniques. CBCT can produce 3-dimensional images of structures located in different spatial planes.[15-17] Other advantages of CBCT include a much lower radiation dose, a much lower

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cost, and less image distortion compared with other computed tomography modalities.[18]

It has been known for some time that CBCT can be used to locate impacted canines 3 dimensionally and determine the degree of root resorption.[11,13] A recent study compared CBCT against a traditional panoramic radiograph; the authors found that CBCT was more predictive in determining the position labio-palatally of the impacted canine.[13] Jung et al[13] also found that the extent of root resorption was more accurately classified with CBCT. Botticelli et al[14] speculated that CBCT can lead to a better prognosis after treatment.

CBCT has been used to find radiographic predictors of canine impaction. The strongest predictors were found to be canine angulation in reference to the lateral incisor, the cusp tip angulation in relation to the occlusal plane, and the overall crown position.[11] However, there is a lack of studies assessing the bone quality of the maxilla in the impacted and nonimpacted contralateral canine areas using CBCT. This may be because bone density measurements in Hounsfield units using CBCT are not reliable.[19] Other approaches to measuring bone quality and microstructure, such as trabecular number and fractal dimension analysis, have been proposed and validated.[20] Hsu et al[20] found high correlations between gray-scale values taken by CBCT and bone microarchitecture parameters when measured by micro-computed tomography. Ibrahim et al[21] concluded that CBCT can be used to evaluate the microstructure of trabecular bone at the site of implants, with the most reliable indicator being trabecular number. Similarly, fractal dimension analysis, calculated from CBCT scans, has been shown to be effective in determining bony structures.[22-24] Previous studies have concluded that fractal values calculated from CBCT scans correlate with bone mineral density[25] and trabecular patterning.[23] Due to the irregular and random nature of trabecular bone, measuring fractal dimension may be a more reliable method of analysis compared with the traditional analysis with Hounsfield units.

To our knowledge, previous studies have not proposed bone density of the alveolar process as an etiologic factor of canine impaction. Nevertheless, understanding the effect of the microstructure of the alveolar bone on the etiology of impacted canines may aid in diagnosis and treatment of the disorder. Therefore, we used CBCT to assess the relationship of the presence or absence of unilateral and bilateral maxillary canine impactions and the microstructure of the maxillary alveolar bone, as measured by the bone surface area and the bone fractal dimension. The null hypothesis was that there is no difference in bone density between the impacted and nonimpacted sides as measured by bone surface area and the bone fractal dimension.

MATERIAL AND METHODS

The institutional review board of the University of Minnesota approved this retrospective study (number 1506M73701) using the pretreatment CBCT scans of patients with unilateral or bilateral canine impaction seeking treatment at the University of Minnesota Orthodontic Clinic. Three hundred sixty-nine potential participants were initially identified using the preliminary clinical or radiographic diagnosis at the initial orthodontic examination or during the treatment planning visits. From these 369 patients with unilateral or bilateral canine impaction, 105 had pretreatment CBCT scans. All CBCT scans were completed at the University of Minnesota School of Dentistry. Canine impaction was defined as an unerupted canine when root development was complete, or by the complete eruption of the contralateral canine.[26] Similarly, complete eruption was defined as the tooth in its expected occlusion and position.[26] The inclusion criteria for the study were (1) CBCT scan showing unilateral or bilateral maxillary canine impaction with complementing clinical diagnosis, (2) complete eruption of the contralateral canine in unilateral patients, (3) classification of buccal or palatal impaction based on the location of at least 50% of the crown compared with the alveolar ridge in a coronal cross section, and (4) no prior orthodontic treatment. The exclusion criteria were (1) evidence of systemic disease affecting bone health; (2) CBCT scans that displayed oral pathology; (3) congenitally missing teeth, supernumerary teeth, dentigerous cyst, or an enlarged cystic follicle; (4) history of dental trauma or anterior maxillary surgery; (5) evidence of motion or any other significant artifact in the CBCT scan; and (6) periodontal abnormalities. A complete review of each patient's dental and medical histories and the CBCT scans was completed to verify these criteria. Forty-nine subjects were selected based our inclusion and exclusion criteria (20 male, 29 female; age at time of the scan, 10-34 years). There were 31 subjects with unilateral canine impaction and 18 with bilateral impaction. Of the 31 subjects with unilateral impactions, 20 were identified as having palatal impactions and 11 had buccal impactions. In those with bilateral impactions, 18 of the impacted canines were impacted palatally and 18 were impacted buccally.

CBCT scans were acquired with an i-CAT Next Generation scanner (Imaging Sciences International, Hatfield, Pa). CBCT images were acquired in portrait mode (17 cm diameter × 23 cm high field of view) at 120 kV, 5 mA, 8.9-seconds exposure time, and 0.3-mm voxel size.