Histologic Characteristics of the Lateral Pterygoid Muscle Insertion to the Temporomandibular Joint

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This study used low-power light microscopy to examine the histologic organization of the lateral pterygoid muscle interface with the temporomandibular joint. The sample included parasagittal sections of 20 intact temporomandibular joints from young adults (mean age 26.2 years) at autopsy. The lateral pterygoid muscle showed no consistent divisions into separate anatomic muscle heads at the insertion. The muscle fibers attached to the pterygoid fovea of the condyle immediately inferior to the articular surface in all cases. Some additional fibers inserted superiorly into the more anterior part of the articular disc in a minority of cases (31%). Fibers inserting into the disc represented only 2.4% to 6% of the total superior-inferior length of the muscle insertion. It is hypothesized that the muscular force exerted by these few fibers inserting into the disc would not be sufficient to displace the disc anteriorly to the condyle. There were two histologic types of insertion of the lateral pterygoid muscle to the condyle. The superior part of the insertion was characterized by an identifiable tendon inserting through fibrocartilage. In the inferior part of the insertion, the muscle attached to periosteum without an obvious tendon. The presence of this tendon must be recognized in interpretation of soft tissue temporomandibular joint imaging.
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Anatomic and physiologic investigations of the lateral pterygoid muscle insertion to the temporomandibular joint (TMJ) have generated considerable controversy. While studies have consistently shown the presence of two distinct muscle origins at the pterygoid plate of the sphenoid bone, the insertion of the muscle to the components of the TMJ remains unclear. The unresolved issues include whether there are anatomically and functionally distinct upper and lower muscle heads at the insertion site and the relationship of the most superior muscle fibers to the articular disc.

The insertion of the superior fibers of the lateral pterygoid muscle to the TMJ has been the source of much discussion in the literature. Early dissection studies reported that the superior fibers insert solely to the articular disc[1] or to the disc and anterior capsule.[2] More recent histologic studies have demonstrated that the majority of the superior fibers insert to the condyle with only a few fibers inserting to the articular disc.[3–6] The latter studies have emphasized the variability in the relationship of the superior fibers to the condyle and disc, but they have not attempted to measure the proportion of fibers inserting directly into the disc or considered an anatomic relationship to disc position.

Electromyographic (EMG) studies have been similarly inconsistent; some have reported that the lateral pterygoid is a single func-

tional unit,[7] but the majority have reported functionally separate superior and inferior heads.[8–12] Juniper[9] has proposed that the superior head should be considered a separate muscle called the superior pterygoid muscle.

These conflicting studies have led to the common usage of a diagram depicting a separate superior head of the lateral pterygoid attaching entirely to the anterior portion of the articular disc.[13–16] Together with a functional model for the lateral pterygoid muscle, in which the upper head functions independently and antagonistically to the lower head of the muscle during mandibular movements,[8] the idea has been proposed that hyperactivity of the muscle could cause the articular disc to dislocate anteriorly.[17]

The purpose of the present study was to present a detailed description of the microanatomy of the lateral pterygoid muscle interface with the TMJ in young adults. It is anticipated that the results will have implications for TMJ soft tissue imaging and internal derangement etiology.

Materials and Methods

Sample

The autopsy material used for the current study was collected and prepared by Solberg et al.[18] The sample consisted of intact joints that were macroscopically cut into lateral, central, and medial thirds prior to the preparation of histologic sections from each third. The sections were prepared at 90 degrees to the long axis of the condyle, which would on average represent a 20-degree correction from the true parasagittal plane. This protocol was designed to minimize oblique sectioning and erroneous presentation of soft tissue thickness, which were critical to other studies using this material. It is recognized that this angular correction does not provide ideal longitudinal orientation of the fibers of the lateral pterygoid muscle. A total of 16 medial and 18 central sections were selected for the present study. The mean age of the sample was 26.2 years, range 16 to 35 years; 30% were female and 70% male.

Histologic Assessment

Projection microscopy was used to examine the anatomic divisions of the lateral pterygoid muscle at the insertion site and the relationship of the muscle to the articular disc. Medial sections (n = 16) were selected for this purpose because the majority of the lateral pterygoid muscle fibers are reported to insert to the anteromedial aspect of the joint.[19,20] Projection microscopy permitted discussion and consensus judgment by three examiners observing a complete field of view at low magnification. A confidence score with rankings of 1 = possible, 2 = probable, 3 = confident, and 4 = definite was applied to each evaluation.

More detailed descriptive and histomorphometric assessments of the lateral pterygoid insertion tissues were carried out under low-power light microscopy using central (n = 18) and medial (n = 16) sections. Higher magnification was used to positively identify muscle tissue by the presence of striations to differentiate muscle tissue from the adjacent fibrous connective tissue of the disc or tendon.

Results

Anatomic Divisions of the Lateral Pterygoid Insertion

None of the 16 medial TMJ sections showed an obvious division into a distinct upper and lower muscle head at the insertion site. In three of these specimens (19%), loose connective or fatty tissue was interposed between bundles of muscle fibers close to the insertion to the condyle, which produced partial separation but with no consistent organization. In these three specimens, two had three such divisions, and the other had two divisions (Fig 1). The mean confidence score for both the presence of these divisions as well as the absence of divisions in the other specimens was 2.5 on the 4-point scale.

Relationship Between the Lateral Pterygoid Muscle and the Disc

Eleven of the 16 medial sections studied (69%) were characterized by a parallel arrangement of the lateral pterygoid muscle fibers with the disc. In this configuration, muscle fibers traveled parallel and inferiorly to the disc to insert entirely into the pterygoid fovea of the condyle (Fig 1). There was a fibrous mesh of loose connective tissue between the disc and superior limit of the muscle. These fibers connected with the lining tissue of the anterior-inferior joint recess, which in turn was continuous with the articular fibrous connective tissue at the anterior-superior aspect of the condyle.

In the remaining five specimens (31%), there were some muscle fibers interdigitating directly

into the anterior band of the disc (Figs 2 and 3) while the majority of the muscle showed the parallel configuration inferiorly. The distinction between muscle and the fibrous connective tissue of the disc was confirmed by the identification of muscle striations at high magnification. The interdigitation of the muscle with the disc and the muscle with the tendon appear identical at this magnification (Fig 3). The mean confidence score for the assessment of the muscle insertion relationships was 3.5.

Table 1 shows the relative amount of muscle fibers inserting to the anterior band of the disc as a proportion of both the superior-inferior length of the total muscle insertion and the disc thickness at that site. For the five joints with muscle fibers inserting directly to the disc, muscle fibers occupied 20% to 30% of the thickness of the anterior band and constituted 2.4% to 6.3% of the total lateral pterygoid insertion length. Four joints in the sample had anteriorly displaced discs. All four showed the parallel configuration in which the lateral pterygoid inserted only to the condyle (Table 1).

Histologic Features of the Lateral Pterygoid Insertion

In the specimens studied, two histologic types of insertion of the lateral pterygoid to the pterygoid fovea were identified. Superiorly, muscle inserted into a well-organized fibrous connective tissue tendon that in turn inserted into the pterygoid fovea (Figs 1 and 2). The distinction between muscle and tendon was based on differential staining (Figs 1 and 2) and confirmed by the presence of muscle striations visible at higher magnification (Fig 4). A layer of fibrocartilage was identified between the tendon fibers and the compact bone of the pterygoid fovea (Figs 1 and 5).

Inferior to the tendinous insertion, muscle fibers inserted into the periosteum of the compact bone surface without an intermediate tendon or fibro-

Fig 1 Parasagittal histologic section from the medial third of a TMJ from a 33-year-old female. The lateral pterygoid muscle runs inferiorly to the disc (which is anteriorly displaced) to insert into the pterygoid fovea of the condyle. Note that the most superior muscle fibers insert to the condyle via a tendon. Loose connective tissue (arrow) has produced partial separation of the muscle into two divisions close to the insertion. (Hematoxylin-triosin stain in all figures).

Fig 2 Parasagittal histologic section from the central third of a TMJ from a 34-year-old male. A few muscle fibers insert in the anterior aspect of the disc (arrow) with the majority of the muscle inserting inferiorly into the pterygoid fovea of the condyle.

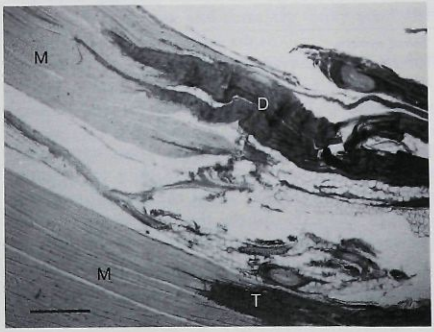

Fig 3 Higher magnification of the disc-muscle insertion identified in Fig 2. Note the interdigitation of muscle fibers (M) with the disc (D) superiorly, while inferiorly muscle fibers interdigitate with the tendon (T). (Bar = 0.05 mm.)

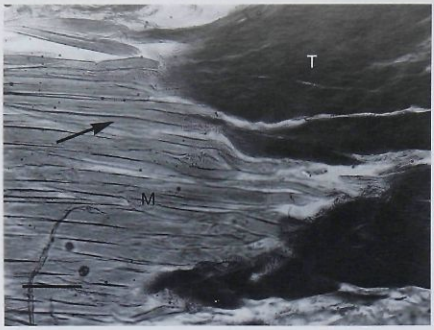

Fig 4 Photomicrograph of the muscle-tendon interface in the medial third of a TMJ from a 16-year-old female. Note that the distinction between muscle (M) and tendon (T) is based on differential staining and the presence of muscle striations (arrow). (Bar = 0.02 mm.)

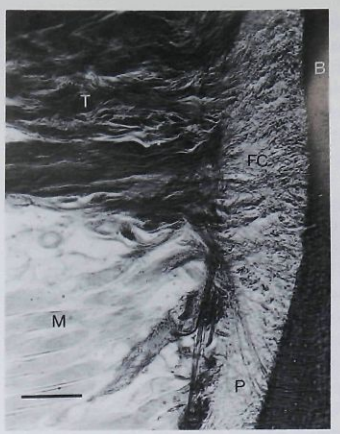

Fig 5 Photomicrograph of the lateral pterygoid insertion in the medial third of a TMJ from a 16-year-old female. Superiorly, the tendon (T) of the lateral pterygoid inserts to the compact bone (B) by a layer of fibrocartilage (FC). Inferiorly, the muscle (M) inserts directly to periosteum (P). (Bar = 0.02 mm.)

Table 1 Relative Amount of Lateral Pterygoid Muscle (LPM) Fibers Inserting to Disc*

Joint	Disc: Anterior band thickness (mm)	Total LPM insertion length (mm)	Length of LPM inserting to disc (mm)	Proportion of anterior band with LPM fibers (%)	Proportion of LPM inserted to disc (%)
1	1.9	8.8	0.4	20	4.5
2	1.5	10.0	0.5	30	5.0
3	1.5	6.4	0.4	25	6.3
4	1.1	7.2	0.2	20	2.8
5	1.5	12.3	0.3	20	2.4
6–16**				0	0

*Medial sections.
**Includes all joints with disc displacement (n = 4).

cartilage layer (Figs 1, 2, and 5). There were small secondary tendinous insertions inferior to the main tendon in 3 of 18 (17%) of the central sections and 4 of 16 (25%) of the medial sections (Fig 2). The tendinous insertion occupied 48.4% (range 18% to 80%) of the overall superior-inferior length of the insertion in the central sections and 44.5% (33% to 72%) in the medial sections.

Discussion

The present study examined the histologic organization of the insertion of the lateral pterygoid muscle to the components of the TMJ in an effort to resolve the controversy over the relationship of the muscle to the joint. The autopsy material studied is believed to be clinically relevant because the age range of the sample (16 to 35 years) is consistent with the population likely to seek treatment for TMJ disorders[21] and especially the segment of the population with internal derangements.[22] Four of the joints in the sample had obvious disc displacements. However, it must be emphasized that in this cross-sectional autopsy study no history of pain or mechanical dysfunction was available for correlation with the anatomic findings. The study

is also limited by the small sample size and the availability of only one technically acceptable section from each joint region. However, it is difficult to acquire material from this clinically important age group.

Contrary to common belief, anatomically separate superior and inferior lateral pterygoid bellies were not found. While there was variability in the insertion of the most superior fibers of the muscle to the joint, the most frequent model (69%) was the parallel configuration in which muscle fibers inserted only into the pterygoid fovea on the anteromedial surface of the condyle rather than to the articular disc. This finding is consistent with Wilkinson's hypothesis that the articular disc attaches to the roof of the superior lateral pterygoid fibers by a "foot" of connective tissue.[6]

In the five specimens in which a few of the superior muscle fibers inserted directly into the articular disc, this muscle insertion occupied less than one third of the thickness of the disc at that site and at most represented 6% of the overall insertion length. This represents the first attempt to measure the proportion of lateral pterygoid muscle fibers inserting directly to the disc. It seems unlikely that the proportion of fibers inserting into the disc in comparison to those inserting into the condyle would change markedly from section to section.

A disc displacement etiology by spasm of the lateral pterygoid muscle is not supported by this anatomic study. This does not mean that the lateral pterygoid does not exert any action on the disc, but rather that hypertonic contraction of these few fibers would be unlikely to cause the articular disc to shift independently to an anterior position. This conclusion is consistent with reports from previous dissection studies stating that anterior tension on the lateral pterygoid muscle did not pull the disc anteriorly.[3,6] Furthermore, the presence of lateral pterygoid muscle fibers inserting directly into the disc apparently does not predispose to disc displacement, because none of the five joints with muscle fibers inserting directly to the disc had displaced discs (Table 1).

Variation in lateral pterygoid muscle insertion relationships has also been described in other histologic investigations. Meyerberg et al[3] examined 25 TMJs and reported that 60% had a few lateral pterygoid muscle fibers inserting into the articular disc. In a sample of 15 TMJs, Moritz and Ewers[4] reported that the inferior fibers of the lateral pterygoid always attached to the pterygoid fovea, and in 12 of the cases (80%), some superior fibers attached anteromedially to the disc. In 9 of the 15 joints (60%), an additional insertion of superior fibers into the medial joint capsule was also found.

This study shows that dissection alone is not sufficient to accurately display the anatomy of the lateral pterygoid/TMJ interface. Previous studies showing distinct muscle heads at the insertion site may have been based on artifacts of blunt dissection. Furthermore, histologic sections are required for study under sufficiently high magnification to differentiate muscle tissue from the adjacent fibrous connective tissue of the disc, tendon, and capsule. These technical issues may account for some of the conflicting interpretation by earlier authors.

The classical literature describes the existence of two distinct types of tendinous insertion of muscle to bone.[23,24] In a direct insertion, a layer of fibrocartilage, called a "plug," is present between the tendon fibers and the compact bone. In an indirect insertion, muscle fibers blend into the compact bone without the presence of a defined intermediate fibrocartilage layer. The layer of fibrocartilage in the direct insertion makes the distinction between the two types of insertion easily identifiable under light microscopy.

In the present study, both types of insertion were identified in the interface of the lateral pterygoid muscle to the condyle. A direct insertion with a dense organized fibrous connective tissue tendon was observed in the more superior part of the insertion, and fibrocartilage was present at the tendon/bone interface. An indirect insertion was located inferiorly and did not have an organized, dense, fibrous tendon. It is interesting to speculate that these upper and lower insertion types may represent separate functional muscle bellies reported by EMG studies and certainly imply some differential stimulus to these sites.

The results of this study have important clinical implications for the interpretation of magnetic resonance imaging (MRI) of the TMJ. The clinician should not expect to see separate upper and lower muscle bellies at the insertion site. The consistent presence of a dense, fibrous connective tissue tendon at the superior aspect of the muscle insertion to the condyle must also be recognized and care must be taken to differentiate the low signal from the tendon in this location from anterior disc displacement. Beltran[16] has commented similarly that the tendon of the inferior belly of the lateral pterygoid should not be confused with the disc on MRIs. However, he complicates the issue by stating that the superior belly is attached to the disc by a tendon that was not observed in the present study. It is noteworthy that some recent textbooks

are presenting a more anatomically accurate diagram of the relationship between the lateral pterygoid muscle and the TMJ.[19]

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Resumen

Características histológicas de la inserción del músculo pterigoideo lateral en la articulación teporomandibular

Este estudio examinó la organización de la interfase histológica del músculo pterigoideo lateral con la articulación temporomandibular (ATM) utilizando microscopía de luz a bajo aumento. La muestra incluyó secciones parasagitales de autopsias de 20 ATM intactias de adultos jóvenes (edad promedio: 26.2 años). El músculo pterigoideo lateral no mostró divisiones consistentes en cuanto a cabezas musculares anatómicas separadas en la inserción. En todos los casos las fibras musculares estaban insertadas en la fosa pterigoidea del cóndilo inmediamente inferior a la superficie articular. En algunos casos (31%) se observaron algunas fibras adicionales insertadas en sentido superior en la parte mas anterior del disco articular. Las fibras que se insertaban en el disco representaban solo del 2.4% al 6% de la longitud supero-inferior total de inserción muscular. Se presenta la hipótesis de que la fuerza muscular ejercida por estas pocas fibras insertadas en el disco no sería suficiente para desplazar al disco anteriormente al cóndilo. Se observaron dos tipos histologicos de inserción del músculo pterigoideo lateral al cóndilo. La parte superior de la insercion estaba caracterizada por un tendón aparente. La presencia de este tendón debe ser reconocida en la interpretación de las inágenes diagnósticas del tejido blando de la ATM.

Zusammenfassung

Histologische Eigenschaften der Ansatzstelle des M. pterygoideus lateralis am Kiefergelenk

Diese Studie untersuchte die histologische Struktur der Ansatzstelle des M. pterygoideus lateralis am Kiefergelenk lichtmikroskopisch. Die Probe umfasste 20 parasagittale Schnitte von 20 intakten Kiefergelenken junger Erwachsener (mittleres Alter 26,2 Jahre) in Autopsie. Der M. pterygoideus lateralis zeigte an der Ansatzstelle keine deutliche Aufteilung in einzelne anatomische Muskelköpfe. In allen Fällen setzten die Muskelfasern an der Fovea pterygoidea des Kondylus unmittelbar unterhalb der Gelenkflächen an. Einige zusätzliche Fasern inserierten oberhalb davon in den vorderen Teil des Diskus, aber nur bei einer Minderheit der Fälle (31%). Von der gesamten in superior-inferiorer Richtung gemessenen Länge der Muskelansatzstelle machten die in den Diskus einstrahlenden Fasern nur gerade 2.4%–6% aus. Man nimmt an, dass die Muskelkraft dieser wenigen in den Diskus inserierenden Fasern nicht ausreicht, um den Diskus vor den Kondylus zu verschieben. Der M. pterygoideus inserierte auf zwei histologisch verschiedene Arten am Kondylus. Der obere Teil des Ansatzes war gekennzeichnet durch eine erkennbare Sehne, die durch Faserknorpel hindurch ansetzte. Im unteren Teil der Ansatzstelle inserierte der Muskel ohne sichtbare Sehe direkt am Periost. Das Vorhandensein der erwähnten Sehne muss bei der Interpretation von Weichteilbildern des Kiefergelenkes beachtet werden.