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Evaluation of Mandibular Bone Architecture in Individuals with Periodontitis Stage II Grade B Using Fractal Analysis

Evre II Derece B Periodontitisli Bireylerde Mandibular Kemik Mimarisinin Fraktal Analiz Yöntemiyle Değerlendirilmesi

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Abstract: Objective: Fractal analysis is a method employed in the medical and dental fields to examine the microarchitecture of bone tissue on a range of radiographic images. For this, it is achieved through the utilization of diverse image-processing techniques and mathematical operations. In the context of periodontal diseases, the evaluation of bone tissue plays a pivotal role in diagnosing the disease. The objective of this study was to analyze the mandibular bone of individuals with periodontitis stage II grade B on panoramic X-ray images using the fractal analysis method. Methods: In this study, the angulus region, the premolar/molar region, and the incisive region of the mandibular bone were identified as relevant regions for fractal analysis on panoramic images of 50 healthy individuals and 50 patients diagnosed with periodontitis stage II grade B by a specialist periodontologist. Consequently, fractal dimensions were calculated for 300 regions of interest across a total of 100 images. Fractal analysis was conducted using the Image J program, a freely available software, using the White and Rudolph method. The fractal dimension was measured in three regions of the mandible, and the results were statistically analyzed with Python using the independent groups' t-test to evaluate the fractal dimension in the patient and control groups. Results: The statistical tests revealed no significant difference between the patient and control groups in terms of fractal dimensions in the angulus and molar regions ($p>0.05$). However, a difference was observed between the groups in the incisive region ($p<0.05$). Conclusion: The microarchitecture of bone tissue in the mandible is adversely affected by periodontal disease. Fractal analysis can provide supplementary data for evaluating bone in the field of periodontology.
Keywords: periodontitis stage II grade B, Fractal analysis, Bone loss.

Öz: Amaç: Fraktal analiz tıpta ve diş hekimliğinde çeşitli radyografik görüntüler üzerinde kemik dokusunun mikro mimarisinin incelenmesi için kullanılan, çeşitli görüntü işleme teknikleri ve matematiksel işlemlere dayanan bir metottur. Periodontal hastalıklarda, kemik dokusunun klinik ve radyolojik değerlendirilmesinin hastalığın teşhisinde önemli bir yeri vardır. Bu çalışmada evre 2 derece B periodontitisli bireylere ait mandibula kemiğinin, panoramik röntgen görüntüleri üzerinde, fraktal analiz yöntemi ile incelenmesi amaçlandı. Gereç ve Yöntem: Bu çalışmada 50 sağlıklı birey ile uzman periodontolog tarafından evre 2 derece B periodontitis teşhisi konmuş 50 hastaya ait panoramik görüntüler üzerinde mandibular kemiğin angulus bölgesi, premolar/molar bölgesi ve incisiv bölgesi fraktal analizde kullanılacak ilgili bölgeler olarak belirlendi. Böylece toplam 100 görüntü üzerinde 300 adet ilgili bölge üzerinde fraktal boyut hesaplandı. Fraktal analiz White ve Rudolph yöntemi kullanılarak ücretsiz bir yazılım olan image j programı ile gerçekleştirildi. Hasta ve kontrol gruplarında mandibulada fraktal boyutun değerlendirildiği 3 adet bölgede ölçülen fraktal boyut Python programı kullanılarak bağımsız gruplar t-testi kullanılarak istatistiksel olarak analiz edildi. Bulgular: Yapılan istatistiksel testlere göre angulus ve molar bölgede hasta ve kontrol grubu arasında fraktal boyutlar açısından anlamlı fark görülmezken ($p>0,05$), incisiv bölgede

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gruplar arasında fark olduğu saptanmıştır (p<0,05). Sonuç: Mandibuladaki kemik dokunun mikromimarisi periodontal hastalıkta olumsuz yönde etkilenmektedir. Fraktal analiz periodontoloji alanında kemiğin değerlendirilmesi için ek bilgi sağlayabilir.
Anahtar Kelimeler: Evre 2 derece B periodontitis, Fraktal analiz, Kemik kaybı.

Introduction

Periodontal diseases, known as one of the most important causes of tooth loss are accepted that occur due to several factors (Meyle and Chapple, 2015). The tooth loss occurs when periodontal diseases affect periodontal ligaments and alveolar bone (Savage et al., 2009). The treatments of periodontal diseases include fundamentally preventing infections and re-achieving lost hard and soft tissues to maintain healthy oral tissue. Many procedures have been conducted, from basic implementations to surgery methods for the management of periodontitis. Among these practices, education of oral hygiene (Jönsson et al., 2012), studies on diet (Harris et al., 2012), smoking cessation (Chaffee et al., 2016), removal of plaque and calculus (Krishna and De Stefano, 2016), the using antibiotics for medical treatment (Jepsen and Jepsen, 2016), open flap debridement (Petsos et al., 2019), grafts (Pradeep et al., 2017), and regenerative materials (Miron et al., 2021) are appeared in.

An accurate clinical examination is essential for the diagnosis of periodontal diseases. Besides evaluating clinical parameters, the radiological examination is also essential (Corbet et al., 2009). The periodontal examination includes probing, the measurement of clinical attachment levels, bleeding on the probe, plaque indexing, the status of furcation, mobility, occlusal trauma, suppuration, and the radiological assessment of bone levels. It is essential to evaluate these parameters together for an accurate periodontal examination and diagnosis (Shaddox and Walker, 2010).

Fractal analysis (FA) is a series of mathematical processes defined by Mandelbrot that identify complicated images that cannot be analyzed using Euclidean Geometry (Mandelbrot and Mandelbrot, 1982). FA is generally realized on digital images and can produce a unique value called fractal dimension (FD). This parameter determines the extent to which the object fills its spaces and features self-similarity. Many methods and analyses exist to estimate FD, including box-counting (Updike and Nowzari, 2008). FD calculating on radiographs is a descriptor of complicated model bone tissue related to teeth (Ruttimann et al., 1992).

In previous studies, the FA has used the evaluation of bone level alteration associated with periodontitis (Cha et al., 2001; Shrout et al., 1998; Updike and Nowzari, 2008). It’s deduced that FD can distinguish between healthy bone and bone with periodontitis except for

bone with mid-severity periodontitis (Updike and Nowzari, 2008). Previous studies investigated the potential effect of FA using digitized panoramic radiographs (Cesur et al., 2020; Kolcakoglu et al., 2022; Zeytinoğlu et al., 2015). It is shown that the difference in type and resolution of the image can cause the prediction of FD (Baksi and Fidler, 2012; Pornprasertsuk et al., 2001). The current study aimed to examine the mandibular bone of individuals with periodontitis stage II grade B on panoramic X-ray images using the fractal analysis method.

Methods

This study was approved by the Karabuk University Non-Interventional Clinical Research Ethics Committee (20 May 2020, 2020/206). Panoramic radiographs of fifty individuals diagnosed with periodontitis and fifty healthy individuals without any periodontal problems were evaluated using the fractal analysis method. Radiographs of patients diagnosed with periodontitis after clinical and radiological examinations by a specialist periodontologist (F.K.), along with radiographs of periodontally healthy individuals who visited the clinic for other reasons, were collected and evaluated in the digital environment by expert oral, dental, and maxillofacial radiologists (A.P. and K.A.P.), with measurements performed. All digital panoramic radiographs were selected from the radiographs taken on the same device (I-MAX OPG, Owandy Radiology, France; 86 kVp, 12.5 mA, and 4 to 14 s exposure time). Bone trabeculations on panoramic radiographs were analyzed using the 'Image J' application. These radiographs were processed using image features on the "image J" application. Consequently, the numeric values of the trabecular structure in bone tissue were calculated with the "image J" application by habilitating to the FA.

Fractal Analyses

Selection of Region of Interest

Region of Interest (ROI) selection was made using circular areas of 75x75 pixels in 3 different regions of the mandibular bone not affected by periodontal disease. Two of the three regions evaluated by FA were determined in the apex region of the first molar and central teeth, and the third region was determined in the center of the area between the angulus mandibula and the mandibular canal.

Image Processing

ROI was selected and obtained by cutting from the original image after opening the DICOM file. The cropping image was converted into a TIFF file. The principal image was achieved for the analysis, and then this image was duplicated.

The duplicated image was filtered with a Gaussian filter. The filtered image was subtracted from the principal image. After the subtraction, the gray value of each pixel on the obtained image was added to 128 and binarized. The binarized image was eroded and dilated one by one, respectively. Finally, the skeletonize function was applied to the binarized image, and FD was calculated with the method of box-counting (Figure 1).

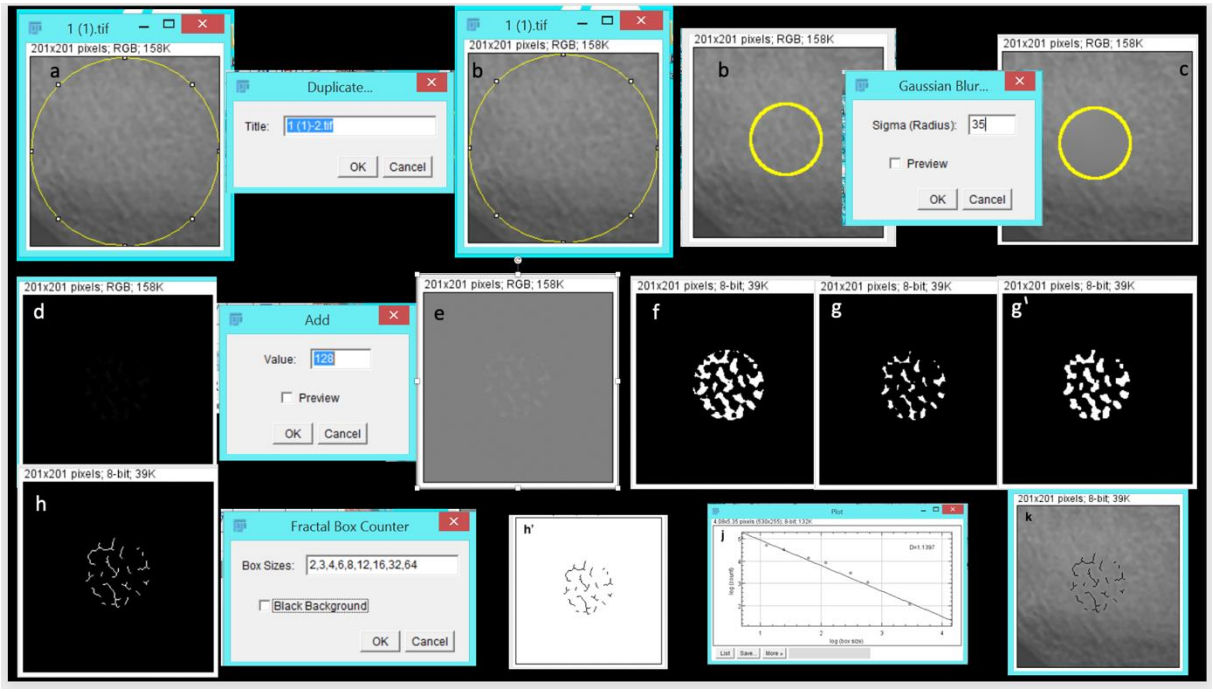

Figure 1. a) Original Image b) Duplicated Image c) Filtered Image d) Subtracted Image e) 128 Value Added Image f) Binarize Image g) Eroded Image g') Dilated Image h) Skeletonize Image h') Skeletonized Image With White Background j) Graphic That Shows Fractal Dimension k) Matched Image

Statistical analysis

Study data were analyzed using "Python" (an open-source programming language). The intraclass correlation coefficient (ICC) was used to evaluate the similarity between the reviewers. The mean and standard deviation for each group were calculated. The Kolmogorov-Smirnov tests were used to assess the distribution of the parameters. The parametric and non-parametric methods were the independent T-tests for group differences and discrete parameters, respectively. The level of significance was set at $p<0.05$.

Results

Before statistical analysis of the FA scores, the consistency between the scores recorded by two dentomaxillofacial radiologists (A.P. and K.A.P.) was evaluated. It was observed that

there was a strong positive relationship between radiologists. The consistency was found to be 0.946 and 0.916 in groups and intergroups, respectively.

A total of one hundred individuals were evaluated on panoramic radiographs, with fifty healthy individuals and fifty patients with periodontitis stage II grade B. The radiographs were taken from 2 mm from the bone loss in the angulus mandible, the interdental area in the molar region, and the incisive region. The fractal dimension values obtained from the angulus and molar regions on panoramic radiographs were not statistically significantly different between periodontitis patients and healthy individuals (0.127, 0.091). However, the fractal dimension obtained from the incisive region statistically differed significantly between the two groups (0.038). The fractal dimension obtained from the molar and incisive regions was found to be higher in patients with periodontitis than in healthy individuals. However, the healthy group demonstrated superior results, albeit slightly superior in the angulus region (Table 1).

Table 1: The Mean And P-Values of Fractal Dimensions Were Obtained from The Angulus Mandible, The Interdental Area in The Molar Region, And the Bone Areas in The Incisive Region on Panoramic Radiographs of Healthy Individuals and Individuals with Periodontitis

	Healthy individuals	**Patients with periodontitis**	**P value**
Angulus mandible	1.309 ± 0.036	1.291 ± 0.035	0.127
Molar region	1.279 ± 0.031	1.291 ± 0.029	0.091
Incisive region	1.292 ± 0.043	1.311 ± 0.032	**0.038***

Discussion

Fractal analysis has gained considerable traction as a methodology for identifying potential abnormalities and evaluating pre-existing defects in bone structure. The fractal dimension, calculated on two-dimensional radiographs, indicates bone structure and density changes. A higher fractal dimension is indicative of a more complex bone structure with denser and less porous trabeculae. The most commonly used method to calculate the fractal dimension in the literature is box counting, which was also used in this study to assess the trabecular structure of the mandible (Arsan et al., 2017; Updike and Nowzari, 2008).

Periodontitis is a disease that can occur in acute or chronic forms and has several etiological factors (Meyle and Chapple, 2015). In conjunction with progressing periodontal infections, alveolar bone loss and tooth loss lead to unintended consequences for patients. It was reported that periodontitis can be seen in a vast number of people around the world. For instance, periodontitis-originated infections were seen solely in 8.9% of US people (Eke et al., 2020). On the other hand, it was noted that 11.2% of individuals worldwide also suffer from this disease (Kassebaum et al., 2014).

Bone resorption, a physiological process, is manifested as the loss of alveolar bone as a consequence of periodontal infections (Hienz et al., 2015; Nanci and Bosshardt, 2006). A comprehension of the biological processes that regulate the remodeling and resorption cycle, which ultimately results in bone resorption, will facilitate the elucidation of the underlying pathophysiology of periodontal disease. Furthermore, it will provide insights into the mechanisms of bone loss in other chronic diseases, such as osteoporosis and rheumatoid arthritis (Hienz et al., 2015; Taubman et al., 2005). In the context of periodontitis, it is crucial to understand how bacterial plaque-derived substances induce an inflammatory response in the periodontium (Nanci and Bosshardt, 2006). The resulting increase in inflammatory cell density stimulates the production of cytokines, including PGE2, IL-2, and RANK-L, by osteoclasts. These cytokines accelerate bone destruction and disrupt the equilibrium between bone formation and resorption (Hienz et al., 2015; McCauley and Nohutcu, 2002; Nagasawa et al., 2007).

It is established that the fractal analysis method has been previously utilized on radiographs obtained from individuals with periodontal disease. In these studies, Soltani et al. posited that the deterioration in bone quality increased in tandem with the severity of periodontal disease (Soltani et al., 2021). Similarly, the study conducted by Shrout et al. (1998) revealed that individuals with gingivitis exhibited higher FD levels than those with periodontitis (Shrout et al., 1998). The results of these studies contrast with those of the present study. However, in these studies, the fractal dimension was derived from the center of bone loss. In contrast, in the present study, the healthy bone at the apical part of the area affected by bone loss was taken as a reference. A different study using panoramic radiography stated that FD levels of patients with gingivitis and periodontitis were similar (Eser and Sarıbaş, 2024). It is postulated that the reason for the higher FD in individuals with periodontitis in the present study may be the increase in osteoblastic activity to prevent possible bone loss due to host response and the episodic nature of the disease (Loos and Van Dyke, 2020).

Conclusion

Although the impact of periodontal disease on bone tissue destruction is well documented, this study demonstrated an increase in bone trabeculae in the apical region of bone loss. However, the limited sample size of the study represents a limitation in the interpretation of the results. Future studies with a larger sample size are necessary to validate the findings of this study.

Conflict of interest: The authors declare no conflicts of interest. The data of this study has been presented at the IDU-DENT International Dentistry and Health Congress.

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Peer Review: Internal/External independent.

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