Clinical and Experimental Health Sciences

Mandibular Radiomorphometric Analysis in Patients with Different Stages of Periodontitis

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ABSTRACT

Objective: This study aims to evaluate a possible change in the mandibular trabecular structure of patients diagnosed with different stages of periodontitis and to compare them with gingivitis and periodontally healthy individuals.

Methods: The periodontal diagnosis of 180 patients (90 females and 90 males) was made based on the 2017 World Workshop on the Classification of Periodontal and Peri-implant Diseases and Conditions. The patients were divided into six groups: periodontally healthy (n=30), gingivitis (n=30), Stage I (n=30), Stage II (n=30), Stage III (n=30), and Stage IV (n=30) periodontitis. Seven regions of interest (ROIs) were determined for fractal analysis (FA) on panoramic radiographs. Fractal dimension (FD) and mandibular cortical width (MCW) were evaluated.

Results: The mean age of the study population was 30.64±7.48 years. No statistically significant difference was observed among the groups in terms of FD. There was a statistically significant difference in gender distribution only for the MCW value (p<.05), and this value was found to be higher in male participants (23.87±4.59 mm *vs.* 22.50±3.75 mm). Although significant correlations were found between FD values of different regions (anterior FD, premolar FD, molar FD, angulus FD, and total FD), FD was not significantly correlated with age.

Conclusion: The results of this study suggest that FA calculated from panoramic radiographic images of periodontally healthy patients, gingivitis and different stages of periodontitis shows comparable results and indicates no superiority.

Keywords: Bone, fractals, mandible, panoramic radiography, periodontitis

1. INTRODUCTION

Periodontitis is a chronic, multifactorial disease in which attachment loss occurs as a result of a host-mediated inflammatory reaction in response to bacterial biofilm (1,2). The prevalence of periodontitis was reported to be more than 60% between 2011 and 2020 (3). For this highly prevalent disease, addressing and eliminating risk factors such as smoking, early periodontal treatment, and plaque control have been clearly emphasized (4). However, the detailed periodontal assessment is needed to tailor the treatment procedure. Therefore, both clinical and radiological evaluations are employed (2). The clinical evaluations include parameters which determine disease severity, such as the degree of gingival inflammation, probing pocket depth (PPD), and the presence of bleeding on probing (BOP). Radiographic evaluations serve as a valuable auxiliary tool in periodontal diagnosis and provide an insight into the extent of alveolar bone loss. Although radiographs have several limitations (*i.e.*, two-dimensional image acquisition and low resolution), they are widely used in clinical assessment (5). Furthermore, in the 2017 World Workshop on the Classification of Periodontal and Peri-implant Diseases and Conditions, determination of the extent of radiographic bone loss was presented as an important factor after assessment of interdental attachment loss while determining disease severity (1). However, the limitations of radiographs have led to the recommendation of the fractal analysis (FA) method for the diagnosis and monitoring of trabecular changes developing in the alveolar bone associated with periodontitis (6).

Fractal analysis is a mathematical method which describes irregular and complex structures such as bone tissue, and its numerical result is evaluated as fractal dimension (FD) (7,8). In other words, FA identifies and analyzes complex shapes and structural patterns, while FD is a quantitative measure of this image complexity (9).

Several studies have used FA for the evaluation of trabecular bone changes in radiographs of individuals with periodontally healthy, gingivitis or periodontitis (6,10-18). Mishra et al.

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(12) compared the periodontally healthy group with the periodontitis group and reported that FD could be used as a quantitative method to detect cancellous bone changes in different-stages of periodontitis. Yarkac et al. (13) presented their evaluations without including Stage IV periodontitis patients and they reported that trabecular bone had different FD values in periodontal disease status. Korkmaz et al. (18) included periodontally healthy and Stage III/IV periodontitis individuals in their study and reported that FD values of periodontitis individuals were significantly lower compared to the periodontally healthy. Soltani et al. (16) observed that FD values were significantly different between the bone of individuals with moderate and severe periodontitis and healthy group. However, Eser and Sarıbas (14) reported that there was no significant difference in mean FD values between individuals with gingivitis and periodontitis. To the best of our knowledge, there is only one study available to classify periodontitis into four different stages according to the 2017 World Workshop on the Classification of Periodontal and Peri-implant Diseases and Conditions and to use FA to measure trabecular changes in this patient population (12).

In the present study, we hypothesized that there would be no change in the mandibular trabecular structure of patients with periodontitis and healthy individuals. We, therefore, aimed to use the FA method and evaluate a possible change in the mandibular trabecular structure of patients diagnosed with Stage I, II, III, and IV periodontitis and to compare them with gingivitis patients and periodontally healthy individuals.

2. METHODS

2.1. Study Design and Study Population

This study was conducted at Van Yüzüncü Yıl University, Faculty of Dentistry, Departments of Periodontology and Oral and Maxillofacial Radiology. Prior to study, a written informed consent was obtained from each patient. The study protocol was approved by the Non-Interventional Clinical Research Ethics Committee at the University of Van Yüzüncü Yıl (No: 2024/03-12, Date: 08/03/2024). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Inclusion criteria were as follows: age ≥18 years, having no missing teeth in the mandible, and having periodontal disease or health status determined as a result of clinical and radiological evaluations. Exclusion criteria were as follows: presence of any systemic disease affecting the bone structure and/or use of systemic medications; presence of cysts and tumors affecting the bone structure in the head and neck region; history of radiotherapy and/or chemotherapy; radiographs with poor image quality, movement and/or metal artifacts; presence of pathology in the mandible (cysts, tumors, enostoses, idiopathic osteosclerosis, condensing osteoid, periapical lesions); presence of crowns, bridges, or implants; severe malocclusion. Finally, a total of 180 participants who met the inclusion criteria were recruited. The patients were divided into six groups: periodontally healthy (n=30), gingivitis (n=30), Stage I (n=30), Stage II (n=30), Stage III (n=30), and Stage IV (n=30) periodontitis.

2.2. Periodontal Evaluation

Periodontal diagnosis for each patient was determined according to the 2017 World Workshop on the Classification of Periodontal and Peri-implant Diseases and Conditions. The clinical periodontal parameters (clinical attachment loss (CAL), PPD, BOP (19)) were recorded by a single clinician using a Williams periodontal probe (Hu-Friedy, Chicago, IL, USA). Measurements were taken from six surfaces (mesiobuccal, midbuccal, distobuccal, mesiolingual/palatal, midlingual/palatal, distolingual/palatal) of each tooth, except for the third molars. Additionally, panoramic radiographs (ORTHOPHOS XG, Sirona Group, USA) were obtained from each patient to assess bone loss. Accordingly, the patients were divided into six groups: periodontally healthy, gingivitis, Stage I periodontitis, Stage II periodontitis, Stage III periodontitis, and Stage IV periodontitis. The patients who did not develop CAL and radiographic bone destruction were included in the periodontally healthy, if the BOP score was <10% (20), and in the gingivitis group if the BOP score was ≥10%. Periodontitis assessment was made according to the severity and complexity of the disease (1,21). The patients who had CAL value of 1 to 2 mm were grouped as Stage I periodontitis; CAL value of 3 to 4 mm was grouped as Stage II periodontitis; and CAL value of ≥5 mm was grouped as Stage III and IV periodontitis. Stage III and IV periodontitis were separated according to complexity factors (1). Individuals with generalized periodontitis were included in all periodontitis groups. Accordingly, the number of affected teeth was ≥30%, excluding third molars.

2.3. Radiographic Evaluation

The exposure parameters of the device used for radiographic evaluation were determined as 60 kV, 3 mA, and 14.1 s exposure time (ORTHOPHOS XG, Sirona, USA). The images were converted to Digital Imaging and Communications in Medicine (DICOM) format and Image J software (National Institutes of Health, Bethesda, MD, USA) was used for image analysis. Radiological analyses were performed by a single oral and maxillofacial radiologist. The data on the stage of periodontitis and the periodontal status of other patients were presented blindly to the radiologist. In case of a long radiological examination, the radiologist performed the data analysis on a 23-inch computer in the dark room where the radiographic data was reported and for a maximum of three hours per day to eliminate the loss of gray scale sensitivity. Intra-examiner agreement of the radiologist's measurements was assessed by repeating 20% of the randomly selected data. The reliability analysis demonstrated good intra-examiner agreement for FA of seven regions of interest (ROIs) (intraclass correlation coefficient [ICC]=0.853) and excellent intra-examiner reliability for the mandibular cortical width (MCW) (ICC=0.932).

2.4. Fractal Analysis

The current study was based on the studies of Kato et al. (22) and seven ROIs were determined for FA. Using the rectangle tool of Image J, 40×40 pixel squares were manually created in the right angulus, right molar and right premolar, left angulus, left molar and left premolar and anterior regions. Furthermore, ROIs were determined by drawing bilaterally from the mental foramen region to the third molar region on the cortical bone using the Polygon tool (Figure 1).

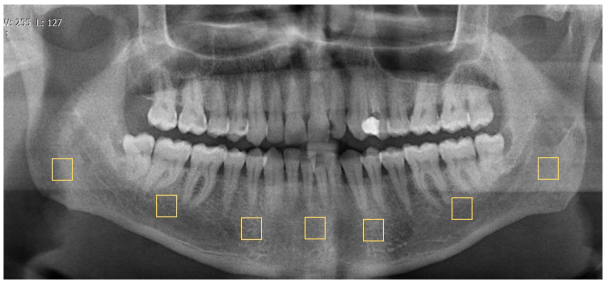


Figure 1. *Selected regions of interest for fractal analysis.*

The stages of FA were performed using the Image J software according to the protocol of White and Rudolph). Each ROI was multiplied after cropping. The multiplied image was blurred using a Gaussian filter (sigma, 35) to eliminate large-scale brightness changes. The blurred image was subtracted from the original image. Then, 128 gray values were added to distinguish between trabecular bone and bone marrow spaces. Binarization was performed to obtain an image in binary color (black and white) format. The noise was removed by erosion and the outlines of the structures were expanded and sharpened. After the inversion process, the black areas represented the trabecular bone and the white areas represented the marrow spaces. Finally, skeletonization was performed. The FA was performed by counting the boxes of 2 to 64 pixels in the skeletonized image using the fractal box counting plugin of Image J (Figure 2). The FD calculated using the software in the ROIs in the angulus, molar, premolar and anterior regions on the right and left sides was recorded by averaging on the right and left sides.

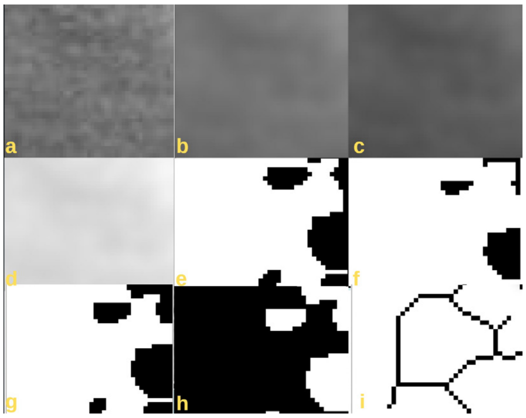
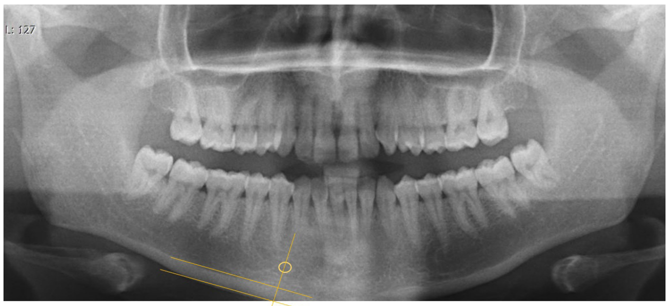


Figure 2. Stages of fractal analysis. Duplicated image after cropping (a). Blurred image using a Gaussian filter (sigma, 35) (b). Subtraction process from the original image (c). Addition of 128 Gy values (d). Binarization (e), erosion (f), dilatation (g), inversion (h), skeletonization (i).

2.5. Mandibular Cortical Width

The cortical bone surrounding the mental foramen region was measured. This procedure was applied to both sides of the jaw. Next, two parallel lines were drawn through the upper and lower borders of the cortex. Then, a third line was drawn perpendicular to these two lines and through the center of the mental foramen. The length between the other two lines of the third line was recorded as MCW. The averages of the right and left side measurements were recorded (Figure 3).



The primary outcome of the study was to compare FA values among the groups. The secondary outcome was to compare MCW among the groups.

2.6. Statistical Analysis

In the study, FA was considered to primary outcome. According to previous study (13); the standard deviation (s) for the fractal analysis ranged from 0.06 to 0.15. Thus, 0.11 was considered to compute sample size. Effect size (d) was assumed to be 0.04, and Z value of 1.96 was used for the 0.05 type I error rate. The sample size was found 29.05 (about 30) by using the equation for sample size calculation ($n = Z^2 s^2 / d^2$). Descriptive statistics for the continuous variables were presented as mean, standard deviation, minimum and maximum values while count and percentages for categorical variables. One-way ANOVA was performed for the comparison of group means. Duncan multiple comparison test was also used to identify different groups. In addition, the Pearson correlation coefficients were computed to the determine linear relationship. Statistical significance level was considered as 5% and SPSS (ver: 21) statistical program was used for all statistical computations.

3. RESULTS

Of a total of 180 participants included in the study, 90 were females and 90 were males with a mean age of 30.64 ± 7.48 years (Table 1). While the mean age of female was 29.73±7.38 years, the mean age of male was calculated as 31.54±7.52 years. In terms of age, a statistically significant difference was found among the groups ($p<.05$). Accordingly, individuals with Stage I periodontitis, gingivitis and periodontally healthy had a lower mean age.

***Table 1**. Descriptive statistics and comparison results for age*

		N	Mean	Std. Dev.	p
Age	Female	90	29.73	7.380	.105[#]
	Male	90	31.54	7.525	
	Total	180	30.64	7.488	
	Stage I	30	28.10[b]	5.950	**.001**[##]
	Stage II	30	35.83[a]	7.751	
	Stage III	30	33.43[a]	8.148	
	Stage IV	30	32.90[a]	7.073	
	Gingivitis	30	26.50[b]	4.241	
	Periodontally Healthy	30	27.07[b]	6.108	

N: number of sample size, Std. Dev: Standard deviation.
(Independent Samples t-test); # # (One-Way ANOVA).
a, b: Different lower case represent statisticaly significant difference among the age groups
p < .05

When the evaluation between gender was examined, the FD of each region evaluated, mean of total FD and MCW values are shown in Table 2. Accordingly, a statistically significant difference was observed only for the MCW value (p<.05), and this value was found to be higher in male (23.87±4.59 mm) than in female (22.50±3.75 mm).

***Table 2.** Descriptive statistics and comparison results for the values of fractal dimension and mandibular cortical width among genders*

		N	Mean	Std. Dev.	Min	Max	p #
Anterior FD	Female	90	0.992	0.277	0.10	1.27	.078
	Male	90	1.057	0.205	0.10	1.27	
	Total	180	1.024	0.245	0.10	1.27	
Premolar FD	Female	90	1.071	0.111	0.56	1.26	.200
	Male	90	1.095	0.138	0.24	1.23	
	Total	180	1.083	0.125	0.24	1.26	
Molar FD	Female	90	1.024	0.132	0.10	1.27	.356
	Male	90	1.041	0.114	0.49	1.21	
	Total	180	1.033	0.123	0.10	1.27	
Angulus FD	Female	90	1.016	0.150	0.53	1.24	.098
	Male	90	0.963	0.266	0.10	1.26	
	Total	180	0.989	0.217	0.10	1.26	
Total FD	Female	90	1.031	0.093	0.53	1.14	.717
	Male	90	1.036	0.113	0.31	1.20	
	Total	180	1.034	0.103	0.31	1.20	
MCW	Female	90	22.509	3.750	15.41	36.10	.030
	Male	90	23.873	4.592	13.75	37.13	
	Total	180	23.191	4.236	13.75	37.13	

FD: Fractal dimension, MCW: Mandibular cortical width, N: number of sample size, Std. Dev: Standard deviation.
 # p < .05 (Independent Samples t-test).

In the intergroup evaluations, no statistically significant difference was observed among the groups in terms of all the parameters examined (Table 3). The correlation evaluation of FD for each region, total FD and MCW values are presented in Table 4. Accordingly, anterior FD had a significant positive correlation with molar, premolar and total FD, while angular FD had a significant positive correlation with MCW and total FD. In addition, molar FD had a significant positive correlation with premolar and total FD, while MCW had a significant positive correlation with angular FD and mean FD. On the other hand, no significant correlation was found between age and other parameters.

***Table 3.** Descriptive statistics and comparison results for the values of fractal dimension and mandibular cortical width among the groups*

		N	Mean	Std. Dev.	Min	Max	p# #
Anterior FD	Stage I	30	1.057	0.198	0.11	1.21	.111
	Stage II	30	1.091	0.089	0.88	1.24	
	Stage III	30	0.913	0.390	0.10	1.27	
	Stage IV	30	1.027	0.205	0.10	1.23	
	Gingivitis	30	1.033	0.207	0.10	1.25	
	Periodontally Healthy	30	1.025	0.263	0.10	1.27	
	Total	180	1.024	0.245	0.10	1.27	
Premolar FD	Stage I	30	1.074	0.140	0.56	1.21	.937
	Stage II	30	1.093	0.076	0.97	1.23	
	Stage III	30	1.091	0.133	0.66	1.23	
	Stage IV	30	1.075	0.145	0.57	1.21	
	Gingivitis	30	1.098	0.062	0.99	1.23	
	Periodontally Healthy	30	1.070	0.169	0.24	1.26	
	Total	180	1.083	0.125	0.24	1.26	
Molar FD	Stage I	30	1.045	0.084	0.77	1.17	.703
	Stage II	30	1.011	0.125	0.52	1.18	
	Stage III	30	1.012	0.182	0.10	1.18	
	Stage IV	30	1.051	0.081	0.81	1.17	
	Gingivitis	30	1.043	0.135	0.49	1.24	
	Periodontally Healthy	30	1.033	0.107	0.67	1.27	
	Total	180	1.033	0.123	0.10	1.27	
Angulus FD	Stage I	30	0.989	0.225	0.10	1.21	.994
	Stage II	30	1.010	0.223	0.10	1.24	
	Stage III	30	0.993	0.231	0.10	1.26	
	Stage IV	30	0.989	0.208	0.10	1.21	
	Gingivitis	30	0.983	0.202	0.53	1.25	
	Periodontally Healthy	30	0.973	0.230	0.10	1.19	
	Total	180	0.989	0.217	0.10	1.26	
Total FD	Stage I	30	1.039	0.081	0.81	1.13	.877
	Stage II	30	1.045	0.073	0.85	1.16	
	Stage III	30	1.015	0.124	0.53	1.15	
	Stage IV	30	1.037	0.084	0.79	1.13	
	Gingivitis	30	1.040	0.089	0.79	1.20	
	Periodontally Healthy	30	1.025	0.150	0.31	1.14	
	Total	180	1.034	0.103	0.31	1.20	
MCW	Stage I	30	23.926	3.451	17.98	30.36	.488
	Stage II	30	23.994	4.714	15.85	37.13	
	Stage III	30	22.307	3.366	15.87	29.18	
	Stage IV	30	22.571	4.120	15.51	31.31	
	Gingivitis	30	23.577	5.274	13.75	36.10	
	Periodontally Healthy	30	22.772	4.213	15.41	32.62	
	Total	180	23.191	4.236	13.75	37.13	

FD: Fractal dimension, MCW: Mandibular cortical width, N: number of sample size, Std. Dev: Standard deviation
#p < .05 (One-Way ANOVA).

Table 4. Pearson correlation coefficients among age, fractal dimension and mandibular cortical width

	Age	Anterior FD	Angulus FD	Molar FD	Premolar FD	MCW	Total FD
Age	1						
Anterior FD	-0.078	1					
Angulus FD	0.045	0.115	1				
Molar FD	0.004	0.233**	-0.005	1			
Premolar FD	0.044	0.274**	0.145	0.265**	1		
MCW	0.107	-0.040	-0.151*	-0.077	-0.100	1	
Total FD	0.018	0.583**	0.689**	0.509**	0.618**	-0.165*	1

FD: Fractal dimension, MCW: Mandibular cortical width
**p < .05; **p < .01 (Pearson correlation analysis).*

4. DISCUSSION

In the present study, we compared the radiomorphometric parameters of the mandible in patients diagnosed with gingivitis and periodontitis with those of periodontally healthy individuals. Therefore, changes in the mandibular microstructure in different stages of periodontitis were investigated. In this study, no statistically significant difference was found in terms of FD values among the groups.

Periodontitis is an advanced gingival disease which causes alveolar bone loss and destruction through host immune and inflammatory response-dependent mechanisms (24). Advanced bone loss can result in tooth loss and a complex treatment procedure. Therefore, radiographs which provide information about bone loss can be critical importance in the evaluation of the diagnosis and prognosis of the disease. Recently, the FA method has been used in radiographs for detailed analysis of these evaluations (10-14,16,18). While using this method, mandibular premolar, molar, canine and antegonial regions were preferred (10,13,16,18). In the current study, the ROIs determined in the mandibular premolar and molar regions were calculated. Additionally, ROIs of the angular and anterior regions were also evaluated. Similar to the previous study (10), in the present study, image processing was also performed as reported by White and Rudolph (23).

In their study, Sener et al. (6) reported that FA could provide quantitative values in periodontally healthy patients and those with moderate periodontitis and, in addition, changes in the trabecular bone could be detected with this method. The authors also found a significant difference between the groups and reported that FD values were higher in the healthy group. Aktuna Belgin and Serindere (10) obtained periapical radiographs from mandibular first molars of 35 periodontally healthy and 35 patients with periodontitis and reported that the calculated FD values were significantly higher in the group of periodontally healthy. Yarkaç et al. (13) used digital panoramic radiographs, periodontitis patients were evaluated as Stages I, II, and III, and they reported similar results to the previous study in terms of FD mean values. In another study, Soltani et al. (16) reported that FD values, except for distal ROIs, were significantly different in cases of moderate and severe periodontitis compared to healthy periodontal bone. However, the same researchers reported that FD values did not represent a statistically significant difference between the periodontally healthy group and the mild periodontitis group. In a study evaluating periodontitis in four stages, Mishra et al. (12) showed that FD values decreased significantly in advanced stages where the severity of the disease increased. However, Korkmaz et al. (18) included periodontally healthy individuals (control group) and individuals with only Stage III/ IV periodontitis in their study and reported that FD values of individuals with periodontitis were significantly lower than those of the control group. In the current study, no significant differences were observed among the groups. Of note, the differences between the results of the reported studies and current study may have been affected by the discrepancies in the jaw regions or inconsistencies in the selection of ROI (25). Although the effect of ROI location on FD calculation is controversial, different areas have been selected as ROIs (12, 17). The image preprocessing and selection of ROI may affect the results until a consensus is reached (9).

Eser and Sarıbas (14) reported no significant difference between the groups in the mean FD values calculated from panoramic radiographs obtained from 64 individuals with gingivitis and 64 individuals with periodontitis. In the current study, periodontally healthy patients, individuals with gingivitis and periodontitis were compared and, similarly, no statistically significant difference was observed among the groups. Thus, this study reports similar results to Eser and Sarıbas (14) in terms of comparing gingivitis and periodontitis groups.

Furthermore, Kayaalti-Yüksek et al. (11) evaluated systemically healthy patients and patients with diabetes mellitus with periodontitis using FA. Five groups were formed consisting of patients with diabetes mellitus with moderate and severe periodontitis, systemically healthy individuals with moderate and severe periodontitis, and systemically healthy individuals with gingivitis. The authors found no significant difference in bone trabeculation in the periodontitis groups. These findings are consistent with our study results, as we found no significant difference in the periodontitis groups in the current study.

Lang et al. (26) evaluated the trabecular structure of peri-implant diseases using the FA method with periapical radiographs and reported that there was no significant difference in FD measurements in the case of peri-implant health, peri-implant mucositis and peri-implantitis. Considering the similarities in the clinical and radiological nature of periodontitis and peri-implantitis, the lack of a significant difference in trabecular integrity changes is similar to the current study.

Moreover, Aktuna Belgin and Serindere (10), Updike and Nowzari (17), and Yarkac et al. (13) reported no significant difference in FD values of jaw bones according to gender. However, Yarkac et al. (13) found a negative correlation between age and FD values. Korkmaz et al. (18) found no significant correlation between age and FD. In the present study, we observed no statistically significant difference in FD values between genders. In addition, we found no significant correlation between age and FD.

In this study, similar to the previous study (27), it was concluded that the effect of FA was limited. Nonetheless, there are some limitations to this study. The mean age of the periodontitis groups (Stage II, III and IV) was found to be higher than the healthy and gingivitis groups. There is another study (10) in the literature with this limitation, and it is thought that the lower mean age in healthy individuals may have affected the findings of the current study. Other limitations include the small number of samples, the use of only panoramic images, and the lack of use of other radiographic diagnostic images and technologies with higher resolution.

5. CONCLUSION

In conclusion, our study results suggest that FA calculated from panoramic radiographic images of periodontally healthy patients, gingivitis and different stages of periodontitis shows comparable results and indicates no superiority. In addition, FA does not offer an advantage in terms of diagnostic potential in different regions of the jaws in current study. Based on these findings, it should be kept in mind that clinical periodontal parameters are crucial in disease diagnosis. Therefore, in detailing the use of FD in periodontal disease diagnosis, different designed, large-scale studies using different radiographic images are warranted.

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Author Contributions:

Research idea: DA, SK
Design of the study: DA, SK
Acquisition of data for the study: DA, SK
Analysis of data for the study: DA, SK
Interpretation of data for the study: DA, SK
Drafting the manuscript: DA
Revising it critically for important intellectual content: DA, SK
Final approval of the version to be published: DA, SK

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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