Original Article

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Dentistry Section

Evaluation of Alveolar Bony Trabecular Pattern in Subjects with Crossbite Malocclusion using Intraoral Periapical Radiographs: A Cross-sectional Study

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ABSTRACT

Introduction: Trajectories of force determines the trabecular pattern of bone. In transverse malocclusions, force trajectories are altered which can affect the trabecular pattern. Hence, it is important to study the trabecular pattern associated with transverse malocclusions.

Aim: Assessment of trabecular pattern changes on Intraoral Periapical Radiographs (IOPA) in subjects with dental crossbites using fractal analysis.

Materials and Methods: This cross-sectional study was conducted in Department of Orthodontics at Saveetha Institute of Medical and Technical Science, Chennai, Tamil Nadu, India, from October 2021 to December 2021. The study involved 30 IOPAs in 15 patients with unilateral first mandibular molar teeth in crossbite. The sample was divided into two groups. Group A has 15 IOPAs of mandibular molars in crossbite side, group B has 15 IOPAs of mandibular molars not in crossbite. A Region of Interest (ROI) of 256×256 pixels were selected between the roots of the premolar and mandibular molars and converted into an 8-bit image with image J software. Fractal dimensional analysis with box counting was used to assess trabecular perimeter and the trabecular number. Normality of the data was assessed by Shapiro-Wilk test and an Independent t-test was carried out to find intergroup differences.

Results: The IOPAs of 15 subjects (9 males and 6 females) were included in the study with mean age of 27±8 years with unilateral mandibular first molar in crossbite. Shapiro-Wilk tests p-values was not significant (p-value >0.05) for both groups ensuring normality of data. The mean fractal dimensions measured were 0.867 (group A) and 1.213 (group B). The mean trabecular perimeter in group A was 86.37±29.31 whereas in group B it was 194.62±43.26 and the intergroup difference was significant (p-value <0.001).

Conclusion: Fractal analysis of IOPAs revealed that the alveolar bone surrounding the teeth in crossbite presented with significant reduction in the trabecular perimeter and number when compared with teeth not in crossbite.

Keywords: Fractal method, Malalignment, Periapical views, Trabecular arrangement, Transverse discrepancies

INTRODUCTION

Alveolar bone is a part of the maxilla and mandible which supports the teeth and the periodontium [1]. The alveolar bone and the periodontium are exposed to continuous remodelling and are highly sensitive to external mechanical loading [2]. It consists of two types of bone: compact bone and the trabecular bone. Trabecular bone is anisotropic and highly porous and unlike cortical bone the trabeculae are composed of both hard and soft tissue elements comprising trabecular struts, plates and intertrabecular spaces. These intertrabecular spaces give way for the blood vessels to provide nutrition [3]. Studies using Dual Energy X-ray Absorptiometry (DEXA) shows bone density in the cortical bone to be 80% and trabecular bone to be 20% in both femur and mandible [4-7].

According to Wolff's law any change in the function or forces applied to bony tissue is followed by certain changes in its internal architecture which are seen as changes in the trabecular pattern. If more forces are directed perpendicular to the bone then the number of trabeculae increases along the line of force and they become more dense around the involved tooth [8].

Graber defined crossbite as a "abnormally malposed one or more teeth, either lingually or labially with reference to opposing teeth" [9]. Helm S, reported the prevalence of unilateral posterior dental crossbites to be 8-17% [10]. In crossbite there is localised tipping of a single tooth or multiple teeth without involvement of the basal bone [11]. In crossbite malocclusion the forces are not directed perpendicular to the underlying bone when teeth are not in ideal occlusion [12]. Previous studies have shown that there is a significant change in bite force and muscle activity when the teeth are in crossbite [13-15]. In a study by Bakke M and Mighler L, reduced bite force in teeth with crossbite was reported [16].

Trabecular pattern can be assessed visually on intraoral periapical radiographs and in digital modalities like DEXA, macroradiography, scintigraphy, magnetic resonance imaging, micro-computed tomography, cone beam computed tomography and magnetic resonance imaging using softwares [11,17]. Though, DEXA is the gold standard for assessing bone density till date, a high radiation exposure is a major drawback for using in routine practice. This study involves fractal analysis with a box counting method to study the trabecular pattern of bone on periapical images. This method has been used to measure the volumetric surface area of volcanic granules in meteorological studies [18]. There are many published studies on fractal method for studying the trabecular changes after orthodontic treatment but there are no reports on trabecular pattern changes in crossbite subjects using intraoral periapical radiographs [19,20].

The present study was aimed to evaluate the trabecular pattern changes on Intraoral Periapical radiographs (IOPA) in subjects with dental crossbites using Fractal analysis.

MATERIALS AND METHODS

The present cross-sectional study was carried out in the Department of Orthodontics, at Saveetha Institute of Medical and Technical Science, Chennai, Tamil Nadu, India, from October 2021 to December 2021 and was approved by the Institutional Scientific Review Board (SRB/SDC/ORTHO-2006/21/009). The study was

done using IOPAs of subjects who reported to the hospital with unilateral mandibular molar teeth in crossbite.

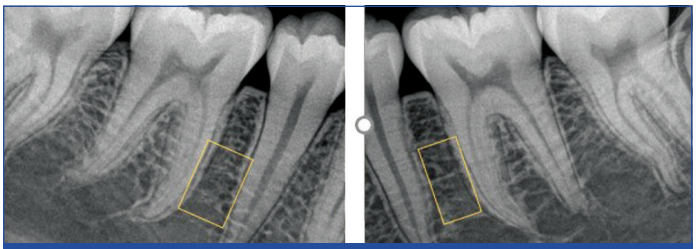
Sample size calculation: The sample size calculation was done with a significance level of 0.05 and power value of 95%. A sample of minimum of eight patients were needed and the effect size was based on a previous study [18]. Sample size was increased to 15 per group as the results obtained would be more generalisable.

Inclusion criteria: All IOPAs of 15 subjects in the age range of 18 to 35 years with unilateral mandibular molar teeth crossbite were included in the study irrespective of the malocclusion, gender and the side of involvement were included in the study.

Exclusion criteria: Subjects with skeletal crossbite, history of previous orthodontic treatment, osteoporosis, osteomyelitis were excluded from the study.

A total of 30 digital IOPAs were taken.

- Group A included 15 IOPAs of the mandibular molar teeth in crossbite.
- Group B included 15 IOPAs of the contralateral molar not in crossbite [Table/Fig-1].



[Table/Fig-1]: Digital intraoral periapical radiographs of crossbite and contralateral non crossbite marked with the region of interest for assessing the trabecular pattern respectively.

Procedure

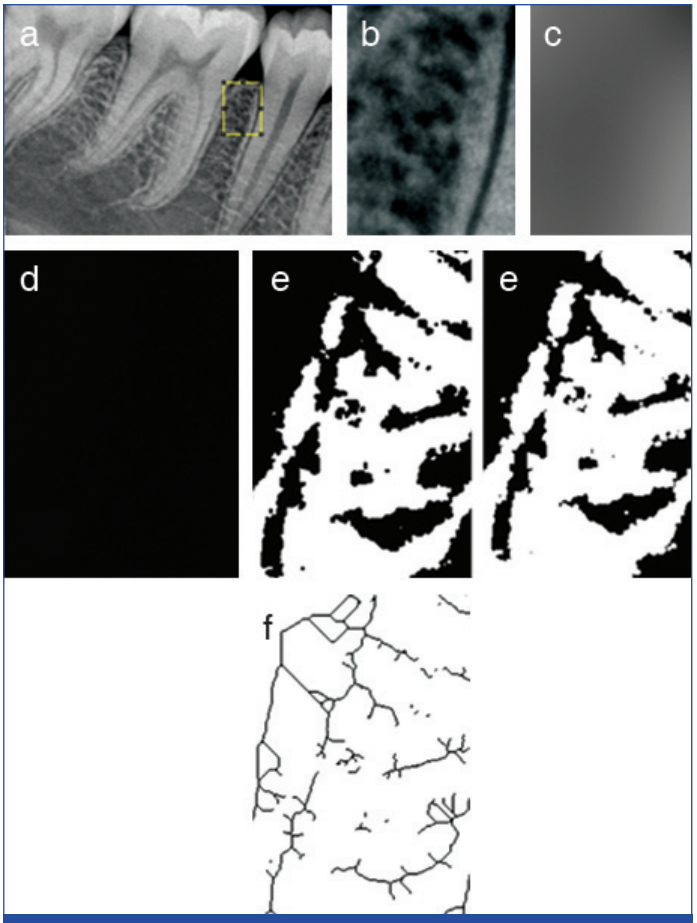
The IOPAs were taken with a paralleling angle technique using an Radiovisiography (RVG) sensor with intraoral x-ray holder and standard exposure parameters [19]. The obtained digital IOPAs were converted to Tagged Image File Format (TIFF) format by one of the investigators (SR). A rectangular region of interest measuring 256×256 pixels were selected between mandibular premolar and molar (TIFF image), placed within the interdental bone and was limited within the interdental bone between roots of premolar and mandibular molars [Table/Fig-2a]. The regions of interest did not include root structure, lamina dura and the periodontal ligament space. Image J 1.44 program was used to analyse the 16 Region of Interest (ROI). Image J software program is a public domain Java image processing program designed by Mac OS X available to National Institute of Health (NIH). It can display, edit, analyse, process and save 8-bit, 16 bit and 32-bit images. It has many applications such as measuring the angle and distances, performing spatial calibrations for providing real world dimension units in millimeters are available to provide real world dimensional units in millimeters.

The IOPAs were converted into an 8-bit binary image after which ROI was isolated. The gaussian blur operation was carried out in order to remove the soft tissue shadow (sigma= 35 pixels) [Table/Fig-2b]. By doing this we can retain large scale variations in bone density thereby removing all fine and medium scale variations [Table/Fig-2c]. The resultant image gets subtracted from the original adding 128 pixels at each pixel location which produces a uniform image of 128 pixels [Table/Fig-2d]. The image is converted into binary, eroded, dilated [Table/Fig-2e]. and skeletonised [Table/Fig-2f] which approximates the trabeculae and marrow.

For identifying object patterns morphological operations were carried out with a structuring element as per the following equation [20]: SK(X)=Sn(X)=[X+nB-(X+nB)B],

where SK(X) is the image subset of skeleton operation,

X is the original image,



[Table/Fig-2]: a) Stages of fractal dimension analysis (a) Cropped region of interest; b) Apply the gaussian blur and duplicate the region of interest; c) The blurred image was then subtracted from the original image; d) Addition of a gray value of 128 to each pixel location; e) Erode and dilate; f) Invert and Skeletonise.

Sn(X) is the image subset of skeleton operation,

N is the ending operation number,

n is the operation sequence number,

U is the union, and

B is the single structuring element.

Then N was plotted as a function on a log-log plot. FD analysis was conducted using the software designed by White SC and Rudolph DJ by means of box counting method [21]. The negative slope of the linear regression curve gives the box counting value [20,22].

Stages of Fractal Dimension Analysis

To determine the morphologic features of the selected area of the radiograph the binary and skeletonised images were evaluated. The total number of black pixels in the binary image divided by the total number of pixels in the region of interest is termed as the trabecular area. Image J software analysis of the skeletonised image involves analysis of the following parameters: length of the trabeculae (total number of black pixels), terminal point numbers (free ends), branch point numbers (crossing points) and the output data is given as a whole number which is the fractal dimension value. These parameters are expressed as a proportion of trabecular length, area, and perimeter which are expressed in terms of fractal numbers by the software [23].

STATISTICAL ANALYSIS

The number of trabeculae and cumulative perimeter of the trabeculae in the ROI was obtained and subjected to statistical analysis using the Statistical Package for Social Sciences (IBM SPSS) version 23.0. Statistics were performed using Statistical Package for Social Sciences (SPSS) software version 23.0. Mean and standard deviations of fractal dimensions, trabecular perimeter and trabecular number was calculated for both group A and group B from the ROI. For checking the normality of the data Shapiro-Wilk test was

performed and for assessing the differences in trabecular number and perimeter in the ROI between the groups an Independent t-test was performed with a significance level set at 0.05.

RESULTS

The IOPAs of 15 subjects (9 males and 6 females) with mean age of 27±8 years with unilateral mandibular first molar in crossbite were included in the study. The p-values for Shapiro-Wilk's test were not significant (group A was 0.09 and group 2 was 0.45), thus the data distribution was parametric. [Table/Fig-3,4] gives the mean, standard deviation, Fractal Dimensions (FD) and independent t-test for assessing the significance of difference between the groups for trabecular perimeter and number. The mean trabecular numbers (8.25±2.43) and perimeter (194.62±43.26) of group B were significantly (p-value <0.001) higher than trabecular numbers (3.38±1.50) and perimeter (86.37±29.31) of group A. The fractal dimensions of group B (1.213) were higher than group A (0.867) (p-value <0.001).

Groups	N	Mean (Trabecular perimeter)	SD	p-value	*FD
Group A	15	86.37	29.31	<0.001	0.867
Group B	15	194.62	43.26		1.213

[Table/Fig-3]: Mean, SD of trabecular perimeter and independent t-test for significance of difference between the groups.
p-value <0.05 was considered as statistically significant; *FD: Fractal dimension

Groups	N	Mean (Number of trabeculae)	SD	p-value
Group A	15	3.38	1.50	<0.001
Group B	15	8.25	2.43	

[Table/Fig-4]: Mean and standard deviation of trabecular number and independent t-test for significance of difference between the groups.
p-value <0.05 was considered as statistically significant

DISCUSSION

This present study was done to assess the pattern and number of trabeculae in the bone surrounding the mandibular permanent molars in patients with and without crossbite assessed using IOPA radiographs. A significant reduction (p-value <0.001) in the trabecular perimeter, fractal dimension and number of trabeculae in teeth with crossbite when compared to teeth without crossbite was noted.

Trabecular bone pattern can be visualised in plain radiography [24] macroradiography [25,26], scintigraphy, magnetic resonance imaging [27] and micro-computed tomography [28]. Though all the methods have their own advantage, plain radiographs are the most accessible and economical method as they are a part of a routine investigation in dental practice, hence authors utilised IOPA's to assess the trabecular pattern in the present study [29]. There are many studies which have previously utilised IOPA's to assess trabecular patterns [30,31]. Trabecular bone patterns have been assessed by both fractal and non fractal methods [7,32]. Many studies have reported using fractal analysis for assessing the trabecular pattern in conditions like presurgical assessment of spinal bone, in patients with osteoporosis [33] and to assess the trabecular pattern after implant placement [34]. Fractal method has been shown to be a reliable method for assessing bone density when compared with other radiographic methods and its main advantage being its non invasive approach [31,35]. The assessment of trabecular pattern in IOPAs may serve as a boon in early diagnosis of diseases such osteoporosis, periodontal diseases and orthodontic relapse.

The branching pattern of the trabecular bone reveals the fractal properties and can be subjected to measurements which inturn determines the bone structure [36,37]. The study by Amer ME et al., points out that the quality of bone can be assessed using fractal analysis with IOPAs taken from any quadrant of the mouth hence authors decided to use IOPAs instead of other imaging modalities [38]. In this study fractal analysis was done using the box counting method to assess the trabecular architecture of subjects with crossbite. In the present study, authors had performed erosion and dilation only once and also skeletonised the image as suggested by White SC and Rudolph DJ [21]. In the present study authors have taken patients only with unilateral molar crossbite thus ruling out any anatomical variations while measuring fractal dimensions.

A recent systematic review on the use of FA in dental images suggested that on periapical images the FD value is approximately 1.5 for a healthy trabecular bone but may vary between 1.74 to 1.05 [20,32]. In the present study the mean fractal dimensions around teeth not involved in crossbite was 1.213 and it was 0.867 for teeth involved in crossbite. Amer ME et al., had studied anatomical variations in trabecular bone structure using FA employing box counting method with image J software [38]. According to them the normal values of FD should be around 1.5 and deviations from this value may be associated with some microstructural modifications in the trabecular pattern. The above finding is in consensus with the current study wherein the FD values of trabecular bone around the teeth in crossbite are less than 1 and also there is a significant reduction in the numbers and perimeters of the trabeculae.

The present study is unique as it involves quantification of trabecular patterns in subjects with crossbite malocclusion. Rothe LE et al., and Yu JH et al., in their study compared the trabecular pattern in orthodontic patients with and without relapse and noted sparse trabecular patterns in the patients with relapse [39,40]. The results of Rothe LE et al., are similar to the present study which shows reduced coarseness of the trabecular pattern on the crossbite (malocclusion) side [39]. This may be because the forces are not directed and distributed to the basal bone [38]. The study by Amer ME et al., pointed out that changes in the mechanical environment can cause changes in trabecular pattern and orientation [38]. They suggested that in conditions like aging and osteoporosis the trabeculae oriented along the line of force are not resorbed easily or are resorbed very late [37]. These results are similar to the present study since, the teeth in crossbite are subjected to forces not directed along the long axis of the teeth and hence there is reduction in number and coarseness of trabeculae.

A systematic review by Andrade AS et al., reported that posterior crossbite with an altered muscle function in children can reduce bite forces and the forces may not be directed to the basal bone [41]. The anterior temporalis is more active in crossbite subjects and the masseter had a lower EMG activity [39]. This evidence is in consensus to the findings of the present study which also suggests that when forces are not adequate and are not directed to the underlying basal bone there is a reduction in the coarseness of the trabecular pattern. Since, the trabecular number and coarseness reduced around teeth in crossbite, modifications in orthodontic force application in terms of vector, magnitude and duration must be considered. Also, after correction of crossbites an attempt to check the trabecular pattern and coarseness can be performed using fractal analysis.

Limitation(s)

Even though sample size calculation was performed authors assume the sample size was less and limited to a particular population. Growth status, age, gender, growth pattern, severity of malocclusion, masticatory efficiency may also affect the trabecular pattern, hence the results cannot be generalised. The results of the study can be used for diagnostic purposes but does not have implications on treatment planning.

CONCLUSION(S)

The research concluded that box counting method employing IOPAs can be used to assess the number and coarseness of the trabeculae. The study results using the fractal analysis concludes that there is significant reduction in the number, fractal dimension (trabecular surface) and perimeter of trabeculae (reduced coarseness)

in mandibular molars with crossbite. A future study involving assessment of trabecular patterns with FA in patients with crossbite both before and after correction should be done to see whether correction of crossbite restores normal trabecular pattern.

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