

Degenerative changes of the mandibular condyle in relation to the temporomandibular joint space, gender and age: A multicenter CBCT study

Cansu Görürgöz^{1,A–F}, Murat İçen^{2,B,C,E,F}, Mehmet Hakan Kurt^{3,A,B,D–F}, Seçil Aksoy^{4,B,C,E,F}, Batuhan Bakırarar^{5,A,C,D,F}, Ingrid Rozylo-Kalinowska^{6,A,D–F}, Kaan Orhan^{3,6,A,D–F}

¹ Department of Dentomaxillofacial Radiology, Faculty of Dentistry, Bursa Uludağ University, Turkey

² Department of Dentomaxillofacial Radiology, Faculty of Dentistry, Nevşehir Hacı Bektaş Veli University, Turkey

³ Department of Dentomaxillofacial Radiology, Faculty of Dentistry, Ankara University, Turkey

⁴ Department of Dentomaxillofacial Radiology, Faculty of Dentistry, Near East University, Mersin, Turkey

⁵ Department of Biostatistics, School of Medicine, Ankara University, Turkey

⁶ Department of Dental and Maxillofacial Radiodiagnostics, Medical University of Lublin, Poland

A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation;

D – writing the article; E – critical revision of the article; F – final approval of the article

Dental and Medical Problems, ISSN 1644-387X (print), ISSN 2300-9020 (online)

Dent Med Probl. 2023;60(1):127–135

Address for correspondence

Cansu Görürgöz

E-mail: cansugorurgoz@uludag.edu.tr

Funding sources

None declared

Conflict of interest

None declared

Acknowledgements

None declared

Received on December 28, 2021

Reviewed on March 3, 2022

Accepted on March 21, 2022

Published online on March 31, 2023

Cite as

Görürgöz C, İçen M, Kurt MK, et al. Degenerative changes of the mandibular condyle in relation to the temporomandibular joint space, gender and age: A multicenter CBCT study. *Dent Med Probl.* 2023;60(1):127–135. doi:10.17219/dmp/147514

DOI

10.17219/dmp/147514

Copyright

Copyright by Author(s)

This is an article distributed under the terms of the

Creative Commons Attribution 3.0 Unported License (CC BY 3.0)

(<https://creativecommons.org/licenses/by/3.0/>).

Abstract

Background. Cone-beam computed tomography (CBCT) is used to provide multiplanar views of the temporomandibular joint (TMJ) bone components as well as TMJ pathologies without superposition, magnification or distortion.

Objectives. The study aimed to analyze degenerative changes in the condylar surface, and their relationship with patient age and gender, and the TMJ space measurements by using CBCT images.

Material and methods. A total of 258 individuals were retrospectively analyzed. The degenerative bone changes of the condylar head were evaluated and classified on the right and left sides. The shortest distances from the anterior, superior and posterior parts of the condylar head to the glenoid fossa were measured to represent the TMJ space. Univariate and multivariate logistic regression analyses then evaluated the effect of age and gender on the presence of degenerative changes.

Results. Condylar flattening was most frequently observed (413 TMJs, 53.5%). However, the presence or absence of the change types did not differ according to the sides. The mean values of the TMJ space measurements on the right and left sides were narrower in the group with changes than in the group without changes. Nonetheless, no statistically significant difference in the TMJ space was found between the groups ($p > 0.05$).

Conclusions. An increased risk of radiographically detectable degenerative alterations in left TMJs was detected for males and for increasing age. Degenerative changes in the condylar surface may affect the dimensions of the TMJ space.

Keywords: temporomandibular joint, cone-beam computed tomography, mandibular condyle, degeneration, age

Introduction

The temporomandibular joint (TMJ) is located between the mandibular condyle (the inferior part of the TMJ) and the glenoid fossa of the temporal bone (the superior part of the TMJ) and is considered to be the most complex articular system in the human body. The TMJ can move on different orthogonal planes with a balanced, dynamic, and complex mechanism.^{1,2}

The optimal condylar head position in the glenoid fossa is one of the most discussed subjects in dentistry. Despite the occlusion being detected directly intraorally, the condylar position in the fossa cannot be interpreted with the naked eye. However, the joint space dimensions could determine the ideal position of the condyle in the glenoid fossa. Indeed, the joint space is a commonly used radiological term to describe the radiolucent region between the condylar head and the temporal bone.³

Temporomandibular disorder (TMD) is a general term to describe conditions affecting the masticatory muscles, the TMJ, and related structures, either individually or all at once.⁴ Furthermore, TMD is often associated with disc displacement and degenerative changes that affect soft and/or hard tissues of the TMJ.⁵ Degenerative bone changes in the TMJ are more common in the mandibular condyle than in the glenoid fossa or the articular eminence, which includes various degrees of flattening, erosion, osteophyte formation, sclerosis, and pseudocysts.^{6–9} It is essential to identify these pathologies, as in-depth knowledge of bone changes is necessary for the accurate diagnosis of disease-related dysfunctions and appropriate treatment planning.¹⁰

Radiographic examination is necessary for the proper diagnosis of TMD,¹¹ with many imaging techniques and diagnostic modalities used to examine the joint. TMJ radiography assesses the degree of disease, progress, and treatment response.¹² Meanwhile, panoramic radiography, conventional tomography, helical or multi-slice computed tomography (MSCT), and cone-beam computed tomography (CBCT) are used to evaluate the bony components, while magnetic resonance imaging (MRI) can examine the soft tissues, such as the disc or capsule of the TMJ.¹³

CBCT is reported to be more useful for detecting condylar surface pathologies than conventional imaging modalities. Indeed, the superimposing of structures in conventional radiography could result in misdiagnosis due to poor radiographic evaluation.^{6,7} The Diagnostic Criteria for TMD (DC/TMD) indicate that CT imaging is required for determining degenerative joint disease.¹⁴ However, the relatively high radiation dose and cost limit CT use for TMJ examination.¹⁵ Recently, CBCT imaging has been used as an alternative method for evaluating the TMJ bone components in all three dimensions without superimposition and structural distortion.¹⁶

This study aimed to analyze degenerative condylar changes and to determine the possible relationship between degenerative condylar changes and age, sex, side (right/left), and joint space distances.

Material and methods

Study design

The local Research Ethics Committee approved the protocol of this multicenter study (No.: 14/3 and Ref.: 36290600/124), and the study complied with the 1964 Declaration of Helsinki ethical guidelines.

The digital images of patients who underwent CBCT examination at the Dentomaxillofacial Radiology Departments of Ankara University, Zonguldak Bülent Ecevit University, and the Near East University for various reasons from 2013 to 2019 were retrospectively analyzed. The CBCT records of the bilateral TMJs of 258 individuals (148 females and 110 males) aged 8–82 years (mean age: 39.81 ± 15.6 years) were evaluated.

The study included CBCT images with completely visible bilaterally TMJs, all posterior teeth present, degenerative condylar changes in at least one TMJ, and cases without a history of systemic diseases. Exclusion criteria for the study included low-quality images, images with radiologic signs of metabolic bone disease, noticeable periodontal diseases, prosthetic restorations, a history of orthodontic treatment, disorders that may affect joint morphology such as rheumatoid arthritis, a history of surgery, trauma, cyst, or tumor in the maxillofacial region, and congenital or developmental disorders.

Imaging procedures

All CBCT scans were performed based on local imaging protocols. The technical parameters and dedicated software of the CBCT units used are presented in Table 1.

CBCT evaluation

A single informed and calibrated specialist in dental radiology (CG with 6 years of experience, Mİ and SA with more than 10 years of experience) analyzed images at each center. A standard positioning was defined before the evaluation, and the examiners placed each image in that position.

Adjustments to the CBCT images ensured that the vertical reference line ran through the patient's midsagittal plane in the axial and coronal views. The hard palate was oriented in the sagittal view so that the horizontal reference line was positioned through the anterior and posterior nasal spine. The tool "TMJ module" was activated. When the largest mediolateral width of the condylar process was visible in the axial plane, paracoronal and

Table 1. Technical parameters and software programs of the cone-beam computer tomography (CBCT) devices used

		CBCT device		
		ProMax®3D Max	NewTom 3G®	Veraviewepocs 3D®
Technical parameters	FOV size	130 × 55 mm, 230 ×160 mm	12-inch	40 × 80 mm
	voxel size	0.200 mm³, 0.400 mm³	0.300 mm³	0.125 mm³
	kVp	96	120	90
	mA	8–12	3–5	5
	scan time [s]	9–15	–	9.4
Software program		Romexis 3.7	NNT 3.0	3D Tomo X
Vendor		Planmeca Oy	Quantitative Radiology	IORB
Monitor	NEC MultiSync 21.3-inch flat-panel 2048 × 2560 pixel resolution		Nio Color 3MP 2048 × 1536 pixel resolution	EIZO RadiForce MS230W 23-inch LCD monitor
	Sharp NEC Display Solutions		Barco	Eizo Nanao Corporation

FOV – field of view.

ProMax 3D Max by Planmeca Oy, Helsinki, Finland; NewTom 3G by Quantitative Radiology, Verona, Italy; Veraviewepocs 3D by J. Morita MFG Corp., Kyoto, Japan.

parasagittal cross-sectional slices were obtained for qualitative and quantitative analysis (Fig. 1).

Records for each patient included age, sex, degenerative alteration types, and TMJ space measurements. Bone changes were detected in at least two consecutive sections to avoid misinterpretations, and images were excluded when all examiners doubted the classification.

Diagnostic classification of degenerative changes in the condylar surface

Previously reported definitions of flattening (Fig. 2A), sclerosis (Fig. 2B), erosion (Fig. 2C), osteophytes (Fig. 2D), subchondral cyst (Ely's cyst) (Fig. 2E), ankylosis (Fig. 2F), and loose joint bodies (Fig. 2G), evaluated degenerative changes of the condylar head.^{17,18}

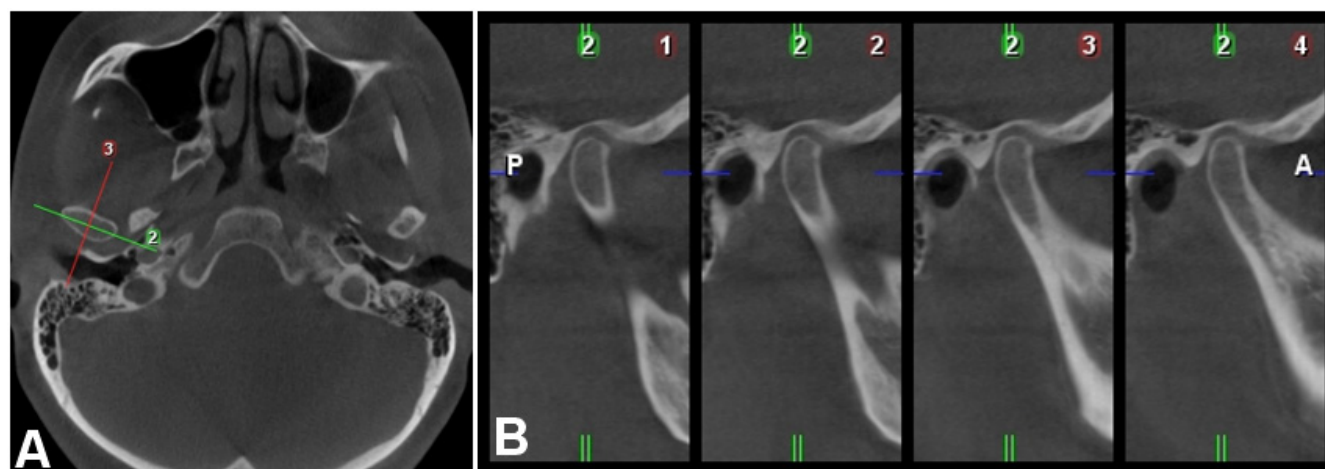


Fig. 1. A – axial image showing the largest mediolateral length of the condyle; parasagittal slice of the condyle (green line) and parasagittal slice of the condyle (red line); B – parasagittal reconstruction of the temporomandibular joint (TMJ) in maximum intercuspation

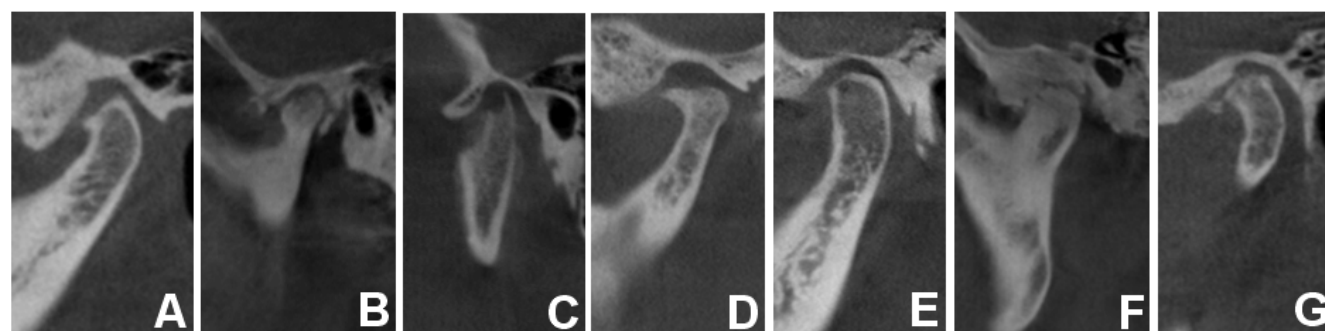


Fig. 2. Classification of degenerative bone changes

A – flattening; B – sclerosis; C – erosion; D – osteophyte; E – subchondral cyst; F – ankylosis; G – loose joint bodies.

The TMJs were classified into 2 groups: (1) without-change (when the condyles had a smooth, clear cortical bone surface); and (2) with-change (flattening, erosion, osteophytes, sclerosis, subchondral cyst, ankylosis, and/or loose joint bodies).

TMJ space measurements

The TMJ space calculations used dedicated software programs on the central parasagittal view, with a horizontal line parallel to the palatine plane used as the reference line. Linear measurements were made at selected points of the glenoid fossa and the condylar head at the short-



Fig. 3. Measurement of the joint spaces in the central parasagittal view
The distance between the most superior surface of the condylar head and the top point of the glenoid fossa (S) on the horizontal plane was measured as the Sjs. Two tangent lines (dashed lines) were drawn from the S point to the most prominent part of the anterior and posterior condylar head. The shortest distances between these points and the fossa wall (A and P) were measured as Ajs and Pjs, respectively. Ajs – anterior joint space; Sjs – superior joint space; Pjs – posterior joint space; PP – palatine plane.

est distances. All landmarks used for measurements are presented in Fig. 3.

Statistical analysis

All statistical analyses employed SPSS Statistics for Windows, v. 11.5 (IBM Corp., Armonk, USA). Student's *t* test compared normally distributed variables between the TMJ groups, with the Mann–Whitney *U* test applied to non-normally distributed data. Meanwhile, McNemar's test assessed differences in the right and left sides between the 2 groups. Logistic regression analyses determined the relationship between the risk factors and the occurrence of degenerative bone changes. A *p*-value <0.05 was considered statistically significant.

Results

Table 2 shows the frequency distribution of degenerative alterations in condyle based on gender and side. Degenerative bone changes were detected in the 467 TMJs (232 TMJs-right and 235 TMJs-left, respectively). A total of 209 of the 258 cases had bilateral condylar bone changes, with the remaining 49 individuals showing unilateral bone changes (26 on the right side and 23 on the left side). According to McNemar's test, there was no significant difference in the degenerative change types between the right and left sides of the TMJ (*p* = 0.668).

Table 3 outlines the absence or presence of condylar bone alterations according to joint space measurements. The mean values of anterior joint spaces (Ajs) and superior joint spaces (Sjs) of the right TMJs, as well as Ajs, Sjs, and posterior joint spaces (Pjs) of the left TMJs were smaller in the with-change group than in the without-change group. However, there was no statistically significant association between the presence of degenerative changes and joint space measurements.

Table 2. Distribution of degenerative bone changes according to gender and side

Degenerative changes		Right side			Left side		
		F	M	Total	F	M	Total
Presence of degenerative bone changes*	without change	14 (9.5)	12 (10.9)	26 (10.1)	19 (12.8)	4 (3.6)	23 (8.9)
	with change	134 (90.5)	98 (89.1)	232 (89.9)	129 (87.2)	106 (96.4)	235 (91.1)
	Total	148 (100)	110 (100)	258 (100)	148 (100)	110 (100)	258 (100)
Types of degenerative bone changes**	Flattening	116 (51.1)	89 (55.3)	205 (52.8)	119 (54.8)	89 (53.3)	208 (54.2)
	Sclerosis	28 (12.3)	15 (9.3)	43 (11.1)	25 (11.5)	12 (7.19)	37 (9.64)
	Erosion	44 (19.4)	42 (26.1)	86 (22.2)	41 (18.9)	42 (25.1)	83 (21.6)
	Osteophyte	24 (10.6)	10 (6.2)	34 (8.76)	21 (9.68)	18 (10.8)	39 (10.2)
	Subchondral cyst	11 (4.8)	2 (1.2)	13 (3.35)	6 (2.76)	3 (1.8)	9 (2.34)
	Ankylosis	0 (0)	3 (1.9)	3 (0.77)	1 (0.46)	1 (0.6)	2 (0.52)
	Loose joint bodies	4 (1.8)	0 (0)	4 (1.03)	4 (1.84)	2 (1.2)	6 (1.56)
	Total	227 (100)	161 (100)	388 (100)	217 (100)	167 (100)	384 (100)

Data presented as number (percentage) (n (%)). * number of patients; ** number of temporomandibular joints (TMJs); F – female; M – male.

Table 3. Comparison of the temporomandibular joint (TMJ) spaces between the groups with and without changes

Joint space measurements [mm]	Right-side degenerative changes				<i>p</i> -value
	without changes		with changes		
	<i>M</i> ± <i>SD</i>	<i>Me</i> (min–max)	<i>M</i> ± <i>SD</i>	<i>Me</i> (min–max)	
Ajs	2.34 ±0.71	2.20 (1.44–4.16)	2.25 ±0.97	2.07 (0.57–7.77)	0.396 ^b
Sjs	3.35 ±0.82	3.27 (1.80–5.34)	3.26 ±1.30	3.22 (0.72–10.19)	0.559 ^b
Pjs	2.18 ±0.80	2.25 (0.57–4.88)	2.18 ±0.95	2.00 (0.60–8.05)	0.665 ^b
Joint space measurements [mm]	Left-side degenerative changes				<i>p</i> -value
	without changes		with changes		
	<i>M</i> ± <i>SD</i>	<i>Me</i> (min–max)	<i>M</i> ± <i>SD</i>	<i>Me</i> (min–max)	
Ajs	2.36 ±0.97	2.23 (0.89–4.47)	2.28 ±1.00	2.15 (0.47–7.73)	0.609 ^b
Sjs	3.40 ±1.16	3.57 (1.20–5.58)	3.34 ±1.25	3.22 (0.30–7.20)	0.821 ^a
Pjs	2.12 ±0.82	2.02 (0.89–4.10)	2.10 ±0.85	2.00 (0.57–6.99)	0.820 ^b

M – mean; *SD* – standard deviation; *Me* – median; min – minimum; max – maximum; ^a Student's *t* test; ^b Mann–Whitney *U* test.

Table 4 presents the prevalence of the degenerative change types on the right and left sides. The most common degenerative bone changes were flattening, erosion, and sclerosis, for the right and left sides. Meanwhile, ankylosis and loose joint bodies were the least common degenerative changes. The presence or absence of the change types did not differ between the left and right sides.

The univariate associations of degenerative bone changes with age and gender were analyzed. Increasing age and being male had a significant association, but only on the left side ($p = 0.004$ and $p = 0.022$, respectively) (Table 5). In the multivariate analysis, male gender and increasing age (odds ratio (*OR*): 4.37; 95% confidence interval (*CI*): 1.40–13.63; $p = 0.011$) had a significant association with left-sided degenerative changes (Table 6).

Table 4. Distribution and comparison of the type of degenerative changes according to side

	Type of change	present	Left TMJ				<i>p</i> -value
			no		yes		
			<i>n</i>	%	<i>n</i>	%	
Right TMJ	Flattening	no	13	24.5	40	75.5	0.731 ^a
		yes	36	17.6	169	82.4	
	Sclerosis	no	194	90.2	21	9.8	0.471 ^a
		yes	27	62.8	16	37.2	
	Erosion	no	133	77.3	39	22.7	0.824 ^a
		yes	42	48.8	44	51.2	
	Osteophyte	no	196	87.5	28	12.5	0.576 ^a
		yes	23	67.6	11	32.4	
	Subchondral cyst	no	236	96.3	9	3.7	0.523 ^a
		yes	13	100.0	0	0.0	
	Ankylosis	no	253	99.2	2	0.8	1.000 ^a
		yes	3	100.0	0	0.0	
	Loose joint bodies	no	248	97.6	6	2.4	0.754 ^a
		yes	4	100.0	0	0.0	

n – number of TMJs; ^a McNemar's test.

Table 5. Univariate logistic regression analysis for the presence of degenerative bone changes

Variables (Reference)		β	<i>SE</i>	<i>p</i> -value	<i>OR</i>	95% <i>CI</i>
Right TMJs	Age	0.017	0.014	0.209	1.018	0.990–1.046
	Gender (M)	0.159	0.415	0.702	1.172	0.519–2.645
Left TMJs	Age	0.052	0.018	0.004*	1.053	1.017–1.090
	Gender (M)	1.300	0.568	0.022*	3.669	1.205–11.171

β – beta coefficient; *SE* – standard error; *OR* – odds ratio; *CI* – confidence interval; * statistically significant ($p < 0.05$).

Table 6. Multivariate logistic regression analysis for the presence of degenerative bone changes on the left side

Variables (Reference)	β	SE	p-value	OR	95% CI
Constant	-0.076	0.642	0.906	–	–
Age	0.057	0.018	0.002*	1.059	1.021–1.098
Gender (F)	1.474	0.581	0.011*	4.368	1.400–13.628

* statistically significant ($p < 0.05$).

Discussion

Osteoarthritis has been described as a low-inflammatory degenerative disorder that initially affects the articular cartilage and subcondylar bone, then causes destructive changes in the cortical and subcortical bone areas. Furthermore, osteoarthritis appears to be a common degenerative and destructive joint change due to primary and secondary trauma or other acute or chronic extreme conditions.¹⁹

Larheim and Westesson described osteoarthritis as prominent inflammatory findings on MRI, whereas osteoarthrosis refers to joints without such symptoms.²⁰ Osteoarthritis leads to bone deformation, including subcortical cysts, surface erosion, osteophytes, and sclerosis. However, osteoarthritis requires more specific and detailed diagnostic guidelines with the increasing use of CBCT.¹⁸

Several studies have reported the variable prevalence rates of structural TMJ alterations.^{8,9,17,21–23} Koyama et al. examined condylar bone changes in 516 patients with TMD using helical CT and detected changes in 617 (63.7%) of 1032 joints.⁹ Also, Koç found that 67.3% of the retrospectively evaluated patients presented one or more osseous TMJ changes on CBCT images.²¹ Meanwhile, Pontual et al. examined the CBCT scans of patients with clinical symptoms or signs of TMJs and found TMJ bone alterations in 227 (71%).²² Cho and Jung examined CBCT images for osteoarthritic changes of the TMJ in Korean children and adolescents and found that TMJ osteoarthritis was much higher in symptomatic cases (26.8%) than in asymptomatic cases (9.9%).⁸ Moreover, Borahan et al. revealed osteoarthritic changes (17.9%) and developmental changes (2.6%) in the CBCT images of 795 patients.¹⁷ Walewski et al. reported a higher prevalence (52.3%) of degenerative TMJ changes in asymptomatic groups,²³ with similar results presented by Krisjane et al. (42.7%).²⁴ These reported differences may be due to variations in patient selection, imaging techniques, or evaluation criteria. The current study detected osteoarthritic alterations in 91.1% ($n = 235$) and 89.9% ($n = 232$) of the left and right joints, respectively. Such high rates were achieved as all images had an osseous alteration on at least one side.

There are disagreements about whether clinical symptoms affect the radiographic evidence of TMJ osteoarthritis. Indeed, some studies have reported a poor correlation between TMJ osteoarthritis and signs and

symptoms of TMD.^{25,26} Wiese et al. did not find any relationship between radiographic findings and pain-related variables.²⁷ In contrast, Kurita et al. mentioned that TMJ pain was associated with mandibular function and osteoarthritic alterations in the articular surface.²⁸ Radiographic examinations have an essential role in evaluating bone changes in the TMJ. Some of these changes can be due to age-related remodeling mechanisms or physiological responses without clinical signs, as radiographs indicate the effect of a previous process and not ongoing processes.²⁹ Therefore, radiographic findings may not always correlate with the clinical situation. In this regard, the current study did not assess the clinical findings of the patients as it was designed to assess the types of degenerative changes of the condyle and to investigate the association between joint space and condylar alterations.

Some authors have reported a correlation between degenerative changes and increased age. Koç reported a significantly higher mean patient age with findings of osseous changes in the TMJ compared to those without any changes.²¹ According to Pontual et al., advanced age is related to having more frequent degenerative bone changes, and bone alterations occur more commonly in females.²² Alexiou et al. showed that older patients had more frequent bone changes than younger individuals.³⁰ Similarly, Borahan et al. reported increased TMJ degenerative changes in individuals over 60 years, which were more common in females than in males.¹⁷ However, several studies found no association between age and osseous alterations.^{22,23,30–32} Cho and Jung evaluated symptomatic and asymptomatic children and adolescents and found no significant difference between the children and adolescents.⁸ Nonetheless, the older age group had a higher prevalence of degenerative changes. In addition, Crusoe-Rebello et al.³¹ and Isberg et al.³² concluded that there was no relationship between older age and the incidence of bone alterations. The present study found no correlation between age and degenerative changes in the right TMJ, whereas aging was a risk factor for condylar alterations on the left side. The difference may be related to an unbalanced distribution of biomechanical stress on TMJs caused by chewing side preferences. During mastication, bilateral usage is necessary, but unilateral predominance is a well-known and relatively consistent phenomenon.³³ However, due to its retrospective design, this study did not include information related to parafunctional activity and chewing side preferences.

It is widely accepted that females are more likely to develop TMDs, with several studies revealing more frequent osteoarthritic changes in female patients, which is mainly due to hormonal differences between genders.^{21,22,28,29} In contrast, some authors found no gender-based differences.^{23,24} In research by Cho and Jung, the prevalence of osteoarthritic changes was higher for males in the symptomatic group, while no significant gender differences were observed in the asymptomatic group.⁸ The current study detected an increased risk of condylar degenerative changes in males with increasing age. However, the results may be associated with gender differences in willingness to seek help and may reflect the true predilection. Indeed, treatment-seeking rates may be lower in males than females, with the former only visiting the clinic at an advanced stage of the disease.

Borahan et al. reported a more common distribution of osteoarthritic changes on the right side, which could reflect individuals' chewing side preference.¹⁷ However, Koç²¹ and Pontual et al.²² observed a higher prevalence of bone changes on left TMJs, but this difference was not significant. Similarly, this study showed no significant difference in degenerative changes between the sides.

In the current study, flattening, erosion, sclerosis, and osteophyte lesions predominated on both sides. These findings are in line with Güler et al., who scanned patients with bruxism using MRI.³⁴ A similar result was also outlined in a CBCT study by Alexious et al., who found that erosion, flattening, and osteophytes were predominant, but sclerosis was the least common lesion.³⁰ Meanwhile, Koç evaluated bone changes in the condylar head, articular fossa, and articular eminence and revealed more frequent osseous changes in the condyle than in temporal bone components.²¹ In that CBCT study, flattening was the most common finding for condylar head and articular eminence, but erosion in the articular fossa was more frequent.²¹ Indeed, flattening is the most frequently detected degenerative feature reported in the literature.^{7,21,22,29,30,35} These results can be explained by the probability that flattening indicates an adaptive change, with the early finding of progressive disease or alteration secondary to internal derangement. Also, it can be related to the mechanical (masseter and temporal muscles) overloading of the TMJ.²² However, the imaging findings reported from other studies disagree with this result. Cho and Jung concluded that the most frequent radiographic findings were erosion (15.6%) and sclerosis (5.4%) for the symptomatic and asymptomatic groups, respectively.⁸ These authors also found that erosion was found more frequently in patients with pain and limited mouth opening. Nah et al. evaluated 220 TMJ patients using CBCT, and the most common finding was sclerosis (30.2%), followed by erosion (29.3%), flattening (25.5%), and osteophytes (8.0%).¹⁸ Meanwhile, Mani and Sivasubramanian detected erosion as the most predominant change.³⁵ The discrepancy between findings may

result from imaging technique differences, racial/ethnic diversity, age groups, and/or diagnostic criteria.

Structural changes may indicate different stages of degenerative joint disease. Erosion findings can correspond to acute changes and is a sign of the TMJ being in an unstable state and changes occurring on the bone surface. Flattening and osteophyte formation are detected in the advanced stage of the disease. Indeed, osteophytes, flattening, and sclerosis formations indicate the adaptation of the body to repair the joint.³⁶

Panchbhai reported different TMJ space analysis methods and their comparisons and associations with other parameters in a review article.³⁷ Meanwhile, Koç classified measurements of less than 1.5 mm in all directions (anterior, superior, and posterior) of the TMJ as reduced joint space.²¹ Furthermore, the research found a statistically significant difference between the mean age and joint space narrowing. It was concluded that joint narrowing accompanied osseous changes in the TMJ.²¹ The current study found narrower joint space values in the with-change group than in the without-change group, though the difference was not statistically significant. Similarly, Tsuruta et al. found no significant difference in Ajs or Pjs measurements, neither between the presence and absence of bone change nor between the bone-change subgroups.³⁸ In addition, the joint space measurements were not categorized as continuous variables since there was no clinical or prognostic reason for this.

It has been reported that the TMJ space could be regarded as a diagnostic metric for TMD.³⁹ However, the bone changes that might occur are not very predictable in an altered joint space or vice versa. To better understand this relationship, the disc position must be one of the parameters evaluated in future studies.

A potential limitation of the study is that the findings do not explain the longitudinal alterations in the condyle due to the study's observational design. In addition, the observational design limits the degree of the cause-and-effect relationships. Furthermore, degenerative lesion-type frequency without clinical symptoms was described due to the study's retrospective design. Moreover, changes in the other osseous structures of the TMJ were out of the scope of the present study. Even though degenerative changes in the condyle are more common than articular eminence,²¹ their relationship to alterations is still unclear.

Conclusions

Flattening, erosion, and sclerosis were the most common degenerative changes in the articular surface of the condyle. Degenerative condylar changes may affect the dimensions of the TMJ spaces. Increasing age and being male was associated with radiographically detectable degenerative findings in the mandibular condyle. Further longitudinal studies are needed to investigate these findings.

Ethics approval and consent to participate

The local Research Ethics Committee approved the protocol of this multicenter study (No.: 14/3 and Ref.: 36290600/124), and the study complied with the 1964 Declaration of Helsinki ethical guidelines.

Data availability

The datasets generated and/or analyzed during the current study are not publicly available, because they contain information that could compromise the privacy of research participants.

Consent for publication

Not applicable.

ORCID iDs

Cansu Görürgöz  <https://orcid.org/0000-0002-3083-1660>
Murat İçen  <https://orcid.org/0000-0002-2779-5646>
Mehmet Hakan Kurt  <https://orcid.org/0000-0001-8312-5674>
Seçil Aksoy  <https://orcid.org/0000-0002-6400-4911>
Batuhan Bakırarar  <https://orcid.org/0000-0002-5662-8193>
Ingrid Rozylo-Kalinowska  <https://orcid.org/0000-0001-5162-1382>
Kaan Orhan  <https://orcid.org/0000-0001-6768-0176>

References

- Okeson JP. *Management of Temporomandibular Disorders and Occlusion*. 7th ed. St Louis, MO: Elsevier Health Sciences; 2014:4–5.
- Katsavrias EG. Changes in articular eminence inclination during the craniofacial growth period. *Angle Orthod*. 2002;72(3):258–264. doi:10.1043/0003-3219(2002)072<0258:CAEID>2.0.CO;2
- Mallya SM, Lami EW. *White and Pharoah's Oral Radiology. Principles and Interpretation*. 8th ed. St Louis, MO: Elsevier; 2019:580.
- Suvinen TI, Reade PC, Kemppainen P, Kononen M, Dworkin SF. Review of aetiological concepts of temporomandibular pain disorders: Towards a biopsychosocial model for integration of physical disorder factors with psychological and psychosocial illness impact factors. *Eur J Pain*. 2005;9(6):613–633. doi:10.1016/j.ejpain.2005.01.012
- Emshoff R, Puffer P, Rudisch A, Gassner R. Temporomandibular joint pain: Relationship to internal derangement type, osteoarthritis, and synovial fluid mediator level of tumor necrosis factor- α . *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2000;90(4):442–449. doi:10.1067/moe.2000.108801
- Talaat W, Al Bayatti S, Al Kawas S. CBCT analysis of bony changes associated with temporomandibular disorders. *Cranio*. 2015;34(2):88–94. doi:10.1179/2151090315Y.0000000002
- Campos MI, Campos PS, Cangussu MC, Guimaraes RC, Line SR. Analysis of magnetic resonance imaging characteristics and pain in temporomandibular joints with and without degenerative changes of the condyle. *Int J Oral Maxillofac Surg*. 2008;37(6):529–534. doi:10.1016/j.ijom.2008.02.011
- Cho BH, Jung YH. Osteoarthritic changes and condylar positioning of the temporomandibular joint in Korean children and adolescents. *Imaging Sci Dent*. 2012;42(3):169–174. doi:10.5624/isd.2012.42.3.169
- Koyama J, Nishiyama H, Hayashi T. Follow-up study of condylar bony changes using helical computed tomography in patients with temporomandibular disorder. *Dentomaxillofac Radiol*. 2007;36(8):472–477. doi:10.1259/dmfr/28078357
- Emshoff R, Rudisch A, Innerhofer K, Bösch R, Bertram S. Temporomandibular joint internal derangement type III: Relationship to magnetic resonance imaging findings of internal derangement and osteoarthritis. An intraindividual approach. *Int J Oral Maxillofac Surg*. 2001;30(5):390–396. doi:10.1054/ijom.2001.0068
- Librizzi ZT, Tadinada AS, Valiyaparambil JV, Lurie AG, Mallya SM. Cone-beam computed tomography to detect erosions of the temporomandibular joint: Effect of field of view and voxel size on diagnostic efficacy and effective dose. *Am J Orthod Dentofacial Orthop*. 2011;140(1):e25–e30. doi:10.1016/j.ajodo.2011.03.012
- Yadav S, Palo L, Mahdian M, Upadhyay M, Tadinada A. Diagnostic accuracy of 2 cone-beam computed tomography protocols for detecting arthritic changes in temporomandibular joints. *Am J Orthod Dentofacial Orthop*. 2015;147(3):339–344. doi:10.1016/j.ajodo.2014.11.017
- Barghan S, Tetradis S, Mallya SM. Application of cone beam computed tomography for assessment of the temporomandibular joints. *Aust Dent J*. 2012;1:109–118. doi:10.1111/j.1834-7819.2011.01663.x
- Schiffman E, Ohrbach R, Truelove E, et al.; International RDC/TMD Consortium Network, International Association for Dental Research, Orofacial Pain Special Interest Group, International Association for the Study of Pain. Diagnostic Criteria for Temporomandibular Disorders (DC/TMD) for clinical and research applications: Recommendations of the International RDC/TMD Consortium Network and Orofacial Pain Special Interest Group. *J Oral Facial Pain Headache*. 2014;28(1):6–27. doi:10.11607/jop.1151
- Tsiklakis K, Syriopoulos K, Stamatakis HC. Radiographic examination of the temporomandibular joint using cone beam computed tomography. *Dentomaxillofac Radiol*. 2004;33(3):196–201. doi:10.1259/dmfr/27403192
- Caruso S, Storti E, Nota A, Ehsani S, Gatto R. Temporomandibular joint anatomy assessed by CBCT Images. *Biomed Res Int*. 2017;2017:2916953. doi:10.1155/2017/2916953
- Borahan MO, Mayil M, Pekiner FN. Using cone beam computed tomography to examine the prevalence of condylar bony changes in a Turkish subpopulation. *Niger J Clin Pract*. 2016;19(2):259–266. doi:10.4103/1119-3077.164336
- Nah KS. Condylar bony changes in patients with temporomandibular disorders: A CBCT study. *Imaging Sci Dent*. 2012;42(4):249–253. doi:10.5624/isd.2012.42.4.249
- Milam SB. TMJ osteoarthritis. In: Laskin DM, Greene CS, Hylander WL, eds. *TMDs: An Evidence-Based Approach to Diagnosis and Treatment*. Chicago, IL: Quintessence; 2006:105–123.
- Stegenga B, de Bont LG. TMJ disc derangements. In: Laskin DM, Greene CS, Hylander WL, eds. *TMDs: An Evidence-Based Approach to Diagnosis and Treatment*. Chicago, IL: Quintessence; 2006:125–136.
- Koç N. Evaluation of osteoarthritic changes in the temporomandibular joint and their correlations with age: A retrospective CBCT study. *Dent Med Probl*. 2020;57(1):67–72. doi:10.17219/dmp/112392
- dos Anjos Pontual ML, Freire JS, Barbosa JM, Frazão MA, dos Anjos Pontual A. Evaluation of bone changes in the temporomandibular joint using cone beam CT. *Dentomaxillofac Radiol*. 2012;41(1):24–29. doi:10.1259/dmfr/17815139
- Walewski LÂ, Tolentino ES, Yamashita FC, Iwaki LCV, da Silva MC. Cone beam computed tomography study of osteoarthritic alterations in the osseous components of temporomandibular joints in asymptomatic patients according to skeletal pattern, gender, and age. *Oral Surg Oral Med Oral Pathol Oral Radiol*. 2019;128(1):70–77. doi:10.1016/j.oooo.2019.01.072
- Krisjane Z, Urtane I, Krumina G, Neimane L, Ragovska I. The prevalence of TMJ osteoarthritis in asymptomatic patients with dentofacial deformities: A cone-beam CT study. *Int J Oral Maxillofac Surg*. 2012;41(6):690–695. doi:10.1016/j.ijom.2012.03.006
- Wiese M, Wenzel A, Hintze H, et al. Osseous changes and condyle position in TMJ tomograms: Impact of RDC/TMD clinical diagnoses on agreement between expected and actual findings. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2008;106(2):e52–e63. doi:10.1016/j.tripleo.2008.03.021
- Hiltunen K, Peltola JS, Vehkalahti MM, Närhi T, Ainamo A. A 5-year follow-up of signs and symptoms of TMD and radiographic findings in the elderly. *Int J Prosthodont*. 2003;16(6):631–614. PMID:12475158.
- Wiese M, Svensson P, Bakke M, et al. Association between temporomandibular joint symptoms, signs, and clinical diagnosis using the RDC/TMD and radiographic findings in temporomandibular joint tomograms. *J Orofac Pain*. 2008;22(3):239–251. PMID:18780537.
- Kurita H, Kojima Y, Nakatsuka A, Koike T, Kobayashi H, Kurashina K. Relationship between temporomandibular joint (TMJ)-related pain and morphological changes of the TMJ condyle in patients with temporomandibular disorders. *Dentomaxillofac Radiol*. 2004;33(5):329–333. doi:10.1259/dmfr/13269559

29. Palconet G, Ludlow JB, Tyndall DA, Lim PF. Correlating cone beam CT results with temporomandibular joint pain of osteoarthritic origin. *Dentomaxillofac Radiol.* 2012;41(2):126–130. doi:10.1259/dmfr/60489374
30. Alexiou KE, Stamatakis HC, Tsiklakis K. Evaluation of the severity of temporomandibular joint osteoarthritic changes related to age using cone beam computed tomography. *Dentomaxillofac Radiol.* 2009;38(3):141–147. doi:10.1259/dmfr/59263880
31. Crusoe-Rebello IM, Campos PS, Rubira IR, Panella J, Mendes CM. Evaluation of the relation between the horizontal condylar angle and the internal derangement of the TMJ – a magnetic resonance imaging study. *Pesqui Odontol Bras.* 2003;17(2):176–182. doi:10.1590/s1517-74912003000200015
32. Isberg A, Häggglund M, Paesani D. The effect of age and gender on the onset of symptomatic temporomandibular joint disk displacement. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 1998;85(3):252–257. doi:10.1016/s1079-2104(98)90004-x
33. Koppe T, Schöbel SL, Bärenklau M, Bruchhaus H, Jankauskas R, Kaduk WM. Factors affecting the variation in the adult temporomandibular joint of archaeological human populations. *Ann Anat.* 2007;189(4):320–325. doi:10.1016/j.aanat.2007.02.018
34. Güler N, Yatmaz PI, Ataoglu H, Emlik D, Uckan S. Temporomandibular internal derangement: Correlation of MRI findings with clinical symptoms of pain and joint sounds in patients with bruxing behavior. *Dentomaxillofac Radiol.* 2003;32(5):304–310. doi:10.1259/dmfr/24534480
35. Mani FM, Sivasubramanian SS. A study of temporomandibular joint osteoarthritis using computed tomographic imaging. *Biomed J.* 2016;39(3):201–206. doi:10.1016/j.bj.2016.06.003
36. Wiberg B, Wanman A. Signs of osteoarthritis of the temporomandibular joints in young patients: A clinical and radiographic study. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 1998;86(2):158–164. doi:10.1016/s1079-2104(98)90118-4
37. Panchbhai AS. Temporomandibular joint space. *Indian Journal of Oral Health and Research.* 2017;3(2):47–56. doi:10.4103/ijohr.ijohr_37_17
38. Tsuruta A, Yamada K, Hanada K, et al. The relationship between morphological changes of the condyle and condylar position in the glenoid fossa. *J Orofac Pain.* 2004;18(2):148–155. PMID:15250435.
39. Lee YH, Hong IK, An JS. Anterior joint space narrowing in patients with temporomandibular disorder. *J Orofac Orthop.* 2019;80(3):116–127. doi:10.1007/s00056-019-00172-y