The Incidence and Nature of Fibrous Continuity Between the Sphenomandibular Ligament and the Anterior Malleolar Ligament of the Middle Ear

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The purpose of this study was to determine the structural interrelationship between the temporomandibular joint (TMJ) and the middle ear, in terms of fibrous continuity between the sphenomandibular ligament (SML) of the mandible and the anterior malleolar ligament (AML) of the middle ear. Thirty-seven specimens of the TMJ and middle ear were obtained from adult human cadavers. The temporal bone, petrotympanic fissure, mandibular fossa, and middle ear were dissected en bloc, fixed, sectioned, stained, and observed microscopically. Of the 37 specimens, 67.6% had a continuity of the SML through the fissure passing near the malleus of the middle ear. The AML was present at the fissure in 64.9% of the specimens, with 58.3% passing through and not stopping at the fissure. Results indicated a fibrous continuity between the SML and the AML. Structural differences between the two ligaments were also noted. The SML contained randomly arranged fibrous connective tissue with numerous interposed blood vessels. The AML had a smooth arrangement of fibers within the connective tissue, and few blood vessels were apparent. The clear anatomic relationship observed strongly supports the contention of a functional interrelationship between the TMJ and the middle ear.

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key words: temporomandibular joint, middle ear, malleus, sphenomandibular ligament, anterior malleolar ligament, petrotympanic fissure, fibrous continuity

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The presence of otic symptoms, such as vertigo, stuffy sensation, ringing of the ear, or tinnitus, in association with temporomandibular joint dysfunction, has long been reported by many investigators. Costen[1] was one of the first investigators to postulate that pressure of the retruded condyle on the auriculotemporal nerve could result in the development of these symptoms. Research has proven that it is anatomically impossible for the condyle to press on this nerve.[2–5] In one study,[6] the author assumed that hearing defects and vertigo are the result of the relationship of the temporomandibular joint (TMJ) with the muscles of the middle ear and the facial muscles. This author[6] believed that hyperfunctioning of the masseter muscle could lead to tensing of the middle ear muscles, because both muscles are supplied by the trigeminal nerve.

Williamson[7] attributed the cause of vertigo to a decrease in blood supply to the middle and inner ear from a sympathomimetic reflex resulting in vasoconstriction. Other hypothetical explanations of the relationship of the TMJ with the middle ear have been based on the structural relationship of the sphenomandibular ligament (SML) of the mandible and the anterior malleolar ligament (AML) of the middle ear.[8–11] The embryologic origin of both ligaments was found to be from the same cartilage, Meckel's cartilage.[2,8,9,12–17] However, the structures and possible function of the two ligaments after the fetal stage are vague. Although much has been written about the TMJ and the middle ear in various anatomy and otolaryngology textbooks, the exact interrelationship between them has been controversial.[16,18–26] This lack of clear definition of the structural correlation between the TMJ and the middle ear through the SML and AML provided the main incentive for the present study.

The objective of the present study was to investigate whether there is a structural relationship between the TMJ and the middle ear through a fibrous continuity of ligaments, specifically the sphenomandibular ligament and the anterior malleolar ligament, from the mandible and the malleus of the middle ear. In addition, the structural appearance and width of both ligaments were noted.

Materials and Methods

Eighty-two TMJ and middle ear specimens were obtained from the Anatomy Laboratory at Tufts University School of Health Sciences. These specimens were chosen from adult human cadavers ranging in age from 55 to 85 years. Removal of the temporal bone, along with the petrotympanic fissure (PTF) and mandibular fossa, was performed en bloc to maintain the structures needed for the study and to preserve their structural relationships. The PTF, the mandibular fossa, the chorda tympani nerve, the external auditory meatus, the middle ear, the anterior malleolar ligament, and the surrounding bony petrous pyramid were included. Of the 82 dissections, only 37 could be used. Reasons for not including specimens were *(1)* there was difficulty in obtaining the proper decalcification stage of the majority of the dissections; *(2)* the malleus was not present in the cadavers for four specimens; and *(3)* the tissues were not properly oriented in the desired plane during sectioning of some specimens.

After the specimens were dissected and had reached their appropriate stage of decalcification, they were sectioned and stained with Gomori's one-step trichrome.[27] Each specimen was placed on a glass slide and was viewed under the microscope. Photographs of each slide were taken with the Zeiss photomicroscope 2 (Zeiss, Germany). A photograph of a calibrated slide with 0.01- and 0.001-inch intervals was also taken. The percentage attachment of both the SML and AML at the malleus and PTF, and the actual widths of these ligaments at both sites, were determined by measuring each specimen photograph with the calibrated slide photograph. These measurements were made to determine the extent of fibrous continuity between both ligaments. In addition to the obtaining of the correct measurement of the fibrous attachments of these ligaments, the structural appearance of the SML and AML was also observed and noted.

The specimens were divided into two subgroups for statistical analysis. Group 1 included the specimens (SML/AML) present at the PTF but not at the malleus. Group 2 included the specimens present at the PTF and also at the malleus. The mean, standard deviation (SD), and the standard error (SE) were calculated for each group. Student's *t* test for two independent samples was used for comparisons. Point biserial correlation (rPB) determined the strength of relationship between the width of the fibers and incidence of attachment.

Results

After the tissues were sectioned and stained, they were examined under the microscope. The various sites required for this study are shown in Figs 1 and 2. Laterally (Fig 1a), the malleus of the middle ear and the PTF can be seen. The SML, AML, and the chorda tympani nerve were clearly occupying the fissure. Medially (Fig 2a), the articular eminence was shown, with the PTF and its occupants: the SML; the AML; and the chorda tympani nerve.

Level of Continuity Between the SML and AML

The SML was found to be near the malleus in 67.6% of the 37 specimens. The AML was present at the PTF in 64.5% of the specimens; in 58.3% of these specimens, the AML did not stop at the lips of the fissure, but continued through it to accompany the SML. The SML was found to pass through and attach directly on the malleus in 8.1% of the 37 specimens. The AML was found near the malleus in

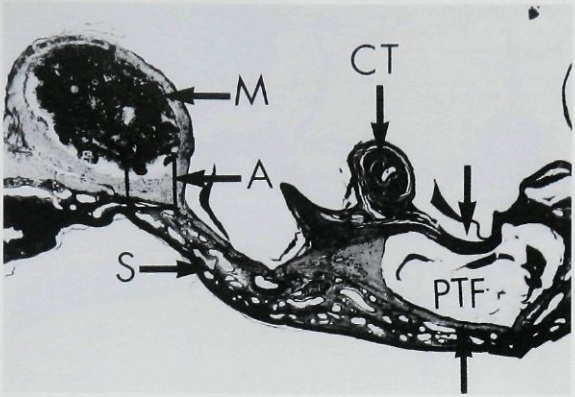

Fig 1a The sphenomandibular ligament (S), with its numerous blood vessels, is seen passing through the petrotympanic fissure (PTF), and running adjacent to and with the anterior malleolar ligament (A) to attach to the malleus (M). CT = chorda tympani nerve (Gomori's one-step trichrome stain; magnification × 18).

Fig 1b Enlargement of the malleus in Fig 1a. The anterior malleolar ligament (A) is attached to the malleus (M). The sphenomandibular ligament (S) is seen adjacent to the anterior malleolar ligament (A). Note the numerous blood vessels (bv) within the sphenomandibular ligament (Gomori's one-step trichrome stain; magnification × 22).

all specimens, and the SML was found near the PTF in all specimens.

In 81.8% of the specimens, the AML and the SML were found to run close to each other, either passing through the fissure or attaching to the malleus. In 10.1% of the specimens, fibers of the AML intermingled within the SML, with strands of AML occasionally crossing through the SML. In the remaining 8.1%, the SML appeared to encircle the AML, with the latter on both sides of the fissure and between the former.

The widths of the SML and the AML were measured at two areas: the malleus of the middle ear and the PTF. These measurements were made to determine if the size of the ligaments at their attachment area could have any significant influence on their continuity. The measurements of these widths are listed in Table 1. These measurements were further categorized into two subgroups according to the area where they were located: the PTF or the malleus. Data for the subdivisions are in Tables 2 and 3. For group 1, the specimens were present at the PTF but not at the malleus. For group 2, the SML was present at the PTF and at the malleus. Table 3 has the same divisions as has Table 2, but in Table 3, the AML is the point of

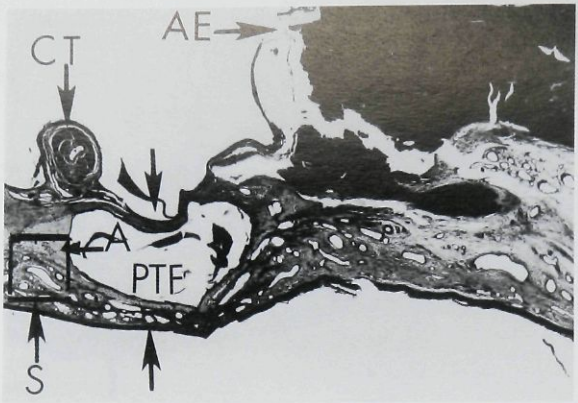

Fig 2a Petrotympanic fissure (PTF) area, with the sphenomandibular ligament (S) and anterior malleolar ligament (A). Both ligaments can be seen traveling through the PTF. CT = chorda tympani nerve, AE = articular eminence of the temporomandibular joint (Gomori's one-step trichrome stain; magnification × 18).

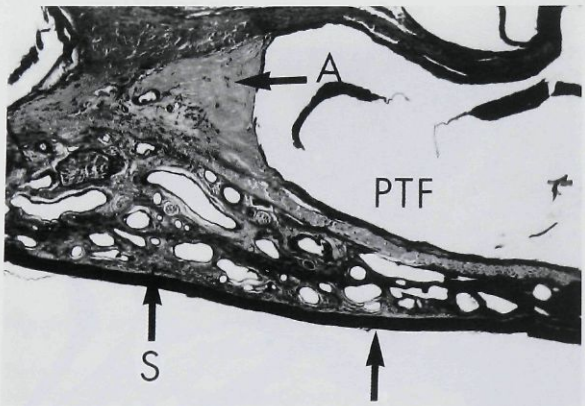

Fig 2b Enlargement of the petrotympanic fissure in Fig 2a. Note the anterior malleolar ligament (A) and the sphenomandibular ligament (S) running adjacent to one another, both passing through the PTF. The larger portion of the PTF area is occupied by the sphenomandibular ligament, in comparison to the anterior malleolar ligament, which occupies a smaller area (Gomori's one-step trichrome stain; magnification × 22).

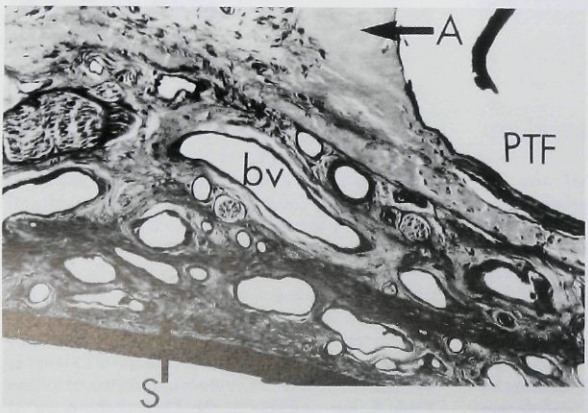

Fig 2c Enlargement of Fig 2b. The different structural appearance is revealed between the anterior malleolar ligament (A) and the sphenomandibular ligament (S), at the petrotympanic fissure (PTF) (bv = blood vessels) (Gomori's one-step trichrome stain; magnification × 27).

focus. The mean, SD, SE, and rPB are also indicated. The results presented in Tables 2 and 3 indicate the absence of any statistical significance as to the size of either ligament to its continuity.

Structural Appearance of SML and AML

One of the most striking findings observed during the histologic examination was the structural difference in appearance between the SML and the AML. This structural difference is best demonstrated in Fig 2c. The SML contained connective tissue fibers distributed in a random fashion, with numerous blood vessels scattered between them. The blood vessels appeared mostly as venules, with a thin lamina propria and a large lumen. In some areas, arterioles could also be noted. The connective tissue fibers had a wavy configuration with typical connective tissue nuclei transposing them. In contrast, the AML connective tissue consisted of well-organized and defined fibers. Almost no blood vessels were apparent in this ligament. Fibers of the AML were found to be distributed in an orderly fashion, lying adjacent to another, with their nuclei between them.

Discussion

The purpose of the present study was to determine the structural interrelationship between the TMJ and the middle ear, in terms of fibrous continuity between the SML of the mandible and the AML of the middle ear. The present findings clearly establish a fibrous continuity between these ligaments. The SML was found to be present in the middle ear in 67.6% of 37 specimens, with 8.1% attaching directly to the malleus. The AML was found to be present at the PTF in 64.5% of the specimens, with 58.3% traveling through the fissure with the SML.

The widths of the SML and AML were measured at two areas: the malleus of the middle ear and the PTF. These measurements (Table 1) were made to determine if the size of the ligaments at their attachment areas could have any significant influence on their continuity. The measured widths of the SML and AML were further categorized into two subgroups according to the areas at which they were located: the PTF or the malleus. The subdivisions of the SML and the AML are shown in Tables 2 and 3. Group 1 included the specimens present at the PTF, but not at the malleus. Group 2 included specimens present at the PTF, and also at the malleus. Student's *t* test for two independent samples was used for compar-

Table 1 Measurements (× 0.001 inch) of Width of SML and AML at Malleus and PTF

	SML		AML	
Dissection	At malleus	At PTF	At malleus	At PTF
1	–	12	7	–
2	+	6	5	+
3	+	4	5	–
4	+	3	3	+
5	–	8	4	–
6	–	8	6	+
7	+	4	1	–
8	+	20	8	+
9	+	5	10	+
10	+	8	8	–
11	–	3	6	+
12	–	15	5	–
13	+	6	5	+
14	+	5	4	–
15	+	7	5	+
16	+	6	5	+
17	–	10	6	–
18	+	6	8	+
19	+	6	6	+
20	+	4	6	+
21	+	8	7	+
22	+	3	5	+
23	+	5	4	–
24	+	5	3	+
25	+	5	7	–
26	+	6	5	+
27	–	6	7	+
28	–	4	6	–
29	–	6	5	+
30	+	8	4	–
31	+	6	5	–
32	+	6	6	+
33	+	5	4	+
34	–	4	9	+
35	–	10	8	+
36	+	3	5	+
37	–	1	8	+

Table 2 Subdivisions of the Widths of the SML (× 0.001 inch)

	No. of samples	Mean	SD	SE
Group 1	12	7.25	4.05	1.17
Group 2	25	6.00	3.25	0.65

Student's *t* test = 0.9346, *df* = 35, rPB = .1685
P > .10 (not significant)

Table 3 Subdivisions of the Widths of the AML (× 0.001 inch)

	No. of samples	Mean	SD	SE
Group 1	13	5.07	1.80	0.49
Group 2	24	6.04	1.78	0.36

Student's *t* test = 1.5616, *df* = 35, rPB = .25523
P > .10 (not significant)

isons, and point biserial correlation (rPB) determined the strength of relationship between the width of the fibers and incidence of attachment. The results indicate the absence of any significance in regard to this relationship of the size of either ligament to its continuity.

The findings of the present study contradict various anatomy and otolaryngology textbooks that describe the SML as attaching only to the spine of the sphenoid bone,[18,19,22,24,26,28–30] and the AML present at the malleus,[12,20,21,23,25] with no further description of the attachments of either ligament. Some authors[12,17,18,31,32] have described the principal attachment of the AML close to the PTF, with additional fibers passing through the fissure to attach to the spine of the sphenoid bone, offering some continuity with the SML. Others[18,19,24,29,33,34,35] suggest that the AML may be found at the PTF, they but do not describe its further course or direction. The only supporting physical evidence previously described as to the continuity of the ligaments was reported by Mahan et al,[11] who had dissected, sectioned, and stained six specimens. A well-defined AML was apparent under gross examination and in histologies of all of their specimens. Fibers of the AML were found to extend through the PTF. However, no report of sample size showing this continuation was offered.

The present study provides a large database of 37 specimens, all of which were dissected, sectioned, and stained. The findings not only establish clear continuity between the SML and the AML, but also define histologically the structural nature of both ligaments. Extensive examination of available literature[36–47] indicates no previous descriptions of these ligaments. In the present study, the SML was found to be composed of irregular connective tissue fibers randomly arranged, with the presence of a rich blood supply. On the other hand, the AML was found to be composed of smoothly arranged connective tissue fibers, with almost no vascular supply (see Fig 2c). An explanation of the presence of a different vascular supply to each ligament may be postulated. The AML resembles any other ligament or tendon in the body. When sufficient tension is applied to this ligament, it tightens and its vascular supply is reduced. One may assume that tension is being applied to the AML. Because the SML appears to be very vascularized, one could assume that this ligament is not placed under constant tension, as opposed to the AML.

The rich blood supply in the SML may provide a reason for the occurrence of pain in the ear. The smooth muscle fibers present in the blood vessel walls contain sympathetic fibers. These are supplied by visceral sensory afferent fibers that could initiate pain in the region if sufficient tension were applied to the ligament. According to several researchers[11,48] this tension may be observed in overclosure and extreme protrusive movements of the mandible. Nerve fibers within the SML, which are thought to be anterior tympani nerve fibers, were also found; they may provide a different explanation for the presence of pain when tension is applied to the ligament.

Some investigators[11,48] believe that protrusive movement of the mandible allows the SML to become taut. With a reduced vertical dimension (such as in edentulous or partially edentulous patients), this ligament becomes tense, causing a change in the position of the malleus. Mahan et al[11] found that inferior distraction of the mandible (seen in TMJ surgical procedures that require sufficient access) may lead to damage of the middle ear, including displacement of the malleus from the tympanic membrane.

If we assume that during TMJ dysfunction combined with loss of sufficient vertical support of the mandible, a more protrusive and inferior positioning of the jaws may occur, we could speculate that the position of the malleus within the middle ear may become influenced because of the continuity of the SML with the AML. To support this theory and to determine the functional interrelationships between the TMJ and the middle ear, additional clinical research is needed. The findings of the present study can allow us only to postulate an explanation for middle ear symptoms when TMJ dysfunction is present.

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Resumen

La Incidencia y Naturaleza de la Continuidad Fibrosa Entre el Ligamento Esfenomandibular y el Ligamento Maleolar Anterior del Oído Medio

El propósito de este estudio fue el de determinar la correlación estructural entre la articulación temporomandibular (ATM) y el oído medio; en cuanto a la continuidad fibrosa entre el ligamento esfenomandibular (LEM) de la mandíbula y el ligamento maleolar anterior (LMA) del oído medio. Se adquirieron 37 espécimenes de la ATM y el oído medio de cadáveres humanos adultos. El hueso temporal, la fisura petrotimpánica, la fosa mandibular, y el oído medio fueron disecados en bloque, fijados, seccionados, teñidos y observados bajo el microscopio. De los 37 espécimenes, 67,6% presentaban la continuidad del LEM a través de la fisura que pasa cerca del martillo del oído medio. El LMA estaba presente en la fisura del 64,9% de los espécimenes, y un 58,3% pasaba directamente sin parar en la fisura. Los resultados indicaron que existía una continuidad fibrosa entre el LEM y el LMA. También se notaron diferencias estructurales entre los dos ligamentos. El LEM contenía tejido conectivo fibroso dispuesto al azar con numerosos vasos sanguíneos interpuestos. El LMA presentaba un arreglo de fibras lisas dentro del tejido conectivo, y pocos vasos sanguíneos. La relación anatómica clara observada soporta enfáticamente el argumento de una correlación funcional entre la ATM y el oído medio.

Zusammenfassung

Das Auftreten und die Beschaffenheit einer fibrösen Kontinuität zwischen dem Sphenomandibularligament und dem anterioren Malleolarligament des Mittelohrs

Das Ziel dieser Studie war es, die strukturelle Wechselbeziehung zwischen dem Kiefergelenk (TMJ) und dem Mittelohr zu bestimmen, die fibröse Kontinuität zwischen dem sphenomandibulären Ligament (SML) der Mandibula und dem anterioren Malleolarligament (AML) des Mittelohrs. Siebenunddreissig Exemplare von TMJ und Mittelohren wurden von erwachsenen menschlichen Leichen erhalten. Der Temporalknochen, die Fissura petrotypanica, die Fossa mandibularis sowie das Mittelohr wurden en bloc seziert, fixiert, geschnitten, gefärbt und mikroskopisch betrachtet. Von den 37 Exemplaren hatten 67.6% eine Kontinuität vom SML durch die Fissur ziehend nahe dem Malleus des Mittelohrs. Das AML war in der Fissur vorhanden bei 64.9% der Exemplare, bei 58,3% durch die Fissur verlaufend und nicht an der Fissur endend. Stukturelle Unterschiede zwische den zwei Ligamenten wurden ebenfalls beschrieben. Das SML enthält zufällig angeordnetes fibröses Bindegewebe mit zahlreichen dazwischentretenden Blutgefässen. Das AML hat eine glatte Faseranordnung innerhalb des Bindegewebes, und wenige Blutgefässe waren vorhanden. Die beobachtete klare anatomische Beziehung unterstützt stark die Behauptung einer funktionellen Wechselbeziehung zwischen dem TMJ und dem Mittelohrr.