ejbps, 2016, Volume 3, Issue 9, 263-267. Research Article SJIF Impact Factor 3.881

EUROPEAN JOURNAL OF BIOMEDICAL AND PHARMACEUTICAL SCIENCES
http://www.ejbps.com

ISSN 2349-8870
Volume: 3
Issue: 9
263-267
Year: 2016

FRACTAL ANALYSIS OF PERIAPICAL REACTIVE BONE FOLLOWING ENDODONTIC TREATMENT

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Article Received on 20/06/2016 **Article Revised on 11/07/2016** **Article Accepted on 01/08/2016**

ABSTRACT

Objective: The primary aim of the study was to assess any significant changes of the bony structures of periapical reactive bone following endodontic treatment which could be demonstrated by fractal analysis of digital radiographs. **Study design**: A study was conducted where 50 adult patients requiring root canal treatment were randomly selected. Pre root canal and Post root canal treatment digital radiographs were taken and were subjected to fractal analysis. **Result**: The results demonstrated that there are significant changes of the bony structures of periapical reactive bone following endodontic treatment which could be demonstrated by fractal analysis of digital radiographs. **Conclusion**: This study demonstrated that fractal dimension of reactive bone decreases significantly 6 months after successful RCT. This is consistent with the hypothesis that suggests that the dense reactive bone would change toward a more normal density after successful RCT.

KEYWORDS: Fractal dimension, Periapical, Reactive bone.

INTRODUCTION

Periapical radiographs play an important role in the diagnosis, treatment and prognosis of periapical lesions of endodontic origin [1, 2]. Reactive bone formation in the jaws is stimulated by odontogenic infections which includes those related to inflammation or necrosis of dental pulp, which is typically found adjacent to the periapex region, with or without widening of the periodontal ligament space. Few studies have assessed reactive bone formation after root canal treatment and its regression after the cause of inflammation is eliminated [3, 4].The evaluation of bone in periapical area is usually subjective on radiographs and is further impaired due to the superimposition of anatomical structures [5].

Fractal structure has a peculiar feature of self-similarity [3] and these are omnipresent in nature. Trabecular bone also has the property of self-similarity and is a better indicator of the bone metabolic activity, more useful in monitoring changes in its structure, potentially providing added valuable information than cortical bone. In human alveolar bone, fractal properties are demonstrated by trabecular pattern of bone which is affected and changes appearance in case of any dental problem; both in periapical infection or periodontal bone loss. Bone texture analysis is a noninvasive method to evaluate bone structure.

Fractal dimension (FD) was introduced by Mandelbrot[3], is a simple method to detect and quantify changes of alveolar bone mineral content from digital radiographs and is expressed numerically as “fractal dimension” [4, 6]. It measures self-similarity and indicates a figure’s complexity. FD expresses the roughness of the texture by characterizing self-similarity of the texture gray-level variations over different scales [6]. Box counting algorithm [6- 8] is mainly used to quantify the trabecular pattern by counting the trabecular bone and bone marrow interface.

Fractal geometry is a rapidly growing area of mathematics with immense potential. It is postulated that fractal geometry may help us to explore the enigma of morphogenesis, tumorogenesis, aniogenesis, classifying disease entities and many unfolded mysteries of human life.

FD has been used for assessment of Osteoporosis, bony healing, and differentiating gingivitis, periodontitis and normal conditions in healthy adults on dental radiographs [9, 10]. It is still contentious whether a decreasing bone density removes fine trabecular structure by increasing the number of abrupt and irregular density changes with an increased FD or whether a decreasing density eliminates larger interconnecting trabecular branches with a decreased FD [11, 12]. A study done to assess bone texture after implant placement showed increase in fractal dimension after implant placement suggesting an increased bony microstructure in the peri-implant sites after implant placement [13]. Another study done on implants showed that fractal dimension acquired from the panoramic radiograph would be a useful predictor of implant stability demonstrating increased trabecular architecture post implant placement [14].

The values of fractal dimensions are not sensitive to change in angulations. Hence, even non-standardized periapical radiographs may provide a reliable method for determining fractal dimensions, which could be useful in analysing changes in alveolar bone density in various bone disorders [15].

The primary aim of the study was to assess any significant changes of the bony structures of periapical reactive bone following endodontic treatment which could be demonstrated by fractal analysis of digital radiographs.

MATERIAL AND METHOD

The present study was conducted in the department of Oral Medicine and Radiology after institutional ethical board approval. Fifty adult patients requiring root canal treatment, attending the department Out Patient Department were randomly selected.

Inclusion Criteria:

1. Patients above 16 years
2. Radiographically visible periapical radiolucent lesions 2 mm or more in diameter associated with necrotic maxillary or mandibular posterior and anterior teeth.

Exclusion Criteria:

1. Patient with a history of systemic disease or any disease that would affect bone metabolism like malignancies with secondary bone metastasis or significant renal impairment.
2. Patients using drugs or hormones (corticosteroids, thyroid hormone) which may cause adverse effects on bone metabolism.

Digital periapical radiographs were made within a week prior to root canal treatment (RCT), and all 50 patients had follow-up radiographs six months after completion of RCT.

All radiographs were taken using a standardized method to facilitate reproducible projection geometry on the intra oral X-ray unit (Skanray Technologies Pvt Ltd., Mysore , India) operating at parameters of 70kvp,10 mA and 0.4sec exposure. Images were acquired using a number 1 charge-coupled devices (CCD) sensor (Suni Medical Imaging Inc., 6840 Via Deloro Suite 160, San Jose, CA 95119) and X Ray Vision Assistant software (Suni Medical Imaging Inc.).

The CCD images were saved as bitmap films (BMP) format. The ROI was selected within the periapical lesion taking care not to include any part to the tooth periapex. It was ensured no radiopaque lesions or anatomic landmark were located around the region of ROI. The ROI in the pre and post treatment radiographs were identified by rotational adjustments of the digital images to align roots in serial images. One pair of ROIs were selected around the periapical lesion for each patient, as decided independently and jointly by the two observers with a minimum of 5 years of experience in maxillofacial radiology. Both observers underwent training until they were comfortable with ROI placement and FD assessment. The intra-observer agreement in ROI placement was assessed by having the same observer view half of the images twice, with a 3 week interval between the viewings. The inter-observer reliability was assessed by having the two observers place the ROIs and assessed the FD separately. All ROI were selected on the image as squares of 80X80 pixels. This was done using Adobe Photoshop CS3 software (Adobe systems, San Jose, CA, USA).

Fractal dimension analysis was carried out using Image J 1.42 software, as a version of NIH Image (National Institute of Health, US). NIH Image is a public domain program that was downloaded from the Internet using Java 1.6.0_10. The saved images were processed for FD using box counting method proposed in previous reports [7, 8, 15].

The transferred cropped ROI was first duplicated and the duplicated image was blurred using Gaussian filter (kernel size=30), to remove the fine and medium scale variations in density, and then saved again. Then, the original ROI and the blurred one are subtracted from each other and 128 was added to the result at each pixel location. The resultant image was converted to binary image with threshold at grey level of 128. The binary image was eroded and dilated to reduce the noise. This image was finally skeletonized and used in the next step.

Using Image J, the fractal dimensions of the outlined image was calculated by the Box Counting function [3] (Fig 1). Initially, the Image is converted by square grid of equally sized tiles; widths of the square boxes are 2, 3, 4, 6, 8, 12, 16, 32 and 64 pixels. Subsequently, the number of the counted tiles was plotted against the total number of tiles in a double logarithmic scale (Fig 2). Finally, FD calculated from the slope of the line fitted on data points. This procedure was done for pre and post treatment images.

Data analysis
The pre and post root canal treatment radiographic data was collected and entered in Excel. Data analysis was done with the help of SPSS version 15 and SIGMAPLOT version 11 software. Qualitative data was presented with the help of Mean, Standard deviation, Median and IQR, comparison among study group is done with the help of Mann-Whitney test as per the result of Normality test.

RESULTS
The study included total fifty patients whose pre and post-operative fractal values were studied. The data pool consisted of 21 (42%) females and 29 (58%) males with an age range of 16 to 50 years (mean: 33). Double logarithmic plots of the counted number of boxes versus the sizes of boxes showed a good approximate onto a straight line in all cases.

On comparing fractal dimension using Mann-Whitney test among gender (table I and II), males show significant difference in pre and post -operative values. In the male study group the pre-treatment ROI have mean 1.079, Standard deviation 0.133, median 1.08 and post treatment ROI have mean 0.99, Standard deviation 0.18, median 0.13 and the p value of 0.04.

When fractal dimension was compared among different age study group, the results were significant for the age group between 26-30 years (table III). All the age group showed decreased in fractal dimension in post-operative value after RCT except 36-40 years age group.40 out of 50 patients showed decreased fractal dimension in the reactive bone formation area in the ROIs. In 10 patients the fractal dimension values increased after RCT.

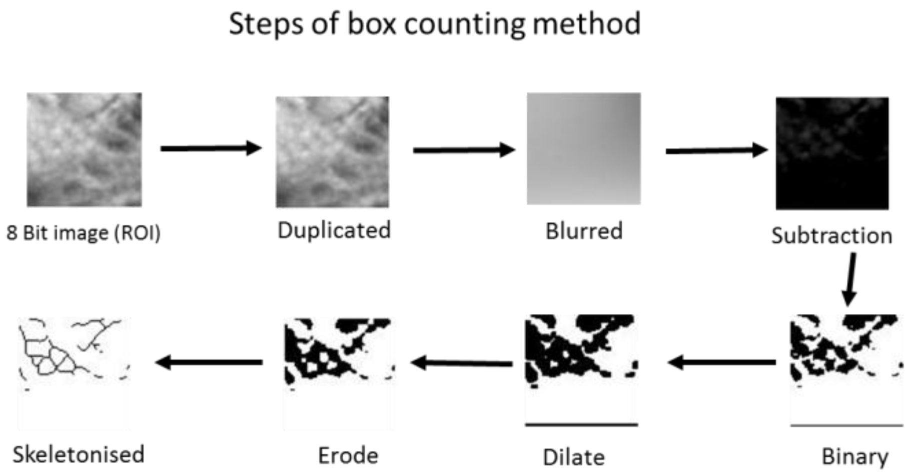

Fig 1: Steps of Box counting method

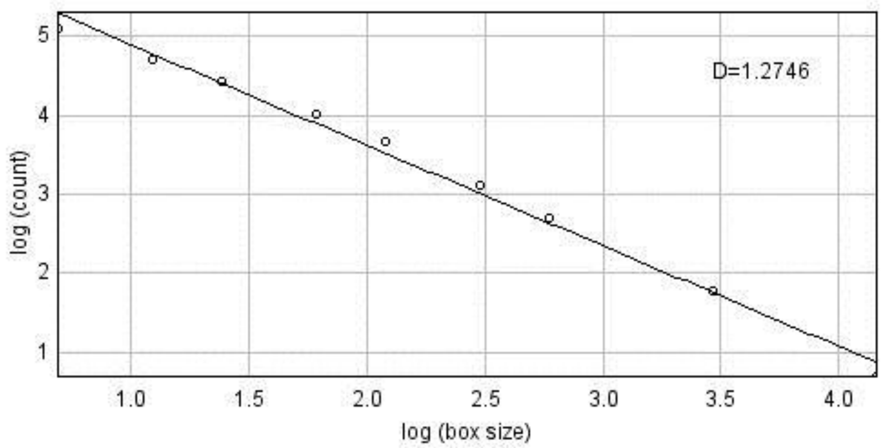

Fig 2: logarithmic scale, fractal dimension is calculated by the slope of the line fitted on the data points.

DISCUSSION
Fractal dimension analysis propounds the concept that identification of sectional fractal dimensions may assist to describe distinct morphological entities within the cancellous structure of bone and thus, the effect of the cellular processes that drive changes in the structure may be studied [11]. Even though higher FD values may specify more complex textures, it is also reported that different fractal sets may share the same FD but have different textures [16-18]. This study demonstrated that

fractal dimension of reactive bone decreases significantly 6 months after successful RCT. This is consistent with the hypothesis that suggests that the dense reactive bone would change toward a more normal density after successful RCT.

There are various established techniques for calculating the FD, including the calliper, box counting and power spectral methods. We chose box counting method of Image J 1.42 software due to its easy availability and usage. The ROI was placed at the apical end of the root. Care was taken to avoid inclusion of any anatomical structures such as inferior alveolar nerve canal. A square of 80X80 pixels was selected as ROI because that would be a convenient dimension for placement in periapical region. Previous studies have suggested that the ROI location is more critical for fractal analysis than its size [19, 20].

Total 50 patients were included in the study whose pre-operative and post-operative fractal values were studied. Most of the patients showed decreased fractal dimension in reactive bone formation area in the ROIs. The fractal dimension values decreases in both male and female group after RCT but the difference is statistically significant only in male study group which means the bone changes in the males are not same as females. Thus it could be concluded that there is a possibility that remodelling of reactive bone progressed at a faster rate in males. A larger sample size needs to be studied with cross tabulations between gender and age. The only age group which showed statistically significant results between pre and post-operative values is 26-30 yrs. This can be attributed to the fact that there was more number of patients in this group.

In 10 cases the fractal dimensions increased in the reactive bone regions. This could be explained by the possibility that in these cases remodelling of reactive bone progressed at a slower rate. Another possibility is that the factors causing the reactive bone formation had not been completely removed by RCT in these cases. Similar results were presented in the study Chen SK et al [7], in which twenty-five of 27 patients showed increase of the fractal dimension after root canal treatment.

The decrease in fractal dimension in our study is in concordance to the study done by Yen-Yun et al [21], which had seventeen patients in one group and 13 patients in the other that showed decreased FD in the reactive bone region after clinically successful RCT. Only these two reference studies mentioned above have been done in the past to see the changes in periapical reactive bone after RCT. FD values decreases during bone healing process as shown in our study; as condensation of bone that has occurred due to infection from the necrosis of the pulp reduces. However, it has also been proposed that FD may differ because of the differences in the anatomy of the subjects and the experimental design[21, 22].

CONCLUSION

This study confirmed within six months of successful RCT, the fractal dimension of reactive bone decreases significantly. This is consistent with the hypothesis that dense reactive bone would change towards a more normal density after successful RCT.

FD can be viewed as a measure of irregularity of many physical processes. The box counting method described and used in this study might be useful quantitative method for determining bone structure of the jaws. Fractal analysis is an economical and non-invasive method, yet if it needs to be routinely used procedure there needs to be a consensus on the method used for fractal analysis. This can be achieved by conducting more clinical trials using larger sample size. As not many studies have been undertaken for assessment of bone reactivity in periapical region after RCT, this study can form the base for further research in different groups of population; eventually rendering FD as prognostic tool for quantitative bone analysis.

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