Assessment of Trabecular Bone Patterns in Periodontitis Patients with Systemic Diseases: A Fractal Analysis Study

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ABSTRACT:

Background & Objectives: Periodontitis results in progressive inflammation – mediated loss of periodontal supporting structures, including trabecular bone. This study aimed to evaluate the trabecular bone pattern changes in panoramic radiographs from patients with periodontitis and systemic diseases using fractal analysis.

Study design: Panoramic radiographs from periodontitis patients without any systemic diseases and patients with periodontitis and systemic diseases like type II diabetes mellitus and hypothyroidism were collected. A region of interest was selected on panoramic radiographs between Mandibular first molar and second premolar. The fractal dimension values for this region were calculated using the box-counting method. The statistical significance of difference was evaluated at $p < 0.05$.

Results: Fractal dimension values were lower in periodontitis patients with diabetes when compared with the other groups, but there was no statistically significant difference in fractal dimension values between the groups ($p > 0.05$).

Conclusion: Fractal analysis serves as an adjunctive non-invasive diagnostic tool when used alongside clinical periodontal measurements and also helps for early detection of bone alterations & helps periodontists to assess bone quality beyond routine radiographs.

Keywords: Fractal analysis, Trabecular bone changes, Periodontitis, Diabetes mellitus, Hypertension.

INTRODUCTION:

Periodontitis is a chronic inflammatory disease and a leading cause of tooth loss, with the multiple contributing factors [(1)]. Alveolar bone alterations serve as important indicators of the initiation and progression of periodontal diseases. Consequently, evaluating changes in alveolar bone architecture is essential for effective prevention, accurate treatment planning, and reliable prognosis of periodontal conditions. Radiographic examination plays a crucial role in various stages of periodontal assessment, and multiple imaging modalities are available to evaluate periodontal tissues, including intraoral radiographs, panoramic radiography, and cone beam computed tomography (CBCT) [(2,3)].

The severity of periodontitis is determined based on both direct and indirect evidence. Direct evidence includes radiographic bone loss or clinical attachment loss documented over a five-year period, while indirect evidence encompasses case phenotype and the percentage of bone loss. Additionally, secondary criteria are considered, such as risk factors including smoking diabetes and thyroid disorders, overall inflammatory burden, and biomarker indicators associated with bone loss [4,5]. Therefore, further analysis of radiographs has the potential to improve the diagnostic utility of these images by enabling more detailed detection of structural changes.

Fractal analysis serves as an adjunctive technique for the quantitative assessment of bone trabeculation. This method identifies complex structural patterns within trabecular bone and quantifies bone complexity using a parameter known as the fractal dimension (FD) [6]. The FD calculated from radiographs reflects the complexity of the alveolar bone architecture surrounding the teeth. Among the various methods available for FD calculation, the box-counting technique described by White and Rudolph is most commonly employed, particularly for binary images such as periapical radiographs. In this approach, FD represents the number of boxes required to cover the trabecular pattern, with higher FD values indicating greater structural complexity of the trabecular bone [7].

Based on the available evidence, only a limited number of studies have evaluated trabecular changes in the alveolar bone of periodontitis patients with and without systemic conditions such as diabetes and hypothyroidism using fractal analysis. Therefore, the present study aimed to assess the effect of periodontitis, with and without associated systemic diseases, on trabecular bone density using fractal analysis, and to evaluate its effectiveness in detecting trabecular bone alterations.

MATERIALS AND METHODS:

This study was conducted in accordance with the principles of the Declaration of Helsinki and received approval from the Institutional Ethics Committee. Written informed consent was obtained from all participants. The study population comprised three groups: 20 patients with stage II/III periodontitis, 20 patients with periodontitis and diabetes mellitus, and 20 patients with periodontitis and hypothyroidism. Periodontal status was established based on dental history, clinical examination, clinical records, and radiographic findings. An additional inclusion criterion was the presence of at least 20 natural teeth [8].

Individuals were excluded from the study if they met any of the following criteria: use of medications known to affect periodontal tissues or bone metabolism; presence of jaw lesions or pathologies; teeth with cervical caries in the region of interest (ROI); previously root-treated teeth or teeth exhibiting periapical pathology within the ROI; and absence of the left mandibular second premolar and/or first molar. Radiographic exclusion criteria included poor-quality radiographs or images affected by artifacts, which could interfere with accurate analysis.

Radiographic analysis

All digital panoramic radiographs were acquired using the same imaging device to ensure standardization. Trabecular bone architecture was evaluated using ImageJ software. The radiographic images were processed using the software's image-processing tools, and quantitative assessment of trabecular structure was performed using fractal analysis. Standardized regions of interest (ROIs) measuring 30 × 30 pixels were selected in the interdental area between the roots of the left mandibular first molar and second premolar.

The Region of interest (ROI) encompassing the interdental trabecular bone was cropped from the original image and duplicated for further processing. A Gaussian filter was applied to reduce density variations caused by soft tissue and to enhance structural details. The filtered image was then subtracted from the original image, and pixel intensity was adjusted to standardize the image. The image was converted to a binary format to clearly visualize the trabecular pattern, followed by erosion and dilation procedures to minimize noise and emphasize the main trabecular structures. The image was then inverted and skeletonized to transform the trabecular bone pattern into a linear representation. Finally, fractal dimension (FD) was calculated using the box-counting method by analyzing the relationship between box size and structural complexity, with the slope of the resulting log–log plot representing the FD value.

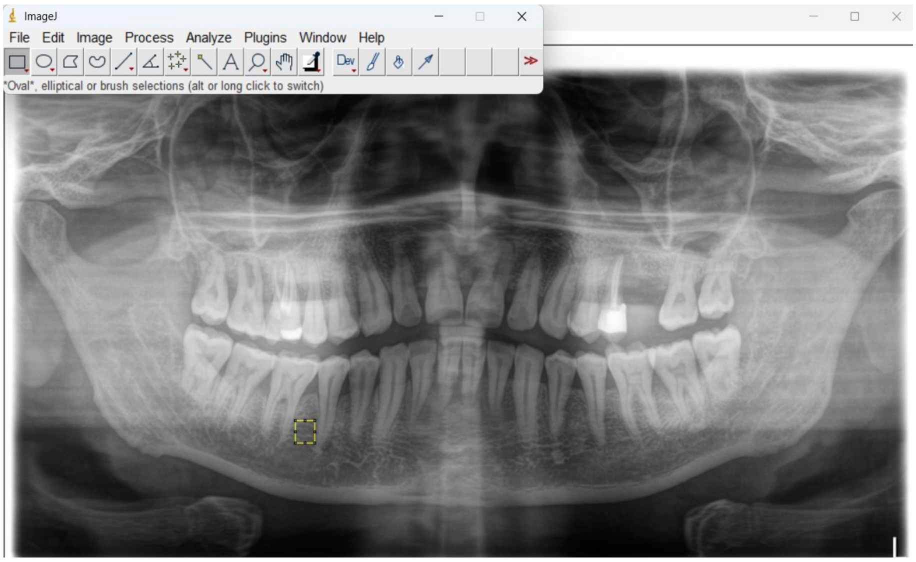

Figure 1: Region of interest selection in the Image J programme

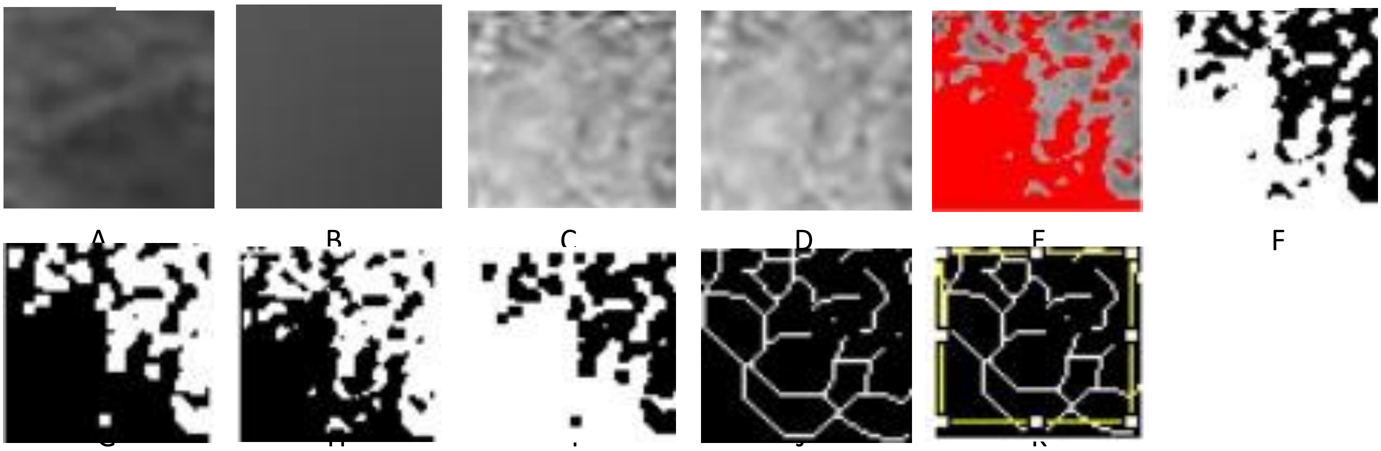

Figure 2: Steps used in image processing

A) Duplicated image B) Gaussian blur C) Subtract D) Add E) Threshold F) Binary G) Erode H) Dilate I) Invert J) Skeletonize K) FD analysis

A total of 60 subjects were included in the study, with 20 participants in each group. The distribution of age and gender among the three groups was comparable, with no statistically significant difference observed in gender distribution ($p = 0.88$) or mean age ($p = 0.24$), indicating baseline homogeneity of the study population (Table 1).

Table 1: Distribution of the participants in terms of age and gender

		Periodontitis		P + DM		P + H		p
Gender		N	%	N	%	N	%	0.88*
	Female	11	55%	7	35%	12	55%	
	Male	9	45%	13	65%	8	45%	
Total		20	100	20	1000	20	100	
Age	mean±SD	35.71 ± 10.28		37.38 ± 10.74		36.40 ± 10.54		0.24*

The mean fractal dimension (FD) values were 1.198 ± 0.143 in the periodontitis group, 1.246 ± 0.139 in the **periodontitis with diabetes mellitus** (P + DM) group, and 1.176 ± 0.141 in the **periodontitis with hypothyroidism** (P + H) group. Although the P + DM group demonstrated higher mean FD values compared to the other groups, the intergroup comparison using the Kruskal–Wallis test revealed no statistically significant difference in FD values among the three groups (H = 2.18, df = 2, p = 0.33) (Table 2).

Table 2: Difference between the groups in terms of Fractal dimension values

Group	N	Mean	Median	Min	Max	SD	Mean Rank	Rank Sum	H value	df	p
Periodontitis	20	1.198	1.218	0.817	1.323	0.143	68.32	1366.40	2.18	2	0.33
Periodontitis + Diabetes (P + DM)	20	1.246	1.276	0.962	1.472	0.139	62.347	1246.94			
Periodontitis + Hypothyroidism (P + H)	20	1.176	1.226	0.823	1.401	0.141	62.53	1250.60			
Total	60	1.224	1.239	0.855	1.428	—	64.44	—			

DISCUSSION:

A fractal is a complex and irregular geometric structure characterized by the property of self-similarity; wherein smaller portions of the structure resemble the overall pattern when examined at different magnifications. This repeating pattern of structural detail occurs across multiple scales. The complexity of such structures is quantified using a parameter known as fractal dimension (FD), a numerical value—often fractional—that describes how completely a structure occupies space. Fractal analysis has been widely applied to evaluate bone changes associated with periodontal disease; however, existing studies have reported inconsistent findings, highlighting ongoing uncertainty regarding its diagnostic significance [(9)].

his study aimed to evaluate fractal dimension (FD) values in individuals with periodontitis and in those with periodontitis associated with diabetes and hypothyroidism using panoramic radiographs, and to assess the potential contribution of the fractal analysis (FA) method to radiographic diagnosis. The results demonstrated no statistically significant difference in FD values between periodontitis patients with and without systemic diseases. Nevertheless, FA may provide additional information regarding bone-related changes, such as bone loss, and may contribute to risk assessment when used alongside conventional clinical periodontal measurements [10]. Furthermore, incorporating FA into maintenance-oriented periodontal therapy—such as closer monitoring of patients exhibiting lower FA values and reinforcement of oral hygiene measures—may offer clinical benefits.

One of the earliest investigations on this topic was conducted by Shrout et al., who reported that in the posterior mandibular region, FD values of the interdental bone were higher in patients with gingivitis compared to those with periodontitis [11]. Conversely, other researchers, such as Dosdogru et al., compared healthy individuals with those affected by periodontitis and observed "no statistically significant difference" in the mean FD values between the groups [12]. This indicates that, at least using their methodology, fractal analysis was not consistently able to distinguish between the two populations and revealed an intriguing observation. In their healthy cohort, a "moderate negative correlation" was noted between FD and adverse clinical parameters. In other words, individuals with higher, more intricate FD values generally exhibited less plaque, reduced bleeding, and shallower periodontal pockets. Interestingly, this association was entirely absent in the periodontitis group, implying that the disease process may disrupt the normal link between bone complexity and clinical health.

Ergün et al. reported an increase in postoperative bone density in a patient with hyperparathyroidism due to an adrenal adenoma by comparing bone mineral levels before and after parathyroidectomy using FD on (Digital Panoramic Radiography) DPR [13]. The authors attributed the rise in FD following parathyroidectomy to a decrease in bone resorption resulting from the treatment of hyperparathyroidism. Similarly, Kurşun-Çakmak EŞ et al. calculated FD in four distinct regions on panoramic radiographs of patients with Type-1 and Type-2 diabetes mellitus and found no significant differences in FD values between the diabetes and control groups [14].

Amer et al. reported that the fractal size of trabecular bone was not related to age [15]. Geraets and van der Stelt suggested that inconsistencies among study findings may be attributed to anatomical variations in the regions examined as well as differences in the imaging techniques employed [16]. When applying fractal analysis to the evaluation of bone, it is important to recognize that every step in the analytical process can influence the final results. Numerous factors may affect outcomes, including patient selection, imaging modality, sample size, gender distribution, age distribution between groups, and individual anatomical variations. Therefore, to minimize the influence of these variables, methodological limitations must be addressed, and further studies with larger sample sizes and better standardization are required.

CONCLUSION:

In the present study, trabecular bone fractal dimension (FD) values were compared using panoramic radiographs of periodontitis patients with and without systemic diseases. The results demonstrated no statistically significant difference in FD values of trabecular bone between periodontitis patients with systemic conditions (diabetes mellitus and hypothyroidism) and those without systemic disease. However, lower FD values were observed in diabetic periodontitis patients, indicating the presence of subtle alterations in trabecular bone architecture. These findings suggest that fractal analysis serves as a valuable, non-invasive method for the early detection of bone changes and may assist periodontists in evaluating bone quality beyond what is apparent on routine radiographic assessment. Nevertheless, further studies incorporating larger sample sizes and standardized methodologies are necessary to clarify the potential role of FD in periodontal evaluation.

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