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Journal of Oral Medicine, Oral Surgery, Oral Pathology and Oral Radiology

Journal homepage: www.joooo.org

Review Article

# Imaging diagnostics of intracapsular disorders

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ARTICLE INFO

*Article history:*
Received 02-12-2020
Accepted 29-12-2020
Available online 18-02-2021

*Keywords:*
TMJ
Arthrography
MRI imaging
Ultrasonography

ABSTRACT

Temporomandibular joint (TMJ) disorder refers to a cluster of conditions characterized by pain in the TMJ or its surrounding tissues, functional limitations of the mandible, or clicking in the TMJ during motion. TMJ disorders are common and often self-limited in the adult population. Intracapsular Disorders are characterized by structural alterations in the joint itself. Muscle disorders are far more common than intracapsular disorders. Clinical examination only cannot lead to the correct diagnosis of TMJ dysfunctions. The diagnosis and management of temporomandibular disorders (TMD) require both clinical and imaging examinations of the temporomandibular joint (TMJ). Imaging of the temporomandibular joint (TMJ) is continuously evolving with advancement of imaging technologies. Among the basic examinations used are: X ray examination (RTG), arthrography, computer tomography (CT) magnetic resonance imaging (MRI), ultrasonography etc. The present paper attempts to highlight the various imaging modalities for diagnosis of intracapsular disorders.



## 1. Introduction

Temporomandibular disorders refer to a group of musculoskeletal disorders that arise from the masticatory structures.[1] Extracapsular disorders are conditions that affect the structures surrounding the TMJ, while intracapsular disorders are conditions affecting the structures within the TMJ.[2] Imaging can be complicated due to the anatomical complexity of the joint. The purpose of an imaging assessment of the temporomandibular joint (TMJ) is to graphically reflect clinically suspected disorders of the joint. Imaging of the TMJ may reveal osseous or positional abnormalities. Diagnostic imaging has been helpful in substantiating the intracapsular disorders such as internal disk derangements.[3,4] The decision on selecting an examination should be made after considering the history, clinical findings, diagnosis, cost of the examination and radiation exposure.[4] The most accurate imaging techniques are those that include new evidence that have an impact on patient care. Imaging methods for intracapsulr disorders and recommendations for their proper use are listed in this review paper.

## 2. Normal function of the Temporomandibular Joint

TMJ is a ginglymoarthrodial joint, meaning a hinge joint, allowing motion only backward and forward in one plane, and arthrodia, joint which permits a gliding motion of surfaces.[5] The right and left TMJ form a bicondylar articulation.[6] The joint is the union of the temporal bone cavity with the mandibular condyle.[7] The bony components of the joint are separated by a structure composed of dense fibrous connective tissue called the articular disc. Like any mobile joint, the integrity and limitations of the joint are maintained by ligaments. Ligaments do not actively participate in normal function of the joint; rather, they act as guidewires to restrict certain movements (border movements) while allowing other movements (functional movements).[8] Musculature in the head and face contributes to movement and stability of joint.[9] When

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https://doi.org/10.18231/j.jooo.2021.004

the mouth opens there is a combination of rotational movement of the discomandibular space and action of the translational discotemporal space; the rotation occurs before the translation. The condyle can move laterally through a rotation and then an anterior sliding of the same condylar structure, and an anterior translation/rotation in the medial direction of the opposite condyle. The condyle can move backward, while the opposite condyle slides forward. The bilateral or ipsilateral TMJ protrusion occurs by anterior sliding. Many pathologies can impact the TMJ and potentially cause varying degrees of clinical dysfunction.[10]

## 3. Intracapsular Disorders of TMJ

TMD is defined by the American Academy of Orofacial Pain (AAOP) as a complex term covering a number of clinical problems involving the masticatory muscles, the joint and the associated structures.[11] Intracapsular Disorders are mainly characterized by structural alterations in the joint itself. The normal physiologic relationship between the condyle, the disc that moves between it and the part of the skull called the fossa have been altered and compromised. This interferes with form and function and frequently produces pain.Once change occurs in the structure of the condyle–disc complex, normal biomechanics can be altered. These disorders fall into one of two broad types: derangements of the condyle–disc complex and structural incompatibility of the articular surfaces.Although the clinical examination is the most important step in the diagnosis of these disorders, special imaging techniques are needed due to the complex anatomy and pathology. It is very common to take an image of the joint when there is locking, pain and articular sounds. One important thing to consider when imaging the TMJ is the interpretation of the joint function, which can be accomplished by comparing the condyle in the closed and opened mouth position. Several imaging techniques are available for TMJ visualization, as follows.[12]

## 4. 2D Imaging Modalities

### *4.1. Panoramic radiography*

As it provides a maxillary overview, it is useful in the differential diagnosis of odontogenic alterations whose symptoms overlap with TMJD.[13,14] Gross alterations in the articular tubercle morphology and only the lateral part of the condyle can be assessed with this technique, because of the superimposition of images of the skull base and the zygomatic arch.[15] However, it does not provide functional information on condylar excursion.[16] This technique is useful as a screening tool, as it allows the initial diagnosis and assessment of TMJ alterations that are not so subtle.[17]

### *4.2. Plain radiography*

Plain radiography is useful in depicting degenerative joint disease in advanced stages.[4] Conventional tomography has been used extensively to evaluate the osseous components of the TMJ, generally in a lateral orientation but sometimes in combination with frontal views. It consists of transcranial projection of TMJs. Different angulations are used to avoid the superposition of the temporal bone and the opposite TMJ: lateral oblique transcranial projections, anterior-posterior projections, submental-vertex projection, trans pharyngeal view. The transcranial evaluation provides good anatomical assessment of the condyle, fossa, and articular tubercle.[16,18] In this technique, an X-ray beam is obliquely directed through the skull to the contralateral TMJ, producing a sagittal view.[19] Thus, the central and medial portions of the condyle are projected inferiorly and only the lateral joint contour is displayed. It is useful to identify bone alterations and displaced fractures of the head and neck of the mandibular condyle, as well as to assess excursion and to determine radiographic joint spaces.[20] This type of projection is limited by the fact that it produces an image with a large overlap of the skull bones; it also requires the use of a specific cephalostat for standardization, usually requiring complex positioning.[21] Even though with plain radiography condyle position can be assessed, larger variations of condyle position in the glenoid fossa were found, even in asymptomatic population.[22] Some studies have shown that the position of the condyle in the fossa is of little clinical significance.[23] Other studies suggest that the posterior position of the mandibular condyle in regard to the fossa, could represent an indirect sign of an anterior disc displacement.[24] The position of the head during the examination could influence the joint space, which could influence the interpretation of the radiography.[25] The use of flat plane films for TMJ pathology is not sufficient, because this joint requires three dimensional imaging views.

### *4.3. Arthrography*

Arthrography is an invasive imaging technique to evaluate the TMJ. This imaging modality requires injection of radiopaque contrast into the TMJ under fluoroscopic guidance. Once the contrast is injected, the joint can be evaluated for adhesions, disk dysfunction, as well as disk perforation based on how contrast flows in the joint.[26] The space occupied by the disc can then be visualised lying between the layers of contrast material.[27] Fluoroscopic observation of the injection may provide a dynamic study of disc movements, also any abnormal accumulation of joint fluid may be evident.

The more commonly used approaches involves injection of contrast material into the lower joint spaces, referred to as lower joint space or single contrast arthrography. Perforations of the disc or posterior attachment are

demonstrated by contrast material simultaneously flowing into the upper joint space as the lower space is injected. Another variation of the technique involves injecting contrast material into both the spaces and viewing the more central portions of the joint with tomography. Because contrast material is in both the joint spaces, the outline of the disc is profiled, showing its configuration and position. The outline of the disc can often be enhanced by using double contrast arthrography. This technique involves injecting a small amount of air along with a small amount of contrast material into both joint spaces, producing a thin coat around the periphery of both joint spaces that highlights the disc and the joint spaces.[28] Several studies have shown that arthrography is an accurate imaging method for evaluating anterior disc displacement. The accuracy for diagnosing the position of the disc ranged from 84% to 100% compared with the corresponding cryosectional morphology.[29]

## 5. 3D Imaging Modalities

### *5.1. Computed tomography*

CT is useful to evaluate the bony elements of the TMJ as well as the adjacent soft tissues.[30] CT is considered to be the best method for assessing osseous pathologic conditions of TMJ. It allows a multi planar reconstruction (sagittal, axial, coronal) of TMJ structures, obtaining 3D images in closed and opened-mouth positions. A typical imaging protocol is: 120 kV, 100 mA, 1 mm collimation, 1 mm/rotation (pitch), and imaged with a closed mouth. CT also allows 3D reconstructions, which can be used for evaluating congenital anomalies and fractures. Signs of degenerative changes in the joint, like surface erosions, osteophytes, remodeling, subcortical sclerosis, articular surface flattening can be evaluated using CT.[31,32] Changes in the shape and location of the loading zone can also be seen on CT. CT is the main radiological investigation for tumors, growth development anomalies and fractures. Basically, any CT examination of the TMJ should focus on the following: intactness of the cortex, normal size and shape of the condyles and their centered position in the fossa, the adequate joint spaces, centric relation loading zone.

Autopsy studies performed for the assessment of condylar abnormalities showed better results for CT than MRI.[33] Wesetesson et al.[34] found a sensitivity of 75% and a specificity of 100% for the diagnosis of condylar bony changes. Regarding the visualization of the soft tissues of TMJ (disc, synovial membrane, ligaments, lateral pterygoid muscle), CT is not used as a primary diagnostic method. The disc could be visualized on CT scans only with injection of contrast media in the joint (arthrography).

In an earlier report, the accuracy for disc displacement was high (81%) when comparing imaging observations of CT and surgical findings. Some reports considered that CT might replace the technically difficult and invasive arthrography in the diagnosis of disc displacement in TMD. However, the accuracy of the disc displacement was only 40%-67% in CT in studies of autopsy specimen materials. The accuracy of osseous changes of TMJ in CT compared with cadaver material was 66%-87%. Some reports pointed out that radiographic evidence of arthrosis may or may not be associated with clinical symptoms of pain dysfunction. Thus patients without osseous changes in TMJ may have pain, and those with clear signs of bony abnormalities may be pain-free.[35,36]

## 6. Cone Beam Computed Tomography

The goals of TMJ imaging by CBCT are to evaluate the integrity of the bony structures when disorders are suspected, to confirm the extent and stage of progression of disorders, and to evaluate the effects of treatment.[37] Its main advantage is the observation of boney joint structures in the sagittal, coronal, and axial planes, in addition to the possible image manipulation at different depths and three-dimensional reconstruction through specific software. For easier TMJ visualization, the image volume can be reconstructed in planes parallel and perpendicular to the long axis of the condyle instead of the true anatomic coronal and sagittal planes. The advantage of this technique is the lower radiation dose to the patient compared with conventional CT and the spatial resolution of cone beam CT is higher than that of conventional CT. These reconstructed sections also allow for better assessment of the condyle position within the glenoid fossa. The sensitivity of CBCT for assessing bone defects is dependent on the size of the defects, as demonstrated by Marques et al[38] and confirmed by Patel et al.[39] in their investigations of simulated condylar lesions. Extremely small defects, that is, <2 mm, proved to be difficult to detect, although the sensitivity for detecting condylar osseous defects overall was fairly high: 72.9–87.5%. These measurements corroborated those reported by Marques et al, but they substantially exceeded those reported by Hintze et al,[40] who investigated morphological changes such as condylar flattening and osteophytes. It is thus suggested that erosion of the condylar surface may be easier to detect from CBCT images than other morphologic changes. CBCT in general has an acceptable accuracy for diagnosing osseous TMJ abnormalities with fairly high sensitivity, although small abnormalities might be missed. When an inflammatory disorder of the TMJ is suspected, CBCT is recommended for evaluation of subtle osseous abnormalities. Both joints should be imaged for comparison. Cortical erosions most often involve the articular eminence and the anterior aspect of the condylar head. CBCT images also show subchondral sclerosis, flattening of articulating surfaces, subchondral cysts and osteophyte formation.(Figure 1)

A review published by Silvia Caruso et al[41] pointed out the main contributions of cone beam CT in the field of TMJ:

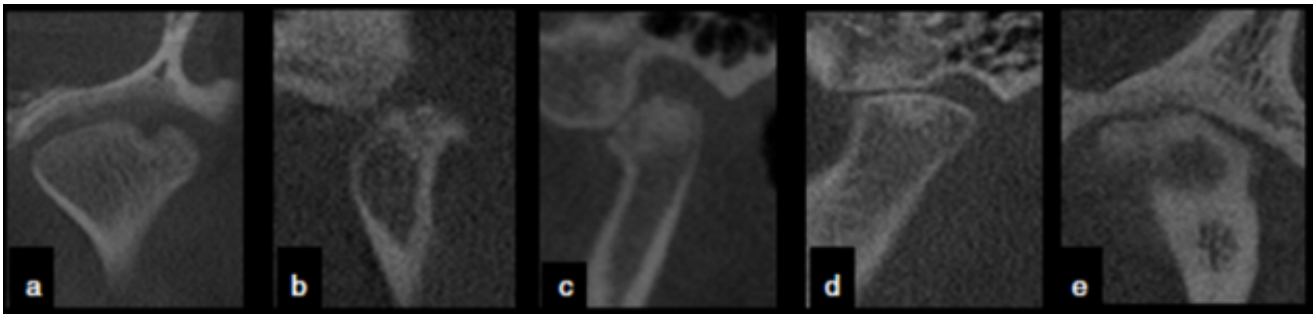


**Fig. 1:** Cone-beam computed tomography (CBCT) assessment of different TMJs in the coronal **(a, e)** and parasagittal (**b-d)** views. **(a)** Coronal view showing extensive erosion. The presence of bone sclerosis, cortical irregularities, and osteophytic formation in **(b)**, **(c)**, and **(e)**

1. It allows the calculation of volume and surface of the condyle,
2. Improves qualitative analyses of condylar surface and allows detecting the mandibular condyle shape.
3. Improves the accuracy of linear measurements of mandibular condyle; clarifies that, in case of facial asymmetry, the condyles are often symmetric, while joint space can change between the two sides, and also clarifies the position of the condyle in the fossa.

Although CBCT provides important information regarding the osseous components of TMJ, it has several limitations, like the artifact which can appear due to the patient's accidental movement during examination (especially in children).[42]

## 7. Magnetic resonance imaging (MRI)

It is a method of choice to study disease processes involving the TMJ soft tissues,[43] (articular disc, synovial membrane, lateral pterygoid muscle). It is considered the gold standard for assessing disc position and is highly sensitive for intraarticular degenerative alteration and can detect the early signs of TMJ dysfunction, like thickening of anterior or posterior band, rupture of retrodiscal tissue, changes in shape of the disc, joint effusion.[44] MRI should be part of the standard evaluation when an internal structural joint abnormality is suspected because MRI provides high resolution and great tissue contrast.[45] Images can be obtained in all planes (sagittal, axial, coronal). In most scanning sequences, T1 weighted, T2 weighted and proton-density (PD) images are obtained. With T1-weighted images, it is possible to obtain excellent anatomic detail; proton density results in satisfactory spatial resolution of joint disc injuries, and is an excellent choice for the evaluation of medial and lateral disc displacements.(Figure 2), while T2-weighted images are used in diagnosing inflammation in the joint and record the presence of joint effusion and medullary bone edema.[46,47] Frequently used section thickness is 3 mm. Reducing the slice thickness improves the quality of the images, but requires longer scanning time.

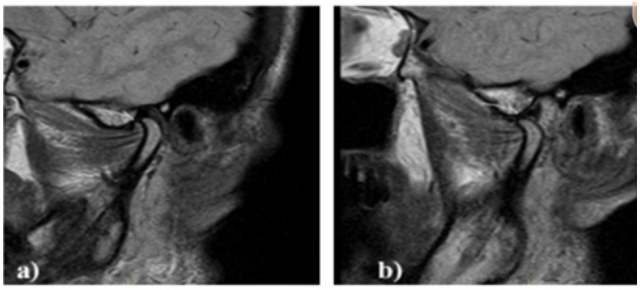


**Fig. 2:** Sagittal, proton density, MRI of a normal TMJ: mouth-closed **(a)**, mouth-opened **(b).** The disc is in a correct position

An axial localizing image is used to direct the long axis of the condyle in the closed-mouth position. Sagittal images are obtained perpendicular to the long axis of the condyle, and coronal images are obtained parallel to the long axis.[48] In MRI examination, a pathological condition is considered to be present relative to the intermediate zone of the meniscus (as a point of reference) and its interposition between the condyle and the temporal bone.[49] Normal disc position, evaluated in the sagittal plane, is with the junction of posterior band aligned approximately at 12 o'clock, position relative to the condyle. Disc displacement is diagnosed when the posterior band sits in an anterior, posterior, medial or lateral position with regard to the condylar surface.[50] In the closed-mouth position, teeth should be in contact, whereas in the opened-mouth position, the jaw should be at the widest comfortable opening. This way, misinterpreted disc positions could be avoided.[51] Contrast-enhanced MR images with gadolinium-based contrast agents have been used in patients with rheumatoid arthritis to image the proliferating synovium more effectively.[52] Synovitis can be clearly visualized on MRI images. Synovial inflammation could lead to joint effusion, defined as an increase in the volume of intra-articular fluid. (Figure 3)

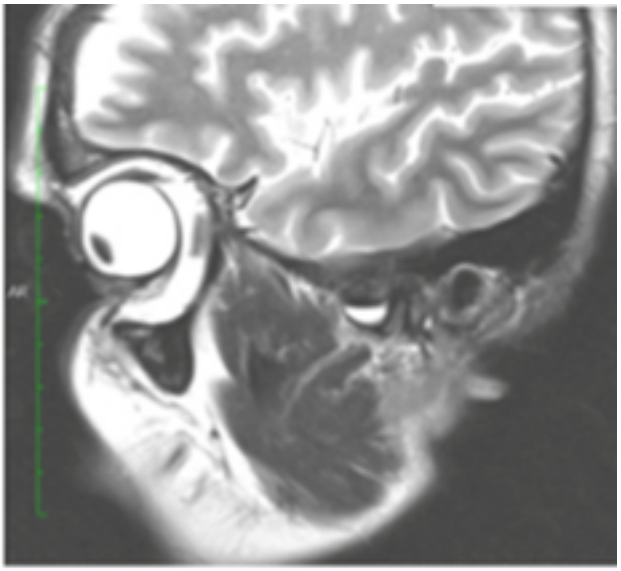

**Fig. 3:** Sagittal, T2 weighted MRI of a TMJ effusion

## 8. High-resolution Ultrasonography

US examination is useful in depicting disc displacement and effusion and to evaluate cartilage as well as disk displacement with both open and closed mouth imaging. It can be used for image-guided injections for both diagnostic and therapeutic purposes. Typically, a linear transducer of 8 MHz or higher is ideal. The patient should be lying supine with the transducer placed parallel to a line extending from the tragus of the ear to the lateral surface of the nose over the TMJ. The joint disk is scanned on the screen as a thin homogeny hypo, as far as the isoechogen strip adjacent to the condylar border. The condylar borders and articular eminence are seen as hyperechogen line. During the examination it is possible to directly observe the joint disk move when the mouth is opening and closing. Normally, the disc is situated between two hyperechoic lines represented by the mandibular condyle and the articular eminence. If the disc is displaced in the closed-mouth position, the diagnosis is disc displacement. If the disc returns to its normal position during opening, the diagnosis is disc displacement with reduction (Figure 4). If not, the diagnosis is disc displacement without reduction.[53–55]Limits to the use of ultrasonography for the diagnosis of TMJ disorders are related to the difficulty in the visualization of the articular disc that is allowed only through the small gap between the zygomatic process of the temporal bone (above) and the head of the condyle (below). It is very difficult to obtain satisfactory images especially when the condyle rotates and translates from the mouth-closed position to the mouth-open position. It is necessary to constantly adjust the position of the transducer to better visualize the disc. Furthermore, only the lateral part of the TMJ can be reached, while the medial part remains hidden by the mentioned structures. As a consequence, medial displacements of the disc are likely to be overlooked. The diagnostic value of high-resolution US is strictly dependent on the examiner's skills and on the equipment used. Therefore, there is a continuous need for trained and experienced radiologists in this field.[56] The new transducers invented have a high focus depth and narrow wave beam. The rebound potential of bone surface is as much as 2/3 waves and only 1/3rd propogate down to deeper anatomic structures. For this reason the transmitter must be placed on a specific place, with the aim to transmit waves through the soft tissues, situated between the condyle and the eminence.[57]

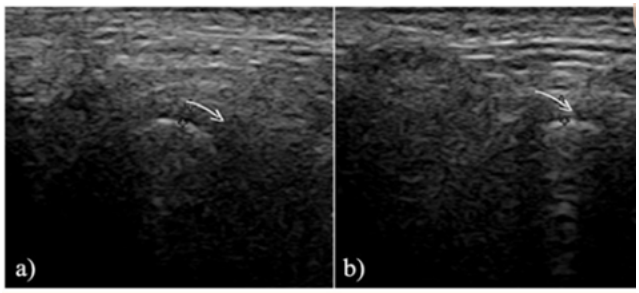


**Fig. 4:** High-resolution US of an anterior disc displacement with reduction: mouth-closed **(a),** mouth-opened **(b)**. The arrow shows the displaced disc

## 9. Conclusion

Temporomandibular disorders are frequent and wide spread in general population. The real causal factors and correct diagnosis should be established in order to provide appropriate management. Substantial improvements have been made in our diagnostic and imaging capabilities. The general radiologist is frequently challenged to manage the diagnostic pathway and to provide a good basis for planning the proper therapeutic strategy. Imaging of TMJ should be performed on a case by case basis depending upon clinical signs and symptoms. MRI is the diagnostic study of choice for evaluation of disk position and internal derangement of the joint. CT scan for evaluation of TMJ is indicated if bony involvement is suspected and should be judiciously considered because of radiation risk. Understanding of the TMJ anatomy, biomechanics, and the imaging manifestations of diseases is important to accurately recognize and manage these various pathologies.

## 10. Source of Funding

None.

## 11. Conflict of Interest

None.

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**Cite this article:** Shenoy P, James J, Chatra LK, Veena K M, Prabhu R. Imaging diagnostics of intracapsular disorders. *J Oral Med, Oral Surg, Oral Pathol, Oral Radiol* 2021;7(1):16-22.