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RESEARCH

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Assessment of cortical and trabecular bone structure in the mandible of patients with Behçet's Disease

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Abstract

Objective Behçet's Disease (BD) may impair bone remodeling, increasing osteoporosis risk. This study evaluates mandibular trabecular bone fractal dimension (FD), mandibular cortical index (MCI), and temporomandibular joint (TMJ) degeneration in BD patients versus healthy controls.

Materials and Methods A total of 106 panoramic radiographs, comprising 53 from BD patients and 53 from healthy individuals, were examined. Fractal analysis was performed using ImageJ software, selecting 50 × 50 pixel regions of interest (ROIs) from the gonial, interdental, and condylar areas. Degenerative changes in the TMJ, including osteophytes, sclerosis, surface flattening, erosion, and subchondral cysts, were recorded. Statistical analysis was conducted with SPSS v.21 (IBM, Armonk, USA), using a significance level of $p < 0.05$.

Results The BD group exhibited significantly lower FD values compared to the control group ($p < 0.05$). Similarly, MCI scores differed significantly between the groups ($p < 0.05$). BD patients showed more pronounced radiological evidence of mandibular cortical resorption than controls. Additionally, degenerative changes in the TMJ were more prevalent among BD patients ($p < 0.05$).

Conclusion Comprehensive evaluation of the mandibular cortex, trabecular bone, and TMJ is crucial in BD patients to effectively detect and monitor osteoporotic alterations.

Clinical Significance BD patients may face considerable oral health challenges, such as jawbone deterioration and TMJ complications. Prompt diagnosis and treatment of these issues can enhance therapeutic outcomes and improve overall quality of life.

Keywords Behçet, Fractal, Panoramic, Osteoporosis, Mandible, MCI

Introduction

Behçet's Disease (BD), initially described in 1937 by Turkish dermatologist Hulusi Behçet, is defined by three key symptoms: "recurrent oral aphthous ulcers, genital ulcers, and hypopyon-uveitis." This chronic, relapsing systemic condition presents a wide range of clinical manifestations, including oral and genital ulcers, skin lesions, ocular, gastrointestinal, and neurological involvement, as well as arthritis [1]. Türkiye holds the highest prevalence of BD globally, with rates ranging from 1:1000 to 1:10,000 [2]. The underlying causes of BD remain unclear;

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however, it is considered a multifactorial multisystem disorder influenced by genetic, immunological, and environmental factors [3]. Genetic predisposition, such as HLA-B51 positivity, significantly increases the likelihood of developing BD [4].

Musculoskeletal symptoms, particularly arthritis and arthralgia, are among the most frequently reported in BD [5]. Joint involvement is prevalent, and research has linked increased nitric oxide levels in the temporomandibular joint (TMJ) region with degenerative changes and associated pain in BD patients [6].

The chronic nature of BD and its associated inflammatory processes may impair bone metabolism, potentially leading to osteoporosis [7]. In a study evaluating whether BD contributes to reduced bone mineral density (BMD), Kirnap et al. [8] identified an elevated risk of osteoporosis, particularly in the lumbar spine. Conversely, Tekin et al. [9] found no statistically significant difference in lumbar spine or femoral BMD values between BD patients and healthy controls.

Early detection of osteoporosis in individuals with BD is critical for improving prognosis. Radiomorphometric indices, such as the mandibular cortical index (MCI), have been developed to assess osteoporotic changes in the mandible using panoramic radiographs [10]. Fractal dimension (FD), a quantitative measure derived from fractal analysis (FA), is a mathematical method used to describe and evaluate complex structural patterns like trabecular bone architecture [11]. FD has demonstrated potential as a tool for differentiating healthy individuals from those with osteoporosis in various studies [12, 13].

Mandibular bone alterations can serve as an early indicator of systemic osteoporosis, as the mandible is a metabolically active bone susceptible to inflammatory and vascular changes associated with BD. Early detection of mandibular osteoporosis is crucial for preventing dental complications, such as tooth loss and functional impairments, and for initiating timely interventions to mitigate systemic bone loss and fracture risk. Panoramic radiography was chosen for this study as it is a widely accessible, cost and dose-effective, and practical imaging tool frequently used in routine dental assessments. While it may not replace advanced techniques like dual x-ray absorbsiometry (DXA) for definitive osteoporosis diagnosis, panoramic radiography offers a useful screening method for detecting early mandibular changes, which could prompt further evaluation.

BD is a widespread condition affecting populations worldwide, particularly in regions along the "Silk Road" (e.g., Türkiye, Iran, Japan, Korea, and China) [14]. However, limited research has been conducted on the mandibular bone structure in BD patients. To the best of our knowledge, this is the first study to apply fractal analysis for evaluating mandibular bone in patients with Behçet's Disease. This study aims to explore the differences in FD values of mandibular trabecular bone between BD patients and healthy controls, along with variations in MCI scores and TMJ degenerative changes. The null hypothesis (H_0) posits that no significant differences exist in FD values, MCI scores, or TMJ degenerative changes between BD patients and healthy controls.

Methods

Study design

This retrospective study analyzed anamnesis and panoramic radiography records of patients who visited the Department of Oral and Maxillofacial Radiology Clinic at the Faculty of Dentistry, Necmettin Erbakan University, from 2020 to 2024. All radiographs used in the study were anonymized. The research followed the principles of the Declaration of Helsinki and received approval from the Non-Drug and Medical Device Research Ethics Committee of Necmettin Erbakan University Faculty of Dentistry (Approval Number: 2024/449).

The study included 53 individuals aged 18–68 (mean age: 43.3 ± 13.7) diagnosed with Behçet's Disease (BD) as the case group, drawn from the clinic's database. The control group comprised 53 systemically healthy individuals matched by age and gender. There were a total of 53 individuals in both the case and control groups, 19 males and 34 females. A total of 106 panoramic radiographs were reviewed. Exclusion criteria encompassed patients with jaw fractures, radiographs showing central mandibular pathologies, low-quality diagnostic images with artifacts, and individuals with systemic conditions such as Paget's disease, renal osteodystrophy, osteoporosis, osteopetrosis, or hyperparathyroidism.

While the control group consisted of systemically healthy individuals who did not use medication, the medications used by individuals in the case group are shown in Table 1. It was observed that the most frequently used drugs by patients were colchicine and vitamin D. FD values did not show statistically significant differences among individuals using different medications ($p > 0.05$).

Imaging procedure

Panoramic X-rays were obtained using a 2D Veraviewpocs X-ray machine (J MORITA MFG Corp, Kyoto, Japan) with the following parameters: 70 kV, 5 mA, and an exposure time of 15 s. These settings followed the manufacturer's recommendations.

Radiological image processing: fractal analysis

To maintain uniformity, all images were resized to 2836×1500 pixels. Fractal analysis (FA) was conducted using ImageJ v1.41, a freely available software tool (link:

Table 1 Medications used by individuals in the control group and comparison of FD values

Medication	Number of patients	Percent (%)	FD (Mean ± SD)
No drug use	15	28,3	Condylar:1.32 ± 0.05 Angulus:1.30 ± 0.09 Interdental:1.33 ± 0.07
Vitamin D	12	22,6	Condylar:1.29 ± 0.08 Angulus:1.38 ± 0.05 Interdental:1.35 ± 0.08
Colchicine	14	26,4	Condylar:1.33 ± 0.08 Angulus:1.34 ± 0.09 Interdental:1.37 ± 0.05
Corticosteroid	2	3,8	Condylar:1.21 ± 0.01 Angulus:1.25 ± 0.02 Interdental:1.37 ± 0.12
Vitamin D + Corticosteroid	1	1,9	Condylar:1.39 ± 0.00 Angulus:1.36 ± 0.00 Interdental:1.34 ± 0.00
Vitamin D + Colchicine	7	13,2	Condylar:1.32 ± 0.10 Angulus:1.38 ± 0.04 Interdental:1.35 ± 0.05
TNF-alpha inhibitors + Corticosteroid	2	3,8	Condylar:1.35 ± 0.06 Angulus:1.36 ± 0.04 Interdental:1.35 ± 0.02
Total	53	100,0	$p > 0.05$

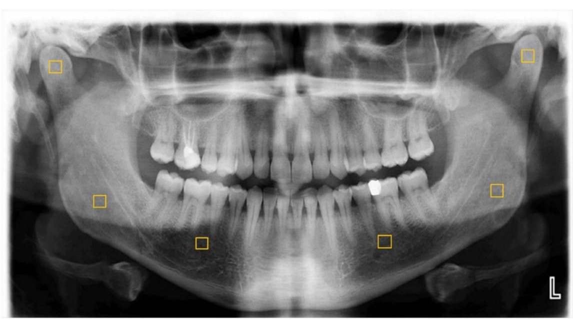

Fig. 1 Selected regions of interest (ROIs) from the right and left condylar, angular, and interdental alveolar trabecular bone areas in a panoramic image. The ROIs are highlighted using yellow squares. Care was taken to ensure that the selected ROIs included only trabecular bone, excluding tooth roots, lamina dura, and borders of the inferior alveolar canal, as the inclusion of these structures could affect the accuracy of fractal dimension (FD) analysis

https://imagej.nih.gov/ij/download.html). To ensure reliability, 20% of the images were re-analyzed by the same observer after a 15-day interval. Intraviewer reliability was 81% for FD and 94% for MCI.

Regions of interest (ROIs) with dimensions of 50 × 50 pixels were selected from six locations on the panoramic radiographs of both groups:

The right and left condylar regions.
The right and left angular regions.
The right and left interdental alveolar bone areas between the second premolar and first molar (Fig. 1).

The FA method employed the box-counting technique outlined by White and Rudolph [15] to calculate FD values (Fig. 2). The steps involved included image blurring, subtraction of the blurred image from the original, addition of gray shades, conversion to black-and-white, noise reduction (using erode and dilate operations), color inversion, and transformation to a skeletal format.

Mandibular Cortical Index (MCI)

The MCI scores of the 106 subjects (53 cases and 53 controls) were assessed by the same observer. This index evaluates cortical bone resorption in the region extending from the distal side of the mental foramen to the antegonial notch. According to Klemetti et al. [16] MCI is classified into three categories:

- C1 (Normal Cortex): The cortical margins are uniform and well-defined.
- C2 (Moderately Resorbed Cortex): Crescent-shaped endosteal defects (lacunar resorption) are visible, with 1–3 distinct layers.
- C3 (Severely Resorbed Cortex): The cortex exhibits significant porosity, with dense remnants of endosteal bone (Fig. 3).

Each panoramic radiograph was analyzed bilaterally, and the classification corresponding to the side with

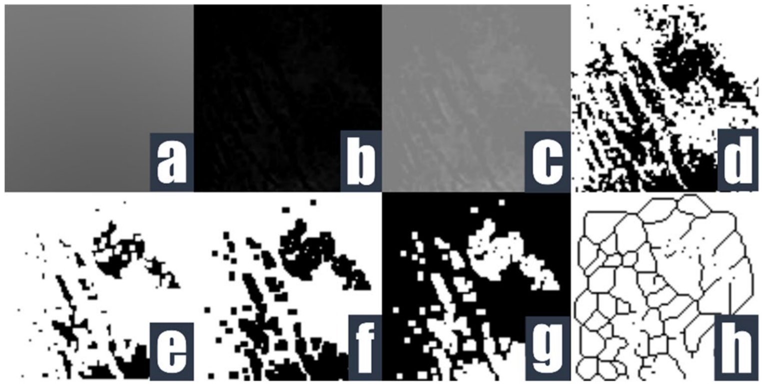

Fig. 2 Fractal analysis stages: **a** Blurring: elimination of large- scale variations in brightness, **b** Subtracting the blurred image from the original image, **c** Adding 128 shades of gray, **d** Binarization: Converting to black and white image, **e** Eroded image: reducing noise, **f** Dilated image: reducing noise, **g** Inverted image, **h** Skeletonized image: to outline the trabecular bone

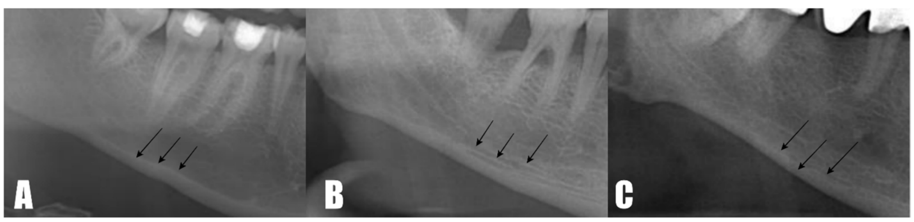

Fig. 3 MCI scores on cropped panoramic images: C1, Normal Cortex: indicated by A, black arrows indicate healthy cortical bone. C2, Moderately Resorbed Cortex: indicated by B, black arrows indicate endosteal defects in the cortical bone. C3, Severely Resorbed Cortex: indicated by C, black arrows indicate significant porosity in cortical bone

more pronounced morphological deterioration was selected as the final score.

TMJ Degenerations

Degenerative alterations in the condylar region were assessed, including osteophyte formation, development of subchondral cysts, subchondral sclerosis, surface erosion, and flattening of the condyle [17].

Statistical analysis

The data analysis was conducted using IBM SPSS software (Version 21.0, Armonk, NY). Descriptive statistics were utilized to summarize the data, and the Mann–Whitney U test was applied to compare FD values between the case and control groups. The Spearman Rho test was applied for the correlation of age and FD values. The Mann–Whitney U test was used to determine the relationship between gender and FD values. Associations between categorical variables were assessed using the chi-square test, with a significance level set at $p < 0.05$ for all analyses. The sample size for the study was calculated using the G*Power 3.1.9.7 software. With an effect size of 0.50 (d = 0.50), a 5% significance level (α = 0.05), and 80% power (1-β = 0.80), the required sample size was determined to be 51 participants per group.

Results

No statistically significant correlation was found between age and FD values ($p > 0.05$). No statistically significant difference was found between gender and FD values ($p > 0.05$). The average FD values for the condylar region and the interdental alveolar trabecular bone demonstrated a statistically significant difference between the case and control groups ($p < 0.05$). Across all measured regions, the case group consistently exhibited lower FD values (Table 2).

The MCI scores significantly differed between the case–control groups ($p = 0.001$, $p < 0.01$) (Table 3). The radiological signs of mandibular cortical resorption were found to be more severe in the cases compared to the controls.

Degenerative changes in the TMJ region were observed significantly more frequently in the case group ($p = 0.034$) (Table 4).

Table 2 Mean FD measurements of the different mandibular regions

ROI	Controls (Mean ± Std. Dev)	Min	Max	Cases (Mean ± Std. Dev)	Min	Max	*p*
Condylar	1.34 ± 0.08	1.14	1.46	1.31 ± 0.07	1.15	1.43	*0.008**
Angulus	1.35 ± 0.07	1.15	1.50	1.33 ± 0.07	1.15	1.46	*0.182*
Interdental dentate	1.38 ± 0.05	1.20	1.46	1.34 ± 0.05	1.24	1.46	*0.000***
Number of patients	53			53			

[*] singificance level is at $p < 0.05$ **significance level is at $p < 0.001$

Table 3 Distribution of MCI scores in case–control groups

	MCI			Total
	C1	C2	C3	
Control	22 (41.5%)	31 (58.5%)	0 (0%)	53 (100%)
Case	6 (11.3%)	44 (83%)	3 (5.7%)	53 (100%)
		p = 0.001, p < 0.01		

Discussion

Chronic inflammation plays a crucial role in the development of osteoporosis, a condition marked by diminished bone mass. Osteoporosis and low bone mineral density (BMD) are significant fracture risk factors and are commonly linked to rheumatologic disorders, including Behçet's Disease (BD), rheumatoid arthritis, ankylosing spondylitis, familial Mediterranean fever (FMF), and systemic lupus erythematosus [18–21]. Bone mineral density (BMD) is a vital factor for dentists when planning treatments, as it significantly impacts the success of procedures like bone grafting, periodontal therapy, and particularly dental implants. The quality and quantity of bone are essential for achieving favorable dental implant outcomes. Therefore, systemic inflammatory conditions that influence BMD require careful assessment by dental practitioners [18].

Despite the importance of this issue, limited research has focused on assessing mandibular bone structure in BD patients. This study sought to evaluate differences in fractal dimension (FD) values of mandibular trabecular bone between BD patients and healthy controls, along with variations in mandibular cortical index (MCI) scores and degenerative changes in the temporomandibular joint (TMJ). The results indicated significant differences in these parameters, leading to the rejection of the null hypothesis (H_0). These findings suggest that BD adversely affects mandibular bone integrity and TMJ health.

The use of ImageJ software, a widely accepted tool for FA calculations, reduces human subjectivity and minimizes potential observer-related biases. However, the resulting FD value may vary depending on the deviations in ROI selection in repeated trials. This study was performed with repeated assessments by a single observer and good intraobserver agreement was obtained. Since testing interobserver agreement is an important component in assessing the reliability of the results, it is recommended that interobserver agreement be assessed in future studies.

While no significant difference was found in the angulus region, it was observed that the FD values measured from the condylar and interdental regions were significantly higher in the control group than in the case group. This can be interpreted as the angulus may be less sensitive than other regions in terms of both mechanical stress and local effects of BD. The condylar region being under greater mechanical stress (such as chewing) and the inflammation of periodontal tissues in the interdental region may have caused the local effects of BD to appear more prominently in these regions.

In the present study, participants were matched by age and gender between the Behçet's Disease (BD) and control groups to minimize confounding effects. No significant relationship was found between demographic data and FD. When the results of the relationship between gender and FD are examined in the literature, there are those reporting similar results to the current study, but there are also those reporting lower FD in women [22, 23]. It has been suggested that men have more complex trabeculae and women have more porous trabeculae. In addition to studies reporting no correlation between age and FD [24], there are also studies reporting that FD decreases with age [25]. This has been attributed to the increased prominence of osteoporotic changes in the bone with advancing age.

The definitive diagnosis of temporomandibular disorders often relies on computed tomography (CT) / cone beam computed tomography (CBCT) scans to identify specific bone abnormalities like subchondral cysts and erosions. On the other hand, panoramic radiography remains essential for initial screening, though oblique joint projection and overlapping structures can obscure the condylar head and interarticular space. However, advanced panoramic radiography units with specialized TMJ programs can enhance accuracy by correcting angulation and minimizing distortion. While the effectiveness

Table 4 Comparison of degenerative changes in the TMJ between cases and controls on right and left

	Right TMJ						**Total**
	Healty	**Osteophyte Formation**	**Sclerosis**	**Erosion**	**Surface Flattening**	**Subchondral CYST**	
Control	43	4	2	0	3	1	53
	81,1%	7,5%	3,8%	0,0%	5,7%	1,9%	100,0%
Case	28	7	7	5	6	0	53
	52,8%	13,2%	13,2%	9,4%	11,3%	0,0%	100,0%
Total	71	11	9	5	9	1	106
	67,0%	10,4%	8,5%	4,7%	8,5%	0,9%	100,0%
	Left TMJ						
Control	42 79,2%	4 7,5%	2 3,8%	0 0,0%	5 9,4%	0 0%	53 100%
Case	29 54,7%	9 17%	4 7,5%	6 11,3%	4 7,5%	1 1,9%	53 100%
Total	71 67,0%	13 12,3%	6 5,7%	6 5,7%	9 8,5%	1 0,9%	106 100,0%

of panoramic radiography for TMJ evaluation is debated, it remains a valuable tool for detecting significant osseous abnormalities in the TMJ [26]. Panoramic imaging was used in the study because it is frequently used and provides the general evaluation of the jaws and teeth, in addition to its advantages in terms of ease of access, cost and x-ray dose. In a recent meta analysis, Schrodar et al. [26] analyzed 16 articles to investigate the diagnostic accuracy of panoramic radiography in detecting degenerative diseases of the TMJ. They concluded the limited accuracy of panoramic radiography in identifying degenerative conditions of the TMJ. Additionally, they emphasized that panoramic radiography will not replace cross-sectional imaging, but will serve as a warning to professionals about the presence of degenerative changes due to their high specificity. However, it has been reported that panoramic radiography can still be used as an initial examination when combined with a clinical assessment. CBCT offers superior image quality, free from overlapping artifacts, and greater accuracy compared to panoramic radiography. However, its use should be limited to cases with significant clinical or radiographic findings that warrant further investigation, ensuring a judicious and cost-effective application of CBCT resources. Future studies incorporating CBCT or MRI would help validate and expand upon our findings.

DXA is widely regarded as the gold standard for diagnosing and monitoring osteoporosis, as it accurately measures both trabecular and cortical BMD and assesses fracture risk. However, its use is often limited by high costs and accessibility issues [27]. In this study, MCI and fractal analysis techniques were employed to identify osteoporotic changes in cortical and trabecular bone using panoramic radiographs. This approach offers several advantages, including low radiation exposure, affordability, and ease of access. On the other hand, Asutay et al. [18] analyzed the differences in BMD between BD individuals ($n=30$) and healthy individuals ($n=45$) using DXA. The mean mandibular body BMD values were 1.294 ± 0.21 g/cm^2 in the control group and 1.216 ± 0.22 g/cm^2 in BD patients, but there was no statistically significant difference. Unlike our study, the potential reasons for the lower BMD values in BD patients not showing a significant difference include the fact that the measurements were made using DXA, the relatively small sample size ($n=75$) and the difference in mean age of the sample. The mean age of the sample used in the study (37.56 ± 8.2 years) is younger than the current study (mean age: 43.3 ± 13.7 years), and the case and control groups were not matched in terms of age and gender. Additionally, Asutay et al. [18] described the effect of disease duration on mandibular BMD and BD patients was subdivided according to disease duration (0–5, 6–10, and > 10 years). They reported that BMD decreased with increasing disease duration, but it was not statistically significant. This issue could not be evaluated due to the retrospective nature of the current study and the lack of data on BD severity and duration in the archive, but it would be useful to test this possible relationship with a larger sample in the future.

While not specific to BD, recent studies have investigated the impact of rheumatologic diseases like rheumatoid arthritis [28], FMF [29], and ankylosing spondylitis [27] on FD values of mandibular trabecular bone. In these conditions, lower FD values were observed compared to healthy controls. Similarly, in this study, lower FD values were consistently measured in BD patients across all regions, with statistically significant differences noted in the condylar and interdental regions ($p < 0.05$). These reduced FD values, particularly in the dentate region, may negatively affect osseointegration and the primary stability of dental implants in BD patients. Consequently, careful preoperative planning, including the selection of appropriate surgical techniques and implant designs, is essential. The lack of definition of cut-off points for the use of FD as a screening test across different groups has been cited as an important limitation. Cavalcante et al. [30] conducted a meta-analysis to assess the reliability of FD as a biomarker for osteoporosis screening. However, the study was unable to establish a definitive cut-off value for FD. While various studies in the literature have reported mean and standard deviation values for FD obtained from different methods and jaw regions, they did not include ROC curve analyses.

Higher MCI scores, indicative of poorer cortical bone health in the posterior mandible, were associated with lower BMD [10]. In this study, C1 scores were more frequent among healthy controls, whereas C3 scores, reflecting severe cortical resorption, were predominant in BD patients. Similar findings were reported in recent studies examining MCI in ankylosing spondylitis [27] and FMF [31], where resorption-related MCI scores were more prevalent in affected patients.

Approximately 75% of BD patients exhibit joint-related symptoms, including seronegative arthritis and nonspecific synovitis. Larger joints such as the knees, wrists, ankles, and elbows are most commonly affected, and erosive forms of arthritis have only been documented in a few BD cases [5]. In this study, although clinical evaluations were unavailable due to its retrospective nature, erosive degeneration was detected in the TMJ of five BD patients. Degenerative TMJ changes were significantly more frequent in the BD group, emphasizing the importance of early radiological assessment and intervention to address TMJ complications in BD patients.

The observed reduction in FD values and the increase in MCI scores in BD patients suggest a higher prevalence of compromised mandibular bone quality and structural integrity. This highlights the utility of panoramic radiographs, coupled with fractal analysis and MCI assessment, as cost-effective tools for the early detection of mandibular bone deterioration in BD patients. Early identification of these changes can prompt timely intervention to mitigate systemic osteoporosis and associated dental complications. Dentists should consider the potential challenges posed by deterioration of bone quality in BD patients. Low FD values, particularly in the interdental areas, may indicate decreased bone density. This requires careful preoperative evaluation before surgical procedures on the alveolar bone. The increased prevalence of degenerative TMJ changes among BD patients underscores the importance of regular TMJ evaluations. Early detection and management of TMDs can improve patient outcomes and quality of life. Given the systemic nature of BD and its impact on bone health, our findings suggest the need for collaboration between dental professionals and rheumatologists. Regular dental assessments, including panoramic radiographs and fractal analysis, could be integrated into the routine monitoring protocols for BD patients.

In the current study, medication data of all patients in the case group were recorded. Drugs such as colchicine, corticosteroids and TNF-alpha inhibitors can be used in the treatment of BD. Glucocorticoid use is the leading cause of drug-induced (secondary) osteoporosis [32]. Contrarily, colchicine is reported to block osteoclastic activity and prevent bone resorption [33] and TNF-alpha inhibitors are reported to increase bone mineral density [34]. It was observed that the most frequently used drugs by patients were colchicine and vitamin D. Vitamin D is necessary for calcium absorption and bone mineralization and is positively associated with bone mineral density [35]. Combined use of these drugs may be necessary in some cases, but their potential effects on bone health should be carefully monitored. Among the patients in the sample, 1 was receiving treatment with a combination of vitamin D and corticosteroids, 7 were receiving treatment with a combination of vitamin D and colchicine, and 2 were receiving treatment with a combination of TNF-alpha inhibitors and corticosteroids. Inadequate vitamin D can lead to decreased bone mineral density and contribute to the development of osteoporosis. Therefore, vitamin D may be considered in drug combinations, especially when using drugs that have osteoporotic effects, such as steroids. Corticosteroids have been reported to reduce vitamin D levels [36]. If corticosteroid use is unavoidable, bone health protective measures such as vitamin D and calcium supplements are recommended. Medications such as TNF-alpha inhibitors, when combined with corticosteroids, may help block bone loss caused by corticosteroids. FD values of individuals in the case group did not differ depending on the drugs they used. Due to the retrospective design of the study, access to details such as duration of medication use, dosage, and individual differences was limited. Therefore, a comprehensive stratification of medication use could not be performed in this study.

Limitations

Panoramic radiographs, which were preferred in the present study, although cost and dose-effective, lack the sensitivity of advanced imaging techniques such as

CT/CBCT, or MRI. They also cause variability in image quality and interpretation. The retrospective design of the study prevented evaluation of clinical symptoms and signs related to TMJ and assessment of severity or duration of BD, which was not included in the patient records and could affect mandibular bone structure. Furthermore, the included BD patients were taking medications known to potentially reduce BMD, such as corticosteroids and colchicine.

Conclusion

Patients with BD demonstrated lower FD values, more pronounced mandibular cortical resorption, and a higher prevalence of TMJ degenerative changes compared to healthy controls. While our results provide valuable baseline data, clinical recommendations for implant placement or TMJ management should be approached with caution due to the study's retrospective design and lack of direct clinical data. It should be considered that the evaluations regarding TMJ degenerative changes are tentative, as they were performed using panoramic imaging. In future studies, in addition to evaluation with cross-sectional imaging such as CBCT, the inclusion of clinical parameters and the use of longitudinal data are recommended.

Abbreviations

BD	Behçet's disease
FD	Fractal dimension
FA	Fractal analysis
MCI	Mandibular cortical index
TMJ	Temporomandibular joint
ROI	Region of interest
BMD	Bone mineral density
DXA	Dual x-ray absorbsiometry
CBCT	Cone-beam computed tomography
CT	Computed tomography
MRI	Magnetic resonance imaging

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Clinical trial number
Not applicable.

Authors' contributions
Consept and design of the study: MT, MB. Data acquisition: RK, MB. Analysis of the data: RK, MT, MB. Drafting of the manuscript: RK, MT, MB. Final approval of the manuscript: RK, MT, MB.

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Data availability
The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This study was performed in line with the principles of the Declaration of Helsinki. Ethical approval was received from the Necmettin Erbakan University Faculty of Dentistry Non-Drug and Medical Device Research Ethics Committee (Approval nm: 2024/449). Not applicable. Due to the retrospective nature of the study, Necmettin Erbakan University Faculty of Dentistry Non-Drug and Medical Device Research Ethics Committee waived the need of obtaining informed consent.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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