Magnetic resonance imaging and computed tomography of the temporomandibular joint: beyond dysfunction*

Ressonância magnética e tomografia computadorizada da articulação temporomandibular: além da disfunção

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Abstract **Several diseases should be considered in the differential diagnosis of disorders affecting the temporomandibular joints. Internal derangement is the main condition responsible for pain related to this joint. Clinical signs may, though, be quite non-specific, and many other conditions present with similar and not infrequently indistinguishable signs and symptoms. In the present study, the authors describe several non-dysfunctional conditions affecting the temporomandibular joints through computed tomography and magnetic resonance imaging, emphasizing the importance of these imaging methods in the diagnosis of inflammatory, neoplastic and traumatic diseases of this region. Considering that clinical presentations are frequently non-specific, radiologists play a critical role in the differential diagnosis.**

Keywords: Temporomandibular joint; Computed tomography; Magnetic resonance imaging.

Resumo **Várias doenças devem ser consideradas no diagnóstico diferencial dos distúrbios que comprometem as articulações temporomandibulares. A disfunção interna é a principal entidade responsável pelos quadros dolorosos desta articulação. Entretanto, os achados clínicos podem ser bastante inespecíficos e diversas outras condições se manifestam com sinais e sintomas semelhantes e, não raramente, indistinguíveis. Neste trabalho demonstramos, por meio de imagens de tomografia computadorizada e ressonância magnética, várias doenças não-disfuncionais, enfatizando a importância dos métodos de imagem no diagnóstico de doenças inflamatórias, neoplásicas e traumáticas desta região. O papel do radiologista é fundamental no diagnóstico diferencial, uma vez que o quadro clínico é, com freqüência, inespecífico.**

Unitermos: Articulação temporomandibular; Tomografia computadorizada; Imagem por ressonância magnética.

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INTRODUCTION

The most prevalent alteration involving temporomandibular joints (TMJs) is internal derangement[(1)]. This term refers to an abnormal disk positioning and inappropriate functional relationship between the disk and articular surfaces. Pain, clicking and restricted functionality constitute frequent complaints among patients affected by this dysfunction. However, this clinical picture is quite non-specific and several other non-dysfunctional diseases, conditions not directly localized in these joints included, may be responsible for symptoms reported by the patients[(2)]. Not rarely, non-dysfunctional diseases such as arthritis and expansile lesions, among others, are initially confused with internal derangement, delaying the definitive diagnosis and consequently the adoption of an appropriate management. Like in the evaluation of dysfunctional conditions, computed tomography (CT) and magnetic resonance imaging (MRI) are quite useful in the assessment of these patients, with higher accuracy than conventional radiographic studies.

The advent of the multislice technology has significantly improved the images acquisition time, besides allowing high-quality multiplanar images acquisition because of the isotropic acquisition properties of the method[(3)]. The high-resolution of the method is ideal for assessing bone structures and their abnormalities. Currently, a 16-channel multislice CT equipment is utilized for 0.75 mm collimation volume acquisitions, with open and closed mouth views. Later, images are analyzed on the axial, coronal and sagittal planes, and the volume rendering technique is utilized for 3D images reconstruction.

MRI is currently the method of choice for evaluating this joint, because of its excellent capability to demonstrate the TMJ anatomy, particularly when a specific surface coil is employed[(1)]. High contrast resolution images demonstrate soft tissues and can be obtained with the mouth closed or at different degrees of mouth opening, therefore providing functional data. In the author's institution, the protocol described on Table 1 is utilized, and the utilization of

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intravenous paramagnetic contrast agent is reserved for cases where an evaluation of a possible inflammatory process is required.

The present study sought to demonstrate by means of CT and MRI, different non-dysfunctional lesions of the TMJ, highlighting the significance of these pathological conditions in the differential diagnosis for patients with complaints regarding these joints.

ARTHRITIS

Different inflammatory processes may affect the TMJ, usually characterized by edema and synovial proliferation, such as retrodiskitis, rheumatoid arthritis, ankylosing spondilitis, psoriatic arthritis, systemic lupus erythematosus and juvenile rheumatoid arthritis[4]. Both the pathophysiology of these conditions as well as the patients' clinical complaints are similar[5]. Generally, symptoms correspond to pain during the active phase of the disease, limited mouth opening, morning rigidity and crepitation as result of secondary osteoarthritis. Clicking, however, is not a frequent symptom.

Imaging studies can demonstrate the presence of cortical erosion and signs of secondary osteoarthritis, ankylosis at terminal stages of the disease included. Bone alterations can be better characterized by CT. In the active phase of the disease, articular effusion, bone marrow edema and synovial contrast-enhancement can be better visualized by MRI (Figure 1), corresponding to the presence of pannus. The contrast-enhancement, however, is non-specific and does not allow the differentiation between primary inflammation and osteoarthritis[5]. Similarly, there is no significant difference in the imaging findings of the different inflammatory processes that may involve this joint (Figure 2). Granulation and pannus formation, like in other joints, typically occur in naked areas of cartilage adjacent to capsular insertions.

A recent study utilizing technetium-99m-labeled leukocyte in an animal model has demonstrated that this scintigraphic method can early and accurately identify an inflammatory process before structural alterations have developed[6].

INFECTION

Granulomatous or pyogenic infections are uncommon, and may occur as a result of hematogenic dissemination of a distant infection or, most frequently, as a result of a direct extension of an oral infection or following TMJ surgeries[4].

Radiological findings are similar to the ones described for arthritis in general[4], with evident intra-articular effusion, thickening and synovial contrast-enhancement (Figure 3), which are better characterized at MRI. Subtle bone irregularities can be better detected by computed tomography (Figure 4). The clinical progression of the disease is rapid, and the clinical history and physical examination are quite characteristic, considering that local increase in volume can be observed as a result of edema and intra-articular effusion. Usually, intense local pain and marked functional limitation are observed.

CORONOID PROCESS HYPERPLASIA

Coronoid process hyperplasia is a generally unpainful disorder characterized by restricted jaw movement. The cause for this

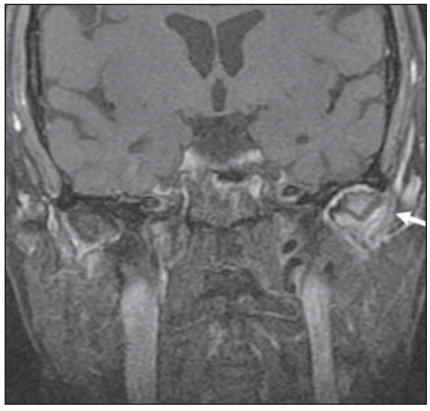

Figure 1. Rheumatoid arthritis. Coronal, T1-weighted, fat-suppressed image after paramagnetic contrast injection. Note the left TMJ involvement, where reduction of the articular space, irregular contour of the condyle and synovial contrast-enhancement (arrow) can be observed.

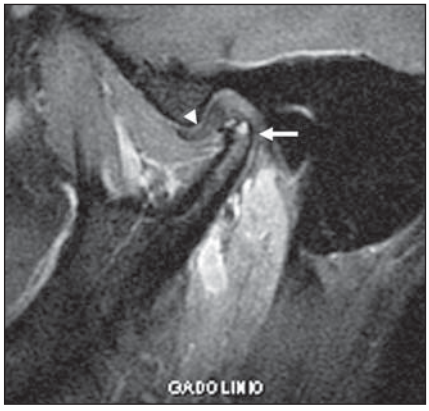

Figure 2. Ankylosing spondilitis. Sagittal, T1-weighted, fat-suppressed image after intravenous paramagnetic contrast injection. Note the irregularity of the mandibular condyle articular surface, with contrast-enhanced subchondral cystic images (arrow). Unaltered intra-articular disk morphology, signal intensity and position (arrowhead).

Table 1 Magnetic resonance imaging sequences utilized for TMJ evaluation at Clínica Axial Centro de Imagem.

Weighting	Plane	Mouth positioning	TE (ms)	TR (ms)	Bandwidth (Hz)	FOV (mm)	Slice thickness (mm)	Matrix	Nex
DP (FSE)	Sagittal	Closed	24	1250	15.63	12	2	256 x 192	2
DP (FSE)	Sagittal	Open	24	1150	15.63	12	2	256 x 192	2
T2 (FSE)	Coronal	Closed	120	3330	20.83	17	3	320 x 192	3
DP (FSE)	Coronal	Closed	24	1200	19.23	17	3	320 x 192	2
DP (FSE)	Coronal	Open	24	1200	19.23	17	3	320 x 192	2
T1 (FSE with fat suppression)	Sagittal	Closed	Min.	450	20.83	12	2	256 x 224	2
SPGR* (pseudodynamic study) *flip angle* 30	Sagittal	Progressive opening	Min.	100	10.42	12	4	256 x 128	2

TE, echo time; TR, repetition time; FOV, field-of-view; Nex, number of excitations; DP, proton density; FSE, fast spin-echo; SPGR, spoiled gradient-echo; Min., minimum.

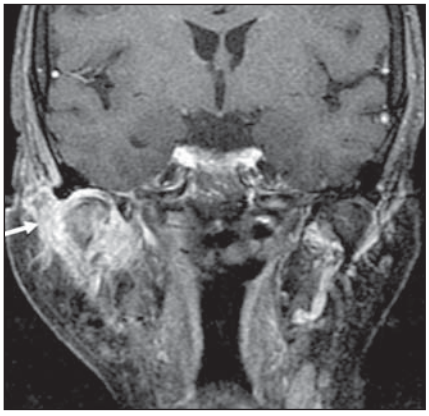

Figure 3. Pyogenic arthritis. Coronal, T1-weighted, fat-suppressed image after paramagnetic contrast injection. Note an extensive inflammatory process involving the masticatory space at right, with an evident and intense synovial contrast enhancement on the right TMJ (arrow).

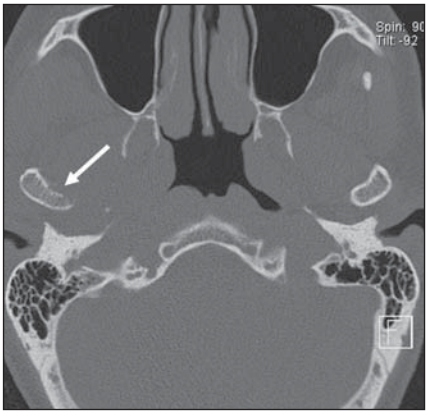

Figure 4. Pyogenic arthritis (the same patients in Figure 3). Axial CT image with bone window demonstrating the cortical irregularity in the medial face of the mandibular condyle (arrow).

condition is still to be determined, and both unilateral[7] and bilateral[8] presentations are reported in the literature. In these cases, the coronoid process elongates at least 1 cm above the lower border of the zygomatic arch with possible impingement on the zygomatic bone (Figure 5) of the maxilla, where frequently the presence of bone remodeling and sclerosis is observed. These alterations can be detected by conventional radiography, but CT is more effective for characterizing morphological alterations as well as alterations secondary to the impingement of the hyperplasied coronoid process against the zygomatic bone and the proximal contiguous segment of the zygomatic arch[9]. Considering that this condition is poorly known by radiologists, and its occurrence may be underestimated[10]. Generally, the surgical management with coronoid process resection is successful.

SECONDARY NEOPLASTIC PROCESS

Metastases to the TMJ are not frequent, but this hypothesis should not be disregarded in the differential diagnosis of painful syndromes affecting this region. Most frequently, secondary lesions arising from adenocarcinomas (Figure 6) affect the mandible. In order of frequency, metastases from primary lesions in the breasts, kidneys, lungs, colon, prostate, thyroid, stomach, skin and testicles may affect this region[11]. Lesions are most frequently found in the molar and premolar regions, with involvement of the mandibular condyle being less frequent. Computed tomography can demonstrate the presence of lytic or blastic bone lesions, depending on the nature of the primary lesion[12]. MRI, however, presents a higher resolution for demonstrating soft tissue components and respective extent, particularly on T1-weighted, fat-suppressed sequences after intravenous paramagnetic contrast agent injection.

SYNOVIAL CHONDROMATOSIS

Synovial chondromatosis is characterized by a cartilaginous metaplasia in the synovial membrane producing small cartilage nodules that can break off from the synovial membrane. These fragments may be found freely within the joint cavity and eventually calcify. Rarely this condition affects the TMJ, but, generally, cases where this joint is involved affect patients in their fourth and fifth decade of life, and most frequently involve women[13]. Symptoms reported by patients are vague, and usually their complaints are related to pain and

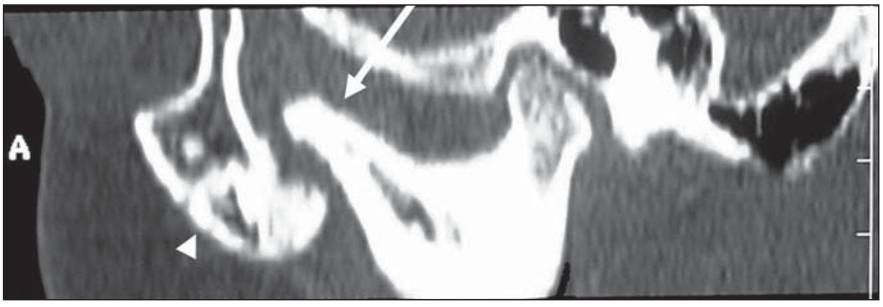

Figure 5. Coronoid process hyperplasia. Sagittal CT image reconstruction demonstrating coronoid process elongated against the zygomatic bone (arrowhead).

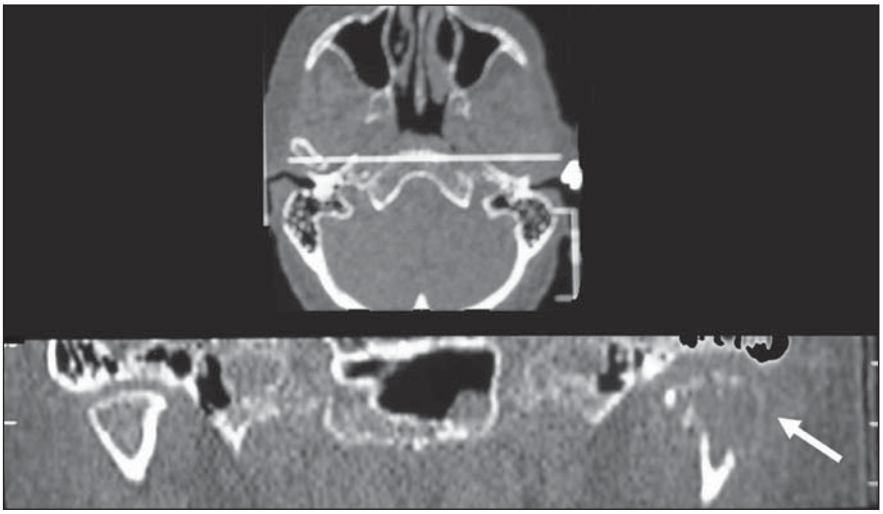

Figure 6. Colon adenocarcinoma metastasis. Coronal CT image reconstruction demonstrating osteolytic lesion on the left mandibular condyle (arrow).

swelling in the region, with facial asymmetry and occlusal problems included. CT studies demonstrate the presence of generally multiple intra-articular calcified bodies (Figure 7). The mandibular condyles may be preserved or with signs of osteoarthritis, with irregularities on the joint surface being observed[14]. In cases where a higher aggressiveness is observed, destruction of the condyle and articular fossa may be found, with intracranial extension included, as already reported[15,16].

MRI can demonstrate the presence of intra-articular effusion, signs of paramagnetic contrast-enhanced synovitis, and presence of intra-articular masses with heterogeneous signal, generally, with hyperintensity on T2-weighted sequences[12], which may be located within the upper as well as in the lower compartments of the joint, and also posteriorly to the mandibular condyle. Calcified lesions present with hypointense signal on T1- and T2-weighted images[14], especially on gradient-echo sequences.

OSTEONECROSIS

Avascular necrosis of the mandibular condyle corresponds to an area with cortical and medullary infarction, resulting in structural weakening that predisposes to collapse and degenerative alterations[17]. This condition may be associated with hematological disorders, bone dysplasia, chemotherapy, corticosteroid therapy, trauma, or occurring as a result of orthognatic surgery complications[18]. However, the majority of cases are related to advanced stages of internal derangement of the TMJ[18].

Pain is the predominant symptom, and may be constant, sometimes reported as pulsatile, exacerbated by the articular movement. Other frequent complaints include headache, otalgia, masticatory muscle spasm and pain, limited mouth opening and crepitation.

Radiographic and tomographic findings include asymmetric condylar morphology, focal defects and depression on the articular surface of the condyle, besides decrease in the condylar volume (Figure 8).

MRI is quite sensitive in the diagnosis of osteonecrosis[17] and, besides morphological alterations, can demonstrate the presence of altered signal intensity in the condylar bone marrow. This alteration is characterized by signal hypointensity on T1-weighted sequences, and variability in signal intensity on T2-weighted sequences (Figure 8), depending on the phase where the study is performed. In a earlier stage, signal hyperintensity can be observed on T2-weighted sequences, corresponding to the presence of edema resulting from vascular congestion. On the other hand, at the later phases of the process, signal hypointensity can be observed on T2-weighted sequences, corresponding to medullary replacement by fibrotic tissue and bone sclerosis. However, it should be highlighted that these alterations are not pathognomonic of avascular necrosis, and MRI does not allow rule out the hypothesis of medullary fibrosis not resulting from osteonecrosis[11]. Additionally, histological evidences may demonstrate the presence of edema, with no evidence of osteonecrosis, or as a possible precedent factor[19].

CALCIUM PYROPHOSPHATE DIHYDRATE DEPOSITION DISEASE (PSEUDOGOUT)

Metabolic arthritis rarely affects the TMJs. Most frequently this condition affects women with > 40 years of age. The pathophysiology of the disease is still to be completely known. Crystals of calcium pyrophosphate dehydrate must originate from articular chondrocytes and their release would occur because of a mechanism of reparation of cartilaginous surface lesions. Therefore, the level of these crystals may be high in the synovial fluid of the affected joint, and normal in the blood and urine of these patients[13].

The clinical picture is generally characterized by acute onset of pain, with local pain and edema. Imaging studies can demonstrate the presence of gross or subtle intra-articular calcifications, the subtle ones being more easily detected by CT (Figure 9). Erosion may be found both in the mandibular condyle and in the articular fossa; however, late detection of the corresponding radiological alterations may occur in cases of few, sparse crisis episodes along an extensive period of time[20].

TRAUMA

The prevalence of condylar process fractures corresponds to 25%-50% of all mandibular fractures, the condylar/subcondylar region being the most frequently fractured portion of the mandible.

These fractures can be classified as condylar neck fractures and condylar head

Figure 7. Synovial chondromatosis. Axial CT image showing free intra-articular bodies at right (arrow).

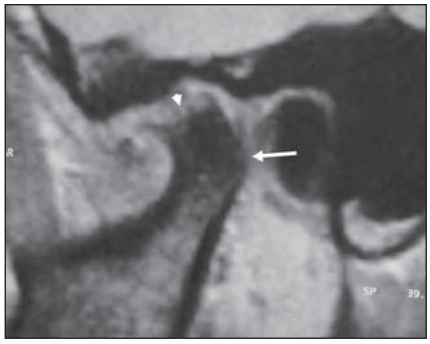

Figure 8. Osteonecrosis. Sagittal MRI T2-weighted image: note the marked irregularity of the condyle contour (arrowhead), with heterogeneous signal, and medullary sclerosis in the remaining condyle characterized by the signal hypointensity (arrow).

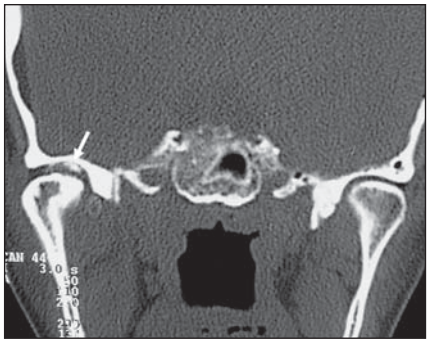

Figure 9. Calcium pyrophosphate dihydrate deposition disease. Coronal CT image demonstrating free intra-articular bodies in the right TMJ, with irregular articular surface (arrow).

fractures. Condylar neck fractures can be high, medium or low (Figure 10), depending on their positioning. On the other hand, condylar head fractures can be subdivided into intracapsular (Figure 11) and extracapsular[5].

Intracapsular fractures are less common and, most frequently affect children. Extracapsular fractures involve the subcondylar region and most frequently occur unilaterally, eventually in association with contralateral mandibular angle fracture[21]. The differentiation between high condylar neck fracture and extracapsular condylar head fracture is somewhat arbitrary. Condylar process fractures can further be subdivided into displaced and nondisplaced fractures. Typically, because of the traction exerted by the pterygoid muscle, fractures are medially displaced.

The evaluation of the type and degree of disk displacement is critical for the therapeutic planning, considering the angle between the mandibular head and ramus, the contact between the fracture ends (particularly the degree of contraction in the vertical plane that affects the occlusion), the transverse displacement, and the position of the fractured head as related to the articular eminence and articular fossa, these parameters being useful in the decision making about a surgical or non-surgical approach[5].

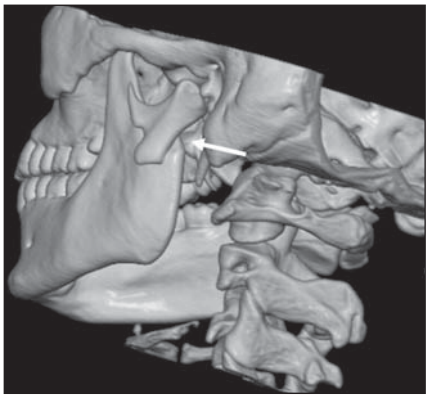

Figure 10. Multislice CT. 3D reconstruction demonstrating low condylar neck fracture with displacement (arrow).

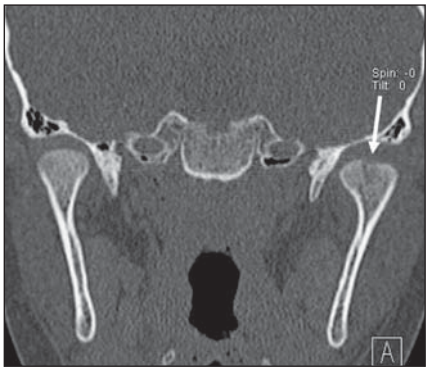

Figure 11. Intracapsular fracture of the left mandibular condyle demonstrated on coronal CT image (arrow).

Generally, the initial evaluation is performed by means of conventional radiography, particularly panoramic radiography of the mandible, because of the low expensiveness, high availability and experience with the method. CT is considered as the imaging method of choice for evaluating facial traumas. The multislice technology has considerably reduced the CT images acquisition time, achieving an improved coverage of the sample volume, besides allowing imaging of different high-resolution angles and planes, and excellent 3D images reconstruction, constituting a quite useful tool in the planning of reconstructive surgeries[21].

MRI can be useful in the identification of post-traumatic disk displacement, as well as capsular, cartilaginous and ligamentous lesions, playing a significant role in the pretreatment evaluation of condylar process fractures. The treatment is aimed at an appropriate reduction and consolidation of the fracture, preservation of the dental occlusion and articular function, besides a good aesthetic outcome. Functional disorders, dental maloccusion, pseudoarthrosis, pain, ankylosis and osteoarthritis constitute complications of inappropriate fracture consolidation[5] (Figure 12).

The selection of open or closed reduction techniques depends on the injury type and severity, presence of unilateral or bilateral fracture, as well as the patient's age and comorbidities.

Generally, the conservative treatment is preferred in cases of unilateral or bilateral nondisplaced fractures in children. The surgical management is reserved for cases of displaced fractures, even the unilateral ones, provided the articular movement amplitude is impaired or dental malocclusion is present.

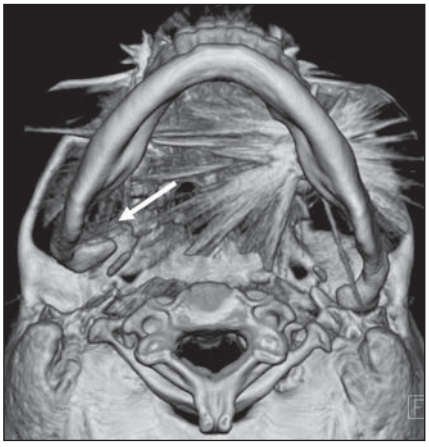

Figure 12. 3D reconstruction by the volume rendering technique (VRT) demonstrating the inadequate positioning of the right mandibular condyle in relation to the articular fossa (arrow).

CONCLUSIONS

Internal derangement corresponds to the main pathologic entity found in patients with TMJ-related complaints. Pain, clicking and functional limitation predominate in the clinical picture. However these signs and symptoms are non-specific and may be found in several non-dysfunctional conditions, including inflammatory processes, expansile lesions and post-traumatic alterations, among others.

Imaging methods are quite useful in the diagnosis of these conditions which frequently are not considered as primary clinical suspicion.

MRI and CT present a higher diagnostic accuracy as compared with conventional radiology, considering their higher anatomical resolution. CT is ideal for evaluating bone structures, while MRI allows the evaluation of soft tissues, the intra-articular disk included. Frequently, these methods are complementary in the study of the TMJ abnormalities, playing a relevant role in the differential diagnosis of several conditions affecting this region.

Additionally, other studies demonstrate that differentiated and symmetrical morphological alterations of the styloid process radiographically evaluated in patients with temporomandibular joints disorder occur independently from gender and age[22].

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