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ORIGINAL RESEARCH ARTICLE

Radiomorphometric Analysis of Dental and Trabecular Bone Changes in Bruxism Patients

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Abstract

Purpose: The aim of the study was to analyze the changes detected in panoramic radiographs due to bruxism with qualitative and quantitative scales.
Materials and Methods: 173 panoramic radiographs of 93 healthy and 80 bruxist individuals were included. Maxillary and mandibular teeth were classified as anterior and posterior on radiographs; widening of the periodontal ligament (PDL) space, attrition, presence of pulp stones, and pulpal sclerosis were scored. Fractal dimension (FD) analyses were calculated in 10 regions of interest (ROI) including bilateral condylar region, gonial region, ramus, apical areas between the 1st molar -2nd premolar, and the 1st premolar and the canine. Data were analyzed with descriptive statistics, Kolmogorov–Smirnov, Independent sample t-test, and Spearman correlation tests.
Results: 98 women and 75 men were included. There was no statistically significant difference between the genders ($p>0.05$). The incidence of widening of the PDL space, attrition, and pulpal sclerosis was significantly higher in bruxist patients than in the control group ($p<0.001$). The incidence of widening of the PDL space ($p=0.004$), pulpal sclerosis ($p<0.001$), and the presence of pulp stones ($p<0.001$) were significantly higher in the posterior regions. The mean FD of the condyle was 1.18 ±0.16 in the healthy group and 1.20 ±0.11 in the bruxist group.
Conclusions: The incidence of widening of the PDL space, attrition, and pulpal sclerosis was higher in bruxists. FD didn't demonstrate significant differences in the mandibular trabecular structures of bruxist and healthy individuals.

Key words: bruxism; clenching; fractal dimension; panoramic radiograph; radiomorphometric analysis

Introduction

Bruxism is defined as nonfunctional contact of the maxilla and mandible with repetitive and unconscious contraction of the masseter and temporal muscles resulting in clenching or grinding. Tooth wear is an important etiological/accelerating factor of periodontal disease and temporomandibular joint disorders (TMJ).[1,2] Bruxism is a parafunctional movement that can occur during sleep (nocturnal) or while awake. Although its etiology is not clearly known, it is known that it is affected by morphological, physiological and parafunctional factors and tends to decrease with age.[3,4] The clinical findings of bruxism are abrasion on the tubercle crests, impression marks on the tongue margins, linea alba at the bite line, gingival recession, masseter hypertrophy, abfraction, or fracture in the fillings. The symptoms of bruxism are the characteristic grinding sound that can awaken the sleep partner of the bruxist, pain in the TMJ and masticatory muscles, headache intensifying in the temporal region, hypersensitivity in the teeth, and increased tooth mobility. The diagnosis of bruxism is obtained by evaluating the clinical examination and dental anamnesis findings together.[2,3] On the other hand, the diagnosis of bruxism is controversial since the majority of patients with nocturnal bruxism are not aware of this condition. Therefore, objective diagnostic criteria are needed.[5] Methods such as clinical and radiological examination findings, the patient's own or sleep partner's statement, polysomnography, sound and image recordings are used in the diagnosis.[5–7] Although polysomnography is the most widely accepted objective diagnostic method, access to this technique, in which sleep monitoring is performed all night long with special equipment in certain centers, is difficult and expensive.[8] Clinical and radiological findings come forward in diagnosis in order to plan dental treatments completely. Bruxism causes excessive occlusal forces on the teeth and supporting structures.[5] This force can be approximately three times the force that occurs during functional tooth contacts.[4] Due to increased occlusal load, enlargement of periodontal ligament (PDL) space, root resorption, root fractures, pulp stones, and changes in alveolar bone trabeculation can be observed on radiographs.[2,4] The fractal dimension (FD) has been shown to provide information about the structure of trabecular bone and bone mineral density on two-dimensional radiographs. There are discrepancies in the literature due to the method used to obtain the fractal dimension and the differences in image processing methods before analysis. The most widely used fractal analysis method is the box-counting method; in a systematic review, it was stated that the studies generally showed a more complex trabecular bone structure with high fractal dimension.[9] The aim of this study was to analyze the radiographic changes due to bruxism in panoramic radiographs with qualitative and quantitative scales. The null hypotheses of the study; radiomorphological changes in the periradicular tissues, crown, and pulp in the anterior and posterior regions of both jaws are not different between bruxist and healthy individuals (1), and the fractal dimension will not show a significant difference (2).

Material and Methods

In this study, panoramic radiographs of the patients who were diagnosed with bruxism in the clinical examination, and of the non-bruxers who applied to Istanbul Okan University, Faculty of Dentistry, DentoMaxillofacial Radiology (DMFR) Department between 2019-2021 were evaluated. The study was approved by the Ethics Committee of the relevant institution with the decision numbered 133/18. In the power analysis performed by examining similar studies, it was calculated that the sample size should be at least 78.3[6], A total of 173 panoramic radiographs, including 93 healthy and 80 bruxist patients, were included in the study. The inclusion criteria of the study were that the structures to be examined were present and clearly visible; absence of artifacts related to the position, patient movement, foreign body, etc.; standard exposure parameters (66 kV, 8 mA, 16 s) and the patient whose radiograph will be evaluated is older than 18 years. Radiographs were taken on the Planmeca ProMax (Planmeca, Helsinki, Finland) panoramic radiography device and the resultant images were analyzed using Romexis software (v4.6.1.R, Planmeca, Helsinki, Finland). The presence of pathologies that may cause changes in the periodontal ligament space such as amelogenesis imperfecta, deep dentin caries, pulp pathology that cause changes in enamel density; the presence of diseases such as osteoporosis, bisphosphonate use, Paget's diseases affecting bone metabolism and pathologies such as cysts and tumors in the jaws; patients with a history of orthodontic treatment; missing more than 1 tooth in one of the maxilla anterior, maxilla posterior and mandible anterior areas; missing 1st molar, 1st and 2nd premolars and one of the canine teeth in the mandible; radiographs of poor diagnostic quality; radiographs including exposure parameters different from the standard values, and the patient's being younger than 18 years of age were excluded from the study. The diagnosis of sleep bruxism was made clinically according to the following diagnostic criteria recommended by the American Academy of Sleep Medicine (AASM). • The patient reports or is aware of grinding sounds or clenching during sleep. • One or more of the following clinical signs are present: o Abnormal wear of teeth o Discomfort, fatigue, pain in the jaw muscles or locking in the jaw on awakening, o Hypertrophic appearance when the masseter muscle is contracted voluntarily, o The jaw muscle activity that cannot be explained by another factor, such as sleep disturbance, medical or neurological disorder, drug use, or substance use disorder.[10] The patient group that met the specified diagnostic criteria was examined by a DMFR specialist, in this way the bruxist group was defined. The bruxist group of the study comprised 80 panoramic radiographs that met the inclusion criteria of patients in this group. Panoramic radiographs of 93 patients, who were examined by the same specialist and found to meet the requirements for the healthy group, formed the control group. The following radiomorphometric features of these panoramic radiographs were evaluated by two DMFR specialists (CB, BA). To measure the reliability of the data, two observers re-examined the same 20% of the data one week after the first review. For reproducibility, each observer re-examined 20% of the randomly selected data two weeks after the first assessment. In radiographs, teeth were classified into 4 groups: maxilla anterior, maxilla posterior, mandible anterior, and mandible posterior. Widening of PDL space, attrition, pulp stone, and pulp sclerosis parameters were scored in 4 stages: I. The pathology specified in the relevant group is not present, II. There is pathology in 1-3 teeth, III. There is pathology in 4-5 teeth, IV. There is pathology in more than 5 teeth. Radiographic examples of the pathologies examined are shown in Figure 1. Fractal dimension analysis was performed on radiographs transferred to ImageJ software (v1.52 software for Windows, a version of the National Institutes of Health Image software) as TIFF (Tagged Image File Format). 10 ROIs (Region of Interest) were selected for fractal dimension analysis. These were the bilateral condylar region, gonial region, ramus, the apical area between 1st molar and 2nd premolar, and apical areas between 1st premolar and canine in the mandible (Figure 2). Fractal analysis was performed according to the box-counting method.[3,6,11,12] The steps of the box-counting method, which is the most used method in the literature, were selected in order of ROI selection – duplication – application of the 'Gaussian blur' filter (sigma=35 pixels) – subtracting from the original image – adding 128 shades of gray to each pixel in the image – Obtaining a 'Binary' (black and white) image – Removing noise from the image with the 'Erode' option – Making the processed area more visible with the 'Dilate' option – With 'Invert' Outline of areas of trabecular bone – 'Skeletonize' is the linear acquisition of the outline of the ROI area for fractal analysis. In this final image, ROIs were divided into squares (boxes) of 2, 3, 4, 6, 8, 12, 16, 32, and 64-pixel sizes with the ImageJ program for fractal analysis. The program divided the squares (boxes) containing trabeculae for each pixel by the total number of boxes in the entire ROI area and plotted the values logarithmically. The slope that best fits the curve in this graph gave the fractal dimension. For ease of implementation, these image processing steps were recorded as macros in ImageJ and applied for each ROI.

Statistical Analysis

Intra-observer agreement was calculated using Cohen's kappa coefficient, and inter-observer agreement was calculated using the Intraclass Correlation Coefficient (ICC). Descriptive statistics were used in the analysis of dental parameters. Categorical data, with frequency and percentage; numerical data were expressed as mean ±sd. Whether the fractal dimension data showed homogeneous distribution was evaluated with the Kolmogorov Smirnov test, and the data were analyzed with the independent sample t-test and Mann–Whitney U test. SPSS 21.0 (SPSS, Chicago, IL, USA) program was used in data analysis. Type I error level was accepted as 0.05.

Results

98 female (47 healthy, 51 bruxists) and 75 (46 healthy, 29 bruxists) male individuals were included in the study. The mean age was 35.98 ±12.05 in bruxist individuals and 32.70 ±10.02 in the control group. Cohen's kappa coefficient showing intra-observer agreement was calculated as 0.96 ±0.03 for the first observer (CB) and 0.97 ±0.02 for the second observer (BA). The ICC was calculated as 0.93, so the interobserver agreement was measured as excellent. Table 1 shows the number and percentages of dental parameters of the bruxist group and control group affected by the anterior and posterior regions of the maxilla and mandible. The incidence of PDL enlargement, attrition, and pulp sclerosis in all teeth was significantly higher in bruxist patients compared to the control group ($p< 0.005$). The presence of pulp stones did not show a statistically

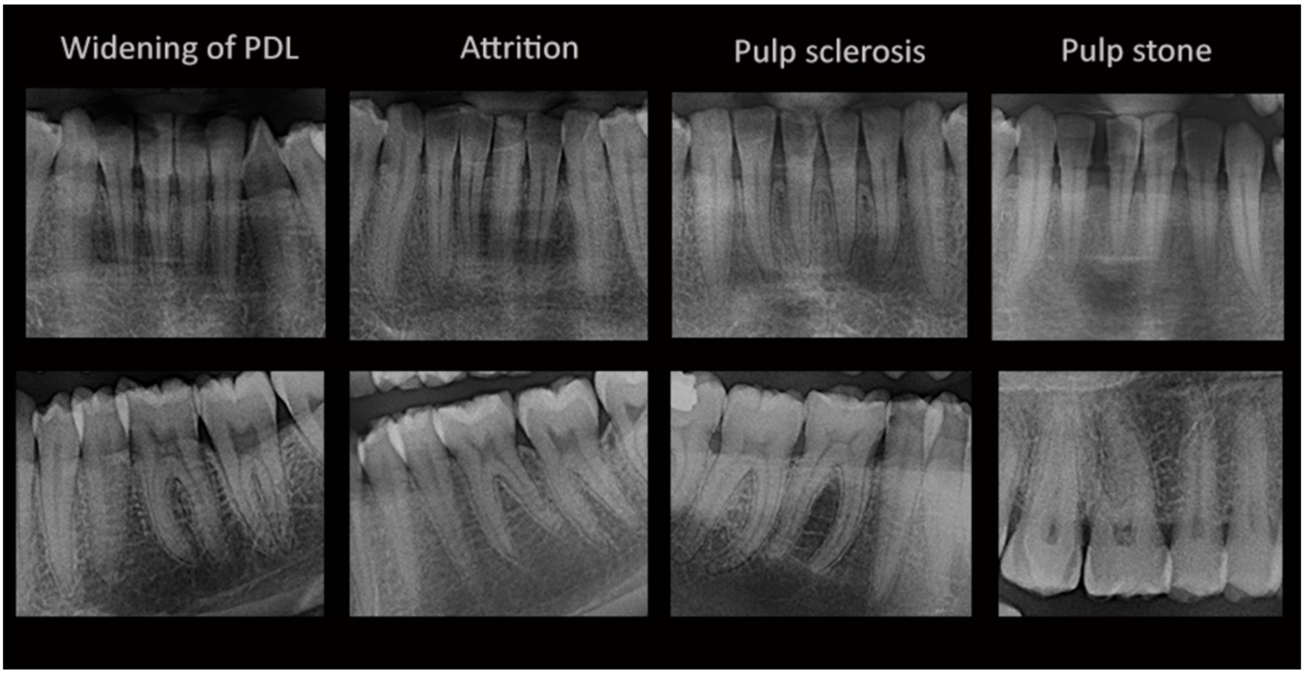

Figure 1. Radiographic examples of the widening of periodontal ligament (PDL), attrition, pulp sclerosis and pulp stone are shown.

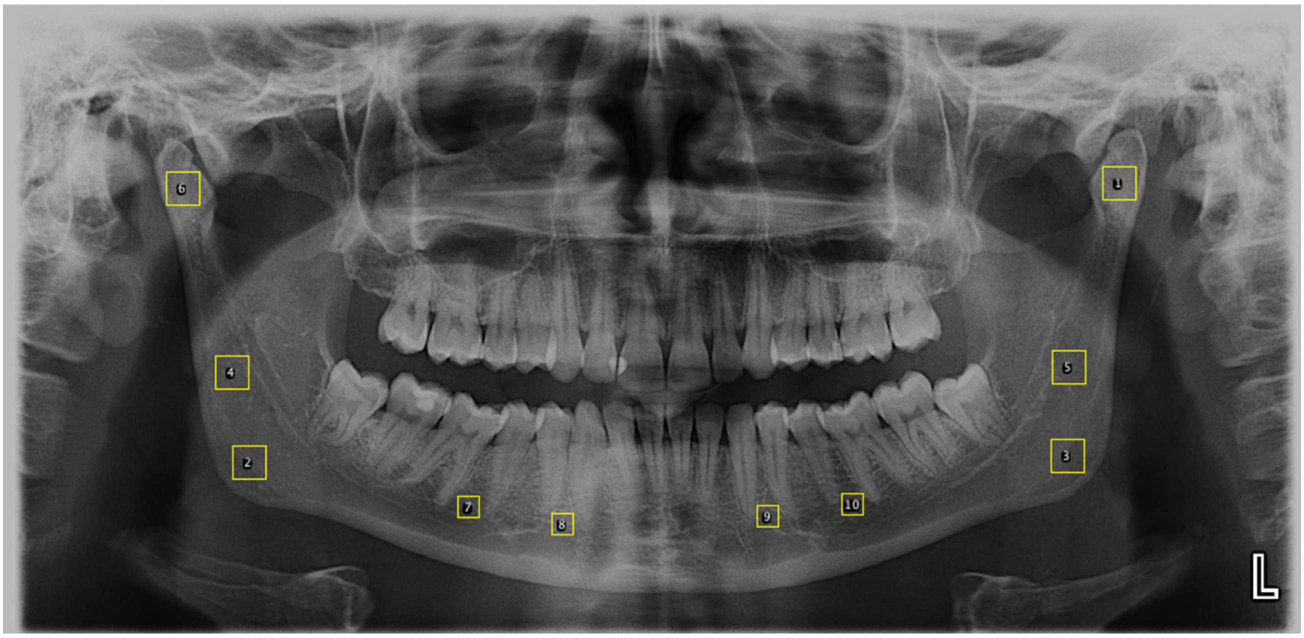

Figure 2. The regions where fractal dimension analyzes were performed are indicated with yellow boxes and numbers bilaterally. (1, 6: condylar region; 2, 3: gonial region; 4, 5: ramus; 7, 10: the apical area between the first molar and second premolar; 8, 9: the apical area between the first premolar and canine.)

significant difference between the bruxist and control groups (p= 0.878). The incidence of attrition (p=0.566) did not show a statistically significant difference according to its location in the anterior and posterior regions of both jaws. The incidence of widening in the PDL space (p=0.004), pulp sclerosis (p<0.001), and pulp stone (p<0.001) were statistically significantly higher in the posterior regions than the anterior ones in both jaws. Among all dental parameters, the most common radiological change in bruxist individuals is pulp sclerosis in the posterior teeth (p<0.001) (Maxilla posterior: 78.25%; mandible posterior: 56.25%. The sum of the percentages is shown in Table 1). In the study, 1730 fractal dimension analyzes were performed on 10 ROIs determined in the apical area between the right and left condyle, gonion, ramus, between the 1st molar and 2nd premolar, and between the 1st premolar and the canine in each radiograph. FD values, 95% Confidence Interval limits and p values obtained from the independent sample t-test for the healthy and bruxist groups are summarized in Table 2. FD analysis did not show a statistically significant difference between the healthy and bruxist groups (p>0.05). FD analysis did not show a significant statistical difference between the genders (Table 3) and between the right and left sides in the indicated areas (p>0.05).

		Maxilla Anterior				Maxilla Posterior				Mandibula Anterior				Mandibula Posterior			
Number and Percentage of Affected Teeth (n & %)		0	1-3	4-5	5 >	0	1-3	4-5	5 >	0	1-3	4-5	5 >	0	1-3	4-5	5 >
Widening of PDL	**Bruxist**	35 % 37.63	34 % 36.55	5 % 6.25	6 % 7.5	41 % 44.08	31 % 38.75	3 % 3.75	5 % 6.25	36 % 45	21 % 26.25	15 % 18.75	8 % 10	28 % 35	33 % 41.25	14 % 17.5	5 % 6.25
	Healthy	77 % 82.79	12 % 12.90	4 % 4.30	0	76 % 81.72	17 % 18.27		0	72 % 77.41	19 % 20.43	2 % 2.15	0	70 % 75.26	22 % 23.65	1 % 1.07	0
	p value	*<0,001*				*<0,001*				*<0,001*				*<0,001*			
Attrition	**Bruxist**	62 % 77.5	8 % 10	4 % 5	6 % 7.5	57 % 71.25	9 % 11.25	5 % 6.25	9 % 11.25	62 % 77.5	6 % 7.5	5 % 6.25	7 % 8.75	57 % 71.25	9 % 11.25	5 % 6.25	9 % 11.25
	Healthy	86 % 92.47	6 % 6.45	0	1 % 1.07	84 % 90.32	6 % 6.45	2 % 2.15	1 % 1.07	88 % 94.62	4 % 4.30	1 % 1.07	0	84 % 90.32	6 % 6.45	2 % 2.15	1 % 1.07
	p value	*,004*				*,003*				*,001*				*,001*			
Pulp Stone	**Bruxist**	76 %	4 % 5	0	0	42 % 52.5	30 % 37.5	5 % 6.25	3 % 3.75	78 % 97.5	2 % 2.5	0	0	57 % 71.25	19 % 23.75	4 % 5	0
	Healthy	88 % 94.62	5 % 5.37	0	0	42 % 45.16	44 % 47.31	7 % 7.52	0	92 % 98.92	1 % 1.07	0	0	73 % 78.49	17 % 18.27	3 % 3.22	0
	p value	*,912**				*,516**				*,475**				*,266**			
Pulp Sclerosis	**Bruxist**	64 % 80	6 % 7.5	4 % 5	6 % 7.5	17 % 21.25	20 % 25	22 % 27.5	21 % 26.25	55 % 68.75	9 % 11.25	5 % 6.25	11 % 13.75	35 % 43.75	16 % 20	16 % 20	13 % 16.25
	Healthy	88 % 94.62	3 % 3.22	1 % 1.07	1 % 1.07	37 % 39.78	28 % 30.10	22 % 23.65	6 % 6.45	85 % 91.39	5 % 5.37	1 % 1.07	2 % 2.15	61 % 65.59	16 % 17.20	12 % 12.90	4 % 4.30
	p value	*,003*				*<0,001*				*<0,001*				*,001*			

Table 1. Numbers and percentages of exposure of dental parameters of the healthy and bruxist groups to the anterior and posterior regions of the maxilla and mandible.

Mann-Whitney U test. *p<0.05 statistically significant.

		Mean FD ± SE	%95 Confidence Interval		p value*
			Minimum	Maximum	
Condyle	Healthy	1.18 ± 0.16	1.15	1.20	p=0.366
	Bruxist	1.20 ± 0.11	1.19	1.22	
Gonion	Healthy	1.31 ± 0.08	1.29	1.32	p=0.206
	Bruxist	1.30 ± 0.08	1.28	1.31	
Ramus	Healthy	1.20 ± 0.10	1.19	1.22	p=0.784
	Bruxist	1.20 ± 0.09	1.18	1.21	
1.molar -2. premolar	Healthy	1.33 ± 0.08	1.31	1.34	p=0.408
	Bruxist	1.33 ± 0.08	1.32	1.34	
1. premolar - Canine	Healthy	1.30 ± 0.07	1.29	1.31	p=0.515
	Bruxist	1.31 ± 0.06	1.30	1.32	

Table 2. Average values of fractal dimension of healthy and bruxist groups.

*p value calculated according to independent sample t-test.

		N	Bruxist		Healthy	
			FD+sd	p*	FD+sd	p*
Condyle	Female	98	1.19 ±0.11	0.259	1.17 ±0.14	0.108
	Male	75	1.22 ±0.12		1.18 ±0.17	
Gonion	Female	98	1.28 ±0.07	0.178	1.30 ±0.09	0.589
	Male	75	1.32 ±0.08		1.31 ±0.07	
Ramus	Female	98	1.19 ±0.09	0.829	1.19 ±0.09	0.995
	Male	75	1.21 ±0.10		1.21 ±0.11	
MPM	Female	98	1.33 ±0.08	0.454	1.34 ±0.08	0.123
	Male	75	1.34 ±0.07		1.31 ±0.08	
PMC	Female	98	1.30 ±0.07	0.439	1.30 ±0.07	0.758
	Male	75	1.31 ±0.05		1.31 ±0.06	

Table 3. The fractal dimension values (r correlation coefficient) and p values of the healthy and bruxist groups by gender.

*p-value was obtained by independent sample t-test. SD: standard deviation, MPM: Apical area between the first molar and second premolar, PMC: Apical area between the first premolar and canine.

Discussion

Bruxism seen during sleep is a parafunctional activity that includes teeth clenching and grinding, which occurs when protective neuromuscular mechanisms are disabled at the subconscious level.[4] It has been shown that the biting forces that occur during sleep bruxism can exceed the maximum voluntary bite forces.[7,13] This can cause injury and discomfort to the chewing system and TMJ. Clinical findings of bruxism include tooth wear, tooth, implant, and restoration fractures, changes in the periodontium, pain in the masticatory muscles, fatigue, click in the TMJ, anterior disc displacement, masseter hypertrophy, pulp stone, pulp sclerosis, loss of lamina dura. In the study, the diagnosis of sleep bruxism was made according to the AASM diagnostic criteria, in which many clinical findings were evaluated together.[10] Radiomorphometric data obtained from panoramic radiographs of bruxism patients and fractal dimension analyzes of mandibular trabecular bone were compared with panoramic radiographs of healthy individuals in the current study. Radiomorphometric examination results showed that the incidence of widening of the PDL space, attrition, and pulp sclerosis increased with bruxism. On the other hand, due to the increased bite forces seen in bruxism, the structure of the trabecular bone in the mandible was examined by fractal dimension analysis on the condyle, gonion, ramus, and selected dentoalveolar regions, and no significant difference was observed due to bruxism. In the light of these results, the first of the null hypotheses was rejected and the second one was accepted. The direction, duration, magnitude, and localization of the increased occlusal forces applied to the teeth and periodontium during clenching or grinding vary. Under these forces, areas of tension and compression occur in the alveolar bone walls around the tooth root via the periodontal ligament. Increased occlusal forces can alter the height, number, and thickness of trabeculae, reshaping alveolar bone with bone resorption and apposition.[14,15] The inability to control occlusal forces in bruxism induces osteoclastic activity in the bone, which may cause alveolar bone resorption and widening of the periodontal ligament space.[2,4] In addition, while both parameters did not show any significant differences in maxilla anterior and posterior regions ($p>0.05$); it was observed significantly more frequent in the posterior regions of the mandible than in the anterior. Attrition-type wear occurs irreversibly in the interdental contact areas, depending on age or parafunction. Although bruxism is one of the factors that cause attrition; it is not possible to conclude that this condition, which has a multifactorial etiology, is only due to bruxism.[16,17] In this study, the incidence of attrition was found to be significantly higher in bruxist patients compared to the control group; It was observed more frequently in posterior fields than anterior ones. One of the changes caused by excessive occlusal forces on the teeth is the changes seen in the pulp. Similar to our study, Tassoker[18] in her study with panoramic radiographs reported that the incidence of pulp stones did not show a significant difference between bruxism patients and healthy groups. Pulp sclerosis, unlike pulp stones, is diffuse calcifications observed throughout the pulp chamber and root canal. It is known that it increases significantly with age, and it has been reported that 90% of individuals aged 50-70 years have pulp sclerosis.[19] In our study, the mean age of the bruxist group was 35.98; and the mean age of the healthy group was 32.70. Among these groups, pulp sclerosis was found to be significantly higher in the bruxist group than in the healthy group. The difference in these two patient groups, whose average age is young, can be interpreted as bruxism is a facilitating factor for pulp sclerosis. It has been reported that the clenching force increases linearly as the number of tooth contacts, occlusal forces, and occlusal contact areas increase.[20] In bruxism patients, occlusal forces affect the molar teeth most, followed by the premolars and anterior teeth; it is also known that as the intensity of clenching increases, the load on the anterior teeth decreases.[20] In our study, PDL enlargement, attrition, pulp sclerosis, and pulp stones were observed more frequently in posterior teeth than anterior teeth. This situation can be interpreted as a sign that posterior teeth are exposed to more force than anterior teeth in accordance with the literature. In previous studies examining panoramic radiographs of patients diagnosed with bruxism, there were differences in the fractal dimension of the condyle.[3,6,11,21] In pediatric patients with sleep bruxism, the fractal dimension of the condyle was higher compared to the healthy group[21], and it was lower in adult patients compared to the healthy group, but there was a statistically significant difference.[3,6] In a study examining trabecular changes in the condyle on panoramic radiographs of patients with a clinical diagnosis of TMJ disease, it was shown that healthy individuals had higher fractal dimension values compared to the patient group and lower fractal dimensions were seen in condyles.[11] In this study, consistent with the literature, it was determined that the mean fractal dimension in the condyle region was lower in healthy individuals, but there was no statistically significant difference between them and bruxist individuals. In the study of Gulec et al.[3], a significant difference in the right condyles of bruxist individuals compared to healthy individuals was associated with unilateral chewing; in our study, fractal dimension did not show a statistically significant difference in right and left condyles. In some studies examining the dentate and edentulous regions with fractal analysis, it has been shown that the fractal dimension is lower in the apical areas of the teeth in dentate individuals, and lower in the condyle region in edentulous individuals. It shows that the structure meets the incoming load with a simpler internal structure, and it has a more complex structure in the dentate mouths in the condyle region. According to the results of this study, there is no difference between fractal dimension values in the areas where the teeth are located between bruxists and healthy individuals; and the results of the widening of PDL space, pulp sclerosis, and attrition findings were significantly higher in the bruxist group when the results are evaluated together, it shows that the increased functional load is absorbed in the alveolar region without being transmitted to the trabecular bone. In addition, although the difference in fractal size averages between the bruxist and the healthy group in the dentate individuals included in our study is not statistically significant, it makes us think that the trabecular structure of the bruxist group meets the load on the temporomandibular joint in a more complex structure. Masseter and medial pterygoid muscles, which are the muscles that close the jaw, adhere to the outer and inner surfaces of the mandible angulus.[7] In patients with bruxism, increased functional load has been shown to lead to a simpler trabecular internal structure in the gonial region and changes in the form of bone apposition in the angulus.[6,7] It is thought that the duration of the load is effective in the emergence of these changes.[7] Consistent with the literature, our study showed that the fractal dimension in the gonial region was lower in bruxists than in healthy individuals.[3,6] However, this difference was not statistically significant, similar to the study of Gulec et al.[3]. In the study of Eninanc et al.[6], the low-level significant difference between the two groups in fractal dimension in the gonial region (p=0.049) was due to more detailed and limited patient selection criteria. Clinical and radiographic findings of bruxism with multifactorial etiologies vary from individual to individual. The limitations of this study are not using polysomnography in the diagnosis of bruxism, not measuring the severity of bruxism with EMG, and not dividing patients as individuals with and without TMJ symptoms.

Conclusion

As a result, in this study, it was shown that the incidence of widening of the periodontal ligament space, attrition, and pulp sclerosis in panoramic radiographs of bruxism patients was higher than in healthy individuals. In addition, it has been reported that enlargement of the PDL space, attrition, pulp sclerosis, and pulp stone parameters are more common in posterior teeth than in anterior teeth. The possible changes in the mandibular trabecular bone caused by the increased occlusal forces in bruxism were examined by fractal dimension analysis and no significant difference was observed in the condyle, gonion, ramus, and selected dentoalveolar regions due to bruxism. This study, in which the radiographic findings of bruxism were evaluated systematically, contributed to the development of objective radiological diagnostic criteria. Future studies with different diagnostic methods and inclusion criteria will contribute to the evaluation of the problem in a wider perspective.

Author Contributions

C.B : Conceptualization, Investigation, Data Curation, Writing - Original Draft , B.A : Methodology, Investigation, Data Curation, Writing - Review & Editing

Conflict of Interest

The authors deny any conflicts of interest related to this study.

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