Acta Otorrinolaringol Esp. 2010;**61(1)**:26-33

Acta Otorrinolaringológica Española

www.elsevier.es/otorrino

ORIGINAL ARTICLE

Tensor veli palatini and tensor tympani muscles: Anatomical, functional and symptomatic links

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Received July 13, 2009; accepted August 10, 2009

KEYWORDS
Tensor tympani;
Tensor veli palatini;
Malleus;
Auditory symptoms;
Temporomandibular Disorders

Abstract
Introduction and objectives: Temporomandibular disorders are associated with symptoms such as tinnitus, vertigo, sensation of hearing loss, ear fullness and otalgia. The connection and dysfunction of the tensor tympani and tensor veli palatini muscles seem to be associated with the aforementioned symptoms. We seek to demonstrate and explain this connection through the morphometry of these structures.
Methods: We studied 22 paired blocks and 1 left side of human temporal bone. Digital measurements were made of the tensor tympani muscles and stapes.
Results: The average length of the stapedial muscle was 5.8 mm (SD 0.61), and that of the tensor tympani was 19.69 mm (SD 1.07). Anatomical connections were found between the tensor veli palatini muscles through a common tendon in all the samples.
Conclusions: There is a need for interdisciplinary management between physicians and specialised dentists in cases of craniofacial pain.

PALABRAS CLAVE
Tensor del martillo;
Tensor del velo del paladar;
Martillo;
Síntomas óticos;
Desórdenes temporomandibulares

Tensores del velo del paladar y del martillo: vínculos anatómicos, funcionales y sintomáticos

Resumen
Introducción y objetivos: Los desórdenes temporomandibulares están asociados con síntomas como tinnitus, vértigo, sensación de pérdida auditiva, plenitud ótica y otalgia. La conexión y disfunción de los músculos tensor del martillo (TM) y tensor del velo del paladar (TVP) parece

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estar asociada a esta sintomatología referida. Se busca demostrar y explicar esta conexión a través de la morfometría de las estructuras.
Métodos: Se estudiaron 22 bloques pareados y 1 izquierdo de hueso temporal humanos. Se realizaron medidas digitales correspondientes al TM y el musculo del estribo.
Resultados: La longitud promedio del musculo del estribo fue de 5,8 mm (DE: 0,61) y la del TM fue de 19,69mm (DE: 1,07). En la totalidad de las muestras se halló conexión anatómica de los músculos TVP y TM a través de un tendón común.
Conclusiones: Se matiza la necesidad de un manejo interdisciplinario entre el médico y el odontólogo especialista en dolor craneofacial.

Introduction

Worldwide, the incidence-prevalence of auditory symptoms caused by temporomandibular disorders (TMD) is high.[1,2] TMD are a subclassification of musculoskeletal disorders and include a wide range of craniofacial and craniocervical conditions with multifactorial aetiology, both in adults and in children.[3] The prevalence of TMD is two to nine times higher in women than in men and their causes can be understood in macrotrauma and microtrauma (bruxism) of the stomatognathic system.[1] Bruxism plays an important role in TMD and craniofacial symptoms, although some researchers believe this association is as yet inconclusive[4].

The complex neuromuscular interaction between the muscles of mastication and the ear through the tensor tympani (TT) muscle was observed by Klockhoff in 1961[5] and was called "otognathic syndrome" by Myrhaug in 1964[6] and subsequently "otomandibular syndrome" by Bernstein in 1969[7] and by Arlen in 1977[8]. Patients with otomandibular syndrome present one or more auditory symptoms, without pathology located in the ear, nose or throat, but with one or more mastication muscles in a state of constant spasm.

Functional and inflammatory disorders of the temporomandibular joint (TMJ) and mastication muscles are highly associated with otologic symptoms such as tinnitus, dizziness, sensation of hearing loss, aural fullness and otalgia.[9,10]

For almost a century, some auditory symptoms have also been attributed a stomatognathic aetiology. Monson and Wright related the position of the mandible and the TMJ with hearing loss in adult and child population in 1920. In 1933, Goodfriend associated otologic symptoms with the TMJ.[11] Finally, in 1934, Costen[12] associated auditory symptoms with joint disorders (Costen's syndrome), and was the first to describe these symptoms in partial or total edentulous patients.[13] Kuttila and Kuttila[14,15] have found that it is possible to diagnose a clear pathology of the ear in less than 50% of patients with otalgia, providing the physician with additional contingency for a more extensive inspection that includes the stomatognathic area.

Ogutcen-Toller and Juniper[16] noticed that the structures carrying sound in the middle ear may be affected by reflex contraction of the TT muscle during a TMD. Schames et al.[17] and Myrhaug[6] state that dysfunction of the TT muscle and tensor veli palatini (TVP) play an important role in the relationship between TMD and auditory symptoms, in addition to calling them accessory muscles of mastication[17].

TT and TVP muscles have been proposed as part of the aetiology of auditory dysfunction, although controversy persists in the medical literature (relative to their anatomy, embryology and clinical symptoms) that there is a relationship between a viable connection between the stomatognathic system and the middle ear. This is essential if we understand that relationships shared between the middle ear and the masticatory system are expressed from various perspectives that affect embryology and morphophysiology (ligaments, vascularization, bones, nerves and muscles).[18]

There is an evident phylogenetic connection with respect to the innervation, irrigation and formation of the structures of the joint, throat and ear, including the Eustachian tube.[17,19,20] It is recognized that, in humans, the development of the TMJ and structures such as the pharynx, the Eustachian tube and the tympanic cavity from Meckel's cartilage is complex; it is still a controversial issue.

In this regard, TT and TVP are considered muscles of mastication since, although they are muscles in the middle ear, they are active during chewing and velopharyngeal movements inherent in the act of chewing and swallowing.[6] With this in mind, there is an established neuromuscular association between the known masticatory muscles (temporalis, masseter, lateral and medial pterygoid, mylohyoid, anterior digastric), a middle ear muscle (TT) and tubal muscles (TVP) based on the common innervation of the motor branch of the trigeminal mandibular (V3). This association, in this sense, makes them mastication muscles.[21-24]

These muscles are connected anatomically and functionally, which can have major consequences during TMD or during phases of bruxism that can change the position of the malleus, the chain of ossicles and the tympanic membrane generating the referred auditory symptoms. Thus, it becomes undeniable that the embryological, physiological and anatomical vicinity of the TMJ and the middle ear make these structures "neighbours", although they are functionally designed for different tasks.

The goal of this research was to pinpoint the morphological link in Colombian mestizos (such a link having already been shown anatomically and histologically in other ethnic groups) for TT and TVP muscles. Another aim was to show the morphometric characterisation of the TT and stapes muscles.

Methods

Twenty-three temporal blocks without injury (7cm laterally) were extracted from the donor bodies of 11 men and 1 woman of mestizo race, which were unclaimed at the Institute of Legal Medicine in Bucaramanga, Colombia. All adult specimens, twenty-two were paired and one from only the left side. The samples were frozen and were then immersed in 0.9% saline solution with thiomersal 1:10000 for a week (to maintain the soft tissue) until the time of their dissection. No formaldehyde was used, to avoid the fixation of tissues that makes the approach more difficult.

The access path for these dissections was the anterior, through the petrotympanic fissure. The approach of this temporal block was made with 15x magnification, manual and micromotor instruments and more round drills of different sizes. The approach sought to separate each block through the petrotympanic fissure to enable access to the TT and TVP muscles in relation to the Eustachian tube (Fig. 1). The records that were to be measured "in situ" were taken first so as to maintain the spatial disposition and leave the morphology unchanged (Fig. 2). Initially, the anatomical connection between the TT and TVP muscles was sought. Next, the length of the TT muscle, including its tendon, was measured (Fig. 3).

The measurement of the TVP muscle was ruled out due to the difficulty in determining its true origin because the temporal blocks did not include the soft palate due to aesthetic drawbacks, resulting from clear deformation of the donor bodies and their having to be rebuilt. The TVP-TT musculo-tendinous complex was extracted from the temporal block with and without the Eustachian tube, and the measurements taken "in situ" were ratified externally to the block (Figs. 4 and 5).

After these records were made, the malleus and the incus were removed from the ossicular chain, leaving the stapes, to dissect the stapedial muscle, and guided by the facial nerve canal (Fallopian canal) in its intrapetrous length. Finally, the "in situ" length and the dissected stapedial muscle including its tendon were measured to seek comparisons with the TT muscle (Fig. 6).

The TT and the stapedial muscles were dissected and measured "in situ" in their fibrous and tendinous portions, respectively. The TT muscle skeletal fibres were measured from the most caudal and ventral location of its semicanal bone. The most rostral and dorsal portion of the tendon and some shared but undefined fibres between the TT and TVP muscles were used as additional anatomic repair, up to the most rostrodorsal portion of the semicanal and before the cochleariform process. The tendinous portion of the TT was taken from the cochleariform process to its insertion into the neck of the malleus. To record the portion of skeletal muscle fibres of the malleus, the measurement was taken "in situ" from the most dorsolateral origin of the muscle to the pyramidal process, and the tendon from this structure to its insertion into the neck of the stapes.

Images were recorded step by step with a digital camera to study the structures in different positions to cover several planes of the system. Each measurement was entered into a data collection form. Parametric tests were also performed. The research was approved by the Ethics Committee of the Industrial University of Santander.

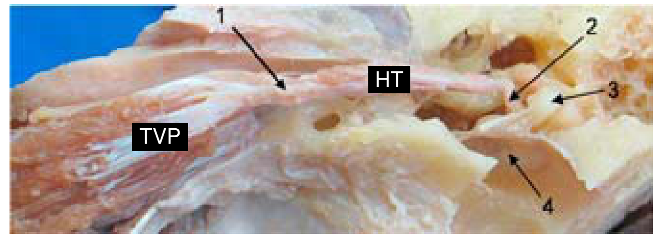

Figure 1 Anterior view of the dissected petrotympanic fissure, exposing the Eustachian tube and the intra- and extra-tympanic muscles. 1. Joint tendon between the tensor tympani (TT) and the tensor veli palatini. 2. TT tendon reaching the malleus (3). 3. Malleus head. 4. Tympanic membrane.

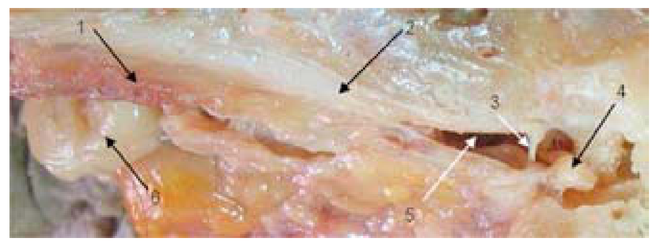

Figure 2 Anterior view of the dissected petrotympanic fissure, exposing the Eustachian tube and the intra- and extra-tympanic muscles. 1. TVP. 2. Tensor tympani (TT). 3. TT tendon. 4. Malleus head. 5. Tympanic cavity. 6. Ostman adipose package.

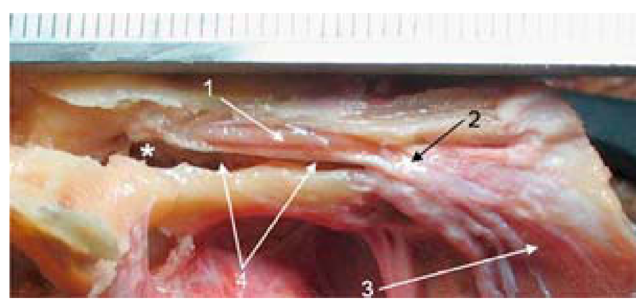

Figure 3 Anterior view of the dissected petrotympanic fissure, exposing the Eustachian tube and the intra- and extra-tympanic muscles. 1. Tensor tympani (TT). 2. Tendon and fibrous area that connects the TT and tensor veli palatini (TVP) muscles. 3. TVP. 4. Bony portion of the Eustachian tube. *Exposed tympanic cavity.

Results

A tendon and fibrous union between the TT and TVP muscles was found in all samples. This finding was paired in the 22 blocks that corresponded to the left and right temporal bones from the same donor. The average length of skeletal fibres from the TT was 17.13 mm (SD: 0.76) and that from the TT tendon was 2.56 mm (SD: 0.31). The average length of skeletal muscle fibres from the stapes was 4.52 mm (SD: 0.41) and that from the tendon was 1.27 mm (SD: 0.2). The average total length (fibres and tendon) of the TT muscle was 19.69 mm (SD: 1.07), and that of the stapedial muscle was 5.8 mm (SD: 0.61) (Table 1).

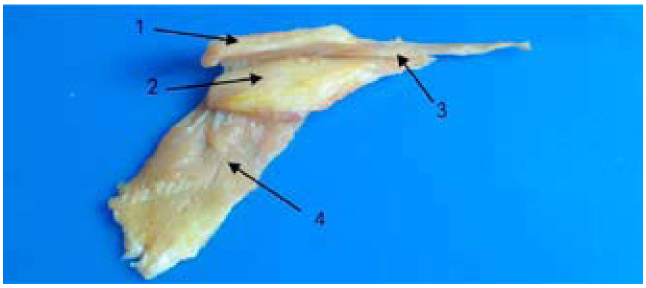

Figure 4 Medial view of the cartilaginous and mucosal section of the dissected Eustachian tube extracted from the temporal block with the intra- and extra-tympanic muscles attached to it. 1. Open medial wall of the Eustachian tube. 2. Medial wall of the Eustachian tube receiving the insertion of the tensor veli palatini (TVP) muscle. 3. Tensor tympani. 4. TVP.

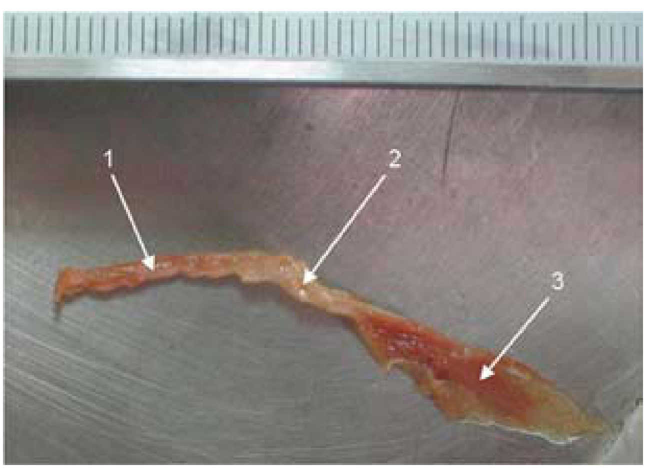

Figure 5 Intra and extra-tympanic muscles withdrawn from the temporal block. 1. Tensor tympani (TT). 2. Tendinous and fibrous union of the TT and tensor veli palatini (TVP). 3. TVP.

Discussion

Under normal conditions, the normal function of the Eustachian tube is to balance the pressure of the middle ear with that of the environment. The TVP muscle dilates the Eustachian tube and communicates with the nasopharynx. This opening of the tuba by the TVP is assisted by the elevator of the veli palatini during velopharyngeal movements such as swallowing and the inhalation phase of breathing.[25-28] Furthermore, the reflex contraction of the stapedial and TT muscles takes place with loud noises and immediately before speaking.[29] This is why Kamerer[30] says that the stapedial muscle also improves external vocalization by reducing the autogenous sound masking effect, although Gray[31] states that the TT muscle also responds to external stimuli activated by vocalization, among others, such as chewing, swallowing and facial muscle movement.

Anatomically, the TT muscle is a long, thin muscle located in a bone semicanal that accompanies the bony section of the Eustachian tube from above and posteriorly. This muscle originates in the cartilaginous portion of the Eustachian tube, its own semicanal and the adjacent region of the major wing of the sphenoid. It extends laterally and dorsally to form a tendon oriented perpendicularly to its fibres in the cochleariform process or spoon edge and is inserted into the neck of the malleus. The stapes muscle is bipennate and is located in a conical cavity almost parallel to the facial nerve canal and the posterior wall of the tympanic cavity. Its tendon emerges through an orifice in the pyramidal apophysis and also extends its fibres perpendicularly towards the stapes.[32]

Rood and Doyle[33] found (in adults and foetuses) a more detailed anatomy of the TVP muscle consisting of a medial portion or "tuba dilator", described by Gray,[32] an outer portion composed of the TVP muscle and intratympanic one composed of the TT muscle that intermingled its fibres

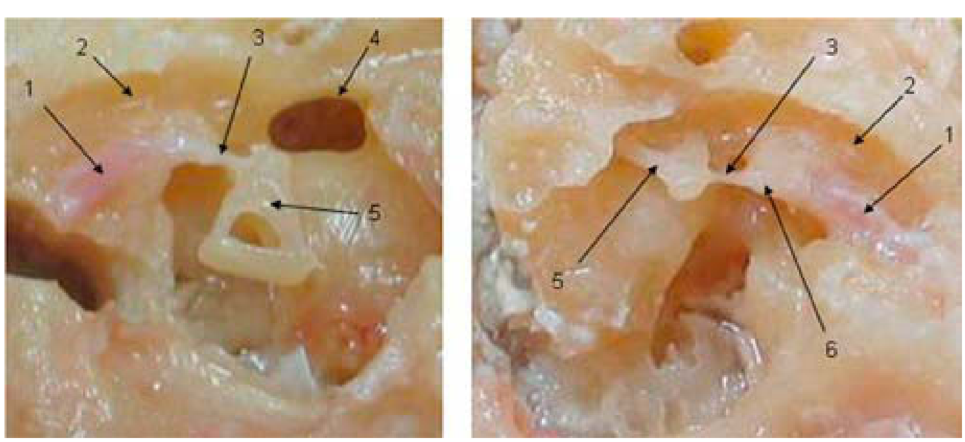

Figure 6 Musculoskeletal complex of the stapedial-stapes. 1. Muscle of the stapes (stapedial). 2. Facial nerve canal (with the facial nerve removed). 3. Tendon of the stapedial. 4. Oval window. 5. Stapes. 6. Pyramidal process.

Table 1 Length in mm of the tensor tympani and stapedius muscles (muscle fibre, tendon and total measurements). Results from the presence of the union between tensor tympani and tensor veli palatini muscles

Sample	Gender	Side	TT-TVP Union	TT Tend. Length	TT Muscle Length	TT Length - Total	STA Muscle Length	STA Tend. Length	STA Length - Total
1	M	L	S	2.52	16	18.52	4	1.5	5.5
2	M	L	S	2.56	17	19.56	4.5	1.3	5.8
3	M	R	S	3.2	17	20.2	4	1.4	5.4
4	M	L	S	2.86	18	20.86	4.5	1.1	5.6
5	M	R	S	2.64	16	18.64	4	1	5
6	F	R	S	2.16	18	20.16	4	1.5	5.5
7	F	L	S	2.38	17	19.38	4.5	1.3	5.8
8	M	R	S	2.46	18	20.46	4.5	1.5	6
9	M	L	S	2.9	16	18.9	4.5	1.1	5.6
10	M	L	S	2.52	17	19.52	5	1.3	6.3
11	M	R	S	2.3	18	20.3	5	1	6
12	M	L	S	2.24	17	19.24	5	1.4	6.4
13	M	R	S	2.18	17	19.18	5	1.3	6.3
14	M	R	S	2.46	18	20.46	4.5	1.5	6
15	M	L	S	2.92	16	18.92	4.5	1.2	5.7
16	M	L	S	2.56	17	19.56	5	1	6
17	M	R	S	2.3	18	20.3	5	1	6
18	M	L	S	2.2	17	19.2	5	1.5	6.5
19	M	R	S	2.18	18	20.18	5	1.5	6.5
20	M	R	S	3.2	17	20.2	4	1.2	5.2
21	M	L	S	2.84	18	20.84	4.5	1.2	5.7
22	M	L	S	2.64	16	18.64	4	1.5	5.5
23	M	R	S	2.64	17	19.64	4	1	5
Average				2.56	17.13	19.69	4.52	1.27	5.80
SD				0.31	0.76	1.07	0.41	0.20	0.61

R: right; L: left; F: Female; M: Male; SD: standard deviation; TT: tensor tympani; TVP: tensor veli palatini; TT-TVP Union: joining of tensor tympani and tensor veli palatini muscles; TT Tend. Length: Length of the tendon of the TT muscle; TT Muscle Length: Length of the TT muscle fibres; TT Length - Total: total length (tendon and fibres of the TT muscle); STA Tend. Length: Length of the tendon of the stapedial muscle; STA Muscle Length: Length of the stapedial muscle fibres; STA Length- Total: total length (tendon and fibres of the stapedial muscle).

with the outer zone of the TVP muscle.[34,35] The lateral area of the TVP originates on the spine of the sphenoid bone, the scaphoid fossa, the TT muscle and the entire lateral bone rim around the sphenoid sulcus. The medial of this muscle arises from the posterior middle third of the membranous wall of the Eustachian tube. These muscles descend and converge on the pterygoid hamulus forming a strong tendon that curves around this process and inserts horizontally into the soft palate as the palatine aponeurosis.

Typically, patterns of movement such as yawning, laughing, swallowing and coughing involve pharyngeal and laryngeal muscles that activate the TT muscle. In 1978, Kamerer[30] expressed the need for a unified theory for these muscles that share a close anatomical relationship; he proved it electromyographically when the TT and TVP muscles worked simultaneously during swallowing and assisting in ventilation of the Eustachian tube, in a manner similar to an air pump. The TT muscle, during its reciprocal contraction with the TVP muscle, thus produces an internal deflection of the tympanic membrane, which appears to break the seal of the mucous membranes of the isthmus of the Eustachian tube. This action helps to expel air and ventilate the middle ear.[36] In 1987, Malkin[37] presented a central functional interaction for both muscles, which consists of the TT muscle serving as a baro-receptor trigger by playing a proprioceptor role from its muscle length, which can be modified by hypotoma during low pressures of the tympanic cavity (gas exchange) and which retracts the tympanic membrane medially and, in turn, retracts the malleus due to the higher external ambient pressure. This malleolar movement makes the TT hypotonic and triggers a reflex mechanism from its muscle spindles to the trigeminal motor nucleus, initiating the contraction of this muscle and the TVP; the contraction opens the Eustachian tube and aerates the tympanic cavity. These normal physiological mechanisms may be hindered by TT muscle hypertonia during TMD, which would be expressed as a tubal dysfunction and accompanying symptoms: subjective hypo and hyperacusis, tinnitus, vertigo, otalgia, sensation of ear fullness and even otitis media.[38]

Barsoumian et al[39] corroborated the findings of Lupin in 1969 and subsequently those of Rood and Doyle, finding in adult cadavers that the fibres of the most external area of the TVP and the fibres of the TT were joined in the middle ear in a small tendinous portion, showing an anatomical connection in the functioning of these muscles. In our research, we found this connection between the two muscles in all the samples studied.

In 2002, Kiernan et al.[40] again found this functional link between the TVP and TT muscles through histological cuts in five human cadavers, which corroborates the findings of others. They claim that the reconfirmation of this finding represents an important step in the understanding of the functional unity between these two muscles in humans.

In this regard, the TT and TVP muscles act simultaneously and synergistically, being able to temporarily increase intratympanic pressure. TVP dysfunction in TMD can modify the medial position of the malleus and the tympanic membrane individually or in combination by anchoring the TT muscle. Similarly, the spatial arrangement of the ossicular chain can be modified by TT muscle tension due to its continuity with the TVP muscle. It is not compromising, therefore, to say that the TVP has an additional bony origin in the handle of the malleus that makes these two muscles an enhanced unit[41]. It must be recalled that the ossicular chain operates in a bio-mechanically efficient but fragile manner, as it is upheld delicately by structures such as the tympanic membrane, the ligaments and the TT and stapedial muscles, which sustain and modulate it to match the biomechanics of the sound energy.

More important than simple proximity and functional contact of two muscles (hypomochlion), the TVP and TT have been shown to be nearly the same muscle by continuity. Both muscles fulfil different functions separately but their dysfunction could alter the normal physiology of the Eustachian tube and middle ear bones. TMD produce tension and contraction of mastication muscles, including the TVP and TT muscles.

Interestingly, the role of the TT has been ignored by otolaryngologists and otologists. Some physiologists attach to it the function of stretching the tympanic membrane for improved reception of sound energy, but in medical circles it is considered as a muscle with practically no function in sound transmission. In contrast, the stapedial muscle is recognized as a powerful muscle in sound modulation and auditory protection and there is also an awareness of how the paralysis of this muscle generates evident audiometric and clinical effects. It is also known that the stapedial muscle improves external vocalization, reducing the autogenous sound masking effect (auditory protective and discriminative function); however, the participation of the TT muscle in this remains unresolved.

In our measurements comparing the length of the TT and stapedial muscles, the difference was a little more than three times greater between the length of the TT muscle and the stapedial muscle. This was without taking into account the thickness, which although it was not measured, was clearly greater in the TT. During the stapedial reflex and normality, there is a muscular movement of about 50 microns, which reduces sound transmission by approximately 50 dB bilaterally and improves perception by 50 dB. This forces us to reflect on the potential capacity of the TT in the medial mobilisation of the tympanic membrane in protection and tuning mechanisms; it must be remembered that it measures three times more in length than the stapedial muscle and is connected to the ossicular chain through the malleus and almost in opposition to the stapedial muscle, which in theory could generate movements three times greater (approximately 150 microns) when activated.[32]

Furthermore, we must consider how a muscle of these dimensions can be considered as an unproductive muscle when it is known that the joint mechanics of the middle ear work with deformities around one nanometre which explain the modulator power of the stapedial muscle.[42] It must also be kept in mind that TT motor innervation depends entirely on the activation of the trigeminal motor nucleus, the almost exclusively neurological centre of the stomatognathic system. Note that, in dysfunction, the rhythmic movement of the tympanic membrane, secondary to the paroxysmal contraction of the TT and stapedial muscles, is known to generate intratympanic myoclonus and to produce changes in the air and liquid impedance of the middle and inner ear, respectively.[43]

If the mastication muscles are hypertonic due to TMD, it is also very possible that the TVP and TT are too, given their common V3 motor innervation. Having a spastic TVP muscle would impede the normal opening and closing of the Eustachian tube by contraction and relaxation of this muscle (patulous tube or ear fullness sensation). This makes TMD important in the normal or altered function of these neighbouring structures, which apparently pertain to other medical disciplines.

The alteration of normal Eustachian tube function can cause tinnitus, vertigo, sensation of hearing loss of low tones, aural fullness and otitis media with effusion, especially in children, secondary to reflex contraction of the TT and TVP.[25-27,44,45] Marasa and Ham[46] argue that dysfunction of the Eustachian tube plays an important role in otitis media with effusion. Children, since they present short, horizontal auditory tubes with large lumens, are more prone to otitis media with effusion, especially in respiratory tract infections.[47] The presence of TMD in children therefore exacerbates these anatomical conditions inherent to immature vertical development of the sphenoid bone and cranial mass.

It is also worth mentioning that we found a TVP muscle of very modest dimensions in the two female samples from an elderly white woman. In connection with this finding, Suzuki et al.[48] showed an inverse correlation between age and TVP size and associated it with increased incidence of otitis media with effusion in the elderly population due to TVP dysfunction. Takasaki et al[49] explain that these changes are histological, generating calcification of the Eustachian tube and also muscle atrophy of the TVP muscle with advanced age.

Conclusions

Was observed in the entirety of the samples the union of the TVP and TT muscles, a finding which ratifies what had been previously reported anatomically and histologically and which constitutes an anatomical substrate in clinical events of otic symptoms secondary to TMD.

The combined importance of the stapedial, TT and TVP muscles in sound transmission, protection and discrimination has been evaluated from a physiological perspective.

It should be considered that the TM has an important location in time and space, which highlights its physiological hierarchy in the transmission and modulation of sound energy in normal conditions.

Although the multifactorial aetiology of some auditory symptoms cannot be observed in a simplistic or reductionist manner and under a single perspective (referring to TMD), we believe that it is imperative to understand the need for interdisciplinary management between physicians and odontologists who are specialized in craniofacial pain and who addresses this possibility; it is also vital to ensure a conservative view in the treatment of muscular tensions of these mastication and hearing muscles. A structure based on teamwork may be the best option for improving the functional state of the stomatognathic system and the concomitant auditory symptoms referred.

Conflict of interests

The authors declare no conflict of interests.

Acknowledgements

We express our gratitude to Dr. Carlos Conde Cotes for his valuable assistance in the first edition of this article. We thank the Institute of Legal Medicine for their valuable donation of samples.

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