A Direct Anatomical Study of the Morphology and Functionality of Disco-malleolar and Anterior Malleolar Ligaments

Estudio Anatómico Directo de la Morfología y Funcionalidad de los Ligamentos Disco-maleolar y Maleolar Anterior

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SUMMARY: The disco-malleolar and anterior malleolar ligaments are common to the middle ear, the temporomandibular joint and the jaw, all of them sharing a common embryological origin; these ligaments' morphometric and functional aspects were studied in 23 temporal bones. Experimental design: The epitympanum roof and the temporomandibular joint roof were elevated by micro-dissection of the middle cranial fossa, exposing both disco-malleolar and anterior malleolar ligaments and their association with the malleus, the temporomandibular joint disc and the mandibular lingula. Principal observations: Both ligaments start in the malleus and take anterior and divergent routes towards the temporomandibular joint and lingula, passing through Huguier's canal. The disco-malleolar and anterior malleolar ligaments' mean lengths were 6.88 mm (SD 0.81) and 4.22mm (SD 1.17), respectively, no statistically significant difference being revealed between the sides. Temporomandibular joint disc traction was applied for verifying malleus mobility; malleus movement was observed when applying disco-malleolar traction in 30.5% of the samples. Correlation was observed between malleus movement and disco-malleolar length ($R^2=-0.499$, $p<0.05$). Both ligaments common to the stomatognathic system and middle ear were present in all specimens. Conclusions: There was an anatomical and functional relationship between human TMJ and the middle ear.

KEY WORDS: Oscicular chain; Temporomandibular joint; Otic symptoms; Disco-malleolar ligament; Anterior malleolar ligament.

INTRODUCTION

The middle ear and the stomatognathic system are closely related. Myrhaug (1964) stated that the ossicular chain and middle ear muscles ontogenically belonged to the masticatory system and serve the hearing system. Interestingly, in other ancestral species (reptile fossils), the jaw was fixed with the ossicles, which constrain acoustic signals (Allin, 1975). This scenario is not currently applicable to humans; however, the close relationship of the temporomandibular joint (TMJ) and the middle ear make them neighbours (embryological, anatomically and physiologically speaking), although performing different tasks (Fig. 1).

TMJ and middle ear development is complex in humans and still debatable (Proctor, 1967). The first branchial arc (Meckel's cartilage) forms the jaws from its ventral part

and the ossicular chain from its dorsal part, partially joining the second branchial arch (Reichert's cartilage) (Strickland *et al.*, 1962). Vascular, nervous and ligamental connections between the TMJ and middle ear growth persist; they survive due to common Meckel's structure continuity through the petro-tympanic fissure, which never completely closes, thereby forming Huguier's canal (Rodríguez Vazquez *et al.*, 1991, 1993). The malleus is closely related to condylar and temporal blastemas with fibrous connections through this petro-tympanic fissure, which Rees (1954) named the disco-malleolar ligament (DML). This is the same structure to which Bossy and Gaillard attributed vestigial characteristics from the first branchial arc (Rees; Bossy & Gaillard, 1963; Youdelis, 1966; Misurya, 1976; Perry & Xu, 1985; Thilander & Carlsson, 1976; Sadler, 1998; Yoshikuni, 1993; Wong, 1985).

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Fig. 1. TMJ and middle ear space superior and posterior access. * Antero-lateral sample orientation. 1. TMJ disc, 2. malleus head, 3. incus, 4. stape, 5. vestibule, 6. cochlea, 7. cut and medially-retied chorda tympani nerve, 8. the DML and AML emerging from the malleus anterior process and sectioned in their pre-septal segment.

Fig. 2. External (from TMJ) and internal views (from middle ear) of Huguier's canal. * Antero-lateral sample orientation. 1. TMJ, 2. Huguier's canal external foramen, 3. scamo-tympanic fissure, 4. petro-tympanic fissure, 5. auditive tube osseous portion, 6. Huguier's canal internal foramen, 7. Huguier's canal septum, 8. tympanic cavity.

The iter chorda anterior (or Huguier's canal) is the structure connecting the TMJ and the middle ear; this is where the chorda tympani nerve exits from the middle ear (Fig. 2) (Tóth *et al.*, 2006). Sato *et al.* (2008) have used radiology (cone beam CT) for finding different dimensions and forms for this TMJ and middle ear or Huguier's canal (Sato *et al.*). Marasa & Ham (1988) have suggested that TMJ inflammatory or functional disorders can spread throughout Huguier's canal to the middle ear and produce otitis media due to this foramen's dimensions (Scolozzi *et al.*, 2004; Regev *et al.*, 2003; Takes *et al.*, 2000).

Pinto's and Komori's dissections in humans (Pinto, 1962; Ash & Pinto, 1991; Komori *et al.*, 1986) and other dissections of adults and fetuses (Rodríguez Vazquez *et al.*, 1993, 1998; Loughner & Larkin, 1989; Morgan *et al.*, 1995; Ioannides, 1983; Mérida Velasco *et al.*, 1997; Coleman, 1970; Alkofide *et al.*, 1997; Rodríguez Vazquez *et al.*, 1992; Gola *et al.*, 1997) have established an anatomical link between the TMJ, the middle ear and the lingula from both sides of Huguier's canal. The DML and anterior malleolar ligament (AML) pass through this canal and connect the malleus' anterior process (Gracilis process) with the TMJ disc and lingula (Hoshino, 1988; Toledo Filho *et al.*, 1985). The DML is an embryological remnant of the external pterygoid muscle; it is located more laterally to the AML and inserts into the postero-supero-medial TMJ capsule and retrodiscal portion of the TMJ disc (Pinto). The AML is placed more medially and joins the maleolo-mandibular or speno-mandibular ligament (EML), being accompanied by the chorda tympani nerve. Hence, the AML was considered to be a continuation of the EML by Burch (1970) because its origin is in the anterior process of the malleus and united spenoid spine and petro-tympanic components of the EML to ultimately become inserted into the lingula or the jaw body's spix spine (Fig. 3) (Garg & Townsend, 2001). The EML is an embryological remnant of Meckel's cartilage and changes its dimensions throughout its entire trajectory from lingula to cranial base to unite the AML on entering the middle ear in Huguier's canal (Loughner & Larkin). Both the DML and AML are fixed in the malleus' ventral area (anterior process). They exit anteriorly from the malleus' anterior process towards the tympanic wall in the petrotympanic fissure (Huguier's canal), expanding it medio-laterally like a horizontal "V" (Ogutcen-Toller, 1995; Ogutcen-Toller & Keskin, 2000). The chorda tympani nerve emerges with the AML (Pinto; Komori *et al.*), both ligaments being separated by an osseous triangular crest in Huguier's canal (Fig. 2).

The possible biomechanical connections between these ligaments are very controversial, especially due to their involvement in any otic-referred symptoms, which may be

produced. Both ligaments are described in this study using dissections of human temporal specimens, the TMJ and middle ear being accessed through the middle cranial fossa. Malleus mobility was registered during masticatory structure traction: anterior jaw (TMJ disc traction) for the DML and jaw overclosure and lateral jaw movements for the AML and EML, respectively.

MATERIAL AND METHOD

Twenty-three fresh temporal blocks (7 cm side) were extracted from 11 male and 1 female non-reclaimed, lesion-free cadavers; these samples were donated by the Instituto de Medicina Legal in Bucaramanga, Colombia, and research on such human samples was approved by the Universidad Industrial de Santander's Ethics' Committee. Twenty-two samples were paired and one (left-hand side) was left unpaired; the samples were frozen and then immersed in 1:10.000 thimerosal in 0.9% saline solution for one week (to keep the tissue soft) until used for dissection purposes. Formaldehyde was not used to avoid it inappropriately fixing the tissues for our study purposes.

The access route for the micro-dissection consisted of a superior approach through the middle cranial fossa. Both epitympanum and TMJ roofs were removed, revealing both disco-malleolar and anterior malleolar ligaments and their attachment to the malleus and the TMJ disc. An electronic calliper (Mitutoyo) was used for recording all measurements in centesimal mm. The tympanic wall septum was used as a reference area for measurements and morphometric description. Pre-septal and supra-septal DML and AML lengths were measured (a 15x optical zoom being used for all measurements).

A colour dotted mark was visually recognised on the malleus head when recording malleus mobility by TMJ-jaw traction. Stereotypical anterior and superior jaw forces were then tested: anterior TMJ disc traction (protrusion) for the DML and jaw over-closure and lateral movements for the AML and EML. These movements tried to reproduce some physiological (protrusion and lateralisation) and pathological (overclosure) scenarios. All specimens were mechanically fixed with screws before traction and tightly immobilised in a table-vice. The movements were done manually by holding the jaw before starting; such protrusion, overclosure and lateralisation range of movement was towards the extreme limit determined by a sample's anatomical parameters. These movements started with the extreme posterior and superior mandible fossa condyle position. The protrusion movement finalised when the condyle-disc complex reached

Fig. 3. Left TMJ, mandible ramus and middle ear medial view. 1. Tympanic cavity, 2. DML bilaminar area union, 3. TMJ disc, 4. alveolar nerve sectioned and retracted over external pterygoid muscle, 5. external pterygoid muscle, 6. EML, 7. styloid process, 8. lingula, 9. AML fixing to EML lateral surface, 10. sphenoid spine.

Fig. 4. Superior and antero-medial view of left middle ear and TMJ. * Antero-lateral sample orientation. 1. TMJ disc, 2. malleus head, 3. incus, 4. DML, 5. AML, 6. chorda tympani nerve, 7. VII cranial pair geniculated ganglion, 8. tensor tympani muscle.

or surpassed the temporal eminence crest in extreme traction. The overclosure movement finalised when the condyle-disc complex reached an extreme orbit in the mandibular fossa; the same initial position was considered for extreme lateral movements. All findings were recorded with digital images and all measurement data was recorded on a collection format. Parametric and non-parametric tests were done.

RESULTS

The DML and AML (fixed to EML) were observed in all samples. DML and AML morphology assumes a triangular form in the petrotympanic fissure with a posterior vertice in the anterior process of the malleus, an anterior base combining with the bilaminar TMJ disc and TMJ capsule area (posterior-supero-medial area), one medial side formed by the AML and chorda tympani nerve emerging from the middle ear and a diffuse lateral side, which we could not relate to any other structure (Fig. 4). The AML

was joined to the most lateral aspect of the EML in the sphenoid spine, descending towards the lingula (Fig. 3). The entire complex (DML and AML) was located in Huguier's canal (petrotympanic fissure). Both ligaments were separated by an osseous crest on the horizontal floor of Huguier's canal (Fig. 5). The DML took a lateral course and the AML a medial one with the chorda tympani nerve as it passed through Huguier's canal to the sphenoidal spine.

Both ligaments' mean lengths were recorded (Table I): the DML was 6.88 mm (SD 0.81) and AML 4.22 mm (SD 1.17). The tympanic wall septum separating the TMJ and the middle ear was used as a reference area for measuring both ligaments' pre-septal and supra-septal lengths (Fig. 6); DML pre-septal length was 1.45 mm (SD 0.19) and supra-septal length 5.42 mm (SD 0.61), having no significant difference between sides (t paired test=0.809, $p=0.44$). AML measurements revealed a shared medial trajectory with the chorda tympani nerve before they became hidden in the petro-tympanic fissure sulcus towards the sphenoid spine. AML pre-septal mean length was 1.45

Fig. 5. Superior and postero-medial view of right middle ear and TMJ. * Postero-medial sample orientation. 1. TMJ disc, 2. middle ear, 3. DML antero-laterally separated from the lateral side of Huguier's canal, 4. DML and AML Huguier's canal septum, 5. AML antero-medially separated from the medial side of Huguier's canal, 6. chorda tympani nerve suprasedal trajectory, 7. TMJ bilaminar zone.

Fig. 6. Superior and antero-medial view of left middle ear and TMJ. * Antero-lateral sample orientation. Continuous black line: DML pre-septal portion, continuous white line: DML supra-septal portion, segmented black line: AML pre-septal portion, segmented white line: AML supra-septal portion.

Fig. 7. TMJ disc anterior traction (protrusion) for the DML. Superior and antero-medial view of left middle ear and the TMJ. * Antero-lateral sample orientation. Fig. A, 1. mastoid aditus, 2. incudal fossa, 3. incudo-malleolar joint, 4. the DML (short arrow) and AML (long arrow) emerging from the malleus anterior process, 5. DML fixing TMJ bilaminar zone, 6. TMJ disc, 7. AML in its supra-septal medial course, 8. the internal face of tympanic membrane, 9. choleariform process, 10. tensor tympani muscle tendon, 11. incudo-stapedial joint, 12. chorda tympani nerve over tensor tympani muscle tendon, 13. chorda tympani nerve and AML medial course, 14. TMJ bilaminar zone stretched in excursive tractional TMJ movements, 15. TMJ disc in extreme protrusive movement.

mm (SD 0.19) and 2.77 mm (SD 0.98) for its supra-septal portion, no significant difference being noted for the sides (t paired test: 0.492, $p=0.63$).

Malleus head anterior mobility was observed (by TMJ disc protrusion, Fig. 7) in 30.5% of the samples for the DML (approximately 1 mm range); such movement was postero-anterior but we could not determine a possible rotational effect for the bone or any tympanic membrane traction deformation. No movement was observed in any of the samples when AML-related traction movements (overclosure and lateral) were made. Correlation was observed between malleus movement and DML length ($R^2=-0.499$, $p<0.05$).

DISCUSSION

A century ago the origin of some otic symptoms (collectively known as temporomandibular disorders) was attributed to stomatognathic system dysfunction. Monson & Wright related jaw position with hypoacusis in the infant and adult population in 1920. Goodfriend correlated otic symptoms with the TMJ in 1933 (Parker & Chole, 1995). Costen (1934) associated such otic symptomatology with

Table I. Results of ligament traction (jaw body closing and protruding) and length measurements in mm for the DML and AML.

Sample	Sex	Side	Closing	Protuding	AML Pre-Sept	AML Supra-Sept	AML Total	DML Pre-Sept	DML Supra-Sept	DML Total
0	M	L	N	Y	1.46	2.38	3.84	1.46	5.74	7.20
1	M	L	N	N	1.45	2.77	4.22	1.45	5.72	6.87
2	M	R	N	N	1.62	0.96	2.58	1.62	5.14	6.76
3	M	L	N	N	1.38	2.14	3.52	1.38	4.84	6.22
4	M	R	N	N	1.58	4.84	6.42	1.58	4.52	6.10
5	F	R	N	N	1.44	1.10	2.54	1.44	5.12	6.56
6	F	L	N	N	1.48	1.18	2.66	1.48	5.02	6.50
7	M	R	N	N	1.60	2.12	3.72	1.60	6.36	7.96
8	M	L	N	N	1.60	2.12	3.72	1.60	5.10	6.70
9	M	L	N	Y	1.54	3.22	4.76	1.54	5.34	6.88
10	M	R	N	Y	1.50	3.60	5.10	1.50	5.86	7.36
11	M	L	N	Y	1.10	2.90	4.00	1.10	6.04	7.14
12	M	R	N	N	1.08	3.40	4.48	1.08	5.54	6.62
13	M	R	N	N	1.60	2.18	3.78	1.60	6.16	7.76
14	M	L	N	N	1.68	2.02	3.79	1.68	5.10	6.78
15	M	L	N	Y	1.56	3.22	4.78	1.56	5.34	6.90
16	M	R	N	Y	1.40	3.80	5.20	1.40	5.98	7.38
17	M	L	N	Y	1.12	3.28	4.40	1.12	7.04	8.16
18	M	R	N	N	1.12	3.40	4.52	1.12	5.54	6.66
19	M	R	N	N	1.42	1.16	2.58	1.42	5.34	6.76
20	M	L	N	N	1.34	2.22	3.56	1.34	4.84	6.18
21	M	L	N	N	1.58	4.84	6.42	1.58	4.52	6.10
22	M	R	N	N	1.78	4.76	6.54	1.78	4.82	6.60
Mean					1.45	2.77	4.22	1.45	5.42	6.88
SD					0.19	0.98	1.17	0.19	0.61	0.81

TMJ disorders, in 1934 (Costen's syndrome) (Shapiro & Truex, 1943). Kuttilla & Kuttilla have found that an evident pathology in the hearing system can be diagnosed in less than 50% of patients suffering from otalgia (Kuttilla & Kuttilla, 1999, 2001). It appears that functional and inflammatory TMJ and craniofacial muscular disorders are associated with secondary otological-referred symptoms (Gelb & Tarte, 1975; Ramirez *et al.*, 2008).

The range of tympanic membrane deformation in conducting sound energy must be understood when trying to ascertain the possibility of motion from the DML and AML on malleus ossicles. Tonndorf & Khanna (1972) used time-average holography to show that an intense acoustic stimulus (111-121 dB) can deform the tympanic membrane by no more than nanometers or possibly a micrometer, depending on the frequency and place for tympanic membrane measurement (Sun *et al.*, 2002). Tympanic

membrane and middle ear vibration produced by sound energy is thus on the nanometer scale. The auditory threshold thus responds to sub-angstrom ossicular motion (Békésy, 1960; Dalhoff *et al.*, 2007), this finding has been widely corroborated by Wada *et al.* (1992, 2002; Koike *et al.*, 2002) using better-quality tympanometry equipment with low probe tone frequency (time-average speckle pattern interferometry) and finite element analysis at different frequencies and pressures in human and other species' hearing systems.

According to Eckerdel (1991), the DML and AML range of movement depends on their fibrous connections to Huguier's canal, thereby corroborating Coleman's findings (Coleman). Our findings concerning 30.5% DML traction malleolar mobility correlated well with Sato *et al.* who showed a spacious Huguier's canal in 29.2% of samples, suggesting a wide foramen which could allow

free passage of its inner structures. The samples' DML traction malleolar mobility was recorded with a 15x optical zoom which surely allows seeing movement ranging from 800-1000 μm or higher, thereby making it just possible to observe a greater range of movement produced by TMJ disc traction but not those produced by middle ear physiological nanometer dynamics. If the ossicular chain can thus transmit a nonometric tympanic vibration through two joints from tympanic membrane to inner ear then, with more than four ligaments and two muscles having an effective area and lever relationship, it would thus be very possible to have a potential DML and AML effect on ossicular chain spatial disposition when TMJ-jaw traction is applied to them by the malleus.

Experiments have demonstrated that AML fixation (stiffness) is dominant at low frequencies. Although low frequency tinnitus has been reported to be very rare, it may vary in pitch from low frequency to high frequency, intermittent or permanent and vary in intensity; it cannot be ruled out that it is caused by ossicular fixation and/or a low admittance pattern. The work of Nakajima *et al.* (2005) has ruled out the idea that ligamental motion may not produce an auditory effect by appreciable excitation of the inner ear due to high-pass filtering by different systems (helicotrema, incudo-malleolar, incudo-stapedial and oval annular ligament joints). They revealed reduced auditory sensitivity (8-10 dB loss) when the AML was partially fixed and a larger loss (15-35 dB) when it was totally fixed. This proved that restraining the ossicles produced an increase in the ear's impedance. They tried to simulate an otosclerosis lesion because AML fixation clinically occurs in combination with this pathology (Zhao *et al.*, 2002). This experimental model also took into account this ligament structure's adjustment power in sound transmission (Huber *et al.*, 2003). In this sense, whether such motion at low frequencies involved in TMJ-jaw motion can produce enough sound to be heard at an auditory threshold close to 1 Hz (the stapes move at least one micron) is not unsure.

Huguier's canal's morphological dimensions play a paramount role in the above possibility. Huguier's canal has a slender funnel-like form in the petrotympanic fissure (being wider near the TMJ and narrower near the middle ear). Sato *et al.* and Eckerdal measured such dimensions at three sagittal places (near the TMJ, the middle area and near the middle ear); these were 4.1, 1.9 and 0.9 mm, respectively, according to Sato *et al.*, and 2.75, 1.9 and 1.05 mm, respectively, according to Eckerdal. Estimations of Huguier's canal length have been seen to differ, being quite ample for Eckerdal (1.9 to 11.5 mm) when compared to our measurements (6.88 mm, SD 0.81) and those of

Komori *et al.*, (2.5 mm, SD 1.8). Regarding ligament width, Loughner & Larkin recorded 0.2 mm (SD 0.2) for the DML and 0.8 mm (SD 0.2) for the AML in 52 samples. Alkofide *et al.* recorded 0.14 mm (SD 0.04) for the AML in 37 samples whilst Cheng & Gan (2008) found 0.81 mm (SD 0.22) for the AML in 9 samples. We did not measure AML and DML width, but corroborated other findings in our dissections with thin and (on some occasions) fragile attributes for these structures. Such heterogeneous Huguier's canal morphology suggests a diverse permissive movement ability for the DML and AML when a force is applied to them and transmitted via ossicular chain vibration dynamics.

To a certain extent we have the same opinion as Eckerdal regarding the idea that Huguier's canal adherence can restrict the ligaments observed in our dissections. On the other hand, we do not consider such adherence able to impede (in the rest of the 30.5% of our samples) nanometer movement transmission from TMJ anterior traction force during protrusion. Differing explanations have arisen from these ligaments' morphology regarding Huguier's canal and this canal's dimensions, strengthened by ossicular chain dynamics' physiology. Cheng & Gan found that the AML's mean pre-septal length was 1.83 mm (SD 0.32), this being close to ours (1.45 mm, SD 0.19); good viscoelastic performance was calculated for tension resistance (1.05 MPa) and stretching resistance (1.51 MPa), thereby assuring force transmission from the TMJ to the middle ear malleus. Disorganised surface collagen disposition was found regarding this structure's morphology (regarding Huguier's canal walls), enveloping a wide and well-organised longitudinal collagen band as a double collagen layer assembly. This characteristic, plus its width, mechanical resistance and sound energy transmission magnitude, makes Eckerdal's adherence model for Huguier's canal doubtful (Eckerdal). Correlation was also obtained between malleus movement and DML length, thereby adding an extra variable to be taken into account (especially for Huguier's canal mixed morphology and proximity), making these ligaments dynamic structures.

Interestingly, ipsilateral referred otic symptoms have been found in TMJ pathologies, as demonstrated by Ren *et al.* (1995) and Kuttilla *et al.* (2005), who found a positive correlation between tinnitus and ipsilateral TMJ disorder. In 1933, Bernstein *et al.* (1969) observed that tinnitus intensity and quality could be modified in extreme jaw movements. This picture of mobility was taken from a surgical scenario when Loughner & Larkin reported that damage to the ossicular chain had been caused by TMJ condylar distraction surgery (Jones & Horn, 1989;

Steigerwald *et al.*, 1996; Tsuyama *et al.*, 2000). Baldursson & Blackmer (1987) reported a correlation between temporomandibular dysfunction and sensorineural hearing loss in a controlled study using 50 patients; a notch loss of audiometric configuration was found at 1-2 KHz (250-4.000 Hz range).

A TMJ disorder may stretch the DML and AML, thereby affecting middle ear structure equilibrium (Eckerdal; Cheynet *et al.*, 2003; Kim *et al.*, 2004; Wright & Bifano, 1997). The spread of forces through cranial bone sutures was treated by Libin in 1987 (Libin, 1987) and suggested that ligaments common to neighbouring structures could become tensioned during normal physiological mobilisation and in abnormal temporal bone trauma. Retrodiscal tissue elasticity can normally act as an energy buffer in spreading movement from the TMJ to the middle ear by such common ligaments; however, TMJ disc luxation or oedematous pressure from an inflammatory disorder could certainly cause tension on the malleus through Huguier's canal (Johansson *et al.*, 1990; Myers, 1988; Williamson, 1990; Luder, 1993; Schaefer, 2001).

It thus seems that otic symptoms (tinnitus, otalgia, dizziness and hypoacusis) corresponding to altered ossicular spatial relationships (such as conductive middle ear pathologies) can also be produced from masticatory system pathologies. Otalgia produced in tympanic membrane tension and tinnitus, dizziness or hypoacusis by the inner ear being stimulated by such mechanical transmission is viable in such a ligamental model (Dai *et al.*, 2007).

Indeed, recalling that the ossicular chain rotational axis was assumed to be a straight line from the malleus' anterior process (where the AML and DML become attached to it) to the incus' short process, then an antero-posterior axis may be obtained having proven complex movement patterns when sound frequencies are increased (Wada *et al.*; Huber *et al.*). If potential roles for both the AML and DML are considered in fixing low frequency sound ranges (such as tensor tympani and stapedial muscle activity execution during sound protection and discrimination mechanisms) (Chan & Reade, 1994), then this produces another possible ossicular fixation mechanism in sound transmission when the mandible is protruded which would be interesting to study as a natural acoustic accommodation reflex.

Concerning EML, we agree with the findings of Abe *et al.* (1997), who found that this ligament was fixed inferiorly to the jaw (lingula) and superiorly to the sphenoid

spine (medial side) and the AML (lateral side); however, we could not account for an additional attachment to the TMJ disc in our dissections. Alkofie *et al.* studied AML and EML structural characteristics in 37 specimens, determining that the EML reached the malleus (8.1%) and the middle ear (67.6%), whilst the AML passed through the petrotympanic fissure with the EML (58.3%), suggesting guaranteed connectivity between both ligaments. Regarding EML mechanics, Burch (1966) found that it relaxed during maximum jaw opening and tensed during overclosure; however, it has been suggested that it can be stretched during lateral jaw movements (Ouchi *et al.*, 1998). Both AML and EML ligaments can thus be tensioned in several situations, which may alter the ossicular chain (Burch, 1970), although this could not be observed in our experiment. Malleus head mobility by DML was positively observed in 30.5% of the samples; however, minor nanometer transmission cannot be ignored for all ligaments (DML, AML, EML) regarding ossicular chain movement magnitude.

Secondary referred pathologies must be measured when considering Huguier's canal morphology, DML and AML anatomy and the presence of pathologies in the stomatognathic and acoustic systems. The present descriptive study's restrictions include the absence of clinical corroborating information using adequate equipment for measuring morphological findings which could link this basic scientific research with future evidence-based studies.

CONCLUSION

Bearing this study's limitations in mind, this article found that:

There was an anatomical and functional relationship between human TMJ and the middle ear; interdisciplinary odontology and otolaryngology management is necessary for diagnosing difficult secondary otic symptoms; and future research is necessary for confirming these findings by using well-designed clinical studies.

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RAMÍREZ, L. M.; BALLESTEROS, A. L. E. & SANDOVAL, O. G. P. Estudio anatómico directo de la morfología y funcionalidad de los ligamentos disco-maleolar y maleolar anterior. *Int. J. Morphol.*, 27(2):367-379, 2009.

RESUMEN: Los ligamentos disco-maleolar y maleolar anterior son comunes en el oído medio, la articulación temporomandibular y la mandíbula, todos ellos comparten un origen embriológico común. Los aspectos morfométricos y funcionales de estos ligamentos fueron estudiados en 23 huesos temporales. Diseño experimental: el techo del epítimpano y el techo de la articulación temporomandibular fue elevada mediante micro-disección de la fosa craneal media, exponiendo ambos ligamentos disco-maleolar y maleolar anterior y su asociación con el maleus, el disco de la articulación temporomandibular y llingula mandibular. Principales observaciones: Ambos ligamentos comienzan en el maleus y toman una ruta anterior y divergente hacia la articulación temporomandibular y llingula, pasando a través del canal de Huguier. Las longitudes medias del ligamento disco-maleolar y maleolar anterior fueron 6,88 mm (DS 0,81) y 4,2mm (DS 1,17), respectivamente, no fueron reveladas diferencias estadísticamente significativas entre las partes. La tracción del disco de la articulación temporomandibular fue aplicada para verificar la movilidad del maleus; el movimiento del maleus fue observado cuando se aplicó tracción del ligamento disco-maleolar en el 30,5% de las muestras. Se observó correlación entre el movimiento del maleus y la longitud disco-maleolar ($R^2 = -0,499$, $p < 0,05$). Ambos ligamentos comunes al sistema estomatognático y el oído medio estaban presentes en todos los especímenes. Conclusiones: Existe una relación anatómica y funcional entre la ATM humana y el oído medio.

PALABRAS CLAVE: Cadena oscicular; Articulación temporomandibular; Síntomas óticos; Ligamento disco-maleolar; Ligamento maleolar anterior.

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