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TMJ :
Sense of motion

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ABSTRACT

In an article published in the ODF Review *in 1987, we described the static relationships existing between and among the different components of the temporomandibular joint. This new article completes that work by supplying a dynamic vision of the range of movement, as well as recent anatomical and electromyographic data concerning the lateral pterygoid muscle.*

KEYWORDS

Temporomandibular joint

Anatomy

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In the article entitled "*TMJ in movement: sense of the form*" published in the *ODF Review* in 1987, we described the relationships existing between and among the different components of this particular joint on the basis of a study using serial anatomical sections and 3D reconstruction[30].

In terms of the traditional, static approach of the joint, the anatomical data concerning the muscle-disc-condyle complex have changed very little; therefore, we refer the reader to this article and more recent publications combining anatomy and imaging[1]. Here, with the help of three histological sections, we will be limited to repeating the principal structures in current anatomical terminology (fig. 1 to 3).

In the etiophysiopathological approach of this new article, it seems more appropriate

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to us to concentrate on the recent information concerning the joint biomechanics and kinematics, as well as the physiology of the lateral pterygoid muscle. Indeed, these facts seem to us to be fundamental to the understanding of the complex functioning of these two 'Siamese' joints, and therefore mechanisms that can lead to their dysfunction.

COMPLEX ANATOMY WHERE ASYMMETRY PREDOMINATES

While the two TMJs are roughly symmetrical, asymmetry predominates, with each joint considered separately. Also, at the bone level, the condylar mass is not distributed equally on both sides of the neck: the medial part has a more obvious overhang than the lateral part, bringing about an insertion recess for the lateral pterygoid muscle which approaches the joint medially. As several studies have shown[6,8,9,13] there is a concentration of strains sustained during function in the lateral part of the joint, with these biomechanical data being expressed from a pathological point of view by the predominance of cartilaginous lesions in the lateral third of the joint. Note that for Hylander[12], this stress gradient would be connected to the deformation of the mandible during function rather than to the mandibular head asymmetry.

Asymmetry also exists at the disc level, with the joint disc not as thick in the lateral part of the joint as in its medial part. This difference could

1: External auditory meatus
2: Tympanic bone
3: Tympanosquamous fissure
4: Upper fibers of the bilaminar zone
5: lower fibers of the bilaminar zone
6: Retrodiscal venous plexus
7: Mandibular fossa
8: Posterior band
9: Intermediate zone
10: Anterior band
11: Temporal eminence
12: Prediscal tendinous sheet
13: Disc fibers of the superior head of the lateral pterygoid muscle
14: Bone fibers of the superior head of the lateral pterygoid muscle
15: Inferior head of the lateral pterygoid muscle
16: Neck of the mandibular condyle
17: Parotid gland.

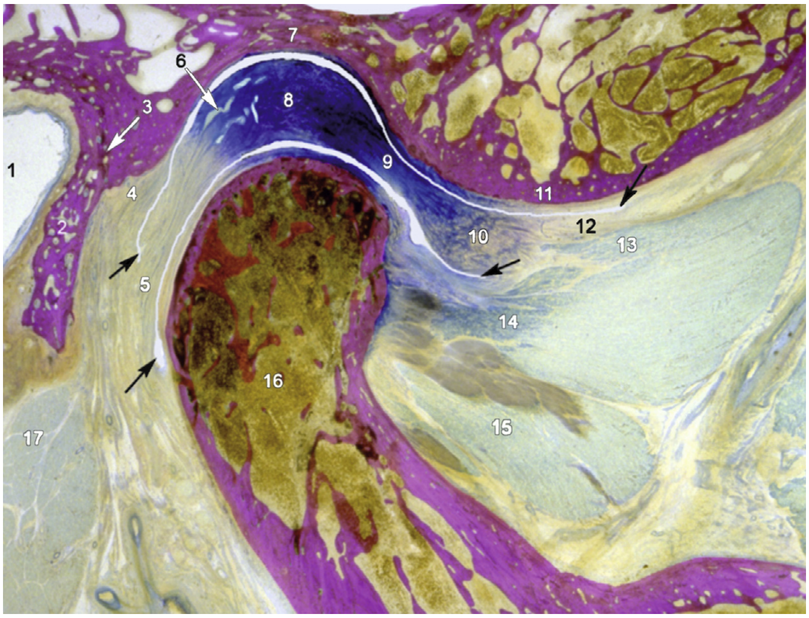
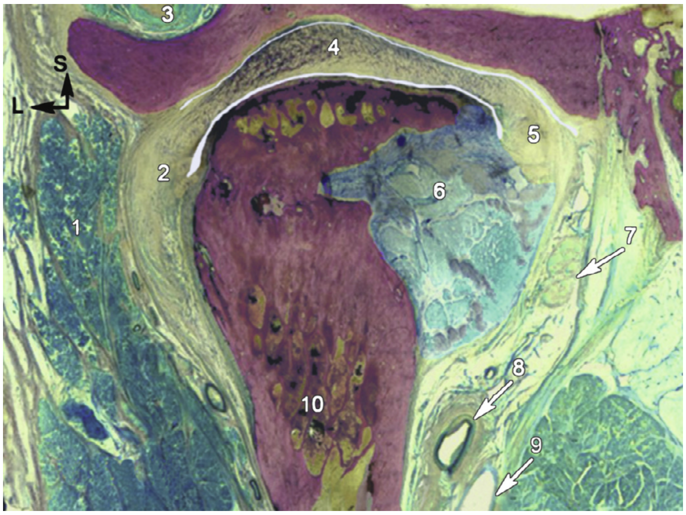


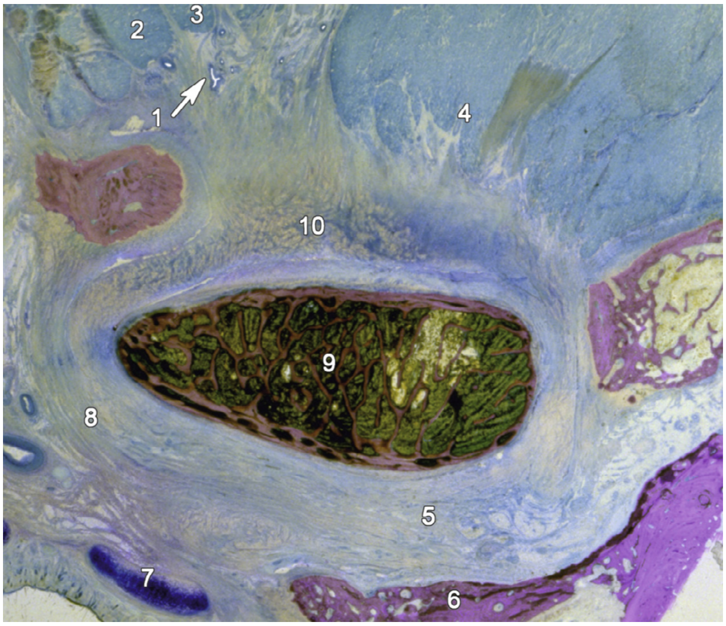
Figure 1
Sagittal section of right TMJ in closed mouth position.



1: Parotid gland
2: Lateral disco-condylar ligament
3: Temporal muscle
4: Posterior band of the disc
5: Medial disco-condylar ligament
6: Insertion of the lateral pterygoid muscle
7: Auriculotemporal nerve
8: Maxillary artery
9: Maxillary vein
10: Neck of the condyle

Figure 2
Oblique frontal section going through the condylar zones.

logically result from a modeling of the disc under the influence of function and the stress gradient, if it did not already exist *in utero*. This asymmetry could then be explained by considering, as analysis of some embryological



1: Anterolateral venous plexus
2: Deep masseter muscle
3: Temporal muscle
4: Lateral pterygoid muscle
5: Bilaminar zone
6: Tympanic portion of the temporal bone
7: Cartilage of the external auditory meatus
8: Lateral portion of joint capsule
9: Mandibular condyle
10: Anterior band of the disc

Figure 3
Axial section going through the anterior ridge.

data suggests[11,26], the disc as an insertion tendon of the lateral pterygoid muscle. Since the muscle is thicker medially than laterally, the difference in disc thickness is then understood, and would go hand in hand with the asymmetry of the attachments of the disc on the condyle. However, for other authors[25], the disc is developed independently of the lateral pterygoid muscle. According to Naidoo[23], it is impossible to draw definitive conclusions on this point. Nevertheless, laterally, the collagen fibers derived from the anterior and posterior bands fuse and join the lateral pole of the condyle, to form a slender and exclusively fibrous disco-condylar attachment. Conversely, the medial attachment is reinforced at its periphery by medial fibers of the lateral pterygoid, which at the same time are inserted back, under, and in front of the medial pole of the disc, giving this medial attachment a resistance much greater than that of its lateral homologue. It is again curious to note that the zone sustaining most mechanical stress has the most fragile disc attachment, especially since this attachment is subjected to lateral pterygoid muscular tension during the opening movement, with the disc and the condyle being pulled antero-medially. Moreover, it is commonly agreed that the stretching of the lateral attachment forms the starting point of disc displacements, as the MRI images that illustrate this association suggest.

On the vascular level, a structural asymmetry is also noted: the lateral part of the joint is less vascularized, with the medullary arteries, branches of the maxillary artery, being detached in the stylomandibular outlet facing the medial joint zone. Most probably, this constitutes a handicap for the lateral zone in the matter of tissue repair.

Would the TMJ have been poorly designed with functional stresses being concentrated in the anatomically weakest zone? Certainly not, but the complexity of the biomechanical specifications has certainly created some weaknesses that appear when the masticatory apparatus is diverted from its original function, and especially when patients inflict permanent stress on it by clenching their teeth.

THE LATERAL PTERYGOID: WAR OF THE HEADS

On the muscle level, numerous authors have considered the distribution of insertions of the lateral pterygoid muscle on the disc and the condyle, with the thought that the latter could oppose the disco-condylar disunity. Analysis of the literature revealed a great disparity on this subject, some studies[5] even going so far as to deny the existence of a disc insertion of the lateral pterygoid. This great variability certainly originates in part from interethnic variations, but also from bias related to the methods of investigation or to the human material examined.

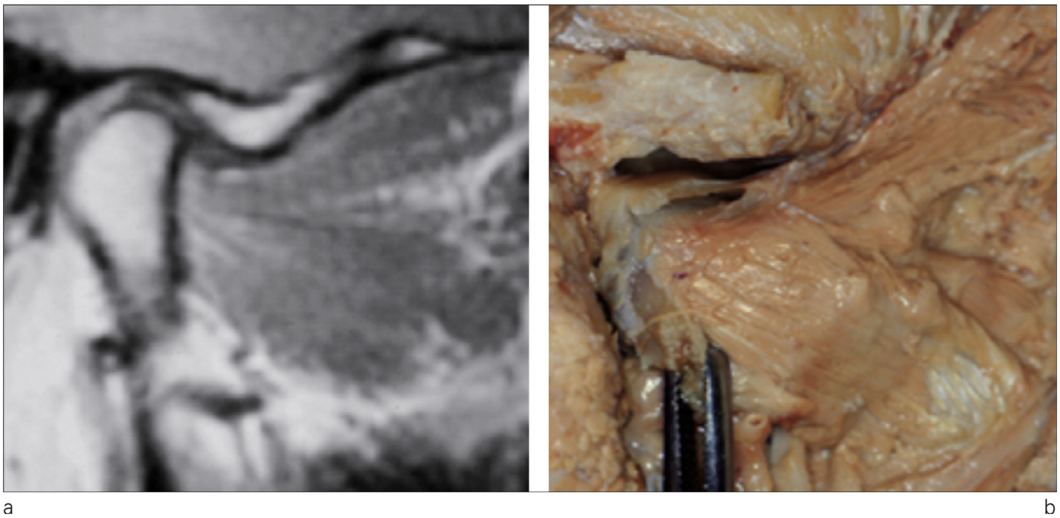
In a carefully conducted histomorphometric study[24], the disc fibers were found to represent, on average, 30 % of the fibers of the superior head of the lateral pterygoid, with a significant standard deviation since this percentage varied from 10 % to 60 % without any connection having been established with age or sex. Further, there does not seem to be a relationship between the resistance to rupture of this lateral attachment, the width of the muscular insertions of the lateral pterygoid on the anterior ridge, and the sex of the subjects[3].

Concerning the actual anatomy of the lateral pterygoid muscle, the "war of the heads" still rages. Only recently, articles have described one, two, even three muscle heads. How is that possible? In reality, everything depends on the access route, the dissection technique, and the approach of the author of the muscle functioning mode. Thus, the design of an activity that is mainly perceived in the sagittal plane leads to a dissectional approach aimed at identifying divisions in this plane, with superior and inferior heads (fig. 4 a and 4 b) or sheets piled above one another.

Even if the organization and, as we will see later, the function of the lateral pterygoid prove to be more complex than we imagined, the debate concerning the number of heads does not take on major clinical value: this muscle, which is roughly conical at the top of the joint, can present different types of organization, with fusion of the fibers making a single muscle body at the front of the TMJ (fig. 5).

EVOLUTION OF ELECTROMYOGRAPHIC DATA

The evolution of anatomical concepts concerning the lateral pterygoid goes hand in hand with that of the physiological concepts concerning it. Indeed, the standard sagittal approach, whereby the muscle is split



Figures 4 a and b
Sagittal MRI section and lateral view of the lateral pterygoid muscle in dissection, showing two well-differentiated heads.

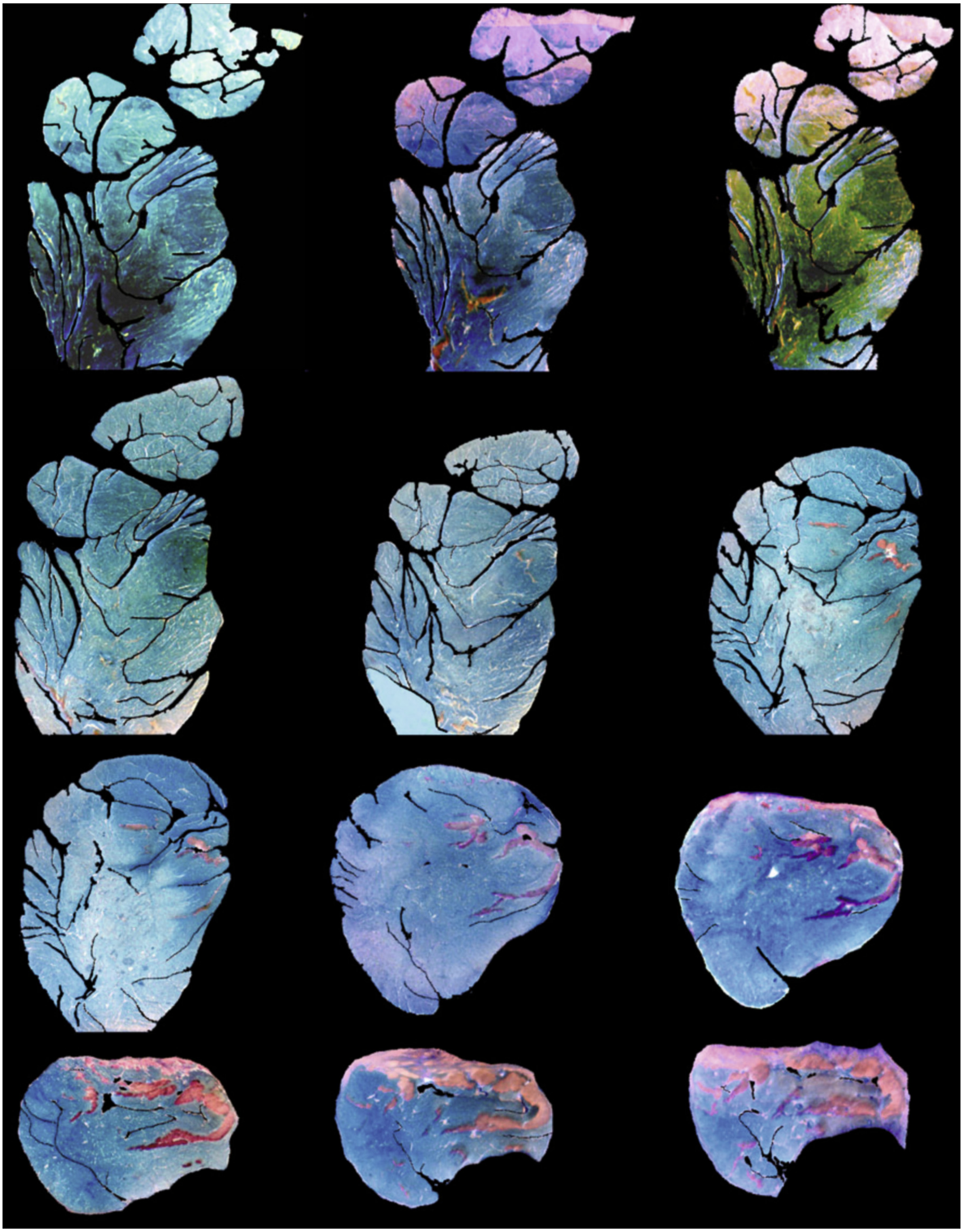


Figure 5
Serial frontal sections of a left lateral pterygoid muscle, categorized in the anteroposterior direction.

into two superior and inferior heads, is expressed from a physiological point of view by a reciprocal design of their respective activities. Thus, the inferior head, oblique at the bottom, front, and inside, is essentially bone and without any connection to the TMJ, and is considered active during oral opening and in propulsion and laterality of the opposite side (contralateral abduction). It is then a true propellant of the mandible. It functions in the concentric dynamic mode, bringing its insertion tendons nearer when the action potentials are highest.

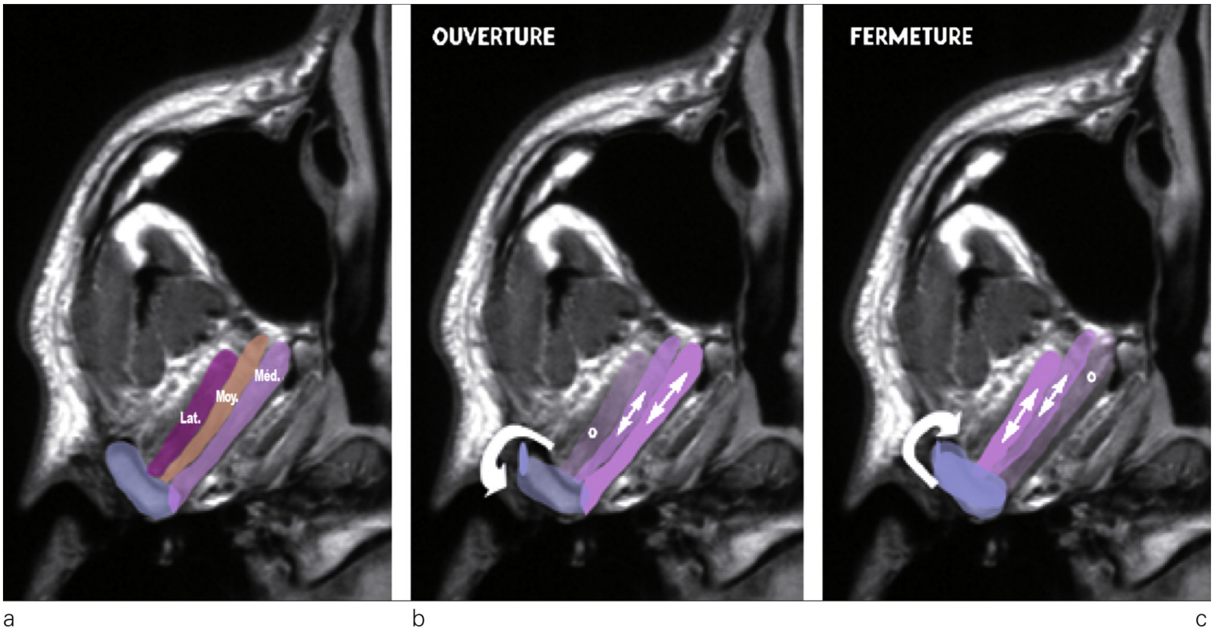
As for the superior head, oblique in front, inside, and located in a horizontal plane, for which the insertion is bone and disc simultaneously, it is considered active during oral closing, retrusion, and return of laterality (contralateral adduction). It functions in eccentric dynamic mode, the activity potentials being highest when the insertion tendons located at each end move apart, which would explain its greatest tissue vulnerability[15,17,24]. The contraction of the superior head, then, precisely controls the return of the condyle into the mandibular fossa during closure by the creation of an agonist-antagonist muscle pair. Due to its location under the base of the cranium and the horizontal direction of its fibers, which are reflected under the temporal eminence, the superior head is ideally located to accomplish this ‘braking’ role. Therefore, it is an antagonist of the retrusion muscles of the mandible, just as the temporal part of the temporal muscle and the digastric muscle. As for the action of the fibers inserted into the anteromedial part of the disc, their assumed role during oral closing would be to progressively bring back the posterior band relative to the top of the condyle, and to lock the disco-condylar coaptation to avoid excessive tension on the disc attachments during function.

This dichotomous description is partially revised today due to new electromyographic data, especially derived from the work of Murray *et al.*[21,22], which supplies a more accurate vision of the muscle range of movement.

According to these studies, the entire medial part of the muscle is active during movements of opening, propulsion, and contralateral abduction, which could correspond to the inferior and intermediate fibers observed on the frontal sections. Thus, the inferior head mobilizes the mandible due to the fibers inserted into the pterygoid recess, while the medial part of the superior head controls the medial zone of the condyle and the disc with these movements. Thus, the medial zone seems to be the true motor element of the disco-condylar complex.

But the novelty especially concerns the differential activity of the superior head in the transverse direction[4]. According to these authors, on the functional level, the superior head can be divided into three parts, medial, middle, and lateral, while until now it has been considered a single unit. As we have just mentioned, the medial part functions in synergy with the inferior head, while the lateral part does not demonstrate activity in these movements but, conversely, is active in closing, retropulsion, and ipsilateral excursion. As for the middle part, it has intermediate activity (fig. 6 a to 6 c).

If one considers that the disc fibers are inserted into the third, the medial

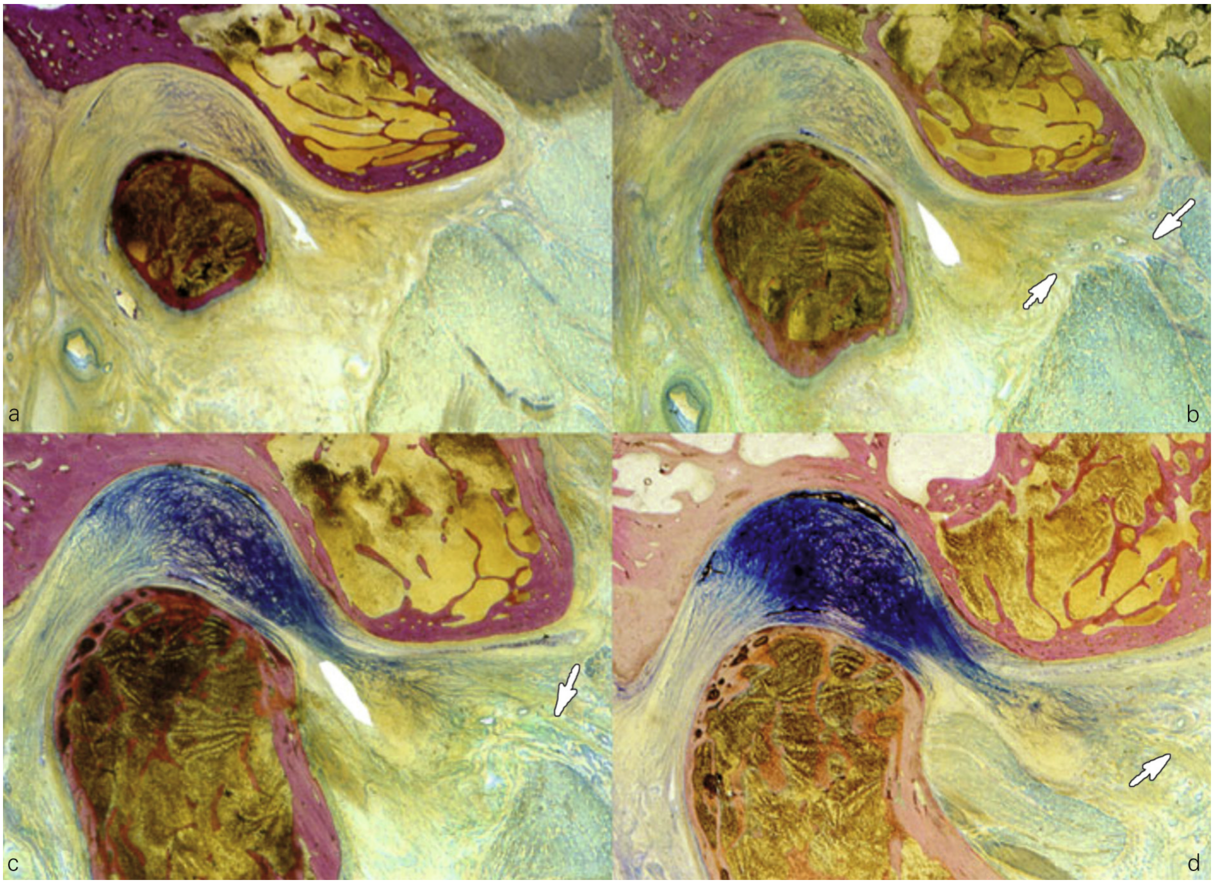


Figures 6 a and c
Diagrammatic representation of the assumed action of the superior head on the disc during oral opening and closing movements, integrating electromyographic and anatomical data.

half of the anterior band, the lateral part of the disc, would indeed, in a way, be left to itself during different mandibular movements, creating a greater disco-condylar clearance between the disc and the condyle around the lateral zone than in the medial part of the joint. Thus, here again is a weakness in the lateral zone of the joint.

Thus, the final muscular action of the lateral pterygoid muscle should be viewed in three dimensions, with selective recruitment of certain groups of fibers according to the mandibular movement to be produced. Thus, this muscle could be compared with an octopus in which the body would be horizontal and the head located in the pterygoid recess, and one could imagine that its multiple components are capable of contracting independently, like the tentacles, upon request, to deform the muscle body, shrinking some fibers and subfibers to ‘run’ the head of the mandible in the three spatial planes. The deformation of the muscle, which is carried out during its contraction, is expressed by a very clear increase in its circumference, associated with a shortening of its length as shown by the MRI sections carried out in lateral excursion.

Note here that while some authors[2,7,16,28] have described disc insertions of deep temporal and masseter muscles, they cannot be compared with those of the lateral pterygoid muscle, whether in terms of size, function, or even the nature of

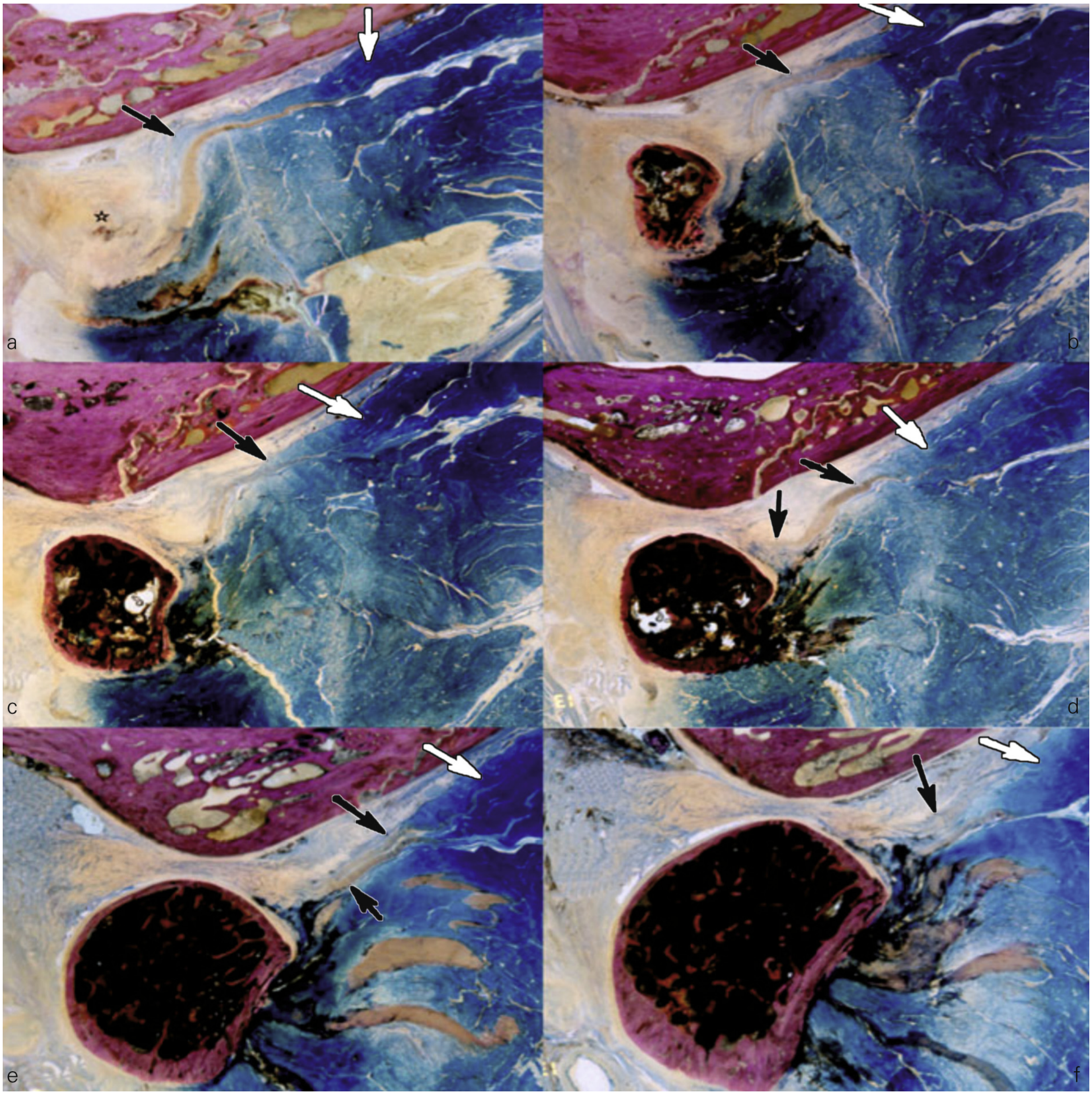


Figures 7 a to d
Sagittal sections involving the lateral part of a right TMJ, illustrating the fibrous connections of the deep masseter and of the temporal fitting tightly around the anterolateral venous plexus.

the insertion[19,28]. Indeed, these attachments, when observed in dissection[10,16], seem substantial; when they are observed with light microscopy, they amount to a few thin fibers which fit tightly around or cross an arteriovenous plexus (fig. 7 a to 7 d). In a series of millimetric sagittal sections (fig. 8 a to 8 f) comparable with histological iconography, described in several publications[2,14,18,27,28], we observed these temporomasseteric insertions at a depth of three millimeters.

Thus, in our opinion, the lateral pterygoid muscle remains the true joint muscle.

Whatever the differences that we have just mentioned on the subject of muscle insertions on the disc, all the authors agree on a predominance of these insertions at the medial zone of the joint, as well as on a great variability in the latter that may, in some cases, form an additional risk factor for lesions of the musculo-condylar complex.



Figures 8 a to f
Millimetric sagittal sections made after post-mortem oral opening, starting from the medial zone of the disc. Muscle fibers (white arrows); insertion tendons (black arrows).*

JOINT BIOMECHANICS

While the anatomical organization of the TMJ, as we have described it up to now, seems to present a weakness of the lateral zone, in ligament as well as muscle and vascular terms, this could prove to be essential to the mechanical specifications of the joint, enabling it to accomplish all movements involved in mastication.

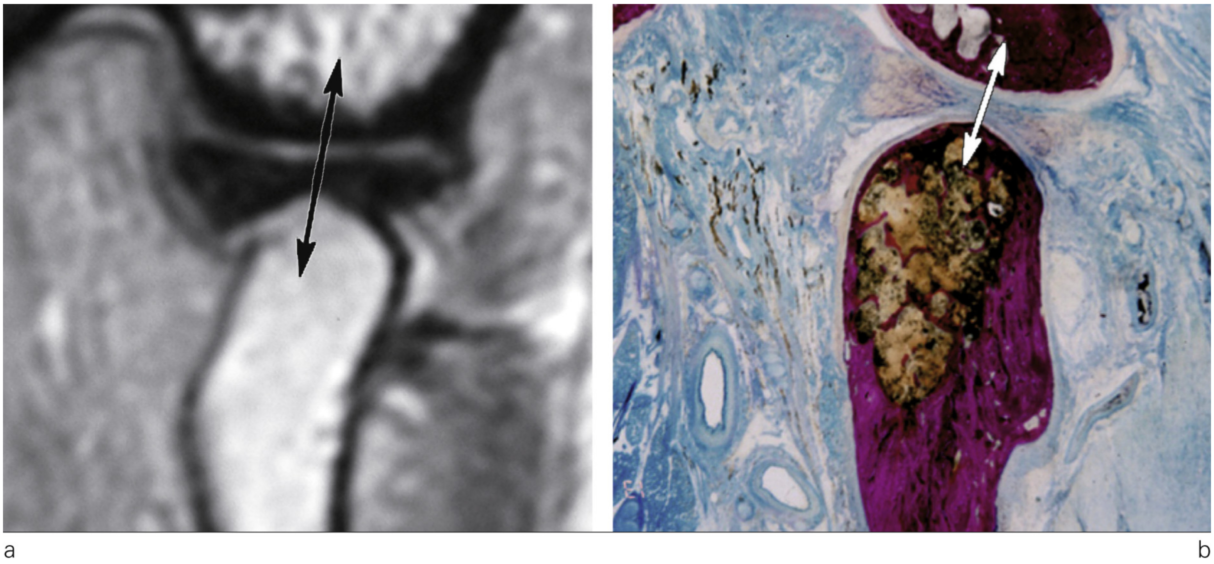
Indeed, it is acknowledged that, during mouth opening, each TMJ releases a rotation movement in the inferior compartment, associated with a translation movement in the superior compartment, each individual opening with a variable percentage of rotation and translation.

When the arches are in occlusion, the contact surface between the anterior wall of the condyle, the disc, and the temporal eminence is maximal, thus ensuring optimal distribution of the stresses (fig. 1 and 2).

During oral opening, the top of the condyle leaves the posterior band and reaches the intermediate zone of the disc. Since this latter is not as thick as the posterior band, the disco-condylar ligaments are loosened and release a slight range of movement between the condyle and the disc, enabling the latter to be deformed to follow the convexity of the temporal eminence. With the contact surface between the two convex bone parts and the interposed disc being then reduced to the minimum, a great freedom of movement can then be expressed around two joint pivots (fig. 9 a and b). Under the action of medial fibers of the lateral pterygoid muscle, which guides the medial zone to the opening, a slight lateromedial displacement of the disc relative to the condyle is observed, made possible by the disco-condylar range of movement released at the lateral zone. The upper bilaminar zone spreads as if aspirated by the displacement of the disco-condylar complex and fills with blood, while the disco-condylar fibers are loosened. It is somewhat likely that the upper fibers act as a mechanical brake for limiting the amplitude of the translation; their richness in mechanoreceptors and in free endings could form a neurophysiological brake, the joint sensors being solicited in the limited movements of the joint.

As for the closing movement, this requires the coordinated action of the levator and retrusion muscles of the mandible, the action of these latter being counterbalanced by that of the lateral pterygoid muscle, which, due to its bone insertions, controls the recoil of the condyle. In this closing movement, the activity of the superolateral fibers of the lateral pterygoid is directed at progressively repositioning the lateral part of the joint disc. As emphasized by Matsunaga *et al.*[16], the muscle fibers that rejoin the pterygoid recess are oriented posterolaterally, while those that spread to the disc have a true posterior direction. It is possible, then, that these two muscle groups, according to their relative strength, could create shearing forces between the disc and the condyle, favoring the distension of the lateral attachment and the creation of disc displacements.

During oral closing, the superior bilaminar zone is compressed, playing the role of hydraulic shock absorber and synovial fluid pump, while the disco-condylar lower fibers are tightened and flattened on the posterior wall of the condyle.



Figures 9 a and b
Sagittal MRI sections made with open mouth.
With the contact surface between the two convex bone parts and the interposed intermediate zone being then reduced to the minimun, a great freedom of movement can then be expressed around two joints pivots.

FROM ANATOMY TO CLINICS

As we have just seen, the TMJ is a joint with complex anatomy and biomechanics, reinforced by its synergy with the contralateral joint. Within the context of a short article, we cannot address all pathological aspects of the ADAMs. Therefore, we have chosen to emphasize the key points that the practitioner must keep in mind in approaching these pathologies: the adaptive potential of the joint, the anatomo-clinical dissociation, the etiopathogenic significance of dental clenching, and psychosocial factors.

Adaptive potential

In contrast to the other synovial joints, the joint surfaces of the TMJ are covered with fibrocartilage and not hyaline cartilage. Besides its biochemical composition, characterized by the presence of type I cartilage, this fibrocartilage is differentiated from the hyaline cartilage by the presence of an external fibrous layer called perichondrium, and an undifferentiated mesenchyme layer composed of prechondroblasts that may become involved in different differentiation pathways. To this is added the fact that the cells of different layers are distributed at random, and not in a column as in hyaline cartilage, conferring on the fibrocartilage a strong adaptive potential without pre-established functional orientation, especially allowing for the reorientation of mandibular growth in dentofacial orthopedic treatments, and explaining the low prevalence of temporomandibular osteoarthritis in comparison with osteoarthritis of the knee, for example. The particular adaptive potential of the joint surfaces is found at the level of the disc, in which the histological structure of the dense zone approaches that of the perichondrium. This especially explains why, when initially reducible disc dislocation becomes non-reducible and once the painful phase has past, one observes a regression in the symptoms and the beginnings of functional recovery if adapted kinesiotherapy is set up. In this situation, the richly innervated and vascularized bilaminar zone that is responsible for pain when it is interposed between the condyle and the temporal is progressively transformed to a pseudodisc, allowing for normal joint range of movement. It is the same in osteoarthritic lesions, where the joint function is not greatly disturbed apart from painful phases of inflammatory episodes.

Anatomo-clinical dissociation

The second essential characteristic of the ADAMs, related to the preceding, is a strong dissociation between structural damage, as can be demonstrated by imaging, for example, and signs and symptoms. Thus, in conjunction with osteoarthritis, a slight structural attack in the inflammatory phase can cause significant functional harm accompanied with pain, while significant damage can be a fortuitous discovery of imaging in a patient presenting, upon auscultation, only joint crepitation (sound of wet sand) as a single sign. This anatomo-clinical dissociation is found in the context of disc displacements, with the MRI examinations showing a significant prevalence of non-reducible displacements in asymptomatic subjects.

Etiopathogeny of the ADAMs

The adaptive potential and the anatomo-clinical dissociation that we have just discussed pose the question of the etiopathogeny of the ADAMs. Indeed, what factors lead to exceeding the adaptability threshold to tip the scales into a pathological context? Concerning disc displacements, in addition to the specific anatomic predispositions, such as hyperlaxity, explaining the frequent appearance of these disorders in young girls of orthodontic age, teeth clenching is an essential etiopathogenic factor. In fact, while the disc is designed to be "chewed" during meals, it must be able "to recover" apart from meals, especially by finding a sufficient hydric load. In fact, the dense part of the disc is neither vascularized nor innervated, and owes its tissue nutrition to absorption of synovial fluid. Prolonged tooth clenching prevents this phenomenon, and increases the friction forces present at the cartilage/disc interfaces that may in the end lead to stretching of the disc attachments[29].

Concerning myofascial pain, there are psychosocial factors which constitute an essential etiological factor. We will not linger on this point here, since these pathologies most often require multidisciplinary management, causing a psychologist or psychiatrist to intervene.

CONCLUSION

The TMJ has a complex anatomy in which the obvious weakness of the lateral joint zone is an integral part of its biomechanical specifications. The related integration of the specificities of this joint and of the ADAMs leads to the elaboration of a noninvasive therapeutic outline, including:

patient education and information[20], management of the pain with medication, re-establishment of orthopedic stability of the joint (obtained first by occlusal appliances), and the setting up of adapted physical therapy once the acute phase has resolved. This handling obviously constitutes the outcome of a rigorous diagnostic approach, which should be re-evaluated in the event of lack of improvement in, or worsening of, signs and symptoms.

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