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# Assessment of condylar anatomy and degenerative changes in temporomandibular joint disorders – A scoping review

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ABSTRACT

Temporomandibular disorders (TMDs) are a group of conditions that cause pain and dysfunction in the temporomandibular joint (TMJ) and muscles that control mandibular movement. In most cases, the etiology is unclear and is considered multifactorial. Recent research suggests that some forms of TMD could be associated with specific TMJ morphological characteristics. This study aims to provide a review of the reported anatomical and degenerative morphological condylar characteristics of subjects with a clinical diagnosis of TMD as described with the use of CBCT imaging, as well as the detection of potential predisposing anatomical factors. This review was developed and reported in accordance with the PRISMA-ScR Checklist. A comprehensive search was performed in five databases. Reports were screened by two independent reviewers based on preselected inclusion and exclusion criteria. 45 studies were included in this review. The most frequently reported degenerative changes associated with TMD were condylar surface erosion, flattening, osteophytes, and sclerosis. Anatomical characteristics included a small condylar size and a posterior position of the condylar head in the TMJ. The anterosuperior area of the condylar head appears to be the most frequently affected. More studies are required to determine potential specific predisposing anatomical characteristics.

## 1. Introduction

"Temporomandibular joint disorders" (TMDs) is a broad term for a group of facial musculoskeletal conditions involving pain and/or dysfunction of the masticatory muscles, temporomandibular joints (TMJ), and associated anatomical structures[1]. It is the most common type of orofacial pain after dental pain, and the most common symptoms include pain affecting the face, head, TMJ, and/or teeth, limited jaw mobility, and TMJ sounds during function.[2,3] Comorbid conditions are also common, including headaches, fibromyalgia, irritable bowel syndrome, tinnitus, chronic fatigue syndrome, depression, and sleep disorders.[4–8]

Recent studies have demonstrated that the pathophysiology of TMD is biopsychosocial and multifactorial.[9,10] Specific predisposing factors, including genetic, hormonal, functional and anatomical factors, have also been identified.[1,11,12] This is an active field of research and there is a lot of interest in the validation of those factors, as part of the diagnostic protocol, prevention, and treatment of TMD.

Condylar anatomy comprises the shape and size of the condyle head, which is the most superior aspect of the condyle, as well as its position. Condylar position can be determined by the relative dimensions of the radiographic joint spaces between the glenoid fossa and the mandibular condyle.[13] Due to the evolution and wider use of three-dimensional (3D) imaging in the dental field, mainly in the form of Cone Beam Computed Tomography scans (CBCTs), the osseous anatomy of the TMJ area has been a subject of investigation, with one area being the anatomy of the condyle. With the use of CBCTs, it is feasible to visualize and quantify alterations in the anatomy of the mandibular condyles by analyzing various tomographic slices in great detail, with significantly lower radiation dose in comparison to medical computed tomography scans.[14,15] In addition, modern technology, such as the use of 3D surface models, enables a thorough assessment of the overall morphological changes.[16]

The objective of this scoping review is to summarize previously reported anatomical characteristics of the condylar head surface in TMD cases and detect common patterns, as well as potential related predisposing factors.

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## 2. Methods

### 2.1. Protocol

The protocol was developed using the methodological framework for scoping reviews proposed by the Joanna Briggs Institute (https://jbi.global/scoping-review-network/resources) and was registered at the Open Science Framework (OSF): https://osf.io/6qcjg/). The scoping review was reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) extension for scoping reviews checklist.[17]

### 2.2. Eligibility criteria

Eligible articles included human studies, with participants of any age and gender. Only studies including subjects with a reported clinical diagnosis of TMD and CBCT images were included. Investigations of patients with syndromes and/or genetic disorders were excluded from the review. Studies including subjects with systemic, idiopathic, and/or genetic disorders that affect bone metabolism and could be related to TMD were also excluded from this review, as well as studies on ankylosed or fractured condyles, as well as studies focusing only on the asymmetry between condyles were also excluded. Investigations in patients that had any kind of therapeutic or rehabilitating intervention including orthognathic surgery, splint therapy, drug therapy, arthrocentesis, and studies on edentulous subjects were also excluded, as they could have a significant impact on TMD status, bone remodeling, and condylar morphology.

No studies were excluded based on geographic location, racial or gender-based interests, or details about the specific study setting. This review considered both experimental and quasi-experimental study designs including randomized controlled trials, non-randomized controlled trials, before and after studies, and interrupted time-series studies. In addition, analytical observational studies including prospective and retrospective cohort studies, case-control studies and analytical cross-sectional studies were considered for inclusion. This review also considered descriptive cross-sectional studies for inclusion. Only primary research studies were included. Text and opinion papers, narrative reviews, conference abstracts, as well as case reports, and case series were not included in this review. Table 1 provides a more detailed outline of the inclusion/exclusion criteria for article selection.

### 2.3. Information sources and search

To ensure a comprehensive search, the following databases were queried from inception to October 2022: MEDLINE (PubMed), EMBASE (Elsevier), Web of Science Core Collection (Science Citation Index Expanded, 2006-present, and Social Sciences Citation Index, 2006-present; Clarivate), Scopus (Elsevier) and Cochrane Library (Wiley) with the use of English Language filters and the Cochrane human studies hedge applied to MEDLINE and EMBASE.[18] Grey literature and further non-database searching were done using American Doctoral Dissertations (EBSCO), Dissertations and Thesis Global (ProQuest), and a keyword search of Google Scholar that harvested the first 100 results as sorted by relevancy using Harzig's Publish or Perish software.[19] The complete search strategy for all databases and search engines is provided in Supplementary Table A. Duplicates were removed using the Bramer method in EndNote.[20] Upon selection of the eligible studies, two authors (KA, HT) independently reviewed the references for each article included in the review as well as the references of relevant systematic reviews and/or meta-analyses to identify other potentially relevant studies for inclusion. The most recent search was executed on October 20, 2022.

An example search strategy that was used is the PubMed full electronic strategy: ((“Mandibular Condyle”[mesh] OR condyl*[tw]) AND (“Craniomandibular Disorders"[Mesh] OR CMD[tiab] OR TMD[tiab] OR ((TMJ[tiab] OR Temporomandibular[tiab] OR craniomandibular[tiab] OR cranio-mandibular[tiab] OR temporo-mandibular[tiab] OR jaw [tiab]) AND (disorder*[tiab] OR disease*[tiab] OR dysfunction*[tiab] OR pain[tiab])))) NOT ((“animals"[mesh] NOT “humans"[mesh]))

**Table 1**
Inclusion and exclusion criteria for article selection.

| Criteria category | Inclusion criteria | Exclusion criteria |
|---|---|---|
| Outcome | Studies investigating the association between condylar morphology and position with temporomandibular joint disorder with the use of CBCT scans | Investigations:<br>- not relevant to the subject of this study<br>- on ankylosed or fractured condyles<br>- on the asymmetry of condyles<br>- on cortical and trabecular osseous abnormalities |
| Study design | -Randomized controlled clinical trials<br>-Prospective clinical trials<br>-Retrospective clinical trials<br>-Case-control observational studies<br>-Cross-sectional surveys | - Systematic reviews[a]<br>- Meta-analyses[a]<br>- Case series<br>- Case reports<br>- Narrative reviews<br>- Unsupported opinion of expert<br>- Editor's choices<br>- Replies to the author/ editor<br>- Books abstracts<br>- Conferences' abstracts<br>- Ongoing studies<br>- Animal studies<br>- In vitro studies<br>- In silico studies<br>- Studies using imaging modalities other than CBCT |
| Participants' characteristics | Studies included should involve only human subjects of any age and gender. | - Investigations in patients with syndromes, systematic, idiopathic and/or genetic disorders<br>- Investigations in patients that had any kind of therapeutic or rehabilitating intervention including orthodontic treatment, orthognathic surgery, splint therapy, drug therapy, arthrocentesis<br>- Edentulous patients |

[a] After checking the reference lists for relevant studies.

### 2.4. Selection of sources of evidence and data charting process

Two authors (KA, HT) screened the titles and abstracts of the identified articles based on the predefined inclusion and exclusion criteria. If eligibility could not be decided by title or abstract, the full text of the article was retrieved to determine eligibility. In cases of disagreement regarding the inclusion of an article in the review, the issues were resolved through discussion between the first and second authors (KA, HT).

Data was extracted from the studies included in the scoping review by two independent reviewers (KA, HT) using a data extraction tool developed for this study. The extracted data included specific details about the participants, concept, context, study methods and key findings relevant to the review question/s. The draft data extraction tool was modified and revised as a critical appraisal of the studies that were included in the review was not included in the methodology, as this study is not a systematic review but a scoping review.

### 2.5. Data items and synthesis of the results

The data was summarized by one reviewer (KA) and reviewed by a second reviewer (HT). The evidence presented was used to directly respond to the review objectives and questions. The characteristics of the included studies as well as the extracted information from each study are presented in tabular form. A narrative summary accompanied the tabulated results and described how the results were related to the review objective and questions (Tables 2 and 3).

## 3. Results

### 3.1. Selection, characteristics of sources of evidence, and summary results

The initial search identified 14,138 articles. After the removal of the duplicate articles 6378 articles remained for screening. After reviewing titles and abstracts, 75 articles had to be screened with the use of their full text. 43 articles met the review criteria and 2 additional eligible articles[21,22] that were identified via manual search of a relevant systematic review[23] were also included for review, for a total of 45 included articles. Fig. 1 outlines the study selection procedure, including the number of excluded studies and the corresponding reasons for exclusion at the full-text screening stage.

Based on the study type, 15 prospective and 30 retrospective studies were included in this review. Regarding study design, among the prospective studies, 13 were cross sectional studies and 2 were cohort studies. Among the retrospective studies, there were 18 cross sectional, 9 case-control, and 3 cross-sectional case-control studies. Table 2 provides a detailed description of the articles and their characteristics.

### 3.2. Synthesis of results

Publication dates ranged from 2010 to 2022. Regarding the characteristics of the participants, in 34 out of the 45 studies, the number of female participants was significantly larger than that of the male participants and there were 3 studies including only female participants.[24–26] There was significant variation in the age of the participants for each study, with representation of all age groups. In specific, 15 studies included participants from the 10–20 age group, 41 studies included participants from the 20–30 age group, 37 studies included the 30–40 age group and 31 studies included participants over 40 years of age.

Significant differences in the distribution of condylar osseous abnormalities between age groups were described in a study by Jung et al.,[27] with the older group most commonly presenting with three or multiple pathological characteristics, whereas in the younger control group, the most common deformity was subchondral bone alteration or erosion. In another study by Ak and Kose,[28] no relationship was found between age groups and the shape of the condyle.

Based on the outcomes presented in each study, among the 45 studies included in the review, 32 studies investigated the mandibular condylar morphology, whereas 18 studies investigated the relative position of the condyles, and 8 studies investigated both types of outcomes (Table 3).

The most prevalent morphological abnormalities reported were erosion of the condylar head surface head which was reported in 20 studies[22,24,25,27,29–44] and flattening of the condylar head which was reported in 19 studies.[22,24,28,29,31–35,37,38,40–42,44–48] The presence of bone overgrowth in the form of osteophytes was reported in 14 studies,[22,24,25,29–31,35,37–42,48] whereas sclerosis was observed in 12 studies.[21,22,25,29–31,33,37,38,40–42,49] The detection of subcortical cysts was reported in 5 studies,[29,38,40,42,50] whereas significant resorption of the condylar surface was reported in 4 studies.[21,26,45,51] A relatively small condylar head size in relation to the average control size was reported in 5 studies.[26,35,45,50,52] Nevertheless, in two studies no significant morphological abnormalities were detected. These results are summarized in Fig. 2. A.

**Table 2**
Characteristics of the studies included in the scoping review.

| Author, Year | Title | Study Type | Study Design |
|---|---|---|---|
| Abdel-Alim et al., 2020[74] | Validity of cone-beam computed tomography in assessment of morphological bony changes of temporomandibular joints | Retrospective | Cross sectional |
| Aboalnaga et al., 2022[56] | Positional and dimensional TMJ characteristics in different temporomandibular disorders: A cross-sectional comparative study | Prospective | Cross sectional |
| Ak and Köse, 2021[28] | Assessment of morphological alterations of temporomandibular joint articular surfaces in patients with temporomandibular dysfunction | Retrospective | Cross sectional |
| Alfaleh, 2020[64] | Relationship between horizontal condylar angle and radiographically detectable morphological changes of the condyle in asymptomatic and symptomatic patients with TMD | Retrospective | Case-control |
| Alkhader et al. 2012[35] | Cone-beam computed tomography findings of temporomandibular joints with osseous abnormalities | Retrospective | Cross sectional Case-control |
| Alkhader et al., 2010[33] | Diagnostic performance of magnetic resonance imaging for detecting osseous abnormalities of the temporomandibular joint and its correlation with cone beam computed tomography | Retrospective | Cross Sectional |
| Al-Rawi et al., 2017[54] | Spatial analysis of mandibular condyles in patients with temporomandibular disorders and normal controls using cone beam computed tomography | Retrospective | Case-control |
| Arayasantiparb et al., 2020[40] | Association between mandibular condylar position and clinical dysfunction index | Retrospective | Cross sectional |
| Bae et al., 2017[34] | Correlation between pain and degenerative bony changes on cone-beam computed tomography images of temporomandibular joints | Retrospective | Cross Sectional |
| Çakur and Bayrakdar, 2016[31] | No proven correlations between bone quality and degenerative bone changes in the mandibular condyle and articular eminence in temporomandibular joint dysfunction | Retrospective | Cross sectional |

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**Table 2** (*continued*)

| Author, Year | Title | Study Type | Study Design |
|---|---|---|---|
| Cevidanes et al., 2010[24] | Quantification of condylar resorption in temporomandibular joint osteoarthritis | Retrospective | Cross sectional |
| Cevidanes et al., 2014[26] | 3D osteoarthritic changes in TMJ condylar morphology correlates with specific systemic and local biomarkers of disease | Prospective | Cross sectional |
| Cho and Jung, 2012[30] | Osteoarthritic changes and condylar positioning of the temporomandibular joint in Korean children and adolescents | Retrospective | Cross sectional |
| Choudhary et al., 2020[39] | Association of temporomandibular joint morphology in patients with and without temporomandibular joint dysfunction: A cone-beam computed tomography-based study | Retrospective | Cross sectional Case-control |
| da-Silva et al., 2020[22] | Relationship between symptoms and imagological signs of degenerative temporomandibular joint disorders using the research diagnostic criteria for temporomandibular disorders and cone-beam computed tomography | Retrospective | Cross Sectional Observational Study |
| Derwich et al., 2020[50] | Temporomandibular joints' morphology and osteoarthritic changes in cone-beam computed tomography images in patients with and without reciprocal clicking—A case control study | Retrospective | Case-control |
| Emshoff et al., 2016[66] | Condylar erosion in patients with chronic temporomandibular joint arthralgia: A cone-beam computed tomography study | Prospective | Cross sectional |
| Gomes et al., 2015[45] | Diagnostic index of 3D osteoarthritic changes in TMJ condylar morphology | Prospective | Cross sectional |
| Han et al., 2021[51] | A long-term longitudinal study of the osteoarthritic changes to the temporomandibular joint evaluated using a novel three-dimensional superimposition method | Prospective | Cohort |
| Hassan et al., 2021[55] | Radiographical investigation of the condylar position using three-dimensional imaging (a comparative Iraqi study) | Retrospective | Cross sectional |
| Imanimoghaddam et al., 2016[49] | Evaluation of condylar positions in patients with temporomandibular disorders: A cone-beam computed tomographic study | Prospective | Cross sectional |
| Imanimoghaddam et al., 2017[21] | Association between clinical and cone-beam computed tomography findings in patients with temporomandibular disorders | Prospective | Cross sectional |
| Jeon et al., 2021[68] | Analysis of three-dimensional imaging findings and clinical symptoms in patients with temporomandibular joint disorders | Retrospective | Cross sectional |
| Jung et al., 2022[27] | Comparison of clinical and radiological characteristics of temporomandibular joint osteoarthritis in older and young people | Retrospective | Case-control |
| Kattiney de Oliveira et al., 2022[58] | Evaluation of the condylar position in younger and older adults with or without temporomandibular symptoms by using cone beam computed tomography | Prospective | Cross sectional |
| Khojastepour et al., 2017[38] | The association between condylar bone changes revealed in cone beam computed tomography and clinical dysfunction index in patients with or without temporomandibular joint disorders | Retrospective | Cross sectional |
| Kiliç et al., 2015[29] | Temporomandibular joint osteoarthritis: cone beam computed tomography findings, clinical features, and correlations | Prospective | Cohort |
| Lee et al., 2019[42] | Anterior joint space narrowing in patients with temporomandibular disorder | Prospective randomized | Cross sectional |
| Leite-de-Lima et al. 2022[47] | Cone-beam computed tomography analysis of degenerative changes, condylar excursions and positioning and possible correlations with temporomandibular disorder signs and symptoms | Retrospective | Cross sectional |
| Lelis et al. 2017[65] | Cone-beam tomography assessment of the condylar position in asymptomatic and symptomatic young individuals | Prospective | Cross sectional |
| Li et al., 2015[61] | Characteristics of temporomandibular joint in patients with temporomandibular joint complaint | Retrospective | Case-control |
| Ma et al., 2022[67] | A comparative study of condyle position in temporomandibular disorder patients with | Prospective randomized | Cross sectional |

(*continued on next page*)

**Table 2** (*continued*)

| Author, Year | Title | Study Type | Study Design |
|---|---|---|---|
| | chewing side preference using cone-beam computed tomography | | |
| Meral et al., 2023[57] | Evaluation of the temporomandibular joint morphology and condylar position with cone-beam computerized tomography in patients with internal derangement | Prospective | Cross sectional |
| Mohamed et al., 2022[52] | Analysis of the relationship between condylar changes and anterior disc displacement with reduction: a preliminary study | Prospective | Cross sectional |
| Nah, 2012[37] | Condylar bony changes in patients with temporomandibular disorders: a CBCT study | Retrospective | Cross sectional |
| Paknahad and Shahidi, 2015[62] | Association between mandibular condylar position and clinical dysfunction index | Retrospective | Cross-sectional |
| Paknahad et al., 2015[53] | Cone-Beam computed tomographic assessment of mandibular condylar position in patients with temporomandibular joint dysfunction and in healthy subjects | Retrospective | Case-control |
| Shokri et al., 2019[60] | Comparative assessment of condylar position in patients with temporomandibular disorder (TMD) and asymptomatic patients using cone-beam computed tomography | Retrospective | Case-control |
| Su et al., 2014[44] | Correlation between bony changes measured with cone beam computed tomography and clinical dysfunction index in patients with temporomandibular joint osteoarthritis | Retrospective | Cross Sectional |
| Talaat et al., 2016[48] | CBCT analysis of bony changes associated with temporomandibular disorders | Retrospective | Case-control |
| Tsai et al., 2021[25] | Differences between the temporal and mandibular components of the temporomandibular joint in topographic distribution of osseous degenerative features on cone-beam computerized tomography | Retrospective | Cross sectional |
| Ulay et al., 2020[32] | Evaluation of the relationship between the degenerative changes and bone quality of mandibular condyle and articular eminence in temporomandibular disorders by cone beam computed tomography | Retrospective | Cross sectional Case-control |
| Verma et al., 2016[41] | Assessment of joint space and arthritic changes in temporomandibular joint as visualized on cone beam computed tomography scan | Retrospective | Case-control |
| Yasa and Akgül, 2018[59] | Comparative cone-beam computed tomography evaluation of the osseous morphology of the temporomandibular joint in temporomandibular dysfunction patients and asymptomatic individuals | Prospective | Cross sectional |
| Yuan et al., 2022[46] | Correlation of clinical manifestations and condylar morphology of patients with temporomandibular degenerative joint diseases | Retrospective | Cross Sectional |

Details regarding the topography of the morphological abnormalities were reported in 7 studies.[25,26,28,41,44,45,51,53] According to the results of these studies, resorption was most frequently reported on the superior part of the condylar head.[41,45,51] The antero-superior and postero-superior surfaces were also reported as most frequently affected.[41,44] Significant fattening of the lateral pole was reported in two studies.[26,45] More details with regards to the location of shape changes were described in a study by Yuan et al.[46] who concluded that TMD affected condyles are concavo-convex in the axial plane in 69 % of the cases, convex in the frontal plane in 50 % of the cases and anteriorly flattened in the sagittal plane in 47 %. Shape-related results were also reported in a study by Ak et al.,[28] according to which sagittal-oval and coronal-flattened condyles were seen more frequently than other shapes. Nevertheless, no statistically significant differences were observed in the topographic distribution of different osseous degenerative features, but surface erosion at the central portion was significantly higher than the lateral portion in a study by Tsai et al.[25]

Results associated with the position of the condyles were included in 17 of the included studies and were characterized by variability.[21,29,30,44,47,49,54–62] A more posterior position of the condyles in comparison to normal controls was reported in half of these studies.[30,35,47,50,57,59,60,62] Similarly, enlarged anterior joint space in TMD cases in comparison to controls was reported in the results of another 3 studies.[49,54,63] In a study by Aboalnaga et al.[56] a more posterior and superior position of the condyles was detected in a group of subjects with TMD with disk displacement in comparison to a TMD myalgia group, with no control group included in their study design. A more superior position in relation to controls was detected in a study by Meral et al.,[57] whereas a more increased anterosuperior joint space was reported in another study by Li et al.[61] No significant association between TMD signs and/or symptoms and changes in the position of the condyles were reported in 4 studies.[21,44,53,58] These results are summarized in Fig. 2. B.

Sexual dimorphism was examined in 10 studies,[29,30,32,35,41,53–55,57] with 8 of them detecting significant differences between the two sexes.[29,30,32,41,53–55,57] In 5 out of those 8 studies,[32,41,53,54,57] females presented with a statistically significant higher prevalence of morphological osteoarthritic changes in comparison to males. There was only one study with opposite results according to which osteoarthritic changes were more frequently observed in males than in females.[30] Positional differences between the two sexes have also been reported. In

**Table 3**
Results summaries of the scoping review.

| Author, Year | Country | Aim | Population Studied | Sample Size (females, males) | Mean age and/or range (years) | Pertinent Results Summary |
|---|---|---|---|---|---|---|
| Abdel-Alim et al., 2020[74] | Saudi Arabia | To correlate clinical symptoms associated with TMD to the osseous changes occurring in affected TMJ | Records of patients who had presented at an academic institution with TMJ related symptoms | 60 (14, 46) | 27.6 (females: 26.8, males: 30.1) | • Limited mouth opening<br>• Positive correlation, between pain and loss of cortication<br>• No significant correlation between CBCT TMD findings and clinical symptoms |
| Aboalnaga et al., 2022[56] | Saudi Arabia | To investigate the morphological and positional TMJ characteristics of different TMDs | Patients examined in the outpatient clinic of the Orthodontic Department | 143 | | • Patient with TMJ disc displacement, with or without reduction, had significantly more posterior, vertical, and medial positioned condyles compared with the myalgia group |
| Ak and Köse, 2021[28] | Turkey | To examine the distribution of condyle and articular fossa shapes in patients with TMD and their relationship with each other | CBCT scans of patients with TMJ dysfunction were evaluated retrospectively. All patients were scanned with CBCT because of TMD diagnosis | 134 (96, 38) | 41.60 ± 16.07 | • Sagittal-oval and coronal-flattening condyles were seen more frequently than other shapes.<br>• No relationship was found between gender or age groups and shape of condyles in all sections. |
| Alfaleh, 2020[64] | Saudi Arabia | To determine the effect of horizontal condylar angle on radiographically morphological changes in the condyles of TMD and non-TMD subjects | CBCTs and clinical notes from patients recruited from the Department of oral and maxillofacial radiology | 146 (76, 70) | 33.82 ± 13.5; TMD: 34.01, non-TMD: 33.68 | • Horizontal condylar angle was increased in the TMD group, but not significantly.<br>• No direct influence on the joint's morphological changes in TMD and non-TMD patients<br>• Both symptomatic and asymptomatic groups had arthritic changes |
| Alkhader et al., 2010[33] | Japan | To determine the diagnostic accuracy of MRI for assessing osseous abnormalities of the TMJ using CBCTs as a reference | Patients with TMD who underwent both CBCT and MRI at a dental hospital | 55 (24, 31) | 41 (13-69) | • Most common osseous abnormalities diagnosed with CBCT: deformity (25 %) and erosion (24 %), sclerosis (19 %), flattening (18 %) |
| Alkhader et al., 2012[35] | Saudi Arabia | To evaluate CBCT findings of TMJs with osseous abnormalities | Records of patients with arthrogenic TMJ disorder and TMJ asymptomatic individuals who consulted a dental clinic and had a CBCT | 64 (42, 22) | females: 33 (15, 60) males: 28 (15-65) | • Osseous abnormalities revealed:<br>- flattening: 88 %<br>- sclerosis: 69 %<br>- erosion: 30 %<br>- osteophytes: 28 %<br>- subcondylar cysts: 17 %<br>• Small and dorsally positioned condyles |
| Al-Rawi et al., 2017[54] | United Arab Emirates | To investigate condylar position and its relation to articular eminence and axial condylar angle in TMD and non-TMD controls | Patients that visited the Oral Diagnostics Department of a Dental College | TMD: 35 (16, 19); non-TMD: 35 (16; 19) | TMD: 27.9 (16–44); non-TMD: 24.7 (16–38) | • Superior and Medial Joint Space were significantly greater in TMD.<br>• Significant differences between TMD males and females: males had flatter axial condylar angles and females showed higher medial joint space compared to control.<br>• Mean axial condylar angle was smaller in joints with TMD which may indicate that the condyle of the affected joints may rotate inward |
| Arayasantiparb et al., 2020[40] | Thailand | To characterize the relationship between radiographic and clinical characteristics of patients with TMD osseous changes. | Subjects were selected from the list of patients who had undergone CBCT at an Oral and Maxillofacial Radiology Dental Clinic | 73 (67, 6) | 38.95 ± 1.76 (20–79) | • Osseous changes:<br>- Flattening: 89.4 %<br>- Osteophyte: 87.3 %<br>- Erosion: 68.3 %<br>- Sclerosis: 15.5 %<br>- Subchondral cyst formation: 9.2 % |

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**Table 3** (*continued*)

| Author, Year | Country | Aim | Population Studied | Sample Size (females, males) | Mean age and/or range (years) | Pertinent Results Summary |
|---|---|---|---|---|---|---|
| | | | | | | • Chief clinical complaints: just pain (35.2 %), crepitation (35.2 %), tenderness to palpation (31.7 %) pain and noise (25.4 %), just noise (19.7 %), limitation of mouth opening (8.2 %)<br>• Statistically significant correlation between crepitation and 4 radiographic characteristics: sclerosis, subchondral cyst formation, erosion, and osteophyte formation<br>• The degree of TMJ osseous changes does not correlate significantly with clinical pain |
| Bae et al., 2017[34] | South Korea | To assess correlation between pain and degenerative bony changes | Records of patients who visited a dental hospital during a two-year period complaining of TMJ pain, sounds, or limitation in mouth opening | 201 (165, 36) | 38 ± 19; 12-81 | • The most frequent condylar bony change was flattening (77.4 %), followed by erosion (59.7 %)<br>• Erosion and flattening were the most common combination of the bony changes (12.7 %)<br>• Osteophytes and erosion can be pain-related variables |
| Çakur and Bayrakdar, 2016[31] | Turkey | To study correlation between bone quality of the mandibular condyle between TMD and non-TMDs | Patients examined because of their symptoms at a Department of Oral Diagnosis and Radiology | 50 (13, 37) | 30.54±13.9 (15-69) | • The following changes were observed: erosion (62 %), sclerosis (48 %), flattening (41 %), osteophytes (36 %), pseudocysts (4 %)<br>• No correlations between bone quality types and degenerative bone changes in TMD patients |
| Cevidanes et al., 2010[24] | United States of America | To determine condylar morphological variations in patients with osteoarthritis including pain intensity and duration | Records of patients who sought treatment at an Orofacial Pain Clinic of a Dental School | Females only; TMD: 29; non-TMD: 36 | TMD: 40.7 ± 15.7; non-TMD: 24.3 ± 10.8 | • All subjects showed either flattening and/or osteoarthritic changes.<br>• Condylar flattening was observed in 60 % of the condyles.<br>• Osteoarthritic surface irregularities, such as erosions and osteophytes, were found in 40 % of the condyles.<br>• Overall 3D TMD condylar morphology significantly different from non-TMD<br>• TMD morphology correlation with pain intensity and duration |
| Cevidanes et al., 2014[26] | United States of America | To assess 3D morphological variations and local and systemic biomarker profiles in subjects with a diagnosis of temporomandibular joint osteoarthritis | Patients recruited from the university clinic and through advertisement | All female: 28 Chronic TMD: 28; initial TMD: 12; non-TMDs:12 | Chronic TMD: 39.9 ± 16; initial TMD: 47.4 ± 16.1; non-TMDs: 41.8 ± 12.2 | • Compared with non-TMD the OA average condyle was significantly smaller in all dimensions except its anterior surface.<br>• Areas indicative of bone resorption mostly along the articular surface, particularly in the lateral pole |
| Cho and Jung, 2012[30] | South Korea | To compare condylar positioning of TMJ in TMD and non-TMD children and adolescents | Retrospective study of CBCTs of patients who visited a hospital | TMD: 181 (115, 66); non-TMD: 101 (40, 61) | TMD: 15.6 (10-18) | • The prevalence of osteoarthritic changes was higher in adolescents.<br>• Erosion was the most common change for the TMD group. |

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**Table 3** (*continued*)

| Author, Year | Country | Aim | Population Studied | Sample Size (females, males) | Mean age and/or range (years) | Pertinent Results Summary |
|---|---|---|---|---|---|---|
| | | | | | | • Posterior condylar position was more frequently observed in the TMD group.<br>• Posterior positioning of the condyle was observed more often in cases of TMJ noise.<br>• Erosion was more common in the samples with TMJ pain or mouth opening limitations as compared to those without them.<br>• In the TMD group, the frequency was higher in males than in females.<br>• Young subject groups present with TMD |
| Choudhary et al., 2020[39] | India | To evaluate the correlation between the TMJ articular eminence inclination, height, condylar bone changes, condyle, and fossa shapes with symptomatic TMDs | Patients visiting the outpatient department of a dental college | TMD: 30; non-TMD: 20 | 20–40 | • Condylar bone changes, osteophyte, and erosion were significantly more in the TMD group. |
| da-Silva et al., 2020[22] | Brazil | To evaluate patients with degenerative changes in the TMJ previously visualized through CBCT, and relate those changes to the quality and quantity of clinical diagnoses and arthrogenic symptoms of TMD | Patients were selected using previously obtained CBCTs at a radiology department of the School of Dentistry | 38 (4, 34) | 48.8 ± 9.2 | • N = 15 individuals with no clinical diagnosis of painful or degenerative conditions: 80 % flattening, 80 % sclerosis, 46.6 % osteophytes, and 25 % erosion, seen in imaging.<br>• Arthralgia cases: 58.3 % flattening in at least one TMJ, 66.6%sclerosis, 33.3 % osteophytes, and 25 % erosion.<br>• 100 % of no TMD cases: flattening, 85.7 % sclerosis, 42.8 % osteophytes, and 14.2 % erosion<br>• 89.5 % of the degenerative changes were clinically underdiagnosed.<br>• Positive association between the presence of symptoms and the number of correct clinical diagnoses of osteoarthritis and/or osteoarthrosis |
| Derwich et al., 2020[50] | Poland | To analyze the morphology of the TMJ based on presence of reciprocal clicking before orthodontic treatment | Patients referred for orthodontic consultation | 105 (79, 26); 25 unilateral clicking, 25 reciprocal clicking, 55 no clicking | 24.9±37.74 (16-47) | • Condyles more often posteriorly positioned.<br>• Subcortical cysts most prevalent abnormality<br>• Small condylar A-P associated with reciprocal clicking. |
| Emshoff et al., 2016[66] | Austria | To assess the association between TMJ condylar erosion and chronic TMJ arthralgia | Patients with TMJ pain were referred to a clinic for orofacial pain and TMDs for treatment of reported pain and dysfunction of the TMD region. Controls/non-TMD were patients who had been referred for different reasons and no history of orofacial pain | TMD: 99 (92, 7); non-TMD 99 (43, 56) | TMD: 37 ± 16.8; non-TMD: 37.4 ± 13.3 | • Condylar erosion: 59.6 % TMD and 21.2 % non-TMD<br>• Significant association between TMJ arthralgia and degree of condylar erosion |
| Gomes et al., 2015[45] | United States of America | To investigate imaging statistical approaches for the classification of 3D osteoarthritic morphological condylar variations | Patients recruited from a university clinic and through advertisement, | Long-term TMD: 69; Initial TMD: 15; non-TMD: 7 | Long-term TMD: 39.1 ± 15.7; Initial TMD: 44.9 ± 14.8; non-TMD: 43 ± 12.4 | • Condylar morphology varied widely between TMD and non-TMD subjects.<br>• TMD average condylar size was statistically significantly smaller in all dimensions except its anterior surface.<br>• Significant flattening of the lateral pole<br>• Areas of bone resorption at the superior surface (3.88 |

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**Table 3** (*continued*)

| Author, Year | Country | Aim | Population Studied | Sample Size (females, males) | Mean age and/or range (years) | Pertinent Results Summary |
|---|---|---|---|---|---|---|
| | | | | | | mm on average) and of bone apposition at the anterior aspect (3.10 mm on average) of the long-term TMD |
| Han et al., 2021[51] | South Korea | To assess the changes in individual condyles from 5 to 8 years in patients with TMJ osteoarthritis | Patients who visited or were referred to a dental clinic that specialized in orofacial pain with symptoms of TMD | 43 (10-33) | 28.2 ± 8.3 (females: 29.3 ± 9.4, males: 26.6 ± 3.0) | • Osteoarthritis leads to both resorption and apposition.<br>• Resorption was mainly observed in the superior region, while high apposition rates were observed in the posterior, lateral, and anterior regions.<br>• The greatest resorption and apposition observed were −7.48 and 2.66 mm, respectively<br>• The medial parts showed greater apposition than the lateral parts in all regions. |
| Hassan et al., 2021[55] | Iraq | To investigate the condylar position in TMD patients | Patients that attended a Department of Dental Radiology for CBCT scanning for different dental problems | TMD: 20 (8, 12); non-TMD: 20 (10, 10) | TMD: 47.4±3.86 (40-50); non-TMD: 42.6±2.48 (39-46) | • Both anterior and superior joint spaces are larger in the TMD group but not significantly<br>• Males had larger superior space than females. |
| Imanimoghaddam et al., 2016[49] | South Korea | To compare condylar position in TMD and non-TMD patients | TMD: no details; non-TMD: referred to the Oral and Maxillofacial Radiology Department For CBCT | TMD: 25 (5-20); non-TMD: 25 (8, 17) | TMD: 28.84 ± 9.84; non-TMD: 28.43 ± 3.24 | • Anterior joint space was significantly larger in TMD than non-TMD cases. |
| Imanimoghaddam et al., 2017[21] | Iran | To assess the association between the clinical and CBCT findings in relation to bony changes in patients TMD | Patients with TMD symptoms attending the Prosthodontics Department of a Dental School | 41 (19, 22) | 42.5 ± 27.5 | • Sex did not have any influence on the study parameters.<br>• Reported osseous changes listed according to frequency:<br>- Erosion<br>- Osteophyte<br>- Flattening<br>- Sclerosis<br>- Resorption<br>• There was no association between the horizontal or vertical position of condyle and pain in joint or masticatory muscles.<br>• Condylar osteophyte was significantly associated with both masticatory muscle pain and crepitus sound.<br>• Overall, no significant relationship was found between the radiographic and clinical findings in patients with type II and type III TMD |
| Jeon et al., 2021[68] | South Korea | To analyze CBCT and MRI findings in TMD) patients and assess the relationship with the clinical symptoms | Patients with clinical TMD symptoms and imaging records that attended a University Dental Hospital | 377 (294, 83) | 33.3 ± 16.23 (10–82) | • Normal condylar head morphology was found in most (65.1 %) of the patients.<br>• Osseous changes were not frequent:<br>- Osteophyte: 1.5 %<br>- Sclerosis: 6.2 %<br>- Flattening: 7 %<br>- Erosion: 7.3 %<br>- Combined: 12.9 %<br>• CBCT findings had little to do with clinical symptoms |
| Jung et al., 2022[27] | Japan | To analyze the longitudinal changes in clinical and | Records of patients who visited the Department of Oral Medicine with TMJ pain. | Older: 33 (2, 31) – Control: 43 (12, 31) | Older: 60.2 ± 8.1 – Control: 17.5 ± 3.4 | • Significant difference in the distribution of destructive |

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**Table 3** (*continued*)

| Author, Year | Country | Aim | Population Studied | Sample Size (females, males) | Mean age and/or range (years) | Pertinent Results Summary |
|---|---|---|---|---|---|---|
| | | radiological characteristics of TMJ-OA in older people | Participants were classified into two groups according to age: older and control groups | | | bony features between age groups<br>• In the older people group, "three or more features" were the most common, whereas in the control group, "erosion" (44.2 %) was the most common. |
| Kattiney de Oliveira et al., 2022[58] | Brazil | To evaluate the presence or absence of discrepancies between the centric relation and maximum intercuspation in TMD and non-TMJ younger and older adults | No details provided | TMD: 40; non-TMD: 40; Older: 40 (10, 30); Younger:40 (13, 27) | Younger: 18–25; Older: 35-50 | • No significant differences between CR and MI position and TMD symptoms were compared in the younger and older.<br>• Significant differences in all measures used when comparing the younger and older. |
| Khojastepour et al., 2017[38] | Iran | To compare CBCT findings pertinent to patients with without TMD and investigate the correlation between these findings and the clinical dysfunction index | Patients with TMD symptoms that required CBCT; Controls were TMD symptom free | 84 (22, 62); 84 (24, 60) | 33.93±13.18 (18-65); 35.67 ±10.75 (18-65) | • Significantly higher prevalence in TMD: flattening, surface erosion, subcortical cyst, subcortical sclerosis, generalized sclerosis, and osteophytes.<br>• Clinical dysfunction index:<br>- Mild: 28.57 %<br>- Moderate: 33.33 %<br>- Severe: 38.09 %<br>• Significant correlation between the total amount of bone change and the clinical dysfunction score |
| Kiliç et al., 2015[29] | Turkey | To determine association between clinical signs and symptoms and CBCT findings of TMJ osteoarthritis | Patients presenting for the evaluation and management of TMD at an Oral and maxillofacial surgery department | 76 (11, 65) | 30.75±12.68 (14-73) | • The most frequent condylar bony changes were erosion, flattening, osteophytes, hypoplasia, sclerosis, and subchondral cyst.<br>• Condylar flattening associated with general pain complaints. |
| Lee et al., 2019[42] | South Korea | To investigate changes in the anterior joint space and the relationship of such changes to clinical symptoms in chronic and acute | Patients randomly selected among consecutive patients who visited an orofacial pain clinic | Chronic TMD: 50 (23, 27); Acute TMD: 50 (22, 28) | Chronic TMD: 35.60 ± 15.81; Acute TMD: 33.09 ± 13.92 | • Most frequent osseous changes:<br>- Flattening occurred very frequently in both acute (41 %) and chronic TMD groups (45 %)<br>- Erosion<br>- Sclerosis<br>- Osteophyte<br>- Subchondral cyst formation had the lowest frequency<br>• Bilateral osteoarthritis was significantly more frequent and anterior joint space was smaller in patients with chronic TMD than in those with acute TMD |
| Leite-de-Lima et al., 2022[47] | Brazil | To describe CBCT features in patients with TMDs in terms of degenerative changes and positioning as well as possible clinical symptoms correlations. | Records of dental school clinic patients diagnosed with TMD | 65 (10, 55) | 40.6 (18–74) | • Most frequent CBCT findings: flattening, posterior condylar positioning.<br>• Significant correlation between:<br>• Osteophyte and lateral capsule pain<br>• Erosion and posterior capsule pain and flattening<br>• Few correlations were noted between degenerative changes and signs of joint pain, whereas condylar positioning did not correlate with signs and symptoms |

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**Table 3** (*continued*)

| Author, Year | Country | Aim | Population Studied | Sample Size (females, males) | Mean age and/or range (years) | Pertinent Results Summary |
|---|---|---|---|---|---|---|
| Lelis et al., 2017[65] | Brazil | To quantitatively evaluate the condyle-mandibular fossa relationship in TMD and non-TMD subjects | Volunteers with or without TMD | TMD: 20 (15, 5); non-TMD: 20 | 18–25 | • 40 % had associated muscle disorder; and 25 % had concomitant arthralgia.<br>• Presence or absence of TMD was not correlated with condyle position. |
| Li et al., 2015[61] | China | To investigate differences between bilateral TMJ in patients with unilateral TMD | Cases that undergone CBCT scans and had bilateral, unilateral or no TMD symptoms | TMD: 123 (62, 61) non-TMD: 36 (17, 19); Unilateral TMD: 29 (17, 12) | TMD: 43 (15–108); non-TMD: 41 (16–108) | • In the unilateral TMD cases, the vertical 60-degree joint space of the symptomatic side was significantly increased compared with the asymptomatic side. |
| Ma et al., 2022[67] | China | To compare the condylar position in TMD patients with and without chewing side preference | Participants randomly selected participants were randomly selected from the patients who sought TMD treatment at a hospital Stomatology Department | 90 TMD (57, 33)'; 20 non-TMD (12, 8) | TMD: 45.3/46.5; non-TMD 41.3 ± 13.1 | • Posterior condyle could not be viewed as a TMD indicator due to the great variety of condyle position in the normal joints.<br>• TMD patients with chewing side preference presented a higher prevalence of joint pain. |
| Meral et al., 2023[57] | Turkey | To evaluate the relationship between internal derangement and morphological features of the TMJ | Patients admitted to the Department of Oral and Maxillofacial Surgery | TMD: 53 (7, 46); non-TMD: 61 (28, 33) | TMD: 35.7±1.5 (18-67); non-TMD: 36.1±1.4 (18-67) | • Statistically different in TMD versus non-TMD<br>• Eccentrically located condyle position; posteriorly and superiorly<br>• The prevalence of internal derangement in females were 6.57 times higher than males<br>• Increased condylar height to glenoid fossa depth ratio |
| Mohamed et al., 2022[52] | Egypt | To predict TMJ anterior disc displacement with reduction from condylar shape, position, and dimensions | Patients with TMD – recruitment information not disclosed | 17 (5, 12) | 33.3±16.23 (18-55) | • Condylar width, height and depth were significantly smaller in condyles with anterior displacement with reduction compared to condylar dimension in normal disc position<br>• Logistic regression analysis could be used to predict the probability of anterior displacement with reduction from condylar dimensions |
| Nah, 2012[37] | South Korea | To observe the bony changes in TMD patients from different age groups | Records of patients referred to a TMD clinic | 200 (156, 64) | 10–79 | • The most frequent condylar bony change observed was sclerosis (30.2 %), followed by surface erosion (29.3 %), flattening of the articular surface (25.5 %), deviation (13.2 %), osteophyte (8 %)<br>• 65.9 % of joints with surface erosion had pain recorded at the chief complaint |
| Paknahad and Shahidi, 2015[62] | Iran | To investigate the correlation between clinical dysfunction index and mandibular condylar position in patients with TMD | Patients referred to a Department of Maxillofacial Radiology of a Dental University for the treatment of TMDs and required CBCT for further investigation | 60 (18, 42) | 33.4±2.94 (20-42) | • Clinical dysfunction index:<br>- Mild: 20 %<br>- Moderate: 58 %<br>- Severe: 22 %<br>• Posterior condylar position was more frequently observed in the severe functional dysfunction group<br>• Condylar position is associated with different severities of TMD |
| Paknahad et al., 2015[53] | Iran | To investigate the condylar position according to gender in patients with TMD and healthy controls | Patients who were referred for the treatment of TMD and non-TMD controls that were referred for different reasons. | 30 TMD (20, 10)'; 30 non-TMD (18, 12) | TMD: 33.4 (20-42); non-TMD: 24(15–34) | • No statistically significant differences regarding the condylar position between TMD and non-TMD<br>• TMD females: Posterior condylar position was more frequent. |

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**Table 3** (*continued*)

| Author, Year | Country | Aim | Population Studied | Sample Size (females, males) | Mean age and/or range (years) | Pertinent Results Summary |
|---|---|---|---|---|---|---|
| | | | | | | • TMD males: Anterior condylar position more prevalent<br>• Overall, no apparent association between condylar positioning and clinical finding in TMD |
| Shokri et al., 2019[60] | Iran | To evaluate the association between TMD and the condylar position | TMD: Patients with symptomatic TMD referred to a Department of Oral and Maxillofacial Prosthodontics; non-TMD: patients referred for other reason with no TMD symptoms | TMD: 48; non-TMD: 48; 101, 29 | TMD: 31; non-TMD: 25 | • Statistically significant relation between TMD and the horizontal position of the condyle<br>• The position of the condyle with TMD was more posterior (52.3 %), and the position of the asymptomatic condyle was mostly anterior (38.5 %) and concentric (33.8 %) |
| Su et al., 2014[44] | China | To investigate the correlation between clinical dysfunction index and condylar bony changes | Records of patients who sought treatment at an Orofacial Pain Clinic | 240 (194, 46) | 36 ± 15.6 | • Clinical dysfunction prevalence:<br>- Absence: 0<br>- Mild: 20.4 %<br>- Moderate: 35 %<br>- Severe: 44.6 %<br>• Maximum condylar bony changes:<br>- Typical morphology: 0<br>- Flattened antero-and/or postero-superior contour: 33.7 %<br>- Proliferation or partial hypodense change with or without roughening on the cortical surface: 37.5 %<br>- Deformed contour without proliferation or partial hypodense change: 13.8 %<br>• Significant correlation between the clinical dysfunction score and the maximum condylar bony changes.<br>• No correlation with joint space changes |
| Talaat et al., 2016[48] | Egypt | To compare CBCT findings and joint space measurement in TMD and non-TMD joints, and correlate these findings with the clinical diagnosis | Patients attending the TMJ and facial pain clinic at a University Dental Hospital | 89 (33, 56); TMD: 46; non-TMD: 43 | 34 ± 21 | • TMD joints had significantly more condylar irregularities, osteophytes, and condylar flattening than non-TMD joints |
| Tsai et al., 2021[25] | Taiwan | To evaluate the topographic distribution of osseous degenerative features in the TMJ | Patients with TMD who sought treatment at an Orofacial Pain Clinic | Only females: 26 | 37.7±16.1 (15-66) | • Surface erosion, subcortical sclerosis, and osteophytes were significantly more prevalent in the condyle<br>• No statistical differences were observed in the topographic distribution of different osseous degenerative features among the mesial, central, and lateral portions in the condyle.<br>• The only exception was the incidence of surface erosion at the central portion the condyle, which was significantly higher than that at the lateral portion |
| Ulay et al., 2020[32] | Turkey | To evaluate whether there is a relationship between the degenerative bone changes and quality of bone in patients with TMD | Patients with TMD complaints admitted to an Oral and Maxillofacial Radiology clinic | 200 (100, 100) | ≥20 | • Flattening was the most common degenerative bone change.<br>• The second most common degenerative change was erosion. |

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**Table 3** (*continued*)

| Author, Year | Country | Aim | Population Studied | Sample Size (females, males) | Mean age and/or range (years) | Pertinent Results Summary |
|---|---|---|---|---|---|---|
| | | | | | | • Sclerosis, osteophyte, and pseudocyst were found to be rarer.<br>• No significant difference between genders in term of type of degenerative bone changes<br>• Degenerative bone changes more common in females |
| Verma et al., 2016[41] | India | To assess the joint space and arthritic changes in TMD | Patients seeking TMD treatment | 60 (22, 38) | 39.65 (16-70) | • No statistically significant differences were found between symptomatic and asymptomatic joints and radiographic arthritic changes among the symptomatic and asymptomatic joints.<br>• Asymptomatic joints may present with radiographic changes, and few of the symptomatic joints may fail to reveal radiographic changes.<br>• The most common radiographic change observed was flattening (66.67 %) followed by osteophytes formation (45 %), sclerosis (41.67 %), and erosion (35 %)<br>• Osteoarthritis of TMJs was seen more frequently in women (63.33 %) than in men (36.67 %)<br>• Most involved surface was anterosuperior (81.2 %), followed by posterosuperior (33.7 %), and superior surface (13.7 %)<br>• In older age groups, patients are exposed to severe progressive degenerative bony changes than those in patients of younger age groups |
| Yasa and Akgül, 2018[59] | Turkey | To evaluate the bone components of the TMJ in TMD and non-TMD | Patients referred to a Department of Oral and Maxillofacial; Radiology for treatment of TMD and required CBCT; Controls were non-TMD patients that required CBC | TMD: 200 (152, 48); non-TMD: 200 (138, 62) | TMD: females 31.13 ± 11.09, 48 males 30.56 ± 10.16; non-TMD: females 25.09 ± 6.23, males 25.35 ± 5.64 | • The presence of TMD was associated with the condyle position.<br>• A posterior condylar position was noted more frequently in the TMD group. |
| Yuan et al., 2022[46] | China | To study the correlation between condylar morphology and clinical manifestations in patients with degenerative joint disease (DJD) of the TMJ | Patients who had visited a hospital Department of Temporomandibular Joint | 131 (101, 30) | 23.65±4 (14-30) | • 66 % of the patients demonstrated unilateral radiographic diagnostic features of DJD, while 34 % demonstrated bilateral features.<br>• Distribution on condylar classification:<br>• Axial plane: elliptical (25 %), concavo-convex (69 %), and Ovoid (11 %)<br>• Frontal plane: round (12 %), convex (50 %), and angulated (38 %)<br>• Sagittal plane: rounded (21 %), anteriorly flattened (47 %), and posteriorly flattened (33 %)<br>• Most prevalent symptoms were joint noises (53 %), clicks (42 %), and crepitus (11 %) |

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**Table 3** (*continued*)

| Author, Year | Country | Aim | Population Studied | Sample Size (females, males) | Mean age and/or range (years) | Pertinent Results Summary |
|---|---|---|---|---|---|---|
| | | | | | | • Condylar anteroposterior diameter and height were correlated with pain<br>• Correlation between condylar shape in the sagittal plane and joint noise |

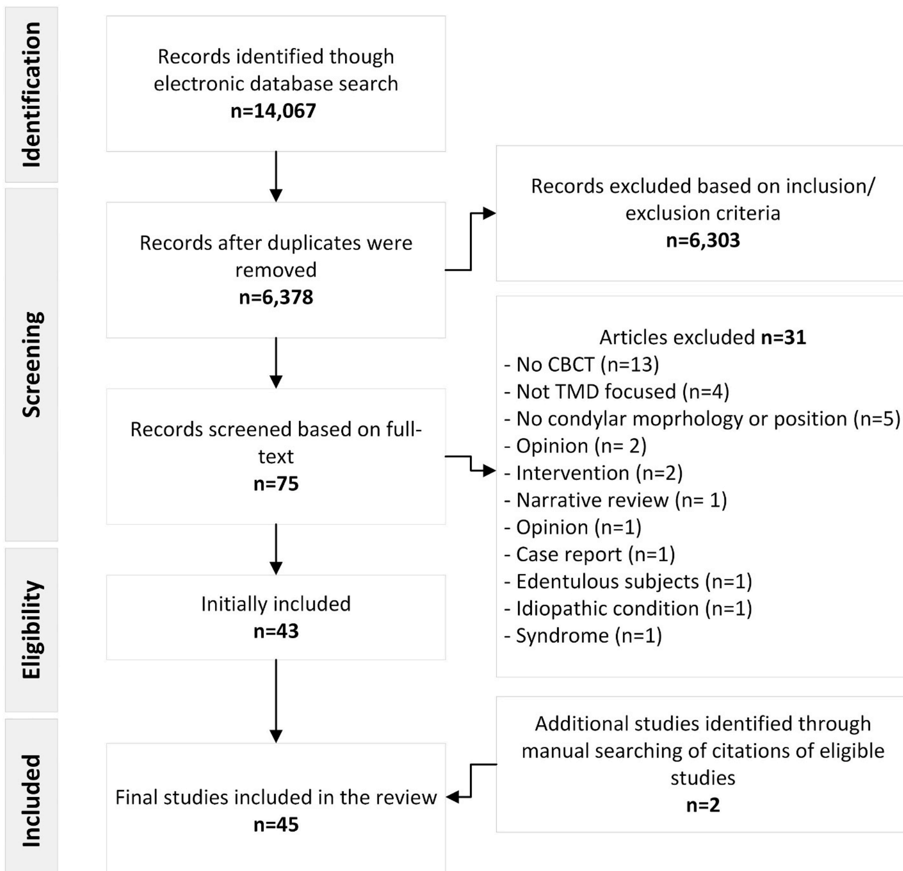


**Fig. 1.** PRISMA flow diagram providing the details of the selection process.

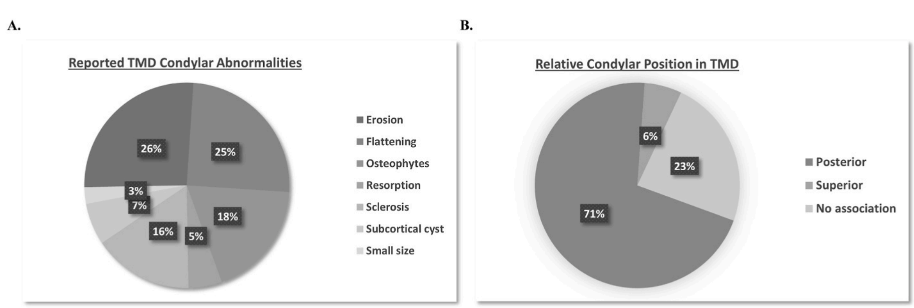


**Fig. 2.** **A.** Pie chart depicting the most frequent osseous abnormalities reported in the case of TMD in percentages across the N=20 out of 45 studies included in this review. **B.** Pie chart depicting the most frequent reported relative position of the condyle in the glenoid fossa amongst the N=17 out of 45 of the included studies.

one study by Hassan et al.,[55] males had larger superior space than females, whereas in a study by Paknahad et al.[53] females with TMD presented more frequently with a posterior condylar position, whereas males with a more anterior condylar position. A higher vertical condylar position was detected in females and flatter axial condylar angles in males compared to controls in a different study.[54]

Finally, in 22 studies, the association between TMD findings and clinical symptomatology was also investigated.[21,22,24,29,30,34,37,38,40,41,43,44,46,47,50,53,62,64–68] In most of these studies (17 out of 22) CBCT findings related to osseous morphological abnormalities of the condyles were significantly correlated with clinical TMD symptoms.[21,22,24,29,30,37,38,40,44,46,47,50,53,62,66,67] TMJ pain was associated with clinical symptoms in several studies. In specific, TMJ pain-related complaints and symptoms were associated with flattening of the condylar head,[29] reduced condylar anteroposterior diameter and height,[69] osteophytes and erosion,[34,47] osteophytes,[21] degree of condylar erosion,[37,66] and a chewing side preference.[67] Pain symptoms and limited mouth opening were also correlated with erosion of the condylar surface in a study by Cho et al.,[30] whereas the overall TMD morphology was correlated with pain intensity and duration in a study by Cevidanes et al.[24]

A statistically significant correlation between crepitation and four radiographic characteristics, including sclerosis, subchondral cyst formation, erosion, and osteophyte formation was reported by Arayasantiparb et al.[40] Condylar osteophytes were also significantly associated with crepitus sounds.[21] Joint noises, in general, were also associated with condylar shape in the sagittal plane in the study by Yuan et al.,[46] whereas Derwich et al.[50] was the only study that associated smaller condylar size in the antero-posterior dimension with reciprocal clicking sounds during clinical examination.

In addition, a significant correlation between the total amount of condylar osseous changes and a validated clinical dysfunction score was described in a study by Khojastepour et al.,[38] whereas clinical symptoms were associated with positional condylar deviations in only one study, with posterior condyle position more frequently observed in patients with severe TMD symptoms.[62]

## 4. Discussion

### 4.1. Summary of the current evidence

Based on the information provided by the studies included in this review, the most frequently reported osseous degenerative changes of the condylar head contour diagnosed in CBCT scans of participants with clinical TMD symptomatology are condylar surface erosion and flattening, followed by sclerosis and osteophytes. Condylar size was only investigated in a limited number of studies, but in all the reported cases condyles had a smaller overall size in comparison to the size of healthy matched controls and/or the contralateral healthy side of the same participants in cases of unilateral TMD.

Topographically, the anterosuperior side of the condylar head appears as the most affected area. On the other hand, less evidence has been reported on the nature and degree of deviation from the normal anatomical position of the condylar head in TMD cases. In most of the studies investigating this parameter, a more posterior position of the condylar head was detected.

Moreover, the results of the included studies confirmed that in cases where sex related differences were examined, females presented with a significantly higher prevalence of TMD abnormalities. In addition, sexual dimorphism was also detected regarding condylar position in the presence of TMD, with females presenting more often with a more superior and posterior position.

Furthermore, most studies included participants over 20 years of age, which appears to be the age during which clinical symptoms of TMD start manifesting. Older subjects presented more often with more than one type of abnormality, which could be either related to the fact that some of these abnormalities are age-related degenerative conditions or that some abnormalities progressively lead to more complications. Nevertheless, TMD symptomatology and associated osseous anatomical abnormalities have also been reported for younger subjects between 10 and 20 years of age.

Based on the results of the included studies, female sex, and small condylar size are characteristics that could be considered as factors that predispose someone to TMD. However, for the detection of more specific anatomical or other predisposing factors, prospective studies and/or retrospective studies on participants with CBCTs taken at different time points, from childhood to adulthood, are required.

### 4.2. Limitations

One of the main limitations in this review which is related to the methodology of the included studies is that there is a lot of variation in the age of the participants for each study, with most authors not including separate result reports per age group. This could be a limiting factor in the interpretation of the results due to the progressive nature of the TMDs. Nevertheless, in those cases where the results were reported based on the age group, relevant observations were summarized.

Similarly, no distinction was made between TMDs of differential etiology in most of the included studies. As a result, only general observations could be made in this review about condylar anatomy in the case of TMD, regardless of the underlying etiology. Additionally, scanning protocols were most often not reported in the included studies, which is important during the evaluation of TMJ with the use of CBCT. Therefore, some of the differences between the results of the studies could be attributed to differences in their imaging protocols.[70–73]

## 5. Conclusions

Clinical TMD is most frequently manifested in CBCT scans with condylar surface erosion, flattening, osteophytes, sclerosis, small condylar size, and a more posterior position of the condyle in the TMJ in central relation. In addition, the anterosuperior area of the condylar head appears to be the most frequently affected by TMD. Females seem to have a higher prevalence of TMD symptoms and condylar anatomical abnormalities.

Based on the current information, morphological abnormalities reported in the presence of TMD symptoms are in most cases degenerative changes. However, female sex and/or a small condylar head size have also been reported in several studies and could be considered as potential predisposing factors for TMD. This information is important for the radiographic assessment of patients and the detection of abnormalities that are associated with TMD.

In conclusion, a more detailed and systematic reporting of anatomical TMJ characteristics in subjects with TMD is required by clinical researchers. The association of certain morphological abnormalities with etiological factors could greatly assist in a more efficient diagnosis of TMD and the optimization of patient care.

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## Declaration of competing interest

The authors have no conflicts of interest to declare.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jobcr.2023.10.004.

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