Update on maxillo-facial imaging: temporomandibular joint

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Purpose

Despite being a small structure, the temporomandibular joint (TMJ) presents a complex anatomy and vast functional capacity, in addition to being the location of several pathologies with a wide range of clinical manifestations. Because of this, we decided to perform a thorough review of its anatomy and most significant pathology, analyzing the different diagnostic imaging techniques used for its evaluation.
Methods and Materials

We decided to perform a thorough review of its anatomy and most significant pathology, analyzing the different diagnostic imaging techniques used for its evaluation.
Results

**Normal anatomy and biomechanics of the temporomandibular joint (TMJ)**

It's a synovial joint between the mandibular condyle (below) and the glenoid fossa and the articular eminence of the temporal bone (above). The articular surfaces are covered with fibrocartilage. An articular capsule with lax connective tissue extends from the back of the temporal bone, glenoid fossa and articular eminence of the temporal bone (above), and from this to the condylar neck (below), forming an inverted pyramid.

The joint is divided in two distinct compartments, upper and lower, separated by the articular disc. The disc is a thin, oval plate composed of fibrous tissue, biconcave on the sagittal plane. Three sections can be distinguished: anterior band, intermediate zone and posterior band. The anterior and posterior bands have a triangular shape and are connected by the thin intermediate zone.

Several ligaments provide dynamic stability to the disc. The posterior ligament, or bilaminar zone, anchors the posterior band to the neck of the mandibular condyle and the temporal bone. The collateral ligaments connect the medial and lateral borders to the corresponding condyle poles. These anchors allow for back-and-forth disc rotation on the articular surface of the condyle. The disc's circumference merges with the capsule's fibers surrounding the joint. Fibers of the superior head of the lateral pterygoid muscle anchor to the anterior-medial portion of the anterior band. In the closed mouth position, the posterior band is centered on the condyle apex (12 hours). Fig. 1 on page 12 Fig. 2 on page 12 Fig. 3 on page 13

The TMJ is a diarthrodial joint that also allows for latero-lateral movement as well as anteropulsion and retropulsion. Normal function requires a coordinated movement of the disc, condyle and mastication muscles (medial and lateral pterygoids, temporal and masseter). The lateral pterygoid permits the opening of the mouth and the rest contribute to the repositioning of the mandible during the closing. The inferior head of the lateral pterygoid attaches onto the anterior face of the neck of the condyle. With an open mouth, the disc rotates forward over the condyle and the condyle-disc complex displaces forward, sitting directly over (or slightly anterior to) the articular eminence. The intermediate zone maintains its position between articular surface of the condyle and the articular eminence, presenting a bow tie shape.

**Imaging techniques**

1.- Radiography
a) Clinical aspects of radiography:
Under normal conditions, the left and right condyles and the mandibular fossa are symmetric in both shape and size. The cortical bone surfaces are thin and soft and cover delicately trabecular bone. It is frequent that the patient refers symptoms of articular disorder with normal radiologic anatomy. In any case, it's usual to find bone alteration in the condyle earlier than in the temporal eminence.

Articular "clicks" are not associated with radiologic alteration, but crepitation is. Nonetheless, on normal asymptomatic individuals, the condyle is centered with respect to the mandibular fossa and moves forward in many symptomatic patients. In spite of that, anatomical variants of the condyle position should be taken into account, as should the central position of the condyles in symptomatic patients.

It is considered a normal motion range with wide open mouth when the condyle reaches the apex of the articular eminence or goes slightly beneath it. If the condyle is clearly forward, it is considered hypermobility.

b) Conventional radiography has long been esteemed to be the best method for initially assessing the anatomy and relationship between the condyle and mandibular fossa in different positions (Farrar series, Fig. 4 on page 14), although it is not always possible to gather technically optimal images.

- **Lateral transcranial radiograph**: Provides a sagittal image of the TMJ, allowing the analysis of anatomy and degree of mobility. The head is put in standard position, with or without fixation devices, and magnification is applied over the TMJ.
- **Towne projection** (also called skull AP Axial): It provides a coronal vision of the head of the condyle and the mandibular fossa. The medial limit of the fossa constitutes a bone bridge that acts as a stop for dislocation in this direction. This projection reveals anatomic detail of the lateral and medial poles of the head, cortical postero-superior surface and neck of the condyle.
- **Submentovertex** (or basal) projection: This view shows lateral and medial condyle poles, anterior and posterior cortical surfaces and provides information on adjacent cranium base structures.
- **Orthopantomography**: It gives general and simultaneous information on both mandibles and the teeth. Along with the Farrar series, it forms the initial approach to TMJ pathology.

2.- **Computerized tomography**

It is a very useful technique for assessing bone anatomy, detecting and staging tumors, analyzing inflammatory changes and fractures. Fig. 5 on page 15 Fig. 6 on page 16
3.- MRI

An optimal TMJ study requires a surface coil that provides a small field of vision (FOV) and a high signal/noise ratio. It is preferable to use corrected sagittal images by scanning in an oblique plane that is orthogonal to the horizontal long axis to the mandibular condyle.

a) Protocol:

- Dynamic sagittal oblique T1-weighted GE sequence: with closed mouth for dynamic joint assessment.
- Coronal oblique T1-weighted SE sequence: provides additional information on medial or lateral dislocation.
- Sagittal oblique T2-weighted TSE sequence: perpendicular to the long axis of the mandibular condyle, it provides information on joint effusion or edema in bone or soft tissue.
- Axial STIR: allows for the identification of the ramus of the mandible and the head of the condyle.

b) Analysis:

MRI assessment of the TMJ should include determining of the position and morphology of the disc in sagittal plane with closed mouth. The disc appears as a low signal structure placed between the hypointense cortical rim of the mandibular fossa and the articular eminence on the upper side and the hypointense cortical rim of the mandibular condyle on the lower side.

Behind the posterior border of the disc lays the bilaminar zone which is composed of fibrofatty tissue and presents a higher signal intensity than that of muscle in T1-weighted images. The elastic fibers are observed with intermediate signal intensity, extending from the superior aspect of the posterior band that inserts in the tympanic portion of the temporal bone. Another band of elastic fibers extends from the inferior aspect of the posterior band to the posterior aspect of the neck of the condyle. Fig. 7 on page 17

The posterior face of the disc's posterior band is marked by a vertical low intensity signal band between the elastic fibers.

When the posterior band of the disc is placed forward of the condyle apex, it is classified as an anterior displacement. If the disc can be observed as a bow tie placed between the condyle and the temporal eminence with open mouth, a recapture or reduction of the displaced disc is considered. The disc can stay displaced forward without recapture.
Later on, it should be assessed on the coronal plane whether medial or lateral rotation of the disc exists. Thus, disc displacement can be catalogued as antero-medial or antero-lateral. Less frequently, the coronal plane can show pure lateral or medial dislocation.

In some instances a fixed disc can be observed in a normal or displaced position. This can mean the presence of adherences, secondary to injury in soft tissue, which will be revealed with T2-weighted images or after administering Gadolinium. Artro-MRI with intra-articular gadolinium chelates is reserved for assessing disc perforation, adherences, or delineating the posterior band.

Pathology
1.- Internal derangement

Temporomandibular disorder is a prevalent clinical syndrome that results in craniofacial pain and includes a set of clinical entities that affect the TMJ or its associated structures. Internal derangement is an orthopedic denomination defining a mechanical failure that prevents soft movement of the joint. Consequently, derangement is a functional diagnosis and the most frequent entity is displacement of the articular disc, which is defined as an abnormal relationship between the disc and the mandibular condyle, articular eminence and mandibular fossa.

It is considered a progressive disorder which peaks at puberty in both genders, with a 3:1 female-male ratio. It presents craniofacial pain and clicking.

Internal derangement is categorized as follows:

- Anterior disc displacement with disc recapture on mouth opening. Fig. 8 on page 18 Fig. 9 on page 18
- Anterior disc displacement without disc recapture. Fig. 10 on page 19 Fig. 11 on page 20
- Chronic anterior disc displacement, with deformed disc, which can be accompanied by perforation in the posterior disc attachment with the posterior band or in the bilaminar zone proper. Fig. 12 on page 21 Fig. 13 on page 22 Fig. 14 on page 23 Fig. 15 on page 24
- Degenerative changes and articular effusion.

There can also be a medial or lateral rotational component. The posterior displacement of the disc is less frequent. Disc displacement can furthermore be classified as total or partial.

As the internal derangement progresses, the elastic fibers in the bilaminar zone lose their elasticity, so that recapture of the disc with open mouth does not happen. The disc stays displaced forward, diminishing or eliminating the condyle translation (closed lockjaw).
In chronical stages, the disc can be displaced forward and deformed, eventually showing perforation of the posterior attachment or the bilaminar zone itself. Perforation paradoxically induces permanent forward displacement of the disc due to the absence of a mechanical stop to the condyle translation. Anyway, direct contact of joint surfaces predisposes for degenerative changes of the TMJ.

Complications of internal derangement

a) Osteoarthritis

Up to 20% of patients with internal derangement present osteoarthritis when diagnosed. As in other joints, it's radiologically manifested as a narrowing of the joint space, joint erosion, bone sclerosis and osteophytosis. Osteophytes typically develop at the margins of the articular surfaces of the condyle and articular eminence. Remodelation of the condyle can be observed in some instances. Fig. 16 on page 24

b) Alterations of bone marrow and avascular necrosis

These are complications that appear on less than 10% of patients with internal derangement. Avascular necrosis is rarely associated with its typical predisposing factors. Its appearance in TMJ tends to be unilateral and is usually preceded by trauma, surgery or inflammatory arthropathy.

- In acute fases, MRI shows signs of hyperemia with transudation of fluid to the medullary space, which appears as a decreased signal on T1-weighted images and an increased signal on T2-weighted ones.
- In cases of chronic avascular necrosis, the normal fatty marrow content is replaced by fibrous hypointense tissue and sclerotic bone. It is characterized by irregularity and flattening of the mandibular condyle, and increase in bone sclerosis and the formation of subchondral cysts. Fig. 17 on page 24 Fig. 18 on page 25 Fig. 19 on page 25.

2. Post-surgical TMJ

MRI provides a precise and non-invasive assessment of the TMJ after surgery. In patients that have undergone diskal plication, an increase in T1 and T2 signal strength can be observed, due to mucoid disc degeneration. In some instances it also shows an altered position.
At the same time, disc implants can be identified as hypointense bands in all sequences, allowing MRI to evaluate presence of granulation tissue, joint effusion, adherences or prosthetic material displacement.

Complications associated to prosthetic material are better evaluated with CT, because they manifest by destruction of foreign body, reactive changes such as erosions, intra-articular calcifications, hypertrophic bone formation or fibrous or bony ankylosis.

3. Arthropathies

Although osteoarthritis is the most common entity, other relevant entities affecting the TMJ are rheumatoid arthritis, gout, calcium pyrophosphate dihydrate deposits and infections.

a) Rheumatoid arthritis

It is characterized by swelling of the synovial membrane, so MRI with contrast is useful for early detection of bone and soft tissue alterations. More so, RM is useful for finding bone changes, medullar alterations, joint effusion, pannus formation as well as position and shape of the disc. Fig. 20 on page 26

Radiological alterations are characterized by bone and soft tissue changes, including joint erosions, with flattening of the mandibular condyle and fossa, narrowing of the joint space, osteoporosis, synovial proliferation and a reduction in the range of motion.

Structural alteration of the disc and displacement of it by destruction of the posterior anchor can co-exist.

In advanced stages, inflammatory joint alterations are indistinguishable from osteoarthritis due to internal derangement of the TMJ. Rheumatoid and psoriatic arthritis, ankylosing spondylitis and erythematous systemic lupus can affect the TMJ and they’re clinically and radiologically indistinguishable. Both diskal displacement and degenerative changes are frequently observed in patients with ankylosing spondylitis. Diskal displacement is attributed to destruction of retrodiskal tissue and medial and lateral disc insertion in the condyle poles. Secondary swelling of the synovial membrane accelerates degeneration, resulting in bone destruction.

b) Arthropathy by calcium pyrophosphate deposit

It can be observed that it mainly affects fibrocartilage and, in rare occasions, crystals deposit on the hyaline cartilage. This is more likely to happen in joints like the knee and wrist. The acute form of arthritis manifested by acute joint effusion with calcium pyrophosphate crystals is a rare clinical entity in the TMJ.
Pseudo-gout is a rare form of illness by deposition of calcium pyrophosphate crystals that usually affects only one joint. It is identified by a calcified mass that affects the mandibular condyle or the articular space, simulating a chondrosarcoma.

c) Septic arthritis

Septic arthritis is a rare entity, produced by direct inoculation, spread from adjacent soft tissues (dental focus, parotid, ear) or hematogenous dissemination.

Diagnosis has to be clinical and the exploration physical, due to its fast progress. Radiographically, the findings can be indistinguishable from rheumatoid arthritis.

4. Tumors

Tumoral pathology is infrequent.

a) The most frequent benign tumor is osteochondroma. Other less frequent benign tumoral processes are osteoma, giant cell tumor, fibrous cortical defect, non-ossifying fibroma and aneurysmal bone cyst.

b) Among the most frequent malignant tumors are secondary extensions of primary mandibular tumors such as osteosarcoma or tumors in adjacent structures like parotid carcinoma. The most usual metastases to the mandible are from the breasts, lungs and kidneys and are more frequent in the mandibular body than in the TMJ.

c) Among pseudotumoral synovial pathologies, synovial osteochondromatosis, pigmented villonodular synovitis and synovial ganglion are the most common.

• Synovial chondromatosis is characterized by metaplasia of the synovial membrane with multiple hyaline cartilage formation points, which may become intraarticular loose bodies, eventually calcifying and thus becoming detectable by conventional radiography. They can also condition an alteration of the joint dynamic. MRI shows significant joint effusion and and signal voids corresponding to the calcified bodies. There can be osteolysis and sclerosis can appear in both the condyle and the gleonid fossa.
• Ganglions contain mucinous fluid. They can develop by herniation of the synovial membrane in surrounding tissues. MRI shows a cystic mass in direct continuity with the articular space.

5. Congenital alterations

Congenital malformations of the TMJ are infrequent. They derive from developmental alterations of the first branchial arch, resulting in condyle agenesis, hypoplasia or bifidous condyle and condyle hyperplasia. These can be associated to anomalies in the external auditory canal and middle ear structures. Diagnosis is usually obtained by conventional radiography. Fig. 21 on page 26

Patients with condyle hyperplasia usually present facial asymmetry and malocclusion. Hyperplasia of the coronoid process can be observed in rare instances. It may clinically resemble a TMJ disfunction.
Fig. 1: Left (descending): articular eminence, anterior band, condylar head, lateral pterygoid muscle Right (descending): posterior band, bilaminar zone, inferior condylar insertion mastoid, external auditory canal

**Fig. 2:** Normal TMJ. Sagittal T2 with mouth open

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**Fig. 3:** Normal TMJ. Sagittal T2 with mouth closed

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Fig. 4: Normal Farrar series: it shows an appropriate relationship between condyle, mandibular fossa and articular eminence at rest and in open and closed mouth positions.

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Fig. 5: Post-traumatic lateral subdislocation of both condyles

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**Fig. 6:** Post-traumatic lateral subdislocation of both condyles

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**Fig. 7:** Bilaminar zone: condylar attachment (left), temporal attachment (right)

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**Fig. 8:** Normal Farrar series

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Fig. 9: Same patient, T1GE where forward disc dislocation can be observed, no deformation, with recapture on mouth opening.

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Fig. 10: Anterior disc displacement without disc recapture, closed mouth

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Fig. 11: Anterior disc displacement without disc recapture, open mouth

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Fig. 12

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**Fig. 13:** Detail of orthopantomography and T1 GE with open and closed mouth were anterior osteofites of the condyle can be observed, as well as forward dislocation of the disc without recapture.

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**Fig. 14:** Forward dislocated disc without recapture, associated to degenerative changes in the mandibular condyle.
**Fig. 15:** Forward dislocated disc, without recapture and deformed.

**Fig. 16:** Two osteoarthritis cases. On the left, coronal TC shows narrowing of articular spaces, irregular articular surfaces (more pronounced on the right side) and flattening of mandibular condyles. On the right, Sagittal T1 SE where osteophytes in the mandibular condyle can be observed.
**Fig. 17:** Coronal T1 SE and Sagittal T1 GE. Avascular necrosis of the left condyle with joint effusion.

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**Fig. 18:** Another case of chronic avascular necrosis. From left to right: T1 SE with open mouth, closed and coronal T1 SE.

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**Fig. 19:** Osteonecrosis of the right condyle. Left: coronal T1 SE. Right: sagittal DP, showing minimal joint effusion.

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**Fig. 20:** Rheumatoid arthritis manifested by joint erosions, flattening of condyle and fossa, narrowing of space and bone sclerosis in the condyle.

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**Fig. 21:** Left condyle hypoplasia.

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Conclusion

Conventional radiography and CT are useful but MRIs essential for an exact diagnosis and adequate therapy planning, due to its contrast resolution that shows not only bone but also structures such as the articular disc. If MRI is not conclusive, or if more detail of the bone structures is needed, resorting to other imaging techniques is advised; reserving arthrography for cases where disc perforation or capsular adherence is suspected.
References
