ORIGINAL RESEARCH

Evaluation of Alveolar Bone Microstructure around Impacted Maxillary Canines Using Fractal Analysis in Dravidian Population: A Retrospective CBCT Study

Prasanna Arvind TR[1], Ravindra Kumar Jain[2], Ravleen Nagi[3], Akriti Tiwari[4]

Received on: 02 April 2022; *Accepted on*: 21 May 2022; *Published on*: 23 September 2022

ABSTRACT

Aim: The aim of this study was to assess alveolar bone microstructure around impacted maxillary canines derived from fractal analysis.

Materials and methods: The present study was a retrospective cone-beam computed tomography (CBCT) study. In total, 61 scans (25 males, 36 females; age range – 12–28 years) were analyzed. About 64 × 64-pixel regions of interest (ROI) in the maxillary alveolar process containing trabecular bone between the premolars were selected. ImageJ software was utilized to process images and bone density was assessed by determining bone surface area (BSA) and bone marrow surface area (BMSA) for the impacted and nonimpacted sides separately. Selected fractals were plotted in a histogram using box-counting method and the results were tabulated. Paired t-tests were used to determine significant differences between the groups and gender differences.

Results: For both buccally and palatally impacted maxillary canines, BSA was increased, BMSA decreased in the region of the impacted canine and the difference was statistically significant ($p < 0.05$) in both genders. Bone fractal dimension (FD) values were greater in the region of the impacted canine for both buccally ($1.47 > 1.21$) and palatally ($1.53 > 1.43$) displaced canines, while bone marrow FD values were greater in the region of the nonimpacted canine for both buccally ($1.37 > 1.28$) and palatally displaced canines ($1.41 > 1.33$). Females had significantly higher BMSA than males around impacted canines ($p < 0.05$).

Conclusion: Denser bone microstructure was noted around impacted canines when compared with fully erupted canines. No gender-related differences were noted for BSA, whereas BMSA was higher in females implying lower bone density when compared with males.

Clinical significance: Retrospective evaluation of bone microstructure surrounding unerupted/impacted canines can provide analytical information about treatment prognosis and anchorage considerations. With FD analysis of CBCT images, BSA and BMSA can be measured and bone density estimated in a reliable manner.

Keywords: Bone density, Cone-beam computed tomography, Fractal dimension, Impaction, Maxillary canine.

The Journal of Contemporary Dental Practice (2022): 10.5005/jp-journals-10024-3343

INTRODUCTION

After the third molar, the maxillary permanent canine is the second most commonly impacted tooth.[1,2] Canine impaction has a multifactorial etiology that includes interactions between environmental and genetic factors.[3] Maxillary canine impactions can be buccal or palatal. Increased space in the dental arch is usually associated with palatally impacted canines, variations in the development of the lateral incisor, and may have a genetic etiology.[4,5] Buccally impacted canines are commonly associated with crowding, maxillary arch constriction, and inadequate space for dental eruption.

Various imaging techniques such as intraoral, periapical, occlusal, panoramic radiography, and CBCT have been utilized to localize the position of the impacted canines. The difficulty in disimpacting a canine is determined by its position and angulation as determined by the imaging technique used.[6–9] Fractal-dimension analysis, which is based on CBCT images, has recently been used to quantify changes in bone microarchitecture, such as BSA and BMSA. The usefulness of FD analysis for evaluation of trabecular architecture on panoramic and periapical images has been well documented. However, limited studies have illustrated the applicability of FD analysis on CBCT images.[10] Recent research has focused on the use of ImageJ processing software on CBCT slices to assess the bone quality surrounding the impacted canine, which has been found to correlate with bone mineral density and trabecular pattern.[11] Due to the irregular and random nature of trabecular bone, FD analysis may be a more reliable method than traditional Hounsfield unit analysis.[12]

[1,2,4]Department of Orthodontics, Saveetha Dental College, Saveetha Institute of Medical and Technical Sciences, Chennai, Tamil Nadu, India

[3]Department of Oral Medicine and Radiology, Saveetha Dental College, Saveetha Institute of Medical and Technical Sciences, Chennai, Tamil Nadu, India

Corresponding Author: Ravindra Kumar Jain, Department of Orthodontics, Saveetha Dental College, Saveetha Institute of Medical and Technical Sciences, Chennai, Tamil Nadu, India, Phone: +91 9884729660, e-mail: ravindrakumar@saveetha.com

How to cite this article: Arvind PTR, Jain RK, Nagi R, *et al*. Evaluation of Alveolar Bone Microstructure around Impacted Maxillary Canines Using Fractal Analysis in Dravidian Population: A Retrospective CBCT Study. J Contemp Dent Pract 2022;23(6):593–600.

Source of support: Nil

Conflict of interest: None

Ethics approval and consent to participate: Ethical clearance for the study was obtained from the Institutional Review Board (IHEC/SDC/ORTHO-1803/21/38).

Availability of data and materials: CBCT scans of patients reporting to the Department of Radiology at Saveetha Dental College were included in the study after they satisfied the inclusion criteria accordingly.

The incidence of maxillary canine impactions varies among different populations with rates varying from 1 to 2.5%[13] and 7.5%[13,14] with the majority of them showing a higher prevalence rate for palatally displaced canines.[15–17] Establishing individual ethnicity-based traits can help in identifying the type of impaction commonly observed in a particular cohort. Gender-based predilection for prevalence of impactions has been studied in many populations to identify sex-related variations.[18]

Identifying bone-density variations between the impacted and nonimpacted sides can allow us to comprehend the etiology and rate the difficulty of disimpaction.[17] Literature is divisive on the role of bone density and its association with canine impactions. It is unclear as to whether elevated bone-density levels are implicated in the etiology of canine impaction or as a ramification of the impaction. Disimpaction of canines surrounded by dense alveolar bone will require a tailored treatment approach demanding greater versatility in biomechanics, hence identifying bone-density variations prior to disimpaction can improve treatment outcomes. Bone-density measurements estimated using grayscale values may vary across centers based on the machines used and also the sites localized.[19,20] This can be overcome by using FD analysis which can assess trabecular patterns and microstructure in a more systematic manner.

The aim of the present study was to determine bone density as assessed by bone surface area and fractal dimensions around impacted maxillary canines using a box-counting method derived from fractal analysis method in Dravidian population.

MATERIALS AND METHODS

The present study was conducted retrospectively by obtaining pretreatment CBCT scans (time frame – past 2 years; 2019–2021) from the Department of Oral Medicine and Radiology at a private dental school. Ethical clearance for the study was obtained from the Institutional Review Board (IHEC/SDC/ORTHO-1803/21/38). Sample-size calculation (effect size of 0.45, alpha-error of 0.05, and power of 80%) was obtained from a previously conducted study with similar methodology that contained a sample size of 49 patients.[10]

Initially, 215 scans with both bilateral and unilateral canine impactions were identified. From this sample, 140 scans with unilateral canine impactions were selected. Scans required for the study were then selected from this cohort by applying selection criteria. Unilateral canine impaction with accompanying clinical diagnosis and complete eruption of the contralateral canine, buccal/palatal impactions based on the location of at least 50% of the crown compared with the alveolar ridge in a coronal cross-section, and no prior orthodontic treatment should have been done were the inclusion criteria. Existing pathology, periodontal problems, congenitally missing teeth, supernumerary teeth, or cyst formation, history of trauma to the maxillary anteriors, and any motion artifacts were all excluded from the scans.

Following application of the selection criteria, a final assessment of each patient's dental and medical records was conducted to confirm the scans that had been identified. In total, 61 scans were selected (25 males and 36 females; age range – 12–28 years) out of which 37 canines were buccal impactions and 24 canines were palatal impactions. Scan acquisitions were performed with Galileos Sirona Dentsply Scanner and analyzed in Galileos Viewer (1.9.4368.23293). All CBCT images were acquired at 120 kV, 6 mA, and 18,817 mS. The slice thickness was uniformly 0.2 mm with a constant field of view (FOV) of 80 mm.

Reference planes were set in both the sagittal and coronal planes to ensure reproducibility of landmarks. Sagittal reference plane was adjusted to pass through the midpalatal suture, and coronal reference plane was adjusted to pass through a line connecting the center of the palate in the maxillary first molar region. Site selection in the maxillary alveolus was identified between the premolars at both the impacted and nonimpacted sides of the selected scans (Fig. 1). For analysis, the images from the scans were saved as JPEG files. These areas were carefully identified to delineate any dental landmarks, presence of cortical bone, or any nerve canaliculi. Coronal sections were identified to obtain the appropriate slice necessary for analysis, and the images were cropped into a 64 × 64-pixel ROI using Microsoft Office Picture Manager (Fig. 2).

For objects that could not be approximated with traditional polygons, fractal measurements were used. Because trabecular bone is irregular, FD analysis was used to examine the microstructure of the bone, which was divided into BSA and BMSA. In terms of bone fractal analysis, a bony region containing 100% bone would have a fractal value of 2, while a region containing 0% bone would have

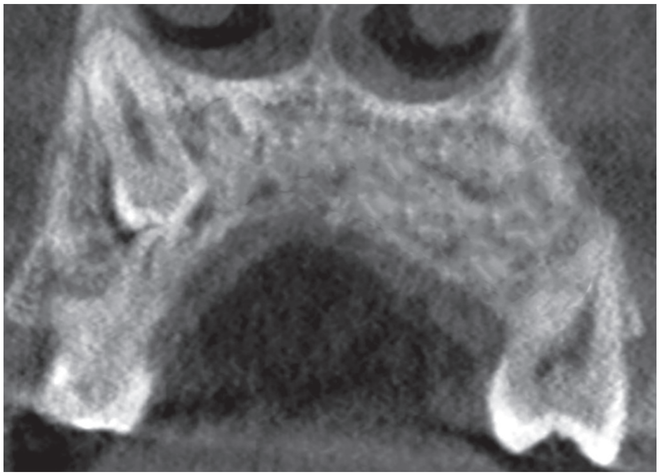

Fig. 1: Axial section of trabecular bone interproximal to first and second premolars selected for analysis in unilateral maxillary canine impactions

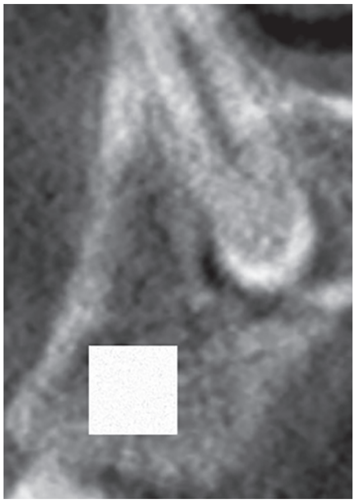

Fig. 2: Axial section of selected sites cropped into 64 × 64-pixel ROI using Microsoft Office Picture Manager

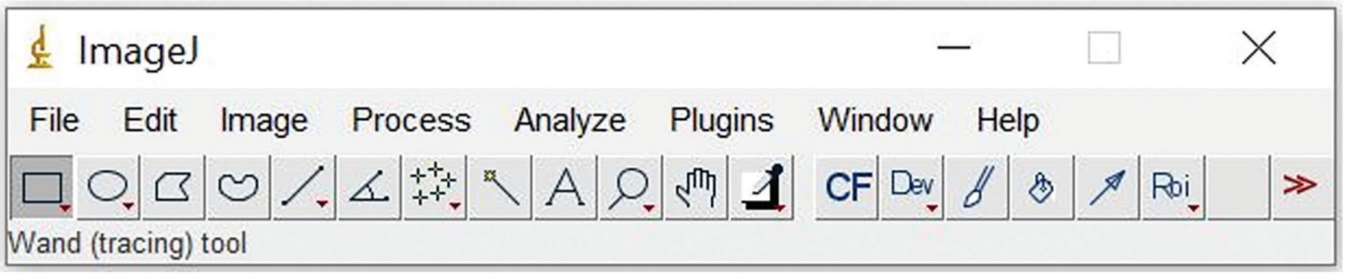

Fig. 3: ImageJ software used for FD analysis in the current study

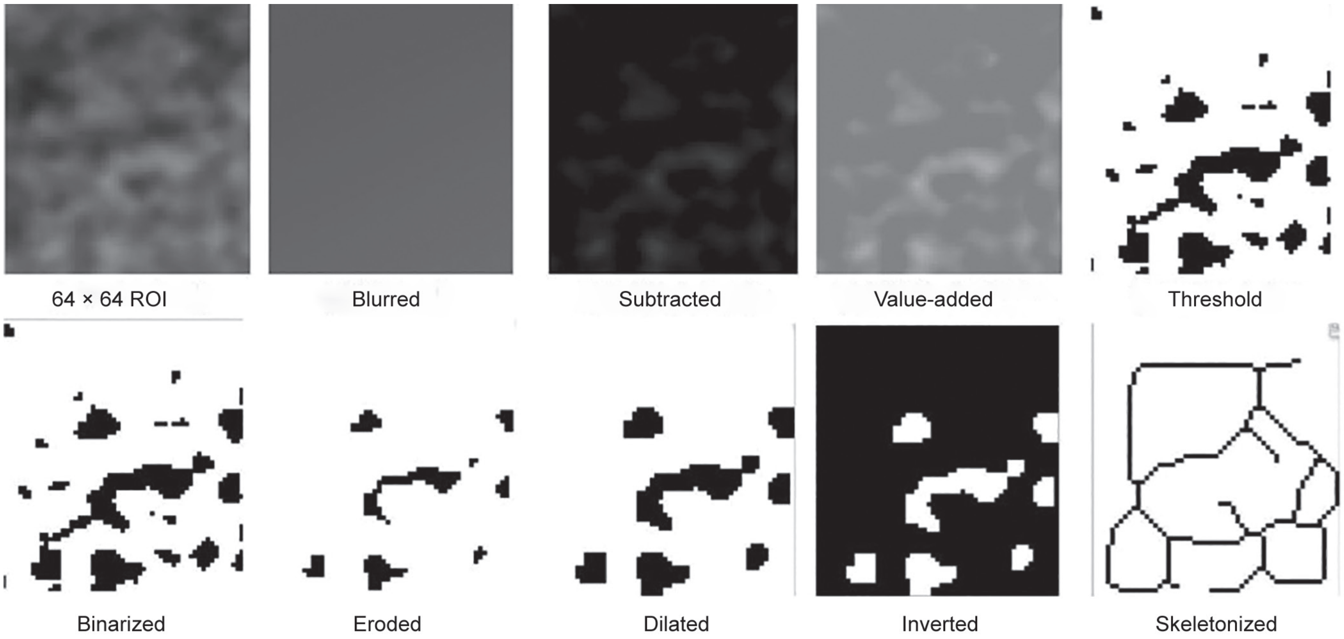

Fig. 4: Steps in image processing for determining BSA

a fractal value of 1. A fractal value of 2 corresponds to 100% marrow space, while a fractal value of 1 corresponds to 100% bone in bone marrow fractal analysis. Fractal values of 1 and 2 are only theoretical because every sample of trabecular bone contains dense bony regions as well as marrow spaces. As a result, the range of possible trabecular bone fractal values, measured in terms of bone or bone marrow, must be between 1 and 2. Bone density analysis was carried out using BSA and BMSA. In regions with greater bone density, BSA was higher, and BMSA was lower, and vice versa in regions with lesser bone density.

Image processing was carried out with ImageJ software (National Institutes of Health, Bethesda, MD, USA) (Fig. 3). Binarization of selected regions into trabecular bone and bone marrow space was performed. The Gaussian blur function ($r = 35$) was used for the initial blurring. This image was subtracted, and each pixel was given a constant value of 128. The image threshold was set to anything from 0 to 128. Bone marrow was estimated to be black, and trabeculae were estimated to be white in the image. Images were inverted after erosion and dilation to aid processing. Inversion was performed on bone marrow images before erosion and dilation. The color-coded image was separated from the binarized image. After processing, the images were skeletonized in preparation for data collection. The "fractal box count" function in ImageJ was used to complete the FD calculations (Figs 4 and 5). All measurements were carried out by the principal investigator and later reverified by the second author of the study after calibration of the ROI.

Statistical Analysis

Normality of data was assessed using Shapiro–Wilk's and Kolmogorov–Smirnov's tests (Table 1). Data obtained were continuous and parametric in nature. Descriptive statistics were used to determine the presence of significant differences between groups. Using SPSS Software Version 13.0, between impacted and nonimpacted sites among buccal and palatally displaced canines, a paired *t*-test was used to compare mean BSA, BMSA, and mean FD. *P* values <0.05 were considered statistically significant. Intra- and interoperator variability was assessed using Kappa's correlation coefficient tests. Measurements on 15 CBCTs were redone after a period of 2 weeks and intraclass correlation tests were carried out.

RESULTS

Kappa's intra- and interoperator reliability tests (Table 2) returned correlation values greater than 85% in the reassessed CBCTs. This indicates a high degree of reliability and reproducibility of the values obtained in the current study.

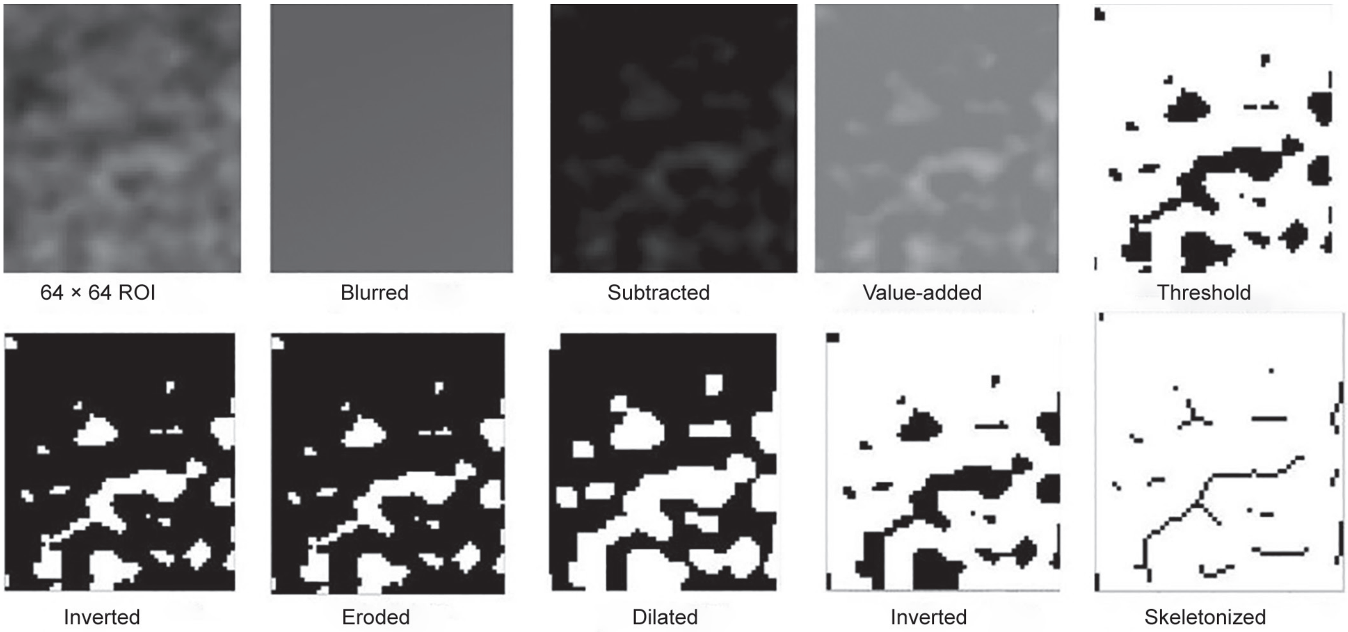

Fig. 5: Steps in image processing for determining BMSA

Table 1: Normality tests to determine the distribution of collected data

	Serial number	*Kolmogorov–Smirnov*[a]			*Shapiro–Wilk*		
		Statistic	*df*	*Sig.*	*Statistic*	*df*	*Sig.*
Bone area – Impacted	Buccal	0.130	37	0.117	0.933	37	0.028
	Palatal	0.163	24	0.099	0.941	24	0.170
Bone area – Nonimpacted	Buccal	0.112	37	0.200*	0.949	37	0.092
	Palatal	0.078	24	0.200*	0.983	24	0.946
Bone marrow area – Impacted	Buccal	0.093	37	0.200*	0.971	37	0.427
	Palatal	0.117	24	0.200*	0.942	24	0.177
Bone marrow area – Nonimpacted	Buccal	0.102	37	0.200*	0.971	37	0.449
	Palatal	0.116	24	0.200*	0.970	24	0.663

[a] Lilliefors significance correction, *Presence of appropriate fit between samples

Table 2: Paired *t*-test used to determine Kappa's correlation coefficient for 15 CBCTs revaluated by the same operator after a period of 2 weeks (intraoperator reliability)

		N	*Mean ± Std. deviation*	*Correlation*	*Intraclass correlation coefficient (ICC)*
Pair I	Bone surface area – A	15	1681.44 ± 204.5 mm^2	0.873	0.856
	Bone surface area – B	15	1715.67 ± 189.3 mm^2		
Pair II	Bone marrow surface area – A	15	3915.61 ± 442.8 mm^2	0.904	0.875
	Bone marrow surface area – B	15	3864.33 ± 366.9 mm^2		
Pair III	Bone fractal dimension – A	15	1.55 ± 0.36	0.861	0.922
	Bone fractal dimension – B	15	1.50 ± 0.49		
Pair IV	Bone marrow fractal dimension – A	15	1.36 ± 0.29	0.915	908
	Bone marrow fractal dimension – B	15	1.30 ± 0.25		

Table 3 shows the comparison of the mean BSA and BMSA between the impacted and nonimpacted sides, respectively, in relation to buccally displaced maxillary canines. The BSA was found to be increased on the impacted side (1945.62 ± 159.7 mm^2) when compared with the nonimpacted side (1659.81 ± 118.1 mm^2), whereas the BMSA on the impacted side was decreased (3784.27 ±

Table 3: Comparison of bone surface area and bone marrow surface area between impacted and nonimpacted side in relation to buccally displaced canines by paired *t*-test

Bone variables	*Samples*	*Impacted side (mean ± SD)*	*Nonimpacted side (mean ± SD)*	*p-value*
Bone surface area	37	1945.62 ± 159.7 mm^2	1659.81 ± 118.1 mm^2	0.00*
Bone fractal dimension	37	1.47 ± 0.24	1.21 ± 0.09	0.45
Bone marrow surface area	37	3784.27 ± 380.9 mm^2	4202.54 ± 403.9 mm^2	0.00*
Bone marrow fractal dimension	37	1.28 ± 0.11	1.37 ± 0.18	0.61

*Significant *p* value; SD, standard deviation

Table 4: Comparison of bone surface area and bone marrow surface area between impacted and nonimpacted sides in relation to palatally displaced canines by paired *t*-test

Bone variables	*Samples*	*Impacted side (mean ± SD)*	*Nonimpacted side (mean ± SD)*	*p-value*
Bone surface area	24	1858.58 ± 172.3 mm^2	1644.79 ± 133.7 mm^2	0.00*
Bone fractal dimension	24	1.53 ± 0.41	1.43 ± 0.28	0.69
Bone marrow surface area	24	3678.45 ± 337.8 mm^2	4167.58 ± 380.5 mm^2	0.00*
Bone marrow fractal dimension	24	1.33 ± 0.25	1.41 ± 0.69	0.56

*Significant *p* value; SD, standard deviation

Table 5: Comparison of bone surface area and bone marrow surface area between males and females on impacted and nonimpacted sides

Bone variables	*Gender*	*N*	*Mean ± SD*	*p-value*
Bone surface area – Impacted	Male	25	1928.48 ± 169.05 mm^2	0.824
	Female	36	1899.50 ± 170.1 mm^2	
Bone surface area – Nonimpacted	Male	25	1676.56 ± 125.7 mm^2	0.977
	Female	36	1638.16 ± 121.3 mm^2	
Bone marrow surface area – Impacted	Male	25	3639.36 ± 447.3 mm^2	0.001*
	Female	36	3814.36 ± 280.8 mm^2	
Bone marrow surface area – Non impacted	Male	25	4187.32 ± 383.1 mm^2	0.912
	Female	36	4189.80 ± 403.5 mm^2	

*Significant *p* value, SD, standard deviation

380.9 mm^2) when compared with the nonimpacted side (4202.54 ± 403.9 mm^2). In terms of BSA and BMSA, statistically significant differences were found between the impacted and nonimpacted groups ($p < 0.05$). Bone FD values were found to be greater on the impacted side and lesser on the nonimpacted side (1.47 > 1.21), while bone marrow FD values were greater on the nonimpacted side and lesser on the impacted side (1.37 > 1.28).

Table 4 shows the comparison of BSA and BMSA between the impacted and nonimpacted sides, respectively, in relation to palatally displaced maxillary canines. The BSA on the impacted side was increased (1858.58 ± 172.3 mm^2) in comparison with the nonimpacted side (1644.79 ± 133.7 mm^2), whereas BMSA on the impacted side was decreased (3678.45 ± 337.8 mm^2) when compared with the nonimpacted side (1644.79 ± 133.7 mm^2). In terms of bone area and bone marrow area, statistically, significant differences were found between the impacted and nonimpacted sides ($p < 0.05$). Bone FD values were greater on the impacted side and lesser on the nonimpacted side (1.53 > 1.43), while bone marrow FD values were greater on the nonimpacted side and lesser on the impacted side (1.41 > 1.33).

Table 5 shows the gender-wise distribution of samples along with assessment of BSA and BMSA on the impacted and nonimpacted sides. Males were found to have higher BSA on both the impacted (1928.48 ± 169.05 mm^2) and nonimpacted (1676.56 ± 125.7 mm^2) sides compared to females (1899.50 ± 170.1 mm^2 and 1638.16 ± 121.3 mm^2, respectively), but the difference was not significant. However, females had higher BMSA on the impacted (3814.36 ± 280.8 mm^2) and nonimpacted (4189.80 ± 403.5 mm^2) sides compared with males (3639.36 ± 447.3 mm^2 and 4187.32 ± 383.1 mm^2, respectively). A statistically significant difference was observed in the BMSA at the impacted side ($p < 0.05$). No significant difference was found with respect to any other parameter assessed between males and females.

Table 6 shows the distribution of buccally and palatally displaced canines between males and females along with BSA and BMSA. A statistically significant difference was noted between the impacted and nonimpacted sides in both the parameters assessed ($p < 0.000$). From the findings, we can note that BSA is greater in buccally positioned canines when compared with palatally displaced canines in both males and females.

Table 6: Gender-based comparison of bone surface area and bone marrow surface area between the impacted and nonimpacted sides with buccal and palatally displaced canines

Gender	*Area of displacement*	*Sample size*	*Bone area (Impacted side) Mean + SD*	*Bone area (Nonimpacted side) Mean + SD*	*p-value*	*Bone marrow area (Impacted side) Mean + SD*	*Bone marrow area (Nonimpacted side) Mean + SD*	*p-value*
Males	Buccal	16	1956.50 ± 174.8 mm^2	1686.06 ± 127.7 mm^2	0.00*	3652.12 ± 458.1 mm^2	4143.50 ± 434.4 mm^2	0.00*
	Palatal	9	1878.66 ± 155.1 mm^2	1659.66 ± 127.8 mm^2	0.00*	3616.66 ± 453.9 mm^2	4265.22 ± 274.6 mm^2	0.00*
Females	Buccal	21	1937.33 ± 151.1 mm^2	1639.80 ± 109.2 mm^2	0.00*	3884.95 ± 281.6 mm^2	4247.52 ± 383.6 mm^2	0.00*
	Palatal	15	1846.53 ± 186.1 mm^2	1635.86 ± 140.7 mm^2	0.00*	3715.53 ± 256.7 mm^2	4109 ± 430.1 mm^2	0.00*

*Significant *p* value; SD, standard deviation

DISCUSSION

The current study was a retrospective evaluation of bone microarchitecture in patients with impacted maxillary canines as measured by BSA, bone FD, BMSA, and bone marrow FD. From the results, we can infer that BSA was greater and BMSA was lesser around impacted canines when compared with the not impacted canines. The same finding was reported for both buccally as well as palatally impacted canines. Similar findings were reported by previous authors who studied bone densities surrounding impacted canines.[10,19,20] Bone marrow surface area values on the impacted side alone demonstrated a statistically significant difference between males and females. Females had a higher BMSA value than males around impacted canines. No other parameter highlighted any gender-related differences with respect to bone density determination. Fractal-dimension analysis was used in this study similar to the study by Servais et al., since FD analysis is more reliable in assessing bone microstructure than grayscale values. The current study was done in Dravidian population aiming to find the microstructural-pattern differences between impacted and nonimpacted sides and the results obtained can be extrapolated only to Dravidian population.

Fractal dimension analysis has been used for many purposes in dentistry, particularly in dental implant planning as well as in orthodontics for determination of midpalatal suture maturation and variations in condylar patterns.[11,21,22] It is helpful in obtaining information from images that cannot be approximated into well-defined polygons. Hence, its role in identifying trabecular patterns in terms of BSA and BMSA can be useful to quantify bone densities. Determining bone density with CBCTs has been a much-debated topic with several studies proposing the need for machine calibration with appropriate artifacts before grayscale values can be successfully converted into Hounsfield units (HUs).[23,24]

Hence, FD analysis instead of grayscale value is more appropriate for deriving conclusions regarding bone-quality assessment. Furthermore, studies have revealed a statistical correlation between microcomputed tomography bone-quality measurements and CBCT fractal analysis values.[12] Increase in BSA, decreased BMSA, and bone marrow FDs around impacted canines when compared with fully erupted canines can be either an etiologic factor or a consequence of canine impactions. Further research is necessary to validate the fact that trabecular bone characteristics play a local etiologic factor for maxillary canine impaction.

Not many studies on evaluating bone microarchitecture using CBCTs have been reported in literature. The application of FD analysis for assessing microstructure around impacted canines in other populations has been reported.[10,11] The alveolar process was imaged in a region of best fit, which was between the maxillary first and second premolars on the impacted and nonimpacted sides of the arch. This was done to ensure consistency and to keep cortical bone, tooth structure, and soft tissue out of the equation. Because the position of impacted canines varies, all scans included standard regions adjacent to the premolar area.[10]

The results were further validated and generalizable thanks to strict eligibility criteria that allowed for the selection of a homogeneous sample. Field of view may affect the accuracy of bone microstructural measurements, according to a study by Timock et al.[8] As a result, all of the CBCT scans in this study had the same FOV of 80 mm and scan settings.

Knowledge of the three-dimensional distribution of bone density would permit a more comprehensive assessment of the intricate relationship between the adaptive capacity of the alveolar bone and its biomechanical environment.[25] In general, the rate of tooth movement is inversely related to bone-density patterns. This finding can be used to justify the use of adjunctive acceleratory procedures during disimpaction.[26] Studies in literature have commented on the role of micro-osteoperforation in accelerating tooth movement that reduces alveolar bone density and bone volume.[27] The findings reported in our study could act as a rationale for conducting trials to determine the effects of micro-osteoperforation on accelerating the disimpaction of impacted canines. Bone density was reported to be higher in both buccally and palatally displaced canines on the impacted side. Awareness about the possibility of increased bone density to be an etiologic factor for canine impaction (buccal or palatal) in a population can be useful for planning preventive procedures and creating awareness among professionals.[2] Bone quality varies between populations and any conclusions about the role of bone density in the etiology or treatment of canine impactions will be pertaining to the parent population alone.

Studies on bone-density changes after orthodontic treatment have reported varying conclusions with certain studies reporting a decrease in bone density[28,29] and some studies an increase in bone density.[30] Verification of bone density surrounding impacted canines pre- and postdisimpaction can be used to establish specific associations between bone density and orthodontic tooth movement. Increased bone density seen on the impacted site as reported in the current study justifies the need for meticulous anchorage planning and judicious force levels to obtain favorable functional and esthetic outcomes. Employing temporary anchorage devices (TADs) to bolster anchorage can allow guided eruption without undesirable movement of the reactive units. Recent approaches to disimpacting maxillary canines (VISTA technique) have focused on reducing bone resistance to accelerate disimpaction and prevent periodontal problems.[31]

The limitations of the study include a relatively small sample size due to a strict selection criteria and the retrospective design. Differences in CBCT image acquisition were not taken into account because of the retrospective nature of the study.

CONCLUSION

From the present study, the following conclusions can be drawn:

For both buccally and palatally displaced canines, there were a significant difference in bone-density values between the impacted and nonimpacted sides. Bone surface area was increased and BMSA decreased on the impacted side (p <0.05) when assessed using fractal analysis employing a box-counting method.

Bone surface area assessments around impacted canines were independent of gender-related variations, while BMSA was higher in females implying comparatively lower bone density.

AUTHORS' CONTRIBUTIONS

Data collection, manuscript idea formulation, and manuscript writing were done by Dr PA. Manuscript idea formulation, rechecking as well as data verification were done by Dr RKJ and Dr RN. Statistical re-evaluation and manuscript verification were done by Dr AK.

ACKNOWLEDGMENTS

The author would like to acknowledge the efforts of his co-authors along with his Department Head for encouraging them to get involved in interdisciplinary research topics involving matters of concern for orthodontic purposes.

REFERENCES

1. Dachi SF, Howell FV. A survey of 3,874 routine full-mouth radiographs: II. A study of impacted teeth. Oral Surg Oral Med Oral Pathol 1961;14(10):1165–1169. DOI: 10.1016/0030-4220(61)90204-3.
2. Grover PS, Lorton L. The incidence of unerupted permanent teeth and related clinical cases. Oral Surg Oral Med Oral Pathol 1985;59(4):420–425. DOI: 10.1016/0030-4220(85)90070-2.
3. Becker A, Chaushu S. Etiology of maxillary canine impaction: A review. Am J Orthod Dentofacial Orthop 2015;148(4):557–567. DOI: 10.1016/j.ajodo.2015.06.013.
4. Ruíz-Mora GA, Arriola-Guillén LE, Rodríguez-Cárdenas YA, et al. Changes in alveolar bone morphology after traction of buccally vs palatally unilateral maxillary impacted canines: A cone-beam computed tomography study. Am J Orthodont Dentofacial Orthop 2021;159(3):258–270. DOI: 10.1016/j.ajodo.2020.01.022.
5. Kokich VG. Preorthodontic uncovering and autonomous eruption of palatally impacted maxillary canines. Semin Orthod 2010;16(3):205–211. DOI: 10.1053/j.sodo.2010.05.008.
6. Botticelli S, Verna C, Cattaneo PM, et al. Two-versus three-dimensional imaging in subjects with unerupted maxillary canines. Eur J Orthod 2011;33(4):344–349. DOI: 10.1093/ejo/cjq102.
7. Mah JK, Alexandroni S. Cone-beam computed tomography in the management of impacted canines. Semin Orthod 2010;16(3):199–204. DOI: 10.1053/j.sodo.2010.05.007.
8. Timock AM, Cook V, McDonald T, et al. Accuracy and reliability of buccal bone height and thickness measurements from cone-beam computed tomography imaging. Am J Orthodont Dentofacial Orthoped 2011;140(5):734–744. DOI: 10.1016/j.ajodo.2011.06.021.
9. Scarfe WC, Angelopoulos C, editors. Maxillofacial Cone Beam Computed Tomography: Principles, Techniques and Clinical Applications. Springer; 2018.
10. Servais JA, Gaalaas L, Lunos S, et al. Alternative cone-beam computed tomography method for the analysis of bone density around impacted maxillary canines. Am J Orthodont Dentofacial Orthop 2018;154(3):442–449. DOI: 10.1016/j.ajodo.2018.01.008.
11. Gaalaas L, Henn L, Gaillard PR, et al. Analysis of trabecular bone using site-specific fractal values calculated from cone beam CT images. Oral Radiol 2014;30(2):179–185. DOI: 10.1007/s11282-013-0163-z.
12. González-García R, Monje F. The reliability of cone-beam computed tomography to assess bone density at dental implant recipient sites: A histomorphometric analysis by micro-CT. Clin Oral Implants Res 2013;24(8):871–879. DOI: 10.1111/j.1600-0501.2011.02390.x.
13. Cooke J, Wang HL. Canine impactions: incidence and management. Int J Periodontics Restorative Dent 2006;26(5):483–491. PMID: 17073358.
14. Laganà G, Venza N, Borzabadi-Farahani A, et al. Dental anomalies: Prevalence and associations between them in a large sample of non-orthodontic subjects, a cross-sectional study. BMC Oral Health 2017;17(1):62. DOI: 10.1186/s12903-017-0352-y.
15. Kau CH, Lee JJ, Souccar NM. The validation of a novel index assessing canine impactions. Eur J Dentist 2013;7(4):399–404. DOI: 10.4103/1305-7456.120648.
16. Kim Y, Hyun HK, Jang KT. The position of maxillary canine impactions and the influenced factors to adjacent root resorption in the Korean population. Eur J Orthodont 2012;34(3):302–306. DOI: 10.1093/ejo/cjr002.
17. Jarjoura K, Crespo P, Fine JB. Maxillary canine impactions: orthodontic and surgical management. Compend Contin Educ Dent 2002;23(1):23–26. PMID: 11887697.
18. Baccetti T. A controlled study of associated dental anomalies. Angle Orthod 1998;68(3):267–274. DOI: 10.1043/0003-3219(1998)068<0267:ACSOAD>2.3.CO;2.
19. Abazi Y, Guglielmo MF, Cenko F, et al. Analysis of bone density in a group of patients with dental inclusion. Balk J Dent Med 2019;23(3):141–146. DOI: 10.2478/bjdm-2019-0025.
20. Seçgin CK, Karslıoğlu H, Özemre MÖ, et al. Gray value measurement for the evaluation of local alveolar bone density around impacted maxillary canine teeth using cone beam computed tomography. Med Oral Patol Oral Cir Bucal 2021;26(5):e669–e675. DOI: 10.4317/medoral.24677.
21. Kwak KH, Kim SS, Kim YI, et al. Quantitative evaluation of midpalatal suture maturation via fractal analysis. Korean J Orthod 2016;46(5):323–330. DOI: 10.4041/kjod.2016.46.5.323.
22. Torres SR, Chen CS, Leroux BG, et al. Fractal dimension evaluation of cone beam computed tomography in patients with bisphosphonate-associated osteonecrosis. Dentomaxillofac Radiol 2011;40(8):501–505. DOI: 10.1259/dmfr/14636637.
23. Cassetta M, Stefanelli LV, Pacifici A, et al. How accurate Is CBCT in measuring bone density? A comparative CBCT-CT in vitro study. Clin Implant Dent Relat Res 2014;16(4):471–478. DOI: 10.1111/cid.12027.
24. Andruch K, Cecotka M. The use of relative voxel grey values in CBCT to evaluate radiological bone density in the mandible. Int J Dent Sci Res 2018;6(3):66–73. DOI: 10.12691/ijdsr-6-3-3.
25. Chugh T, Jain AK, Jaiswal RK, et al. Bone density and its importance in orthodontics. J Oral Biol Craniofac Res 2013;3(2):92–97. DOI: 10.1016/j.jobcr.2013.01.001.
26. Park HS, Lee YJ, Jeong SH, et al. Density of the alveolar and basal bones of the maxilla and the mandible. Am J Orthod Dentofacial Orthoped 2008;133(1):30–37. DOI: 10.1016/j.ajodo.2006.01.044
27. Babanouri N, Ajami S, Salehi P. Effect of mini-screw-facilitated micro-osteoperforation on the rate of orthodontic tooth movement: A single-center, split-mouth, randomized, controlled trial. Prog Orthod 2020;21(1):7. DOI: 10.1186/s40510-020-00306-8.
28. Ma ZG, Yang C, Fang B, et al. Three-D imaging of dental alveolar bone change after fixed orthodontic treatment in patients with periodontitis. Int J Clin Exp Med 2015;8(2):2385–2391. PMCID: PMC4402824.
29. Yu JH, Huang HL, Liu CF, et al. Does orthodontic treatment affect the alveolar bone density? Medicine 2016;95(10):e3080. DOI: 10.1097/MD.0000000000003080.

30. Zhuang L, Bai Y, Meng X. Three-dimensional morphology of root and alveolar trabecular bone during tooth movement using micro-computed tomography. Angle Orthod 2011;81(3):420–425. DOI: 10.2319/071910-418.1.
31. Bariani RCB, Milani R, Guimaraes Junior CH, et al. Orthodontic traction of impacted upper canines using the VISTA technique. J Clin Orthod 2017;51(2):76–85. PMID: 28380468.