Original Article

Using cone beam computed tomography to examine the prevalence of condylar bony changes in a Turkish subpopulation

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Abstract

Background/Purpose: The aim of this study was to characterize the condylar bone changes in the temporomandibular region using cone-beam computed tomography (CBCT) and to determine the prevalence of these changes in a population.
Materials and Methods: CBCT images of the temporomandibular joints (TMJs) of 795 patients (426 females, 369 males) were retrieved from the computer database. The cross-sectional, coronal and sagittal views of 1-mm-thick sections of the TMJ were generated using CBCT. Age, gender, and bone changes on both condyles were recorded, and data were analyzed using a Chi-square test and McNemar's test to evaluate comparisons between qualitative data (IBM Corp., Armonk, NY).
Results: No bone changes were observed in 78.4% ($n = 623$) of the TMJ samples obtained from the right side. Osteoarthritic changes were observed in 17.9% ($n = 142$) and developmental changes in 2.6% ($n = 21$) of the cases. On the left side, osteoarthritic changes were observed in 11.6% ($n = 142$) of the cases while developmental changes were observed in 2.6% ($n = 21$). Moreover, 82.4% ($n = 655$) of the TMJ samples showed no changes. When the age groups were compared in samples obtained from both right and left TMJs, the prevalence of bone changes increased by the age of 60 years and older.
Conclusion: The prevalence of degenerative condylar bone changes increased with increasing age and was more frequent in women and right condyle.

Key words: Bone changes, cone beam computed tomography, temporomandibular joint

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Introduction

Temporomandibular joint (TMJ) disorder is a term describing the pain and dysfunction of the muscles of mastication and the TMJs.[1] The most common clinical signs and symptoms of TMJ disorders are joint and muscle pain, mouth-opening limitation, clicking and crepitation.[2] TMJ disorders have several etiologic factors, such as trauma, emotional stress, degenerative diseases, muscular hyperactivity, inflammatory and orthopedic instability.[1] It is important to identify osseous abnormalities of the TMJ.[3-7] Scrivani *et al*.[8] focused on the most common forms of TMJ disorder, including myofacial pain, intra-articular disc derangement, and osteoarthritis, and proposed different treatment options for each form. As a result, these authors emphasized the importance of carefully

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evaluating the presence or absence of osseous abnormalities that affect the treatment of TMJ disorders.

The temporomandibular joint can be viewed using panoramic and transcranial radiographs, conventional computed tomography (CT), cone-beam computed tomography (CBCT), magnetic resonance imaging (MRI) and arthrography. Monitoring this area can be difficult due to the superimposition of adjacent structures, different angulations of the condyle, limitations of mouth opening in some patients and mandibular movements during the examination.[9] Although several imaging techniques have been used to evaluate the TMJ, it is essential to obtain a clear and precise image of this region.[10] The American Academy of Oral and Maxillofacial Radiology has established the rationale for image selection for the diagnosis, treatment and follow-up of conditions affecting the TMJ. The advantages, disadvantages and indications were set for evaluating TMJ structures, but the imaging of condylar changes, such as erosions and osteophytes, could not be addressed.[11] Most studies have agreed that the imaging of bony abnormalities is adequately accomplished through CT.[12-14] Westesson *et al*.[14] compared CT with MRI and reported that although both methods were adequate for the detection of bony abnormalities, CT depicted the osseous abnormalities with finer detail than MRI.

Cone beam computed tomography was introduced during the last decade. This technique uses X-ray exposure in cone shapes instead of slices, similar to spiral CT, for image acquisition. However, CBCT requires less X-ray exposure, and lower cost to the patient than the spiral CT and this method captures images in a single rotation of the X-ray source.[13,15,16] Honda *et al*.[13] determined that CBCT has diagnostic capabilities equal to or greater than those of helical CT. These authors emphasized that CBCT was a viable diagnostic alternative for detecting bony changes in the TMJ region, reflecting the decreased cost and radiation dose. The radiographic interpretation of the TMJ complex, including the condyle, using CBCT imaging facilitates the consistent and accurate detection of more subtle bone alterations occurring in the TMJ, such as subchondral cysts (pseudocyst, idiopathic bone cavity), subchondral sclerosis, osteophyte formation, surface erosion, ankylosis, depression, bifid condyle, hyperplasia, and hypoplasia, thereby simplifying subsequent clinical decisions.[17]

The aim of this study was to assess the prevalence of degenerative and other (congenital or developmental) types of bone changes in TMJs using CBCT, correlate these bony changes with age, gender, type of alteration, and evaluate distribution of bony changes in age groups.

Materials and Methods

The CBCT images of the TMJs of patients with dental complaints visiting the Marmara University Department of Oral Diagnosis and Radiology Clinic from 2010 to 2013 were retrieved from the computer database and subsequently assessed by a radiologist (MM). The samples included the TMJ images of 795 patients (426 females and 369 males) obtained by the same operator using a ProMax 3D Mid imaging device (PlanmecaOy, Helsinki, Finland) operated at 90 kVp and 10 mA. The CBCT scans were directly assessed on a monitor screen (Monitor 23-inch Acer 1920 × 1080 pixel HP Reconstruction PC). These images were obtained using the following CBCT acquisition protocol:

- Voxel thickness: 0.20 mm
- Thickness of the sagittal and coronal slice along the longitudinal axis of the mandibular condyle: 1 mm
- Acquisition volume: Maxilla and mandible
- Time: 36 s
- Parameters: 90 kVp and 10 mA
- Field of view: 16 cm × 16 cm.

All digital images were viewed using Romexis 2.92 software (PlanmecaOy, Helsinki, Finland). The primary reconstruction of the raw data was restricted to the TMJ cross-sectional region (approximately 1 cm superior to the mandibular fossa and 1 cm inferior to the condylar neck); 1-mm-thick coronal and sagittal views of the TMJ were generated. To reconstruct these images, the examined condyle was traced 1 cm medio-laterally to generate sagittal cross-sectional projections and 1 cm anterio-posteriorly for coronal cross-sectional projections on the axial view. The software generated individual coronal and sagittal cross-sectional reconstructions parallel to the long axis of the condyle. The thickness of the image slices was 1 mm, and the distance between the slices was 1 mm for both coronal and sagittal reconstructions. To ensure efficient evaluation, a clinician (MOB) in the Department of Oral Diagnosis and Radiology evaluated the images. During meetings for the pilot study, a specialist working in the Department of Oral Diagnosis and Radiology trained the radiology specialists, and an agreement on the objective criteria for the qualitative evaluation of the images was forged among the evaluators. The right and left TMJs were evaluated separately, resulting in a total of 1590 TMJ images. The images were directly assessed on a computer monitor screen (Monitor 23 inch acer 1920 × 1080 pixel HP Reconstruction PC). Age, gender, and osseous changes were recorded on an evaluation sheet for each patient. To avoid misinterpretation, the observed bone changes had to be detected in at least two consecutive slices. The osteoarthritic and bone changes evaluated in the present study included flattening (a flat bony contour deviating from the convex form) [Figure 1], erosion (an area of decreased density of the cortical bone and the adjacent subcortical bone) [Figures 2 and 3], osteophyte (marginal bony outgrowths on the condyle) [Figure 4], sclerosis (an area of increased density of the cortical bone extending into the bone marrow) [Figure 5], ankylosis (hyperplastic and irregular contours of the condyle with absence of joint spaces), depression (a concave bony contour), pseudocyst-bone cavity (well-circumscribed osteolytic adjacent subcortical bone area without cortical destruction) [Figure 6], bifid condyle (duplication of the mandibular condyle head) [Figure 7], hyperplasia (excessive growth of the condyles, where irregular enlargement of the condylar neck is observed) and hypoplasia (milder, shorter and poorly formed condylar processes).

Statistical analysis

The data were analyzed using Statistical Package for IBM SPSS Statistics for Windows, Version 22.0 (IBM Corp., Armonk, NY, USA). Descriptive statistical methods were used to evaluate the data. The Chi-square test and McNemar's test were used to evaluate comparisons between qualitative data. Significance was accepted at the $P < 0.05$ level.

Results

This study was based on CBCT images of 369 males and 426 females between 20 and 84 years of age (40.65 ± 13.99).

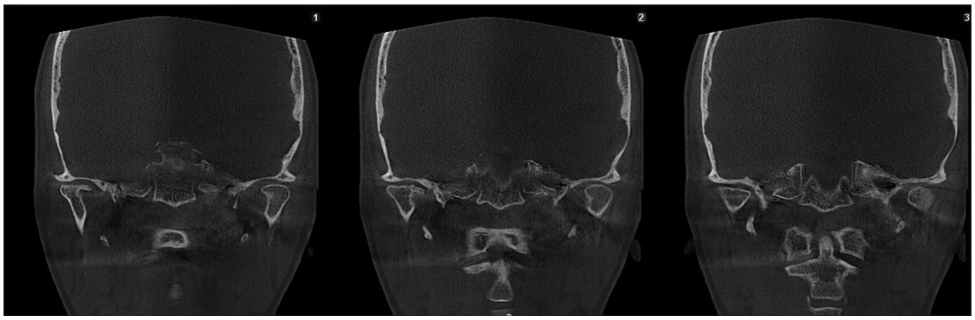

Figure 1: Coronal sections showing flattening of the right condyle

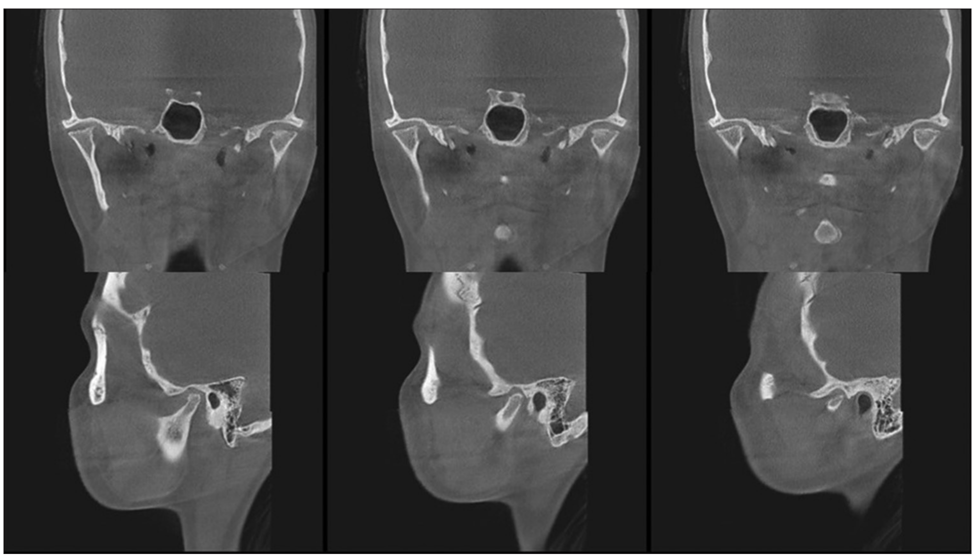

Figure 2: Coronal and sagittal sections showing erosion on the right and left condyles

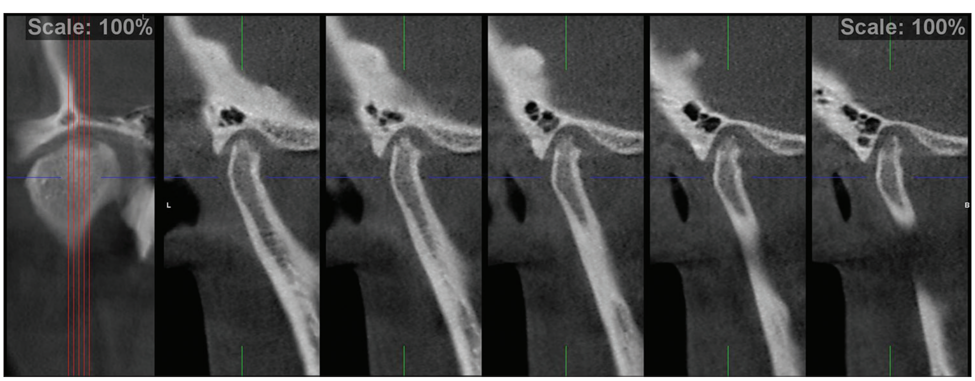

Figure 3: Cross-sections showing erosion on the right condyle

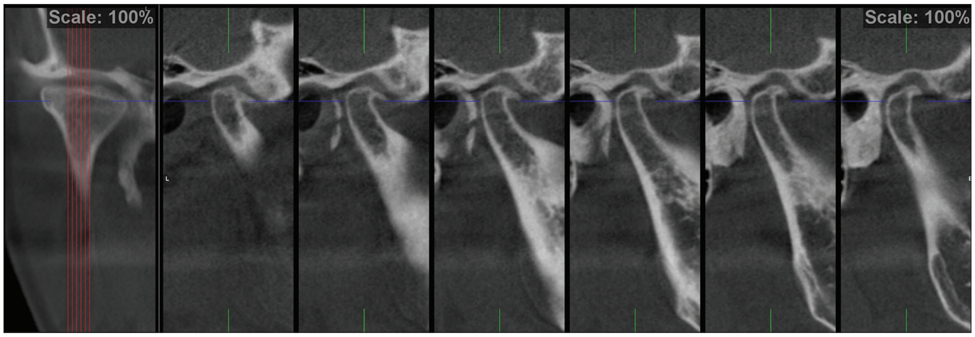

Figure 4: Cross-sections showing osteophyte formation on the right condyle

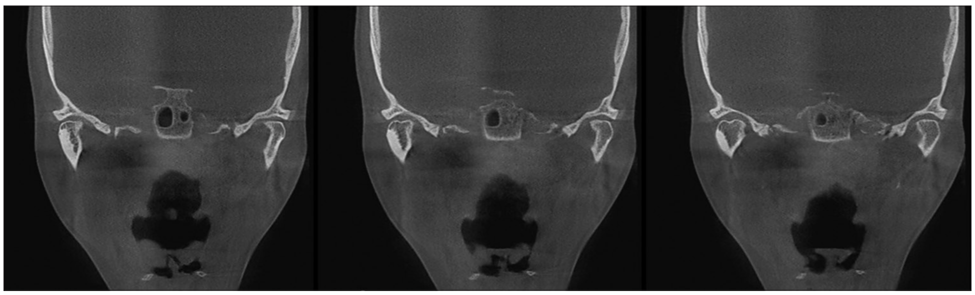

Figure 5: Coronal sections showing sclerosis on medial side of the right condyle

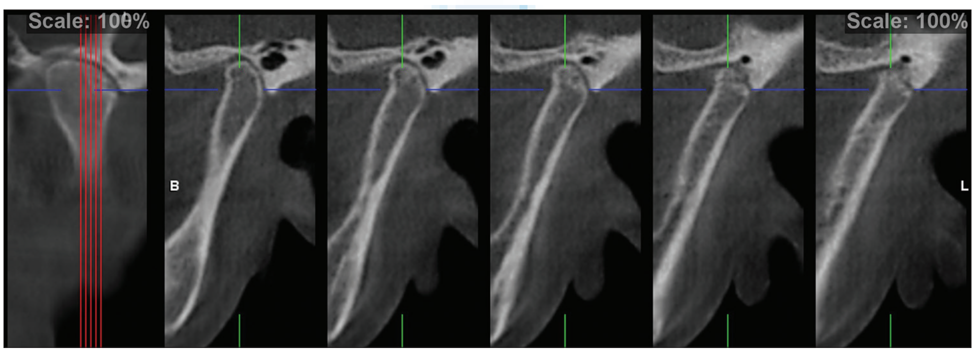

Figure 6: Cross-sections showing bone cavities on the left condyle

Figure 7: Coronal sections showing a bilateral bifid mandibular condyle

Although no bony changes were observed on the right side in 78.4% ($n = 623$) of the TMJs, osteoarthritic changes were observed in 17.9% ($n = 142$) of the cases and developmental changes in 2.6% ($n = 21$). On the left side, osteoarthritic changes were observed in 11.6% ($n = 92$) of the cases and developmental changes in 2.6% ($n = 21$), although no changes were detected in 82.4% ($n = 655$). Developmental and osteoarthritic changes were observed in 1.1% and 3.4% of the TMJs in the right and left sides, respectively [Table 1].

The difference in the prevalence of the bony changes between the left and right sides were statistically significant ($P = 0.001$;

$P < 0.01$) [Table 2]. Osteoarthritic changes detected on the right side were higher compared with the left side.

The distribution of bone changes in TMJs based on gender and age are shown in Tables 3 and 4. When the age groups were compared for the right TMJs, the prevalence of bone changes increased for individuals aged 60 years and older (35.8%). While there was no difference between individuals less than 60 years of age ($P = 0.201$, $P > 0.05$), individuals aged 60 years and older showed higher prevalence and this difference was statistically significant ($P = 0.001$, $P < 0.01$). Furthermore, the prevalence of osteoarthritic bony changes on the right side was higher in females (21.6%) than in males (13.6%), and this difference was statistically significant ($P = 0.019$, $P < 0.05$) [Table 3].

When the age groups were compared for left TMJs, the prevalence of bony changes increased for individuals aged 60 years and older (24.9%). Although there was

Table 1: The distribution of bony changes on the left and right sides

Bony changes	n (%)	
	Right	Left
No	623 (78.4)	655 (82.4)
Osteoarthritic	142 (17.9)	92 (11.6)
Developmental	21 (2.6)	21 (2.6)
Osteoarthritic+developmental	9 (1.1)	27 (3.4)

Table 2: Comparison of the condylar bony changes between the left and right sides

Bony changes	Left n (%)				
	None	Osteoarthritic	Developmental	Osteoarthritic+developmental	Total
Right					
None	562 (70)	38 (4.8)	14 (1.8)	9 (1.1)	623 (78.4)
Osteoarthritic	74 (9.3)	51 (6.4)	3 (0.4)	14 (1.8)	142 (17.9)
Developmental	16 (2.0)	1 (0.1)	4 (0.5)	0 (0)	21 (2.6)
Osteoarthritic+developmental	3 (0.4)	2 (0.3)	0 (0)	4 (0.5)	9 (1.1)
Total	655 (82.4)	92 (11.6)	21 (2.6)	27 (3.45)	795 (100)
P	0.001**				

McNemar's test. $^{**}P<0.01$

Table 3: Condylar bony changes according to age and gender on the right side

	Condylar bony changes (right side) n (%)				*P*
	No	Osteoarthritic	Developmental	Osteoarthritic+developmental	
Age					
20-29	187 (85.8)	26 (11.9)	5 (2.3)	0 (0)	0.001**
30-39	142 (79.8)	27 (15.2)	5 (2.8)	4 (2.2)	
40-49	129 (77.2)	32 (19.2)	5 (3.0)	1 (0.6)	
50-59	114 (75.5)	28 (18.5)	6 (4.0)	3 (2.0)	
60+	51 (63.0)	29 (35.8)	0 (0)	1 (1.2)	
Gender					
Male	307 (83.2)	50 (13.6)	9 (2.4)	3 (0.8)	0.019*
Female	316 (74.2)	92 (21.6)	12 (2.8)	6 (1.4)	

Chi-square test. $^{*}P<0.05$, $^{**}P<0.01$

Table 4: Condylar bony changes according to age and gender on the left side

	Condylar bony changes (left side) n (%)				*P*
	No	Osteoarthritic	Developmental	Osteoarthritic+developmental	
Age					
20-29	187 (85.8)	18 (8.3)	8 (3.7)	5 (2.3)	0.003**
30-39	151 (84.8)	18 (10.1)	2 (1.1)	7 (3.9)	
40-49	131 (78.4)	22 (13.2)	9 (5.4)	5 (3.0)	
50-59	128 (84.8)	14 (9.3)	2 (1.3)	7 (4.6)	
60+	58 (71.6)	20 (24.7)	0 (0)	3 (3.7)	
Gender					
Male	322 (87.3)	29 (7.9)	10 (2.7)	8 (2.2)	0.004*
Female	333 (78.2)	63 (14.8)	11 (2.6)	19 (4.5)	

Chi-square test. $^{*}P<0.05$, $^{**}P<0.01$

Table 5: The types of condylar bony changes on the left and right sides

	n (%)	
	Right	Left
Flattening	50 (6.3)	49 (6.2)
Erosion	55 (6.9)	30 (3.8)
Bone cavity	32 (4.0)	22 (2.8)
Sclerosis	25 (3.1)	21 (2.6)
Depression	17 (2.1)	16 (2.0)
Osteophyte	17 (2.1)	15 (1.9)
Hypoplasia	13 (1.6)	19 (2.4)
Hyperplasia	12 (1.5)	8 (1.0)
Bifid condyle	6 (0.8)	6 (0.8)
Ankylosis	1 (0.1)	2 (0.3)
Total	228 (28.6)	188 (23.6)

no difference between individuals under 60 years of age ($P = 0.216$, $P > 0.05$), individuals 60 years and older showed higher prevalence and this difference was statistically significant ($P = 0.003$, $P < 0.01$). In addition, the prevalence of osteoarthritic bony changes in females (14.8%) was higher than that in males (7.9%), and this difference was statistically significant ($P = 0.004$, $P < 0.01$) [Table 4].

The distribution of the several bone changes on the left and right sides is shown in Table 5. The most frequent osteoarthritic changes observed on the right side were erosion, flattening and bone cavity. However, the most frequent osteoarthritic changes observed on the left side were flattening, erosion and bone cavity while the most frequent osteoarthritic condylar bony changes on both the left and right joints were flattening, erosion, and bone cavity. Depression, hypoplasia, and hyperplasia were observed on the right side while hypoplasia, depression, and hyperplasia were the most common developmental findings on the left side. Sclerosis, ankylosis, and bifid condyle were the least frequent radiographic findings for both sides.

Discussion

Mandibular condyle morphology is characterized by a rounded bone projection with a biconvex contour in the superior aspect and oval surface on the axial plane. Typically, the antero-posterior dimension is shorter than the medial-lateral dimension, whose ends are called medial and lateral poles.[18] A variation in the condylar morphology occurs with age, gender, facial type, infection, occlusal force, functional load, malocclusion type between right and left sides and the onset of developmental or congenital osteoarthritis. Developmental disturbances involving the TMJ might result in anomalies in the size and shape of the condyle.[19] Hyperplasia, hypoplasia, agenesis, depression and bifid condyle formation might be evident upon radiographic examination of the joint.[17]

Furthermore, prevalent morphologic changes are detected in the TMJ of elderly persons due to the onset of joint degeneration.[8,17,20] Osteoarthritis is a noninflammatory disorder of the joints characterized by joint degeneration and proliferation.[21] Although osteoarthritis is an age-related disease, recent studies have identified osteoarthritis in a majority of young patients.[17] The proliferative component of this process is characterized by new bone formation at the articular surface and subchondral region.[21] Radiographic findings in degenerative joint disease might include narrowing of the joint space, irregular joint space, flattening of the articular surfaces, sclerosis and erosion of the condylar bone surface, and subchondral cyst, and in the later stages, osteophyte formations.[19,22,23] In the present study, we listed the potential bone changes in TMJ patients of all age groups.

Koyama *et al*.[24] investigated condylar bone changes in 1032 joints from 516 subjects to clarify the incidence and type of bone changes in the TMJ in patients with temporomandibular disorders (TMDs) using CT. These authors observed condylar bone changes in 63.7% ($n = 617$) of these individuals. Pontual *et al*.[9] evaluated the images of patients with clinical symptoms of TMJs, showing a high prevalence (71%) of degenerative bone alteration in TMJs. Cho and Jung[25] showed that the prevalence of osteoarthritic changes was higher in symptomatic (26.8%) than in asymptomatic adolescents (9.9%). Kurita *et al*.[23] reported a significant relationship between the presence of TMJ pain upon mandibular function and osteoarthritic changes at the articular surface. In contrast, Palconet *et al*.[26] showed a poor correlation between condylar changes observed on CBCT and pain or other clinical signs and symptoms in TMJ osteoarthritis. Hence, we randomly selected CBCT images of the TMJs of patients with different complaints, regardless of the development of clinical symptoms, who visited the clinic. The results showed a lower prevalence compared with the results of previous studies.

Pontual *et al*.[9] showed a high prevalence of degenerative bone alteration, which occurred more frequently in females and increased with age. According to Alexiou *et al*.[27] patients in older age groups had more frequent and more severe bone changes than those in younger age groups, reflecting the development of TMJ osteoarthritis. Similarly, a number of studies have shown that osteoarthritis increases with age and occurs more commonly in females than in males.[7,28-30] Researchers have suggested that the increased occurrence of osteoarthritic changes in women reflect hormonal influences of estrogen and prolactin, which might exacerbate the degradation of cartilage and articular bone and stimulate a series of immunological responses in the region.[31] In the present study, when the age groups were compared, the prevalence of bone changes increased in individuals aged 60 years and older, while there was no difference between individuals under 60 years of age, and the prevalence of bone changes in women was higher than that in men. Conversely, Cho and Jung[25] investigated TMJ osteoarthritis in children and adolescents with or without TMD symptoms. These authors reported a higher prevalence of osteoarthritic changes in adolescents in the older age group. In addition, while the asymptomatic group showed no significant gender differences, in the symptomatic group, the prevalence of osteoarthritic changes was higher in males than in females. Moreover, Crusoé‑Rebello *et al*.[32] and Isberg *et al*.[33] did not observe an association between increased age and the prevalence of bone changes and concluded that individuals 20–49 years of age showed more frequent TMJ changes. Crusoé‑Rebello *et al*.[32] also observed no relationship between males and females, concluding that hormones did not play a role in the TMJ derangements.

In the present study, the distribution of osteoarthritic bone changes in TMJs based on left and right sides were observed in 11.6% (n = 142) and 17.9% (n = 142), respectively, in 1590 TMJs. Osteoarthritic changes were also detected more frequently on the right side than on the left side. In addition, the higher percentage of bony changes on the right side might reflect the chewing habits of people who typically use the right sides of their jaws. Pontual *et al*.[9] showed that although a higher prevalence of left‑side TMJs with bone changes was observed, this difference was not significant compared with the prevalence on the right side. Crusoé‑Rebello *et al*.[32] assessed the influence of horizontal angulation on the degenerative bone changes in the TMJ, suggesting that one joint influenced the other and that the movements of the mandible were coordinated by both joints; consequently, these joints could not be considered separately.

Degenerative bony changes on the condylar bone surface should be carefully diagnosed using radiographic examinations and are characterized by radiological findings of erosion, flattening, sclerosis, subchondral cysts, and osteophytes.[6,8,34] In addition to these symptoms, developmental changes, such as hyperplasia, hypoplasia, agenesis, depression and bifid condyle formation, have been observed on the condylar surface. In the present study, erosion (n = 55, 6.9%), flattening (n = 50, 6.3%), and bone cavity (n = 32, 4%) were observed on the right side, while flattening (n = 49, 6.2%), erosion (n = 30, 3.8%), and bone cavity (n = 22, 2.8%), similar to osteoarthritic bone changes, were the predominant findings on the left side. On the right side, depression (17 joints, 2.1%), hypoplasia (13 joints, 1.6%), and hyperplasia (12 joints, 1.5%) were observed, and on the left side, hypoplasia (19 joints, 2.4%), depression (16 joints, 2%), and hyperplasia (eight joints, 1%) were the most common developmental findings. Ankylosis (n = 1, 0.3%) and bifid condyle (n = 6, 0.8%) were the least frequent radiographic findings for both sides. Pontual *et al*.[9] observed that flattening (59%) and flattening accompanied by osteophyte (29%) were the most common findings in the population and explained that the high prevalence of flattening represents an adaptive alteration, the first change of a progressive disease, degenerative change secondary to internal derangement and might be associated with the overload of the masseter and temporal muscles to the TMJ. Cho and Jung[25] showed that erosion was the most common change for the symptomatic group (15.6%), whereas sclerosis was the most common change for the asymptomatic group (5.4%). In addition, these authors demonstrated that erosion was more frequently observed in subjects with pain or limited mouth opening. Alexiou *et al*.[27] observed that erosion, flattening, and osteophyte were the most common radiographic findings in the condylar head, although sclerosis was the least frequent radiographic finding. Nah[35] reviewed the data of 440 TMJs from 220 consecutive TMJ patients, and the most frequent osteoarthritic bony change observed was sclerosis (n = 133, 30.2%), followed by surface erosion (n = 129, 29.3%), flattening (n = 112, 25.5%), osteophytes (n = 35, 8%) and subcortical cysts (n = 24, 5.5%). In addition, these authors recorded developmental bony changes, such as hypoplastic condyles (n = 53, 12%), hyperplasia (n = 1), and morphological deviation (n = 58, 13.2%), which included 33 TMJs in a cane shape, 16 TMJs with lateral or medial pole depression, six TMJs with posterior condylar surface flattening and three TMJs with a bifid‑shaped condyle.[35] The prevalence of osteoarthritic bony changes observed by these authors was higher than that observed in the present study and lower than the results reported by Cevidanes *et al*.[36] These authors indicated condylar flattening in 60% of cases and osteoarthritic surface irregularities, such as erosions and osteophytes, in 40% of condyles in painful TMJs. As we examined patients attending the clinic for different complaints using CBCT examination, the results obtained in the present study were lower, but the distribution in the rates of bony changes was consistent with other studies.

Conclusion

There is a degenerative bone alteration in TMJs, which occurs more frequently in women and in the right condyle. The prevalence of degenerative bone changes increased with age, particularly in individuals aged 60 years and older. Flattening, erosion and bone cavity are the most prevalent types of degenerative bone changes observed.

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Nil.

Conflicts of interest
There are no conflicts of interest.

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