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Semra Eser, Ebru Sarıbaş, The alveolar bone in periodontal disease by fractal analysis method

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ABSTRACT

Background: Early diagnosis and treatment of periodontitis, which can cause loss of bone support of the teeth, is of great importance. The use of fractal analysis method is being investigated in order to differentiate periodontal disease radiographically. Fractal analysis presents the degree of complexity in the structure of fractal objects as a numerical data, and has been used to measure changes in trabecular bone. The aim of this study was to compare the trabecular bone fractal dimension values of patients with periodontitis and gingivitis using panoramic radiographs, and to evaluate the possible relationship between age and gender with fractal dimension.

Materials and methods: Panoramic radiographs of 64 patients with gingivitis and 64 patients with periodontitis were evaluated retrospectively in the study. Using the radiographs of the patients, fractal dimension values measured from the trabecular bone were calculated with the box-counting method in the Image J program. The fractal dimension values of both groups were compared. In addition, the relationship between age and gender parameters and fractal dimension values was evaluated within the groups.

Results: According to the results of the study, the calculated average fractal dimension value of the patients in the gingivitis group was 1,195, while the calculated average fractal dimension value of the patients in the periodontitis group was 1,196. No statistically
significant difference was observed between the fractal dimension values of the gingivitis group and the periodontitis group ($p>0.05$). No statistically significant correlation was observed between fractal dimension values and age and gender ($p>0.05$).

**Conclusions:** No statistically significant results were obtained for the calculated mean fractal dimension values of the patients in the gingivitis and periodontitis groups.

**Key words:** fractal analysis, periodontitis, gingivitis, panoramic radiography

**INTRODUCTION**

Periodontitis is a disease of the periodontium and therefore of many structures including the gums. It concerns the tissues lying around the periodontium. And the periodontium also includes the cementum of the tooth root and therefore the tooth tissue. Periodontal diseases, which are inflammatory lesions of the tissues surrounding the teeth, are among the most common oral diseases in adults (1). Gingivitis is a disease of the gums characterized by hyperemia, edema, and bleeding symptoms. It is also characterized by loss of attachment and alveolar bone loss (2). Plaque tartar, periodontal pocket, inflammation, and reduced bone level are the findings that can be seen at this level. However, periodontal pocket depth differs between clinically healthy patients and patients with gingival disease. This depth detection with a periodontal probe is also important in determining the staging of periodontitis. (Figure 1) (3). The stages of gingival disorders can start as gingivitis and progress to advanced periodontitis (Figure 2) (4-6). Periodontitis and osteoporosis are known to be common inflammation-related skeletal system disorders. Aging, accumulation of oxidative stress and cellular aging, vitamin D deficiency, smoking have been reported to be factors affecting the progression of osteoporosis and the formation of periodontitis (7). Particularly, the increasing relationship between aging and periodontist has been included in the studies. Diep et al. reported that there is an important need for dental care associated with endodontic conditions in the future elderly (8).

Alveolar bones of the upper and lower jaws consist of cortical (compact) and cancellous (trabecular) bone parts. Trabecular bone is surrounded by cortical bone like an outer sheath. Cortical bone in our skeletal system is protected against external factors, and trabecular bone has undertaken the task of actively maintaining metabolic functions (9).

Radiographs are essential tools for the diagnosis and follow-up of periodontal diseases. It has been stated that the destruction in the bone can only be detected with
conventional radiographs when it reaches 30-50% (10). This may cause the initial stage of periodontitis to be overlooked. Nowadays, technology and artificial intelligence applications have been developed, and a non-invasive diagnostic method containing objective and quantitative data is tried to be developed in the radiographic analysis (11).

Mandelbrot described the shapes of objects that can be found outside of the geometric shapes known in nature, different from the typical geometries taught in schools and complex, with the term ‘fractal’. Fractal analysis has been used in the measurement of many objects existing in nature. The complexity of fractals comes from the endless repetition of details within details. Two features that characterize fractal geometry are the self-similarity property of each part of the figure viewed from separate scales, that is, the resemblance to the whole object, and the variation of a defined scale. That is when the examined area is enlarged or reduced by scale change; there is a similarity to the whole shape in each scale dimension (12). An increase in the fractal dimension (FD) value is observed when the patterns have a more complex structure, while lower values indicate a simpler structure.

A special computer algorithm developed by White and Rudolph generates a number that gives the fractal dimension value representing the morphological features of the architecture, and this value gives us information about the complexity of the structure (13). In addition to this program called Image J, other software types that calculate fractal size such as NRecon, Scion Image CTAn, and TAS Plus have been produced.

When the trabecular structure of the cancellous bone was examined, it was observed that it showed fractal characteristics (14-16). As a result of the studies, it was concluded that the fractal size of the bone and its biomechanical properties are related to (17). It was found that the loss of minerals in the bone and the decrease in density decreased the FD value; likewise, a high FD has been shown to indicate fewer cavities in the more complex bone architecture (13).

It was investigated how the fractal dimensions of trabecular bone of the periapical bone showed a prospective morphological change after two different apexification treatments in teeth with apical periodontitis. The lesion area of the case was evaluated with the fractal analysis method on the periapical radiographs obtained before the treatment and 1 year after the treatment with the Image-J program (18). In addition, Tosun et al. calculated the fractal size of abnormal tissue areas around the root apex on periapical radiographs taken before and after treatment in a retrospective study of 50 patients. And they mentioned a statistically significant difference in FD in the comparison of treated and untreated patient groups (19). In another study, using the fractal analysis method, it was investigated whether it could
distinguish the trabecular bone in this region between healthy peri-implant mucosa and individuals with peri-implant disease on periapical radiographs. They reported that the method used did not have any distinguishing features in terms of FD, but it could be useful in terms of probing depth, the presence or absence of bleeding on probing, and clinical attachment level (20).

The invisible details in the structure of the trabecular bone, which has been proven to have fractal properties, can be evaluated by the fractal analysis method (21). Studies are reporting that the trabecular morphology of the alveolar bone and changes in the trabeculae in case of disease can be detected by this method (22). There are limited studies in the literature investigating the use of fractal analysis to support the radiographic diagnosis of periodontal disease.

We aimed to evaluate the fractal size of patients with periodontitis and gingivitis using panoramic radiographs, and to evaluate the possible contribution of fractal analysis method to radiographic diagnosis, as well as to evaluate the possible relationship of fractal size with gender and age.

MATERIALS AND METHODS

Patient selection

Our study was carried out retrospectively using the records of Dicle University Faculty of Dentistry, Department of Periodontology. This study, which was approved by Dicle University Clinical Research Ethics Committee on 24.02.2021 with protocol number 2021-15, was conducted by the ethical principles of the World Medical Association Declaration of Helsinki. The records of 562 patients who had periodontal treatments in the Dicle University Periodontology Department between 01.10.2017-31.12.2018 were scanned and the patients were selected by the inclusion criteria. Among the patients whose existing periodontal index records and radiographic records were evaluated together, a total of 128 patients, 64 patients with gingivitis and 64 patients with periodontitis, were included in the study.

The inclusion criteria were as follows:

— Having been diagnosed with gingivitis or periodontitis according to the records of the Department of Periodontology, and
— To have a panoramic radiograph that is registered in the system and has diagnostic value.

The exclusion criteria were as follows:
Presence of any systemic disease affecting bone metabolism, Use of drugs that affect bone metabolism, the number of existing teeth is less than 20, presence of overflow filling, root canal treatment, cyst, tumor, lesion in the relevant area, presence of bone fracture in the relevant region, extraction of tooth numbers 5,6 or 7 in the relevant region, to have had periodontal treatment in the last 6 months, patients with panoramic radiographs of no diagnostic value due to various artifacts or positioning errors.

**Radiological evaluation**

All the panoramic radiographs were taken with the Planmeca ProMax 2D panoramic x-ray device at Dicle University Faculty of Dentistry, Department of Oral and Maxillofacial Radiology, and the irradiation parameters were determined as 64 kVp, 7mA.

Radiographic images included in the study were opened and analyzed in Meta Soft Pacs imaging system and saved in Digital Imaging and Communications in Medicine (DICOM) format, which has high image quality.

**Fractal analysis**

The panoramic image was opened in the Image J program and the area to be examined, called ROI (region of interest), was selected (Figure 3). The relevant area was selected to include first the mesial and then the distal of tooth 36, and two separate fractal dimensions were calculated and the average of the two measurements was taken. If tooth 36 was out of consideration, tooth 46 was used in the calculation. The ROI was chosen in a rectangular shape with a size of 23x51 pixels. Narrow interproximal areas that do not allow ROI selection at this site are adjusted to be in the closest pixel to it.

The image was rotated in the desired direction with the 'rotate' option and the relevant region was enlarged with the 'magnifying' feature so that the ROI selected in the posterior of the mandible can be selected in a rectangular shape and at the specified pixel.

— The ROI selected to include the interdental trabecular bone was clipped with the 'crop' feature.
— The cropped ROI was copied with the 'duplicate' feature.
— A 'Gaussian filter' set to 35 pixels was used to remove the density differences created by the soft tissue in the image and to make sharper differences more evident.
— The image filtered by the 'Subtraction' feature has been extracted from the original.
It was set to 128 values with the 'add' property to reveal the density differences in the image.

With the 'Binary' feature, the image was made black and white. Thus, the trabeculae became evident.

The 'erode' and then 'dilate' features were used to eliminate noise and highlight the main lines.

With the 'invert' feature, the image was inverted, and the desired features are brought into view.

Using the 'skeletonized' feature, the trabecular structure in the bone was transformed into complex lines.

With the 'Box-counting' feature, the image was divided into squares of 2, 3, 4, 6, 8, 12, 16, 32, and 64 pixels (Figure 4). Squares containing these complex lines representing trabeculae were counted. This calculation was done separately for each pixel size and the total number of frames was calculated. The number of counted plates was plotted against the total number of plates on a logarithmic scale. A line is drawn through the data points in the graph. The slope of the drawn line gives the FD value, which expresses the complexity of the analyzed image (Fig. 3).

Statistical analysis

In this study, Shapiro Wilk's and/or Kolmogorov-Smirnov Tests were used due to the number of units while investigating the normal distribution of the variables. While evaluating the results, 0.05 was used as the significance level. Chi-square analysis was applied while examining the relationships between groups of nominal variables.

Spearman's Correlation Coefficient was used while examining the relationships between variables that did not come from the normal distribution. While examining the differences between groups, if the variables did not come from a normal distribution, the Mann-Whitney U test was used for comparisons between groups.

RESULTS

Demographic findings

There was no statistically significant relationship between the groups in terms of gender (p > 0.05). 51.6% of the periodontitis group and 50% of the gingivitis group were women. Table 1 shows the gender distribution and statistical relationship in the groups.
There was no statistically significant difference between the groups in terms of age (p>0.05). The mean age of the periodontitis group was higher than the mean age of the gingivitis group, but the difference was not statistically significant. Table 2 shows the age and statistical relationship of the groups.

**FD measurements**

There was no statistically significant difference between the groups in terms of FD values (p > 0.05). Table 3 shows the FD values of the gingivitis and periodontitis groups and their statistical relationship.

Although there was no statistically significant difference between the genders in terms of FD values measured from the radiographs of the patients in the periodontitis and gingivitis groups, the FD value measured from the radiographs of the men was higher (p>0.05). Table 4 shows the relationship between FD and gender.

Although there was no statistically significant relationship between the FD values measured from the radiographs of the individuals regardless of the group, the FD value calculated from the radiographs of the men was higher (p>0.05) (Table 4).

Although there was no statistically significant relationship between the FD values measured from the radiographs of the patients both gingivitis and periodontitis groups and the age values, the FD value increased as the age increased (p>0.05). Table 5 shows the relationship between FD and age.

Regardless of the group, there was no statistically significant relationship between the FD values measured from the radiographs of the individuals and the age values, but the FD value increased as the age increased (p>0.05) (Table 5).

**DISCUSSION**

The clinical significance of the relationship between periodontitis and genetic factors is known. Based on recent research data, it has been reported that genetic and ethnic factors are considered the leading susceptibility or severity factors for devastating periodontitis. A family history of early-onset aggressive periodontitis has been known for a long time. Hereditary syndromes have often been associated with severe periodontitis. They reported that periodontal disease associated with systemic inherited syndromes mainly indicates Mendelian inheritance (23). Shungin et al. presented as a meta-analysis a genome-wide association study
by identifying clinical findings, self-reported dental disease proxies with similar underlying genetic contributions, and then identifying 47 novel and conditionally independent risk loci for dental caries (24). Similarly, they reviewed the literature for gene polymorphisms associated with periodontitis and peri-implantitis susceptibility in the Iranian population (25). In a study investigating epigenetic factors in periodontitis, these epigenetic changes have been reported to be associated with excess inflammatory cytokines, chemokines and matrix-degrading enzymes that can be suppressed by certain histone deacetylases (small molecule inhibitors of certain histone deacetylases) or by small molecule inhibitors of DNA methyltransferases. They noted the importance of providing critical information about the therapeutic and diagnostic potential of epigenetics in periodontal disease (26). For all that, they stated that periodontitis may be an individual risk factor for the development of oral cancer. They suggested that individuals with periodontal problems, especially those with severe periodontitis and coexisting lifestyle risk factors, should be followed closely. They concluded that maintaining periodontal health in at-risk patients can minimize their cancer risk (27). In a genetic microbiological study, they reported that the correlation of mir155 with periodontal parameters and periodontal pathogens further strengthens the evidence for periodontal inflammation as a risk of preeclampsia in pregnant women, especially when associated with chronic periodontitis. They suggested that mir155 can be considered as one of the genetic biomarkers and is an important criterion for the early diagnosis of periodontitis (28).

The fractal analysis method, which is thought to contribute to the radiographic examination by examining the invisible details in the bone structure, has been used to understand objects in many fields such as astrophysics, genetic, economy, agriculture, medicine, and dentistry (29-32).

It has been reported that the FD value calculated by the studies is not affected by variables such as irradiation time (mAs), kilovolt peak acceleration voltage (kVp), and projection angle, therefore fractal analysis can be performed with non-standardized radiographs during the filming of (33-35).

Considering this information, our study aimed to use fractal analysis to evaluate the trabecular bone morphology of patients with periodontitis and gingivitis, as well as to evaluate the possible relationship between fractal dimension, age, and gender.

There are a limited number of studies in the literature regarding the use of fractal analysis to support the radiographic diagnosis of periodontitis. Current studies used cone beam computed tomography (CBCT) and periapical radiography technique (11,36-40).
Although there are many studies on FD calculation using panoramic radiographs in different fields in dentistry (16,22,41), no study has yet been conducted using panoramic radiographs in the evaluation of periodontal disease.

Periapical and bite-wing radiographs are imaging modalities with better resolution than panoramic radiographs. However, the disadvantages are that the number of films to be taken is higher when the whole mouth is evaluated and the radiation dose that the patient will receive is higher than the dose that will be taken with panoramic radiographs (42).

The fact that panoramic radiographs are in widespread use with increasing frequency, the advantageous situation in their application and patient tolerance, and the fact that they allow imaging of larger areas with a lower radiation dose have prompted us to use panoramic radiography in this study.

It has been reported that the box-counting method is widely used and is currently in fractal analysis (22). In this method, the process steps suggested by White and Rudolph are applied. For this purpose, the Image J image analysis program was developed.

In our study, ROI was chosen within the borders of trabecular bone, not including cortical bone, tooth, or periodontal space. Like other studies (11,36), in our study, two separate ROIs were selected from the mesial and distal interdental region of the mandible number 6 tooth, which is frequently affected by periodontitis, FD was calculated from these regions, and the average of the two values was taken.

In our study in which trabecular bone FD measurements of 64 gingivitis and 64 periodontitis patients were compared, it was observed that there was no statistically significant difference between the calculated FD values of the patients in the two groups.

In the study of Shrout et al. in 1998, the FD values calculated from the periapical radiographs of the group with periodontitis and the healthy or another patient group with gingivitis were compared. As a result of this study, it was found that the FD value of the group with periodontitis was significantly lower (43). In our study, digital panoramic radiographs were recorded and used in DICOM format with high image quality. We believe that this situation may have caused the difference between the results.

In the study of Şener et al., in which they measured FD using the periapical radiographs of healthy and moderately severe periodontitis patients, a significant difference was found between the FD values of both groups (11). In the study of Bollen et al., in which they compared periapical and panoramic radiographs, it was reported that FD values measured from periapical radiographs of the same patients were higher (43). This situation
causes us to consider the possibility of different details and resolutions in imaging methods to change the results in diseases that cause local bone loss such as periodontitis.

Coşgunarslan et al. calculated FD from CBCT images of healthy and periodontitis patients and reported that there was no statistically significant difference between FD measurements of the two groups, like our study. They reported that the inconsistency of this result with some studies in the literature may be due to the difference in imaging methods (40). In addition, Magat et al. suggested that CBCT has low image resolution for fractal analysis of trabecular bone (44). Based on this, it can be thought that the results may vary when FD measurement is performed using periapical, panoramic, or CBCT imaging.

In the study of Updike et al., the FD values of healthy, moderate/severe, and severe periodontitis patients were compared. As a result of the study, there was a significant difference between the FD values of the periodontitis groups and the healthy group, but no significant difference was found between the FD values of the moderate/severe periodontitis and severe periodontitis groups (38). We believe that the fact that the result of our study is not fully compatible with this study may be due to the difference in ROI position.

ROI selection is done manually. This leads to practitioner error and the inability to standardize the ROI position (44). It is impossible to select an ROI from the same area in every patient, which may lead to differences in measurements. In the study by Shrout et al., which compared the FD values of the periodontitis and healthy/gingivitis group, ROIs were determined in different sizes according to the shape and size of the interproximal bone (37). As a result of the study, it was reported that there was a significant difference between the FD values of the two groups. We think that the non-parallelism of our results may be due to the variation in the selected ROI sizes. For our study results to be of optimum accuracy, the gender and age distribution of the groups were determined to be homogeneous.

Studies have reported that there was no significant relationship between gender and FD (36,38,45). The results of these studies support the findings of our study. Researchers reported that there was a significant difference between FD values in their studies (36,38). We think that the inconsistency of these results with our study may be due to the difference in age values between groups. Age distribution was determined to be homogeneous in the periodontitis and gingivitis groups so that our study results were not affected by age-related variability. Amer et al. reported that fractal size of trabecular bone was not associated with age (46).

While the results of our study are compatible with some studies in the literature, they are not compatible with the results of some studies (11,36,40). Geraets and van der Stelt
mentioned that the conflicting results may be due to the anatomical differences of the examined region and the methods used to obtain the image (47). When utilizing the fractal analysis to study bone, it should be noted that all the steps in the analytical chain have an impact on the results.

It has been suggested that retrospective evaluation of the bone microstructure surrounding unerupted/impacted canines can provide analytical information on treatment prognosis and anchorage considerations. Bone surface area and bone marrow surface area can be measured by FD analysis of cone-beam computed tomography images, and bone density has been reported to be reliably estimated (48). In addition, Köse et al. observed a negative relationship between fractal dimensions in the mandibular mental region and total orthodontic treatment time. Fractal dimension analysis has drawn attention to its importance for understanding the physiological properties of alveolar bone and predicting orthodontic tooth movement (49). In a study of fractal analysis of periapical bone, it is stated that high resolution shows the least variation in FD values at all compression levels, making it the most reliable and consistent resolution for measuring FD values (50). In a study in which implant evaluation was evaluated in terms of FD, they found that FD values of trabecular bone around the implants were significantly lower than the initial values 6 months after prosthetic loading. However, they reported that no significant decrease or increase was observed at 12 months, with results comparable to peri-implant alveolar bone at 6 months (51). On the other hand, it has been suggested that fractal size of alveolar bone measured from intraoral digital radiographs alone may be an insufficient parameter to determine initial implant stability (52).

Many factors are likely to have an impact on the results, from patient selection in the study to imaging methods, the quality of these methods, sample size, gender and especially age distributions between groups, changes in ROI location and size, personal variations in ROI selection, and patients' anatomical variations. To standardize these variables as much as possible, the limitations of the method need to be developed and more studies with a larger sample size are needed.

CONCLUSIONS

In this study, trabecular bone fractal dimension values were compared using panoramic radiographs of patients with periodontitis and gingivitis, and the following results were obtained:
— There was no statistically significant difference between the groups in terms of fractal dimension values of trabecular bone calculated using panoramic radiographs of the patients in the periodontitis and gingivitis groups.

— In the periodontitis and gingivitis groups, there was no statistically significant difference between fractal dimension values, gender, and age values, according to the comparisons in the fractal dimension values of the trabecular bone, which were made within the group and without any group discrimination.

We believe that the inability to obtain a significant result is due to the wide age range of the population in this study. It is obvious that there is a need for prospective fractal analyzes and follow-ups to be made between different age groups due to the degeneration of the anatomical structure in the trabecular structure with aging.

**Conflict of interest:** None declared

**REFERENCES**

**Figure 1.** Morphological differences between healthy and diseased teeth and their appearance in terms of depth detection with a periodontal probe staging of periodontitis.

**Figure 2.** Stages of gum disease (1: Healthy gums & tooth, 2: Gingivitis, 3: Periodontitis, 4: Advanced periodontitis).
Figure 3. ROI selection in the Image J program.

Figure 4. Fractal analysis steps; a — cropped view of the relevant area; b — duplicated image; c — applying a Gaussian filter; d — image extracted from the original; e — grayscale adjustment; f — binarization; g — eroding; h — dilatation; i — reversal; j — skeletonization.

Table 1. Relationship between groups in terms of gender.

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Table 2. Differences between groups in terms of age.

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Table 3. Differences between groups in terms of FD values.

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Table 4. Differences between genders in terms of FD values.

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**Table 5.** The relationship between FD values and age.