Comparison of Trabecular Bone in Impacted and Normal Erupted Unilateral Maxillary Canine Teeth Using Cone-Beam Computed Tomography in Patients Scheduled for Orthodontic Treatment at the Universitas Airlangga Dental and Oral Hospital

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ABSTRACT

Background. Cone-beam computed tomography is being utilized in more clinical contexts and determining bone density with this method is becoming more important. Dentists, particularly dentomaxillofacial radiologists, orthodontists, and oral surgeons, must have a solid understanding of gray value. The gray values acquired from cone-beam computed tomography images are used to assess dental implant bone density, diagnose dental ankylosis, and diagnose and differentiate pathological lesions.

Objective. To determine the difference in the gray value of the trabecular bone in the impacted and normal erupted maxillary canine teeth using cone computed tomography.

Methods. We retrospectively evaluated the cone-beam computed tomography images of patients scheduled for orthodontic treatment at the Universitas Airlangga Dental and Oral Hospital. On cross-sectional cone-beam computed tomography images, the region of interest determination of 5 mm^2 in the area was placed in the trabecular bone and the gray value measurements were collected using Digital Imaging and Communications in Medicine (OnDemand3D™) dental software. The images were categorized by type of impacted canine teeth after assessing the gray values of all the teeth. Using images on the mesial, distal, buccal, and palatal areas, gray values of impacted and non-impacted teeth were compared. We used the SPSS 24 software.

Results. From a total of 13 patient radiographs, we found types I (6/13), II (6/13), and VII (1/13). The mean pixel values of impacted maxillary unilateral canine teeth were 1972.92 (mesial), 2016.55 (distal), 1990.66 (buccal), and 1904.39 (palatal). The mean pixel values of normal erupted maxillary canines were 1754.93 (mesial), 1710.53 (distal), 1852.94 (buccal), and 1674.49 (palatal). There were significant differences between impacted and normal erupted maxillary canines: mesial (P = 0.018), distal (P = 0.000), buccal (P = 0.003), and palatal (P = 0.036).

Conclusion. There were statistically significant differences between affected and unaffected gray values in the canines in FOV size 51 × 55 mm. However, no statistically significant differences were found in the gray values in trabecular bone of unilateral maxillary impacted canines and normal erupted canines on the mesial, distal, buccal, and palatal sides.

Keywords: impacted, canine, trabecular bone, maxillary, cone-beam computed tomography

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INTRODUCTION

Cases of impacted canines occur around 1%–2.5%, which is the second highest case after impacted third molars. The cases of impaction of the maxillary canines were more than that of the mandible.[1-4] The overall prevalence of impacted maxillary canines was 2.1%. Furthermore, based on the location, the impacted canines in the buccal area showed a slightly higher prevalence of 49.8% than the palatal (43.9%).[5] The prevalence of impacted maxillary canines were reported from 64 patients experiencing 80 cases with 75% unilateral and 25% bilateral distribution.[6] Al-Zoubi et al. stated that impacted maxillary canines on palatally impacted canines (PIC) were 85%, while 69.4% was reported to have unilateral distribution.[1]

The dentistry field uses cone-beam computed tomography (CBCT) in imaging modality to produce three-dimensional images of the sagittal, coronal, and axial areas. CBCT has a much lower radiation dose and less image distortion than computed tomography (CT). The imaging modality can be used to facilitate studies, assist in determining the labio-palatal position of impacted maxillary canines, and accurately determine the rate of resorption at the root of the tooth; hence, suitable as a prognosis in determining treatment plans and after treatment.[7,8] CBCT images have been used to examine the bone density of dental implants, diagnose dental ankylosis, and diagnose and distinguish pathological lesions.[9] The position of the impacted maxillary canine and the angulation of the cusp tip in reference to the occlusal region are described using CBCT in all directions. It can also be utilized for trabecular bone micro-assessment and offers information on the quantity and quality of alveolar bone via the HU index.[10] CT and CBCT were used to acquire Hounsfield units (HU) and GSV values, respectively.[9,11]

The evaluation of the microstructural architecture of bone tissue on radiographs has increasingly been developed. For instance, the FA (Fractal analysis) is used to examine the microarchitecture of trabecular bone with the numerical expression of fractal dimension (FD) as a measure of image complexity. BAF is another method for evaluating the microstructural architecture of bone tissue as a percentage of pixels that represent the trabecular pattern in a binary image. FD and BAF have a statistically significant correlation. BAF provides information on the bone pattern and bone mineral density (BMD).[9,12,13] Furthermore, GSV, bone area fraction (BAF), and FD indicate bone quality. The density change of each tissue is based on the grayscale level of an image, which is shown in the form of pixel value (PV) in the CBCT.[9] The gray scale value (GSV) obtained from CBCT are used in an analog form as the HU values to determine BMD.[14] Many studies have found a linear relationship between GSV and HU and concluded that GSV is useful for BMD assessment.[15] In the literature, GSV obtained from CBCT images were studied for BMD assessments of dental implants, the diagnosis of dental ankylosis, and the diagnosis and differentiation of pathological lesions.[9] Although many factors affect the GSV, many studies found linear correlations between GV and HU and concluded that the GSV is useful for BMD assessment.[15]

Understanding the effect of the adjacent alveolar BMD on the etiology of impacted canines may aid in the diagnosis and treatment of the condition. Only one study on this topic has been published, and it found that higher BMD could play a local causal role in maxillary canine impaction.[16] Previous researchers have also demonstrated its potential use of BMD in examining trabecular structures on CBCT, the feasibility of measuring FD, BAF, and GSV on CBCT with FOV sizes: 40 x 40, 60 x 60, and 100 x 50 mm and recommend using the smallest FOV size when evaluating BD using GSV from CBCT images.[17] The purpose of this study was to determine the difference in GSV of trabecular bone on impacted unilateral maxillary canines using CBCT with FOV image sizes between 40 x 40, 60 x 60, and 100 x 50 mm. This study hypothesizes that there are differences in the GSV of the trabecular bone in the impacted unilateral maxillary canine with normal eruption using CBCT with that image size.

METHODS

The study was reviewed and approved by the Health Research Ethics Commission (KEPK), Faculty of Dentistry, Airlangga University. This is a quantitative, cross-sectional analytic study. Patient age, gender, and position of impacted canines for the right and left side were noted. The sample used was CBCT photographic data of patients scheduled to undergo orthodontic treatment at the Universitas Airlangga Dental and Oral Hospital in 2019–2020. In total, there were 23 CBCT scans with cases of impacted unilateral and bilateral canines in the maxilla. After evaluation according to predetermined criteria, we obtained 13 CBCT photographic data. The inclusion criteria for the study were: (1) Patients aged 16–30 years who had only a case of unilateral maxillary canine impaction, X-ray on CBCT showing impacted unilateral maxillary canine, and normal eruption of the maxillary canine contralateral to the teeth of the same patient experiencing the impacted unilateral maxillary canine. When the root formation is complete and the patient is older than 13, a maxillary canine is described as either an impacted tooth or when the other side of the maxillary canine has completely erupted. Complete eruption, on the other hand, was defined as the tooth at its final occlusion and position. (2) Impaction location on the buccal or palatal area, which had to be at least 50% of the dental crown length to the coronal part; and (3) Patients who had never received prior orthodontic treatment. The exclusion criteria were: (1) CBCT scan results showing oral pathology; (2) no congenital abnormalities; (3) missing teeth; (4) supernumerary teeth; (5) dentigerous cysts or enlarged cystic follicles; (6) no history of trauma to the maxillary anterior teeth such as a history of surgery due to dentofacial fractures; (7) no artifacts on CBCT photos;

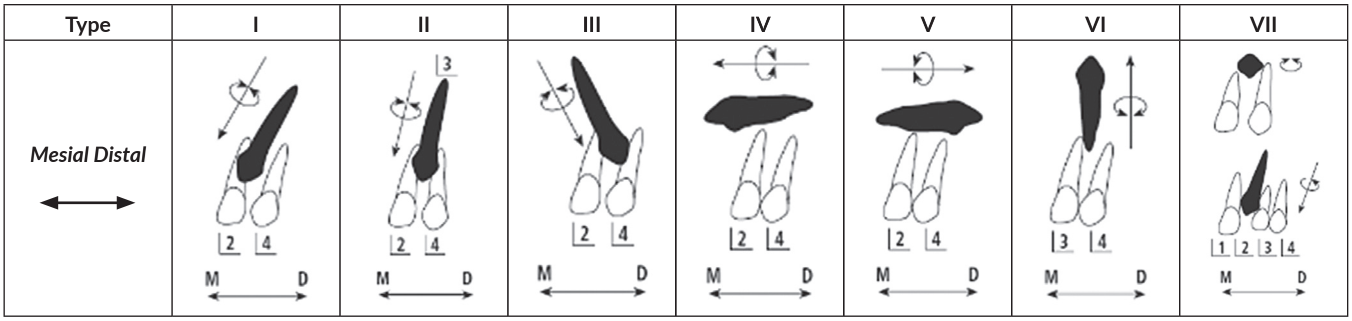

Figure 1. Impacted Canine Classification *(Yamamoto, 2003).*

and (8) no periodontal abnormalities. Yamamoto G, 2003's classification was used to determine impacted maxillary unilateral canine by classifying it into 7 types (Figure 1):[4]

- Type I - Impacted canine with vertical position, axis almost perpendicular to the occlusal area, located between I2 & P1
- Type II - Impacted canines tend to tilt mesially to the occlusal area
- Type III - Impacted canines tend to tilt distally to the occlusal area
- Type IV - Impacted canine with horizontal position and the crown pointing mesially
- Type V - Impacted canine with horizontal position and the crown pointing distally
- Type VI - Impacted canine in an inverted position
- Type VII - Impacted canine with labio-palatal and ectopic position

All CBCT images were acquired by using AUGE SOLIO (Kyoto, Japan) with the following parameters: FOV (Field of View) size of 51 × 55 mm 85 kV, 4 mA, exposure time of 8.9 per second, and voxel size of 0.3 mm. The OnDemand3D™ Dental software was used to carry out the measurement on DICOM data directly from CBCT. The trabecular bone measurement on CBCT radiography was conducted in two groups, including the study group with impacted unilateral maxillary canines and the control group consisting of normal erupted maxillary canines. The first step involved determining the slice thickness of 1 mm (Figure 2) and selecting 2-dimensional slices on the CBCT imaging results, namely coronal and sagittal (Figures 3 and 4). Furthermore, the Region of Interest (ROI) with a size of 5 × 5 mm^2 was determined in the cervical trabecular bone area of the canines and taken from four areas, included mesial, distal, buccal, and palatal (Figure 5). The trabecular bone GSV results were obtained directly in the form of a gray scale calculation with pixel value (PV) units. The mean, minimum, and maximum GV measurements and standard deviations were automatically calculated by the software. The pixel value (PV) results for the two groups were then recorded in a worksheet.

A dentomaxillofacial radiologist evaluated all images. Thirteen photos were chosen at random from the sample and analyzed twice by two observers for intraobserver agreement. Between assessments, there was a one-month gap. In terms of interobserver agreement, the second observer was a five-year-experienced dentomaxillofacial radiologist who reviewed the same images. Both observers have previously been calibrated on where the ROI should be placed. Cohen's Kappa test was used to determine intraobserver and interobserver agreement. The data obtained were analyzed using Cohen's Kappa test, description of research subjects, and bivariate correlation analysis. The bivariate correlation analysis was further divided into two tests, the normality test using the Kolmogorov-Smirnov test and the test of difference between the two groups using the paired t-test.

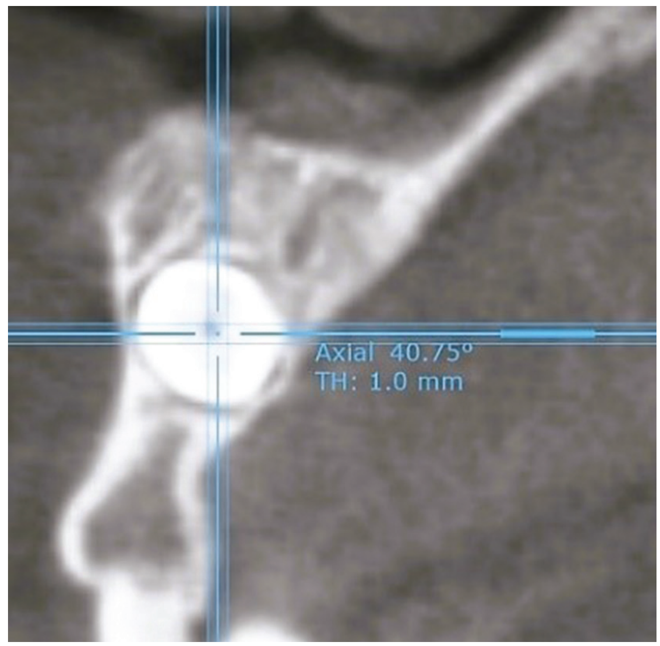

Figure 2. Determination of slice thickness 1 mm.

RESULTS

From 13 CBCT photographic data, there were types I (6/13), II (6/13), and VII (1/13) impacted unilateral maxillary canine teeth.

There was very good agreement between the two raters (Cohen's Kappa reliability coefficient = 0.728; P-value = 0.000).

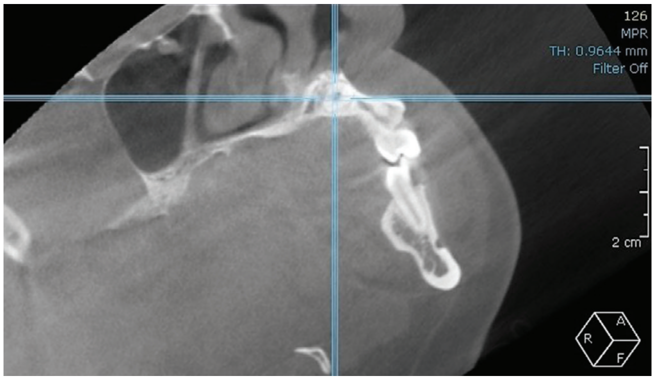

Figure 3. Coronal slice.

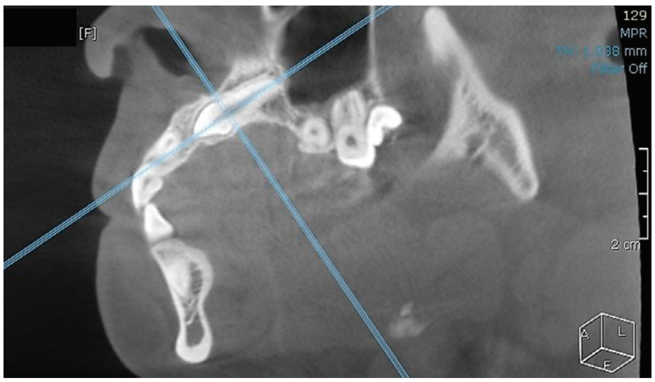

Figure 4. Sagittal slice.

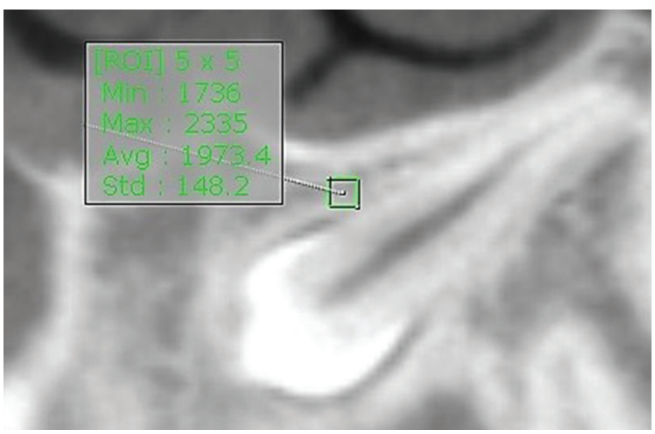

Figure 5. Determination of ROI (Rest of Interest) 5 x 5 mm^2.

Table 1. Mean pixel values (PV) for CBCT photographic data of patients with impacted unilateral maxillary canine and normal erupted canine in each area

Area Position	Impaction			
Side	Mesial (PV)	Distal (PV)	Buccal (PV)	Palatal (PV)
Mean	1972.9231	2016.5462	1990.6615	1904.3923
Range	996.50	702.70	755.20	906.20
	Normal			
Side	Mesial (PV)	Distal (PV)	Buccal (PV)	Palatal (PV)
Mean	1754.9308	1710.5308	1852.9385	1674.4923
Range	770.50	590.20	763.70	686.90

Table 2. Correlation of pixel value (PV) between the trabecular bone quality (gray scale value) of unilateral maxillary impacted canine with normal erupted canine on the mesial, distal, buccal, and palatal areas

Correlation test results using paired T-Test of PV	Side	Mean (PV)	Standard Deviation (PV)	P Value (Sig) < 0.05
Comparison 1	Impacted Mesial	1972.9231	277.51268	0.250
	Mesial Normal	1754.9308	218.38154	
Comparison2	Impacted Distal	2016.5462	248.17475	0.128
	Normal Distal	1710.5308	155.30124	
Comparison 3	Impacted Buccal	1990.6615	205.81589	0.433
	Normal Buccal	1852.9385	213.33731	
Comparison 4	Impacted Palatal	1904.3923	283.02275	0.926
	Normal Palatal	1674.4923	198.99752	

Table 3. Comparison of pixel value (PV) between trabecular bone quality (gray scale value) of impacted unilateral maxillary canine and normal erupted canine teeth on the mesial, distal, buccal, and palatal areas

Paired T-Test results of PV	Side	Mean (PV)	Standard Deviation (PV)	P Value (Sig) < 0.05
Comparison 1	Impacted Mesial	217.99231	288.09631	0.018
	Normal Mesial			
Comparison 2	Impacted Distal	306.01538	226.77463	0.000
	Normal Distal			
Comparison 3	Impacted Buccal	208.09231	258.75708	0.003
	Normal Buccal			
Comparison 4	Impacted palatal	229.90000	350.57999	0.036
	Normal palatal			

The smallest mean PV was 590.20 on the distal of normal erupted canines, while the largest was 996.5 and 906.2 on the distal and palatal of the impacted canines (Table 1). The difference in measurement results in the GSV pixel margins of the trabecular bone in impacted canine and normal erupted canine on four sides in type VII were -528.7 on mesial, -96.1 on distal, -124.1 on buccal, and -484.6 on palatal.

There was no significant relationship between the GSV of trabecular bone in impacted unilateral maxillary canine teeth with normal erupted canine teeth on the mesial, distal, buccal, and palatal areas (Table 2).

There was a significant difference between the GSV of the trabecular bone in the impacted unilateral maxillary canine and the normal erupted canine teeth in the mesial, distal, buccal, and palatal areas (Table 3).

DISCUSSION

CBCT can be used in orthodontic cases for visualization of impacted maxillary canines. The use of CBCT images is to localize the position of the impacted canine teeth. The benefits of using CBCT include the management of impacted teeth, proper localization and better assessment of dental follicles, amount of bone covering the crown, and root resorption of adjacent teeth.[18] Based on CBCT photographic data results from patients with a normal unilateral maxillary canine position, there was a difference of 137.72-pixel value (PV) between the GSV of trabecular bone in the impacted and normal erupted canines. Additionally, the difference between the mean GSV of trabecular bone in normal erupted canine and impacted canine was significant on the distal side with a value of 306.01 PV. The GSV of the trabecular bone on the distal side of the normal erupted canine had the lowest range of 590.20 PV, which led to the conclusion of being the most homogeneous. Moreover, the GSV of the trabecular bone on the distal and palatal side of the impacted canine had the greatest range of 996.5 PV and 906.2 PV, respectively. There was no GSV on each side of the trabecular bone in the impacted canine, which was below 700 PV. This condition indicated that the GSV of trabecular bone on the impacted canine had variations in the PV value between patients. The number of unstable trabecular bone GSV was higher than the normal erupted canine. The microarchitecture of trabecular bone around the area of the impacted and non-impacted canines was assessed, and a localized increase in BMD was deemed possible.[16] However, the alveolar bone BMD around the impacted maxillary canine was evaluated using GSV as a potential etiologic factor for impaction.

The results of the GSV measurement were obtained from the impacted canine trabeculae and normal eruption in that area. One sample of CBCT photographic data consisted of impacted type VII canines, including impacted canines in the labio-palatal position and impacted ectopic or partially canines. The result of pixel margin measurement on each side has different trabecular bone GSV in impacted and normal erupted canines as seen at -528.7 mesial, -96.1 distal, -124.1 buccal, and -484.6 palatal. This situation indicates that the GSV of the trabecular bone in the impacted canine is smaller or lower than that of the normal erupted canine in that area. In addition, the mean GSV of the trabecular bone of the impacted canine was higher than that of the normal erupted canine. There was a difference in the mean GSV of trabecular bone in impacted type I & II canines with GSV of trabecular bone in normal erupting canines. There was no significant relationship between the GSV of the trabecular bone in the impacted unilateral maxillary canine and the normal eruption of the mesial, distal, buccal, and palatal canines. The etiology of the type VII impacted canine is possibly a local factor. It may be due to the wrong location of the seed resulting in the wrong direction of eruption but is not influenced by hard tissue so that the canine is not affected as a whole. Environmental factors such as hard tissue, soft tissue lesions, or pathological conditions, according to Becker A, can cause canines to experience impaction.[19]

There was a significant difference in the GSV of the trabecular bone between the impacted canine and the normal erupted canine in the mesial, distal, buccal and palatal areas. Servais et al. evaluated the relationship of unilateral and bilateral impacted canines and measured the maxillary alveolar bone microarchitecture, bone surface area, and bone fractal dimensions. The surface area of the impacted canine trabecular bone was greater than that of the normal erupted canine. Servais et al. stated that the bone marrow area decreased near the impacted canines compared to non-impacted ones.[16] Furthermore, Köseoğlu Seçgin et al. showed that the trabecular bone around the impacted maxillary canine was denser than the normal erupted canine with a FOV size of 40 × 40 mm.[17] However, there was no statistically significant difference between the GSV of impacted and normal erupted canines at FOV sizes of 60 X 60 mm and 100 × 50 mm. HU values obtained from CT and GVS obtained from CBCT imaging were used for the assessment of BD. In CT, bone density in a particular area is determined by HU. In his research, he recommended using the smallest FOV size when evaluating BD using GSV from CBCT images.[20] Further research is recommended to assess the differences in the GSV between men and women with a larger sample size to concisely determine the BMD effect on the area around the impacted canine teeth.

CONCLUSION

There are statistically significant differences between affected and unaffected GSV canines in FOV size 51 × 55 mm. However, no statistically significant differences were found between trabecular bone GSV in unilateral maxillary impacted canines and normal erupted canines on the mesial, distal, buccal, and palatal sides.

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Statement of Authorship

All authors participated in data collection and analysis and approved the final version submitted.

Author Disclosure

All authors declared that they have no conflicts of interest.

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