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REVIEW ARTICLE

Temporomandibular joint study by magnetic resonance imaging: it is time to inform

Resonancia magnética de la articulación temporomandibular: es el momento de informar

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Abstract

The temporomandibular joint (TMJ) is a mobile synovial joint that articulates the temporal bone, particularly the articular tubercle and the glenoid fossa, with the condyle of the mandibular bone. Inside it, there is an articular disc that divides the cavity into two compartments, which act as a functional unit. To correctly evaluate the status of the TMJ, it is necessary to know its normal anatomy and function. In addition, one must be familiar with the imaging findings present in magnetic resonance imaging (MRI), which must be correlated with the physical examination and clinical symptoms, to reach an accurate diagnosis. Temporomandibular disorders (TMD) are a heterogeneous set of pathologies that involve the TMJ complex and adjacent bone and muscular structures. MRI is considered the gold-standard imaging technique to evaluate TMD. This technique provides information on the anatomical and functional characteristics, in addition to adequately characterizing the different pathological processes and the response to treatment.

Keywords: *Temporomandibular joint. Temporomandibular disorders. Magnetic resonance imaging.*

Resumen

La articulación temporomandibular (ATM) es una articulación sinovial móvil que articula el hueso temporal, particularmente el tubérculo articular y la fosa glenoidea, con el cóndilo del hueso mandibular. En su interior existe un disco articular que divide la cavidad en dos compartimentos, los cuales actúan como una unidad funcional. Para evaluar correctamente el estado de la ATM es necesario conocer su anatomía normal y funcionamiento. Además, se debe estar familiarizado con los hallazgos imagenológicos presentes en la resonancia magnética (RM), los cuales deben ser correlacionados con el examen físico y la clínica, para así llegar a un diagnóstico certero. Los trastornos temporomandibulares (TTM) son un conjunto heterogéneo de patologías que involucran al complejo de la ATM y las estructuras óseas y musculares adyacentes. La RM se considera la técnica imagenológica de preferencia para evaluar los TTM. Esta proporciona información sobre las características anatómicas y funcionales, además de caracterizar adecuadamente los diferentes procesos patológicos y la respuesta al tratamiento.

Palabras clave: *Articulación temporomandibular. Trastornos temporomandibulares. Resonancia magnética.*

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Introduction

The temporomandibular joint (TMJ) is a synovial joint responsible for all mandibular movements, in which the articular tubercle and the glenoid fossa of the temporal bone participate with the mandibular condyle through a disc or articular meniscus. That disc is essential for joint biomechanics and can be affected by different pathological processes. Pathologies that affect the TMJ complex are known as temporomandibular disorders (TMD), where internal disorders are the most frequent[1]. These are characterized by an abnormal anatomical and functional relationship of the TMJ. It is estimated that the prevalence of this condition is 5-12% of the population[2]. Symptoms of these disorders include decreased joint range, masticatory muscle pain, TMJ pain, joint cramps, generalized myofascial pain, functional limitation, and deviation of the mouth opening[3].

The evaluation of TMD includes clinical and imaging aspects, where understanding the anatomy and dynamics of the TMJ is essential[4]. Imaging techniques currently used in TMJ include computed tomography (CT) and magnetic resonance imaging (MRI). In recent years, MRI has been positioned as the imaging technique of choice for the study of TMD. This provides images of the joint anatomy, in addition to morphological and dynamic information of the articular disc, which is essential for the diagnosis of these pathologies[5].

The objective of this review is to address the anatomy and physiology of the TMJ, its evaluation using MRI, in addition to exemplifying the most relevant TMD and proposing an algorithm for the imaging diagnosis of these disorders.

Anatomy, physiology, and dynamics of the TMJ

The TMJ is a diarthrotic joint that acts as a unit, which is formed by the articular tubercle and the glenoid fossa of the temporal bone, and the head of the mandibular condyle, being delimited by a fibrous joint capsule. Interposed between the articular surfaces is a biconcave fibrocartilaginous articular disc, which divides the articular cavity into two independent compartments, one superior and one inferior, which allow condylar translation and rotation, necessary elements for correct mouth opening and closing[1,6,7]. It is morphologically related to the lateral pterygoid muscle anteriorly, and the retrodiscal band posteriorly, which form part of its anatomical structure; while the masseter, temporalis, and medial pterygoid muscles only have a functional role in the joint[6,8]. The arterial supply to the TMJ is mainly provided by branches of the maxillary and superficial temporal arteries and direct branches of the external carotid artery. Venous drainage is provided by the superficial temporal veins and the pterygoid plexus. The auriculotemporal and masseteric nerves, branches of the mandibular nerve (V3)[9], participate in the innervation. The movement of the TMJ is directed by the different agonist and antagonist muscles: this consists of mouth closure (mainly the muscles: temporalis, masseter, and medial pterygoid), mouth opening (mainly initiated by lateral pterygoid muscle fibers), protrusion, and lateralization[8].

Imaging techniques

Imaging evaluation of the TMJ is generally requested as part of the diagnosis of TMD, malocclusion, and intra-articular abnormalities of the TMJ[10,11]. Previously, the imaging evaluation of the TMJ was based mainly on conventional radiograph studies, such as transcranial radiography. Although this provides information regarding bone changes, it does not allow the soft tissues to be adequately evaluated[6]. Later, CT and MRI were used[10,12].

CT is the study of choice when you want to evaluate pathologies that affect the bone structure of the joint, such as degenerative changes, in search of erosions, osteophytes, and bone bridges that ankylose the joint, in addition to remodeling and subcortical sclerosis[13], as well as when traumatic pathology is suspected and when there are doubts about the bone component on the MRI. MRI is the examination with the highest performance in TMD; it provides anatomical images and functions, both of the bone and soft tissue components, mainly of the articular disc[14]. The MRI study of TMJ is performed with coronal and sagittal acquisitions on the axis of the mandibular condyle, both with the mouth closed and open (Table 1)[15].

Imaging study design: MRI

Both TMJs are recorded simultaneously through the use of surface coils but on planes individualized for each side. The patient is placed in a supine position and the following sequences are performed: with proton density (PD), oblique sagittal slices are obtained (which are perpendicular to the long axial axis of the mandibular condyle) in closed mouth positions (in intercuspal position or mandibular maximum intercuspation position) and different degrees of interincisal mouth opening of 10, 20, 30, and 40 mm. These distances are measured from the maxillary incisal edge to the mandibular

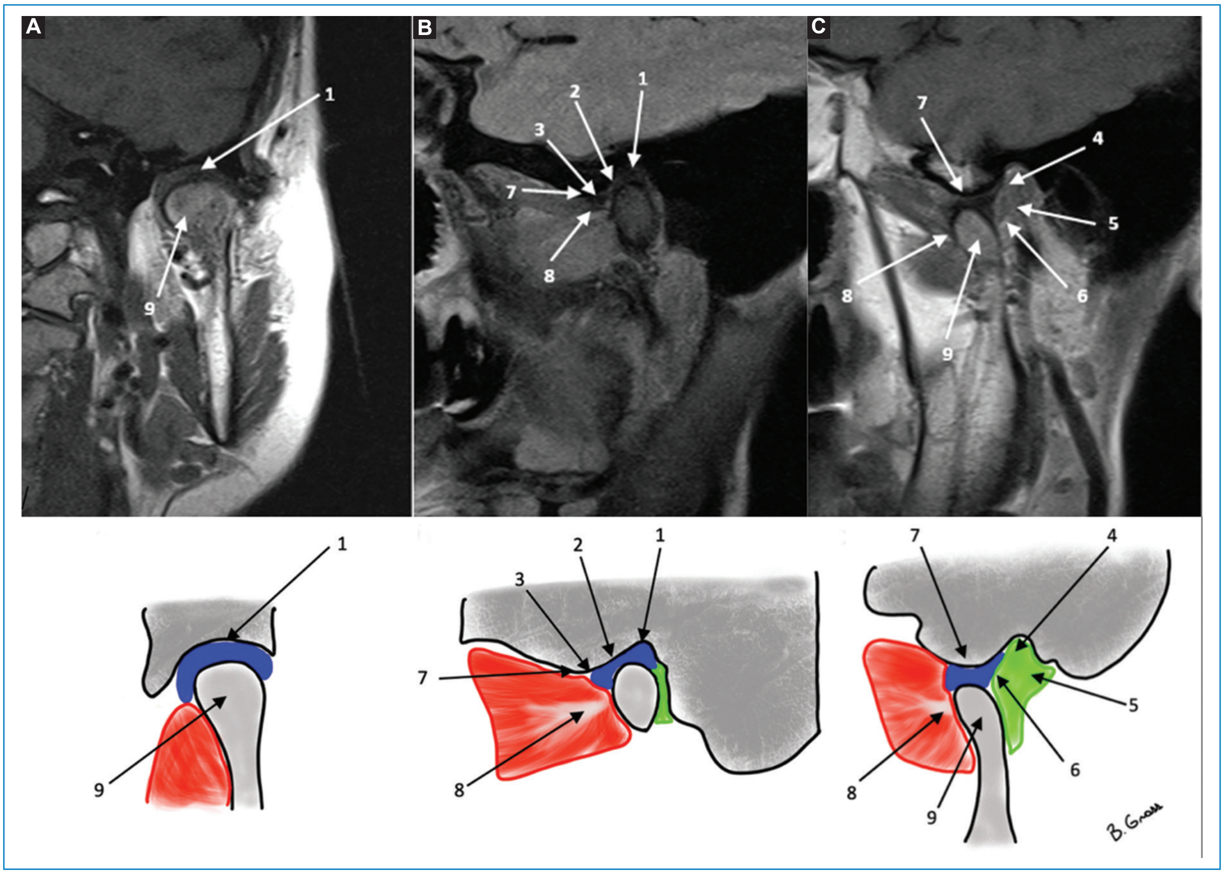


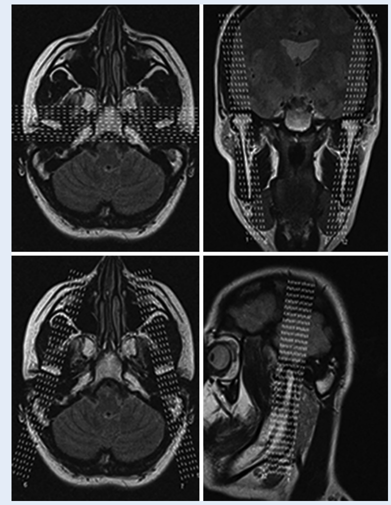
Figure 1. MRI anatomy of the temporomandibular joint. **A:** oblique coronal in closed mouth and **B** and **C:** oblique sagittals in closed mouth and open mouth. Note the biconcave morphology of the disc, its position, and translation-rotation that occurs with mouth opening. **1:** posterior band of the disc; **2:** intermediate zone of the disc; **3:** anterior band of the disc; **4:** superior retrodiscal area; **5:** neurovascular tissue; **6:** inferior retrodiscal layer; **7:** articular eminence; **8:** lateral pterygoid muscle tendon; **9:** mandibular condyle.

incisal edge and are obtained incrementally by placing a bite device into the patient. T2-weighted oblique sagittal slices with fat suppression and oblique coronal slices parallel to the long axis of the condyle on the T1 sequence are also performed, both in closed mouth. This is to adequately evaluate the anatomy and signal of the bone marrow. This oblique coronal plane is important to evaluate disc displacement in a medial or lateral direction. The use of contrast medium is not required in the usual study[15]. The use of contrast medium with gadolinium is reserved for those cases in which inflammatory pathology of rheumatological, infectious, or neoplastic cause is suspected.

Evaluation of anatomical structures on MRI (Fig. 1)

The presence of the articular disc or meniscus and its ligaments generates a division of the TMJ into superior and inferior behavior[6,8]. The disc has an anterior and a posterior band, with a thinner intermediate area, which on sagittal slices gives it a biconcave appearance. The anterior band is located immediately in front of the mandibular condyle and continues with the articular capsule and the lateral pterygoid muscle, generating the anterior unions of the disc. The intermediate zone corresponds to a thin structure that is located between the articular surface of the condyle and the articular eminence. The posterior band is triangular and is centered on the apex of the condyle. The posterior margin of the posterior band is called the retrodiscal zone, with a superior and inferior component, as well as loose connective tissue with vascular and nervous structures, which mix with the joint capsule and temporal bone[4,16,17]. The lateral insertions of the articular disc are generated from dependent fascicles of the lateral pterygoid muscle and the disc bands of the temporal muscle[18].

Table 1. TMJ MRI study protocol

(a) Technical parameters of TMJ MRI	(b) Surface coil in TMJ and graduated sheet for mouth opening 10-20-30-40 mm	(c) Locators to obtain the oblique coronal and sagittal axis on the axis of the condyle
Use of surface coils Localizers (standard axial and coronal T2 TSE and bilateral oblique sagittal) T1 SE coronal oblique MIC for each condyle Oblique sagittal T2 with bilateral fat suppression Oblique sagittal PD with bilateral fat suppression Dynamic study Bilateral oblique sagittal PD in MIC and different mouth openings (10-20-30-40mm) Contrast (only if necessary): T1 TSE post-Gd with fat suppression T1-TR: 400, TE: 16, slice: 2 mm, NEX: 2; matrix: 320 × 216 T2-TR: 3130, TE: 90, slice: 2 mm, NEX: 2; matrix: 320 × 240 PD MIC-TR: 3060, TE: 16, slice: 2 mm, NEX: 2; matrix: 384 × 230 PD (mouth opening)-TR: 2550, TE: 16, slice: 2 mm, NEX: 2; matrix: 384 × 230		

TMJ: temporomandibular joint; PD: proton density; MIC: maximum intercuspation; MRI: magnetic resonance imaging; SE: *spin echo*; TSE: *turbo spin echo*.

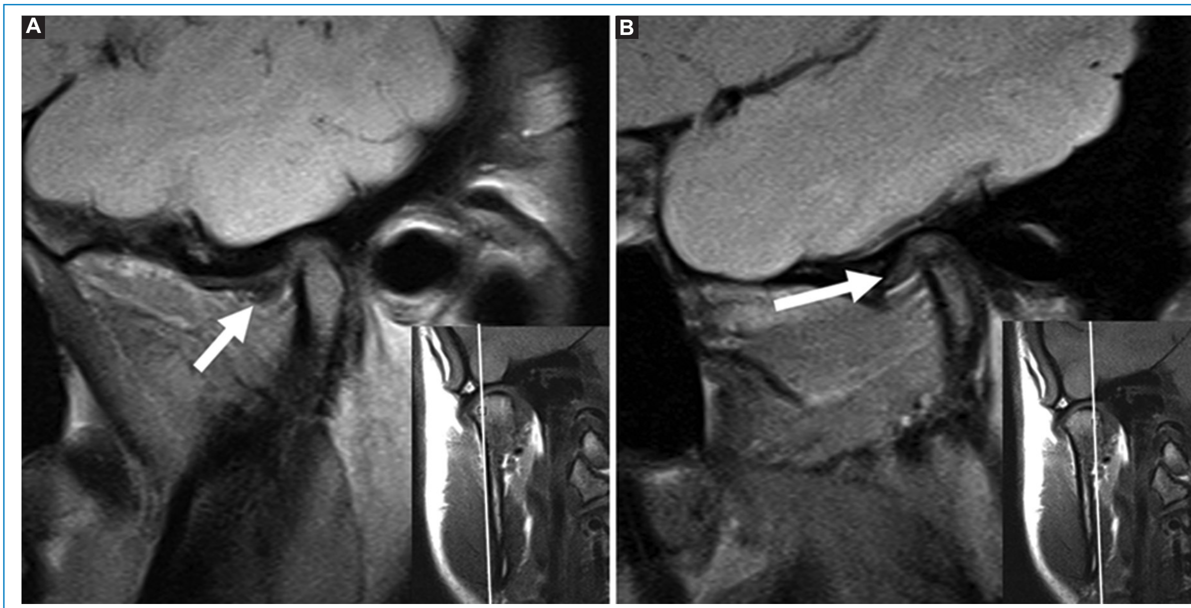


Figure 2. Complete anterior disc displacement. **A** and **B:** oblique sagittal slices in maximum intercuspation in the right temporomandibular joint demonstrating anterior disc displacement, both on lateral slices as well as medial (white arrow).

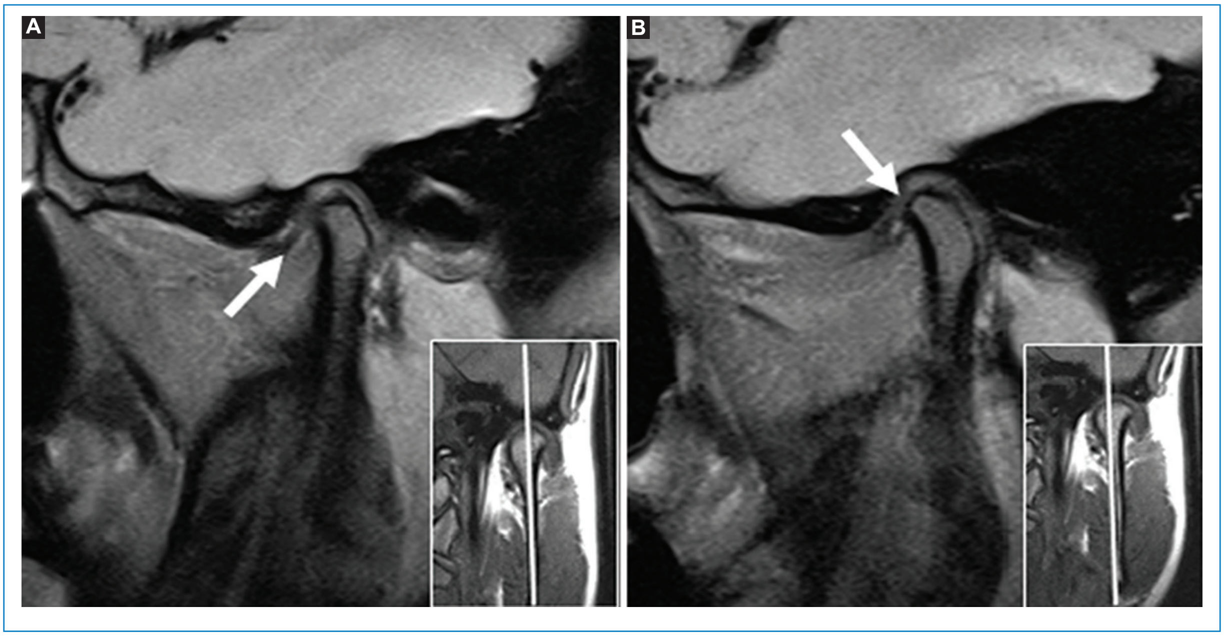


Figure 3. Partial anterior disc displacement. **A**: oblique sagittal slices in maximum intercuspation in the left temporomandibular joint that demonstrate anterior disc displacement on lateral slices, with **B:** normal position on medial slices (white arrow).

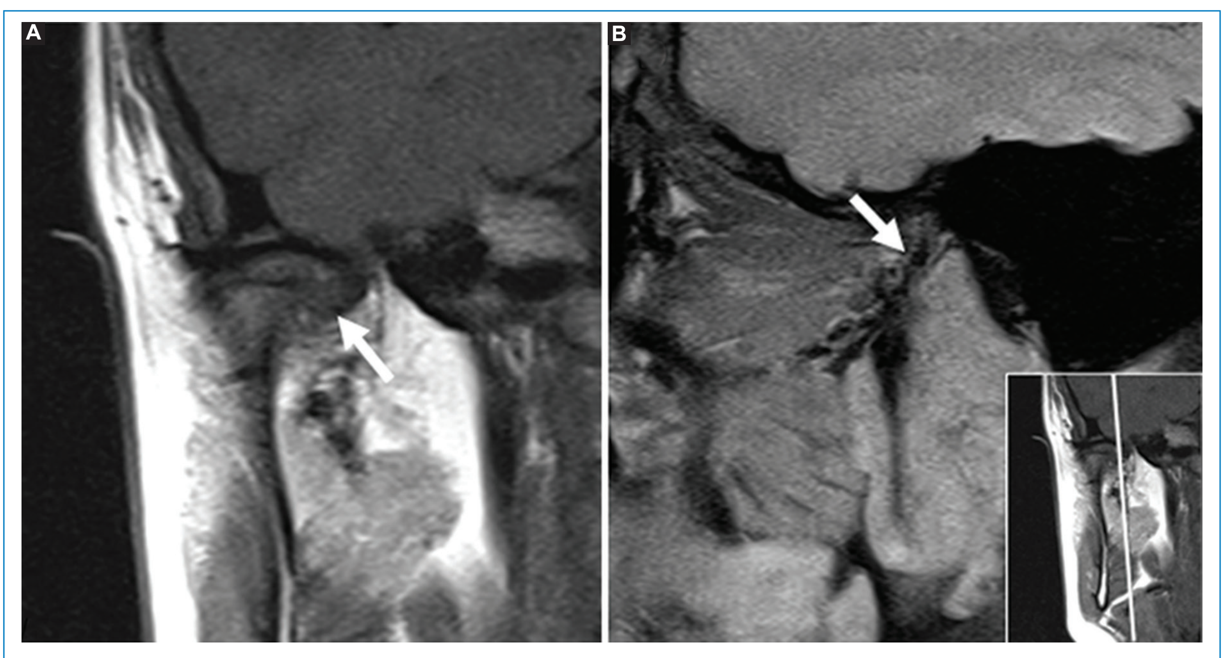


Figure 4. Medial disc displacement. **A:** coronal and **B:** oblique sagittal slices of the right temporomandibular joint medial to the condylar head, demonstrating medial disc displacement (white arrow).

On PD-weighted oblique sagittal images, the meniscus is observed to be biconcave in shape, with a low homogeneous signal intensity, posteriorly related to the retrodiscal area, which shows an intermediate signal intensity. Occasionally, the posterior band may be slightly hyperintense[19]. On coronal slices, the disc is crescent-shaped and should not exceed the limits of the joint capsule (Fig. 1A).

Figure 5. Lateral disc displacement. **A:** coronal and **B:** oblique sagittal slices of the left temporomandibular joint, lateral to the condylar head, in maximum intercuspation that demonstrate lateral disc displacement (black and white arrow, respectively).

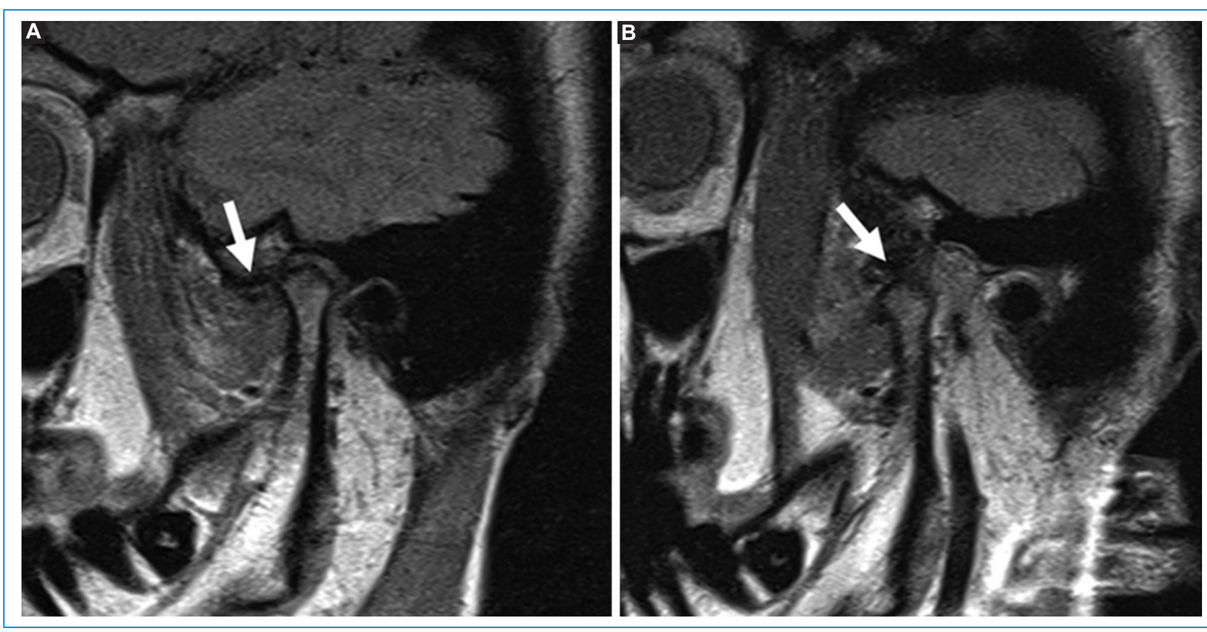


Figure 6. Disc displacement with reduction. **A**: oblique sagittal slices in maximum intercuspation and **B:** in open mouth. At maximum intercuspation, there is anterior disc displacement, which is reduced to its normal position with mouth opening (white arrow).

In the closed mouth position, the normal position of the disc is evaluated by locating the posterior band, which should cover the most superior portion of the condyle at "12 o'clock" on a sagittal projection (Fig. 1B). The intermediate zone of the disc is located between the posterior convexity of the articular tubercle of the temporal bone and the anterosuperior convexity of the condyle[14].

Figure 7. Disc displacement without reduction. **A**: oblique sagittal slices in maximum intercuspation and **B:** in open mouth. Both in maximum intercuspation and open mouth there is anterior disc displacement, without reduction (white arrow).

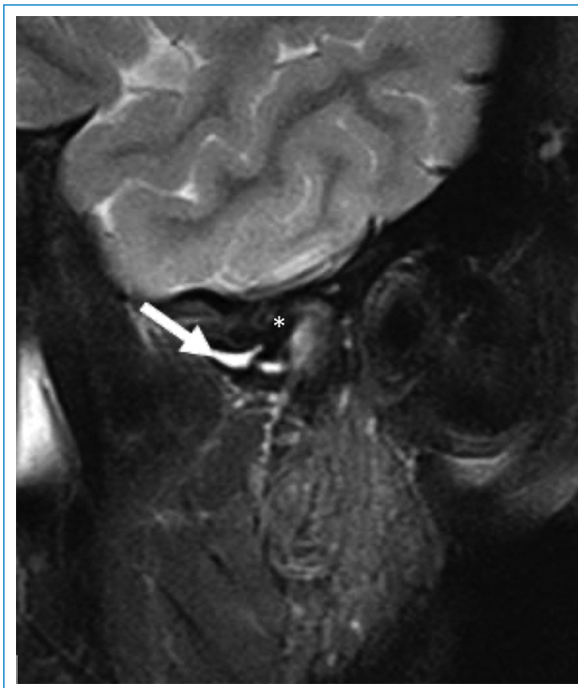


Figure 8. Disc morphological alteration and joint effusion. Oblique sagittal slice in maximum intercuspation demonstrates flattened disc (asterisk) and joint effusion (arrow white).

The mouth-opening movement has two components. First, the condyle rotates and then translates anteriorly while the opening is made. The lateral pterygoid muscle contributes to mouth opening, while the medial pterygoid, masseter, and temporal muscles contribute to occlusion[20].

Regarding the movement of the disc, during the anterior translation of the condyle, it moves to a position between the condyle and the articular eminence, completely contacting the intermediate zone (Fig. 1C)[20].

Various studies indicate that the position of the condyle and intra-articular structures are related to the development of TMD[21]. One of the most important objectives in MRI evaluation is to determine the location of the articular disc, with the displacement of this structure being a characteristic sign of TMD. However, it has been reported that up to 34% of the asymptomatic population have a displaced articular disc as an imaging finding[5,22]. For this reason, special attention should be paid to other signs that may suggest TMD, such as joint effusion, rupture of retrodiscal layers, or increased thickness of the insertion of the lateral pterygoid muscle[5,14].

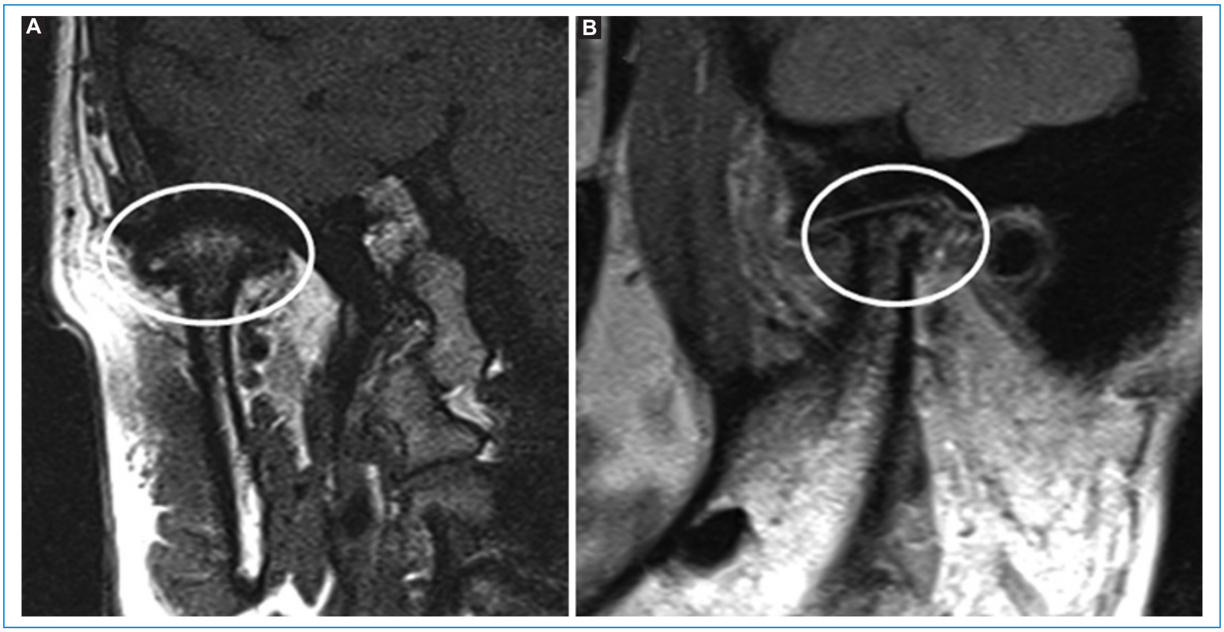


Figure 9. Osteoarthritis of the temporomandibular joint. **A**: oblique coronal and **B:** sagittal slices in maximum intercuspation that demonstrate remodeling and irregularity of the articular surface, with decreased joint space and marginal osteophytes (white circle).

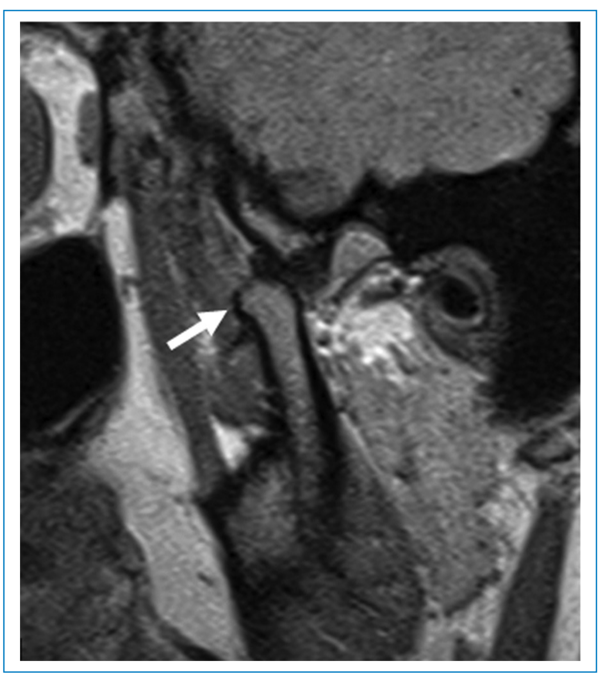


Figure 10. Condylar hypermotility. Oblique sagittal in open mouth with condylar translation in front of the articular eminence (white arrow).

Temporomandibular disorders (TMD)

TMD corresponds to a heterogeneous set of pathologies that involve both the TMJ complex and adjacent bone and muscle structures. It is estimated that they affect between 5 and 12% of the population, with a higher prevalence in women[12,20]. They frequently present with an audible joint crackling sound, associated with joint pain, restriction of joint range, and orofacial pain[23].

Articular disc lesions are the most common cause of TMD, being the most common finding on MRI, being found in up to 70% of patients[11]. TMJ osteoarthritis follows in frequency, being more prevalent in older adults. Other causes of TMD include direct trauma to the TMJ, autoimmune diseases, and synovial osteochondromatosis, among others[1,12].

– Disc displacements. They correspond to displacements or abnormal locations of the disc with the superior part of the condyle. These movements can be anterior, medial, lateral, or posterior; they can also be partial or total, and are evaluated with the mouth closed, both on sagittal and oblique coronal slices[14-16]. The most frequent displacements correspond to the complete anterior and partial or complete anterolateral (Figs. 2-5). While in complete anterior displacement, the entire disc is in front of the mandibular condyle, in partial displacements only one segment is anterior to the condyle[14,16].

Disc displacements are classified into two subgroups according to their behavior with mouth opening: with and without reduction. In those with reduction, the disc

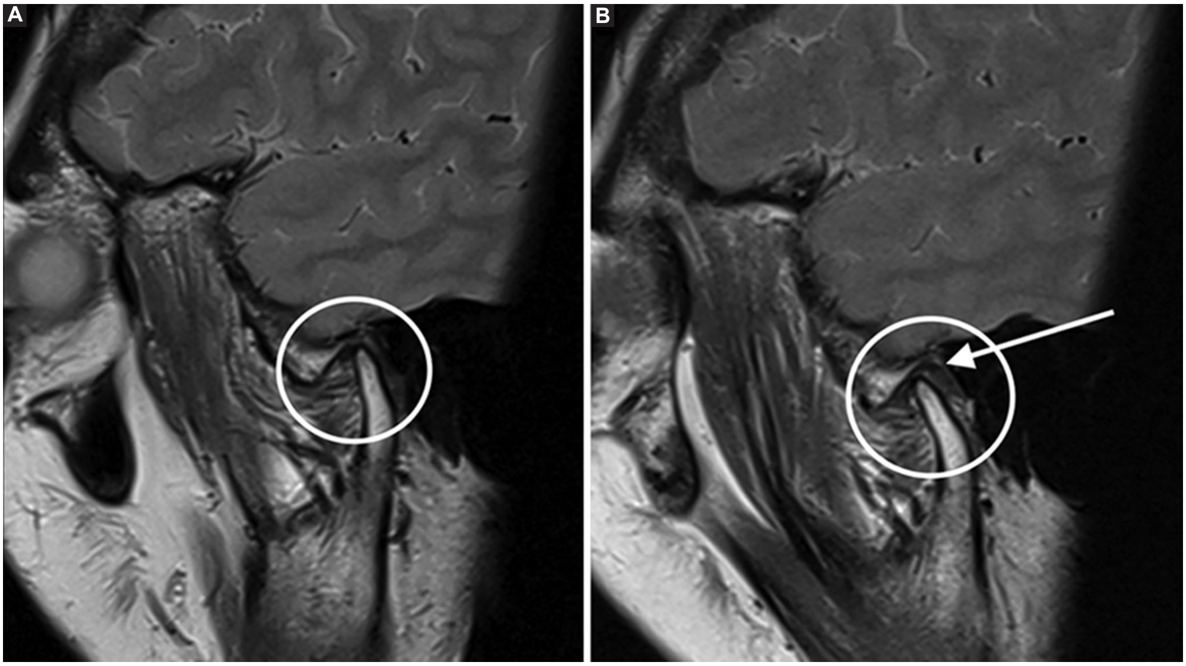


Figure 11. Disc jamming with hypomotility: **A**: sagittal slice in occlusion and **B:** maximum opening 20 mm demonstrating anterior displacement with discal deformation and fibrous metaplasia of the retrodiscal area (white arrow), associated with disc jamming, limiting the condylar translation (white circle).

Figure 12. Condylar hypoplasia. Less development of the right condyle and degenerative phenomena (white circle).

Figure 13. Bifid condyle. Bifid morphology of the condylar head (white arrow).

returns and remains between the articular surfaces during mouth opening (Fig. 6). In disc displacement without reduction, the articular disc remains anterior to the mandibular condyle during all mandibular movements, and the condyle-articular disc relationship is not restored (Fig. 7)[14].

Table 2. Diagnostic approach plan for TMD using MRI based on the anatomical and dynamic evaluation of the TMJ

Evaluation of the disc and its unions	Evaluation of the joint space	Evaluation of the bone	Evaluation of the chewing space
Disc Location Morphology Displacement Unions Retrodiscal area	Widening or narrowing of the joint space Joint effusion Synovial abnormalities Free/loose bodies Capsular abnormalities	Condylar and temporal morphology Bone marrow signal Post-traumatic lesions Tumors and pseudotumoral lesions	Evaluation of the lateral pterygoid muscle and its tendon Evaluation of the visible chewing space

TMJ: temporomandibular joint; MRI: magnetic resonance imaging; TMD: temporomandibular disorder.

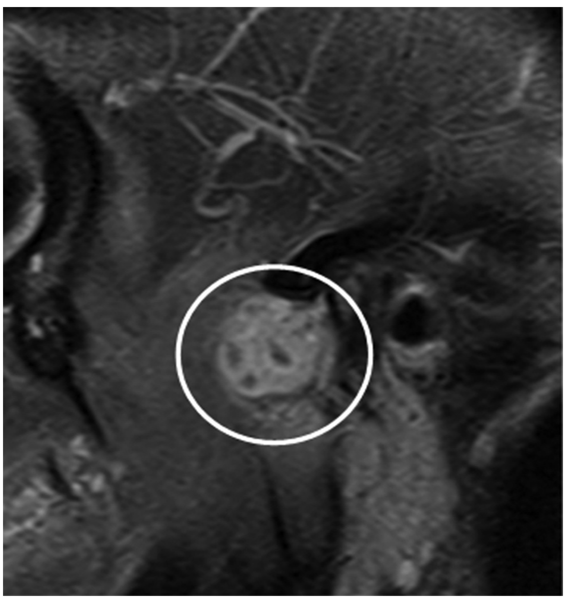


Figure 14. Synovial chondromatosis. Joint space expansion with multiple low-signal loose bodies (white circle).

– Joint effusion: corresponds to a pathological accumulation of joint fluid in joint spaces, associated with an inflammatory process (Fig. 8). The fluid is best evaluated on T2 images with fat suppression[24]. It is a condition frequently found in patients who present joint pain[25]
– Osteoarthritis of the TMJ: although it is a pathology that can be asymptomatic, it is present in a large proportion of older individuals[14], although it can also be seen in young patients, who present with more symptomatic symptoms. It corresponds to the final common pathway of any lesion to the TMJ joint. On imaging, it is characterized by flattening and irregularity of the articular surface, in addition to osteophytes, erosions, cysts, and subchondral sclerosis, usually associated with decreased joint space (Fig. 9)[26]. As a differential diagnosis, when there is erosive involvement of the disc the deposit of calcium pyrophosphate dihydrate must be ruled out, which generates osteoarthritis that is disproportionate for the patient's age. Disc displacements can be precursors of this condition, being frequent in young patients, but they are not the only etiology[27,28]
– Hypermobility and hypomobility of the TMJ: during mouth opening, patients with joint hypermobility can move the mandibular condyle beyond the anterior insertion of the joint capsule, remaining in front of the articular tubercle. By exceeding this limit, the condyle can become trapped in the anterior area of the articular eminence (Fig. 10), producing a mandibular block, with the consequent inability to move the condyle to its normal position[4,29].

Hypomotility corresponds to the inability of the condyle to reach the apex of the articular tubercle[30]. This lower joint mobility is related to a lesser condylar translation (Fig. 11). Among its main causes is disc jamming due to retrodiscal fibrosis, fractures of the condyle, infectious/inflammatory processes, neoplastic infiltration of the masticatory musculature and advanced degenerative phenomena, among others[31]. On the other hand, it must be considered that joint pain also favors TMJ hypomotility[32].

– Alterations in the development of TMJ: these conditions are suspected when there are alterations in facial symmetry, which can be progressive. Furthermore, they can be associated with anomalies of the external auditory canal and/or in the middle ear. In these cases, condylar aplasia, condylar hypoplasia (Fig. 12), hyperplasia, and bifid condyle should be looked for (Fig. 13)[17,33,34].
– Synovial chondromatosis: this is a rare disorder, in which there is a chondrometaplastic process of mesenchymal remnants of the synovial membrane, where the presence of cartilaginous bodies can be found inside the joint space[35]. It generally presents unilaterally with non-specific symptoms, similar to other TMD (Fig. 14)[36,37].

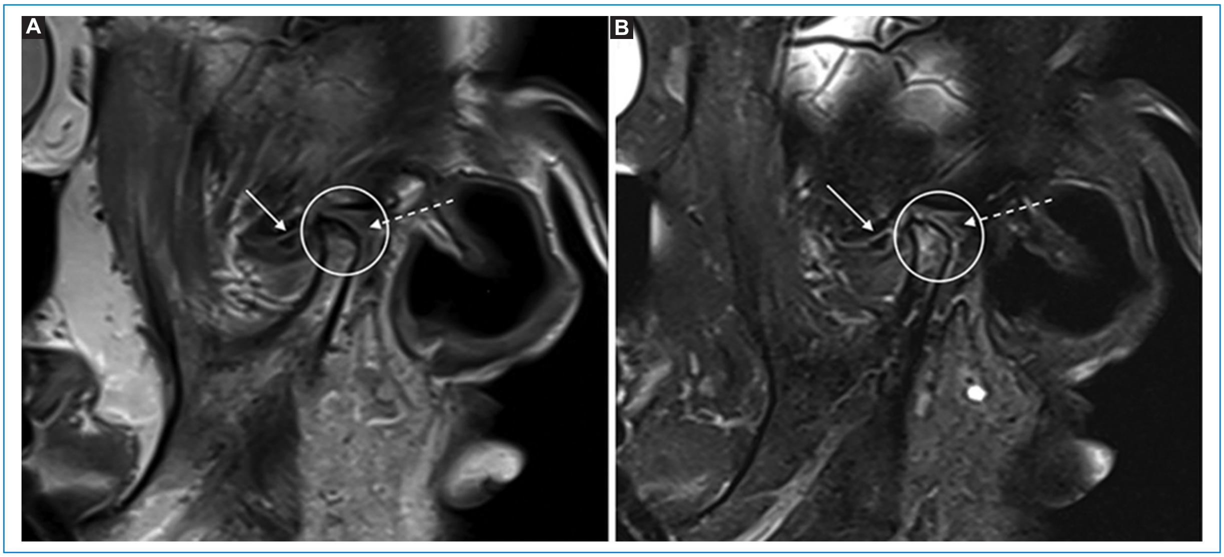


Figure 15. Disc deformation. **A**: sagittal slice on PD and **B:** T2 FS demonstrating rounded articular disc (white arrow) in addition to degenerative osteoarthritis with marked irregularity of the condylar head, subchondral edema (white circle), and retrodiscal edema (dotted arrow).

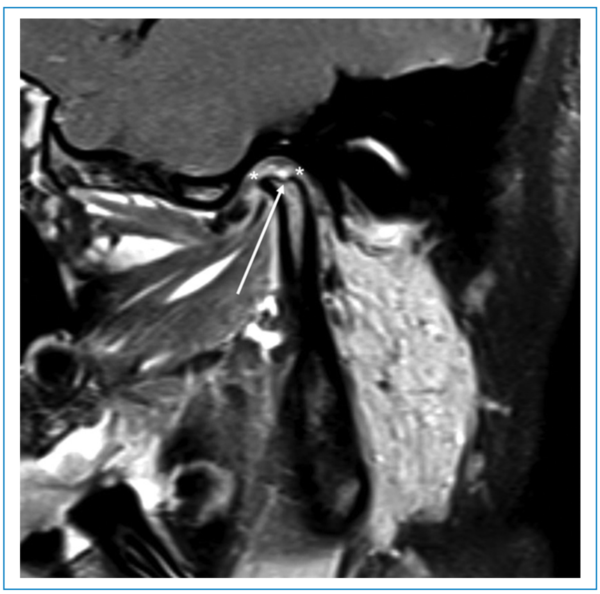


Figure 16. Inflammatory pathology of the temporomandibular joint. A 13-year-old patient with suspected juvenile idiopathic arthritis. Sagittal T1 FS slice with gadolinium showing osteitis (compare hypersignal of the bone marrow of the condyle in relation to the mandibular angle), erosion of the condylar head (white arrow), along with enhancement and synovial thickening of the temporomandibular joint (asterisk).

– Alterations in disc morphology. Disc morphology is evaluated with the mouth closed, on the sagittal plane, and can be classified morphologically as a biconcave (normal) or deformed disc[38]. The type of deformation is related to the degree of displacement that the disc has and the evolution of the pathology[16,17,39]. These alterations can be uniform flattening, flattened posterior band, folding, thickening of the posterior band, and biconvex or rounded shape (Fig. 15)[16,40,41].

– Inflammatory pathology of the TMJ: inflammation of the TMJ can occur as a result of inflammatory arthropathy or be secondary to other TMD. The most common inflammatory pathology is rheumatoid arthritis. It is followed by juvenile idiopathic arthritis, calcium pyrophosphate deposition disease, septic arthritis, ankylosing spondylitis, psoriatic arthritis, and other rheumatological diseases. These present with synovitis, reduced joint space, joint erosion, flattening of the condyle, disc deformity, effusion, and bone edema, so the use of contrast medium is essential to differentiate synovial effusion from synovitis (Fig. 16)[42,43].

Diagnostic approach to TMD using MRI

To study TMD using MRI, a systematic and thorough approach to the disc anatomy along with its adjacent components is necessary. It is suggested to approach the study in four stages, starting with the evaluation of the disc, both in its location, morphology, and signs of displacement, as well as in its unions, mainly the retrodiscal area. Then, continue with the joint space looking for changes in its width, joint effusion, synovial and capsular abnormalities, and the presence of loose bodies. In the third stage, it is suggested to evaluate the bone component of the TMJ, in the condylar and temporal morphology, the bone marrow signal, and the presence of traumatic or tumor lesions. Finally, the masticatory space must be evaluated, mainly the alterations in the morphology, signal, and thickness of the lateral pterygoid muscle (Table 2).

Conclusion

There are a large number of pathologies that can affect the TMJ, so the clinical history and physical examination are essential for proper diagnosis and management. MRI allows us to complement the anatomical and functional evaluation of the TMJ, and together with the clinical evaluation, it allows us to improve the diagnostic and etiological precision of TMD. This is why we insist on the need to know the anatomy and physiology of the TMJ, in addition to carrying out the appropriate MRI protocols and their systematic analysis, both of the intra- and extra-articular anatomical components and of the functional ones of the TMJ itself.

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Conflicts of interest

The authors declare no conflicts of interest.

Ethical disclosures

Protection of people and animals. The authors declare that no experiments have been carried out on humans or animals for this research.

Data confidentiality. The authors declare that no patient data appear in this article.

Right to privacy and informed consent. The authors declare that no patient data appear in this article.

Use of artificial intelligence to generate texts. The authors declare that they have not used any type of generative artificial intelligence in the writing of this manuscript or for the creation of figures, graphs, tables, or their corresponding captions or legends.

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