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Review Article

Phylogenic Oto-stomatognathic Connection of the Mammalian Jaw: A Novel Hypothesis for Tensor Tympani Muscle and TMD-related Otologic Symptoms

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Abstract : Otologic complaints, including otalgia, tinnitus, vertigo, and hearing loss, are known to be related to temporomandibular disorders (TMDs). There have been several hypotheses regarding the clinical correlation between otologic complaints and TMDs, based on clinical phenomena with corresponding symptoms, the close neurological relationship between otic and masticatory structures, and anatomical features of the tympanic cavity and jaw joint. Function of the tensor tympani muscle seems to be crucial to understanding TMD-related otologic symptoms. The tensor tympani inserts into the handle of the malleus and it modulates sound transduction in situations of excessive noise. This muscle is innervated by the trigeminal nerve, like the masticatory muscles. Voluntary eardrum movement by pathological tensor tympani contraction results in various otologic symptoms. Thus, co-contraction of the tensor tympani with the masticatory muscle could be a possible cause of TMD-related otologic symptoms. The tensor tympani is rather unrelated to the acoustic reflex, in which the stapedius is strongly involved. The tensor tympani seem to be controlled by proprioceptive information from the trigeminal sensory nucleus. The peripheral innervation pattern of the tensor tympani and masticatory muscles is also supposed to be interconnected. The middle ear structure, including the malleus, incus, and tensor tympani, of mammals had been adapted for acoustic function and lacks the masticatory role seen in non-mammalian jawed vertebrates. The tensor tympani in non-mammals is one of the masticatory muscles and plays a role in the modulation of sound transduction and mastication. After the functional differentiation of the mammalian middle ear, the nervous connection of the tensor tympani with other masticatory apparatus still remains. Through this oto-stomatognathic vestige, the tensor tympani seems to contract unnecessarily in some pathological conditions of the TMD in which the masticatory muscles contract excessively. We hypothesized that the phylogenic relationship between the tensor tympani and masticatory apparatus is a significant and logical reason for TMD-related otologic complaints.

Keywords : Tensor tympani muscle, Masticatory muscles, Temporomandibular disorder, TMD-related otologic complains, Phylogency

The author(s) agree to abide by the good publication practice guideline for medical journals.
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Introduction

Otologic complaints, such as otalgia, tinnitus, vertigo, and hearing loss have been broadly reported in patients with temporomandibular disorders (TMDs) [1-3]. There have been some hypotheses to account for the physiological relationship between otologic complaints and TMDs, from the 1930s to recently [4-6]. One theory raised in the 1930s emphasized that some otologic complaints in TMDs occur due to compression on the auriculotemporal nerve or the chorda tympani and erosion of the tympanic plate, resulting from the posterior displacement of the condyle [4,5]. Today, the masticatory musculature is regarded as a significant factor in TMD-related otologic complaints, because patients suffering from TMD with myofascial pain have more otologic complaints than those with only internal derangement of the meniscus [1]. Auditory muscles (tensor tympani, tensor veli palatine, and stapedius) that function in modulating pressure in the middle ear cavity and sound transduction were also regarded as key candidates for the otologic symptoms with TMD, based on their involvement in voluntary eardrum movement [6,7].

Mastication and sound transduction both involve the malleus and incus in non-mammalian jawed vertebrates, and an anatomical connection between these two functional apparatuses can be observed in developing mammals [8-12]. Additionally, the masticatory and auditory muscles seem to be intimate in nervous distribution and function in mammals. The oto-stomatognathic relationship of the two musculature groups should be reviewed from a phylogenic point of view in seeking to understand the symptoms.

Literature Study

1. Anatomy of the tensor tympani and its clinical implications

The tensor tympani is mainly contained in the temporal and sphenoid bone and located superior to the body portion of the pharyngotympanic (Eustachian) tube [13]. The muscle originates from the cartilaginous portion of the tube, passes posterior within a bony canal, and ends in the tympanic cavity, inserting into the handle of the malleus.

The relationship between the tensor tympani and the acoustic reflex is unclear; the human acoustic reflex is mainly an action of the stapedius muscle [7]. On contrary the tensor tympani respond to strong sounds, mastication (chewing), and swallowing in EMG tests [14]. Normally, it acts in a neurological reflex to protect against trauma by excessively loud sound and collaborates with velo-pharyngeal muscles for balancing pressure of the tympanic cavity. Aberrant activity of the tensor tympani can cause otologic disorders, including otalgia, tinnitus, and hyperacusia or hypoacusia [6]. In particular, pathological movement of the tensor tympani is known to be associated with TMD disorders [1,2,7,15].

2. Phylogenic basis of the jaw joint in non-mammals and mammals

Recent developmental biology and classical paleology concur with the opinion that the malleus and incus within the mammalian tympanic cavity are homologous to the articulating part of the lower and upper jaws (quadrate and articular bone) of the jaw joint in non-mammalian jawed vertebrates (the articulo-quadrate joint) [12]. This joint remains in mammals as the incudomalleolar joint at the tympanic cavity, but lacking masticatory function. Mammals possess another novel jaw joint, the dentary-squamosal joint or temporomandibular joint, which was formed by the mandible (dentary bone) and a squamous part of the temporal bone (squamosal bone) instead. It has been believed that functional specialization of the malleus and incus to the acoustic apparatus, with loss of masticatory function, occurred during mammalian evolution [8,11]. Although the skeletal structure had been modified during the evolution, the configuration of the muscles concerned corresponds consistently with the bony component. For example, the tensor tympani inserts into the malleus in humans, and the homologous muscle inserts into the articular bone in non-mammalian jawed vertebrates. The innervation of the muscles is also invariable; e.g., the tensor tympani and medial pterygoid are innervated by the trigeminal nerve in mammals and reptiles.

Additionally, the peripheral nervous distribution of the masticatory muscles, tensor tympani, and temporomandibular joint is closely interconnected in humans. The tensor tympani is supplied by axon bundles, ramified from the nerve to the medial pterygoid after passing the otic ganglion without a synapse. Posterior branches of deep temporal nerve that innervate the temporalis usually arise from the masseteric nerve. The masseteric nerve provides the articular branch, the sensory nerve to the temporomandibular joint.

3. Neurological model: the tensor tympani is controlled mainly by sensory input projecting from the trigeminal sensory nucleus

The tensor tympani and tensor veli palatine seem to be referred to the trigeminal sensory nucleus that gleans somatic input from facial and masticatory muscles with the overlaying skin and the solitary nucleus that receives visceral input from the pharynx and soft palate.

Tensor tympani contraction occurs as a response to a jet of air into the eye and in forceful eyelid syndrome [15,16]. Nociception in the trigeminal sensory nucleus projects to the supratrigeminal region capping the trigeminal motor nucleus, and it may control the activity of the tensor tympani and tensor veli palatine with the masticatory muscles [17,18]. Contraction of the tensor tympani and tensor veli palatini are related to the pharyngeal and palatine sensory input projecting to the solitary nucleus (general visceral sensation) and the trigeminal sensory nucleus (general somatic sensation, proprioception) during swallowing and vocalization [19,20].

The tensor tympani may participate in a reflex with the trigeminal sensory and motor nucleus. That is, the trigeminal sensory nucleus seems to deliver proprioceptive information of the facial and masticatory muscles and temporomandibular joint to the tensor tympani. Unlike the stapedius muscle, which participates strongly in the acoustic reflex, the tensor tympani seems to be controlled by general sensations via the trigeminal sensory nucleus [7]. The lower pressure in the tympanic cavity can cause dimensional changes in the tensor tympani, and this barometric information of the muscle may be delivered via proprioceptive afferent signals [6,21]. Logically, the barometric information of the tympanic cavity can provide regulatory guidance to the tensor tympani, instead of the direct acoustic reflex.

4. Function of the tensor tympani in non-mammalian jawed vertebrates and mammals

In non-mammalian jawed vertebrates, the tensor tympani operates between the articular bone (malleus-homologous) belonging to the lower jaw and the cranium [22]. It acts with the masseter, pterygoids, and temporalis muscles during mastication for closing the jaw and it may modulate transduction of friction and a clicking noise. Here, dimensional changes in other masticatory muscles would be crucial regarding the auditory input. During the resting state, free of strong jaw movement, the tensor tympani would manipulate sound transduction, restricting excessive vibration of the tympanic membrane. The muscle would be controlled directly by barometric information or indirectly by acoustic information.

In mammals, the function of the tensor tympani in mastication is vague. Mammals have definite and distinct individual ossicles within the cranial base [8,11]. The malleus of mammals is completely situated within the tympanic cavity and the tensor tympani is also locate within the cranial base. The tensor tympani is no longer involved in actual mastication in mammals. It can be suggested that the soft palatine muscles, tensor tympani, and pharyngeal muscles would modulate the balance of pressure in the oral cavity, nasal cavity, and tympanic cavity. However, little is known about this. Except this assumed modulation for pressure balancing across the cavities, the role of the tensor tympani in the mastication may be very subtle or none.

Immoderate contraction of the tensor tympani with masticatory muscles regardless of sound volume triggers voluntary eardrum movement. Such voluntary eardrum movement might be a pathological condition, resulting in otalgia and tinnitus.

Hypothesis

We hypothesize that the mammalian vestige of the oto-masticatory connection plays a role in pathological contractions of the tensor tympani that result in otologic complications. The tensor tympani acts to coordinate mastication and sound transduction in the primary jaw (incudomalleolar joint) and shares the trigeminal sensory system and trigeminal motor regulation system with the masticatory muscles. In non-mammalian jawed vertebrates, the tensor tympani would contract during mastication and it restrains friction noise from jaw closing by fastening the ear ossicles and tympanic membrane. The regulation of sound transduction by the tensor tympani is supposed to be significantly concerned with proprioceptive sensation, whereas stapedial regulation participates strongly in auditory reflexes.

Mammals, including humans, still possess the nervous connection (trigeminal sensory input and trigeminal motor regulation) between the tensor tympani and masticatory system, although the middle ear structures and masticatory apparatus became functionally and anatomically differentiated in mammals. Aberrant contraction of the tensor tympani by stimulation via this nervous route will develop into a pathological condition of the masticatory muscles.

We do not exclude other possible hypothesized causes for otologic complaints with TMDs. However, our phylogenic hypothesis can shed light on the logical connection between the otic and stomatognathic systems in oto-TMD symptoms, especially myofascial symptoms.

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포유류 귀-씹기계통의 계통발생학적 연결: 고막긴장근과 턱관절장애 관련 증상에 대한 새로운 가설

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간추림 : 턱관절장애는 귀통증, 귀울림, 어지러움 및 청각 손실 등과 같은 귀의 이상증상과 관련이 있다. 씹기근육, 가운데귀공간 및 턱관절의 밀접한 해부학적 관련성을 바탕으로 턱관절장애-귀관련질환에 대한 다양한 가설이 제시되고 있다. 특히 고막긴장근 (tensor tympani muscle)은 턱관절장애 관련 귀질환 (TMD-related otologic complications)을 이해하는 데 중요한 근육이다. 삼차신경이 분포하는 고막긴장근은 망치뼈자루에 붙어 귓속뼈의 소리전달조절 기능을 한다. 병적인 고막긴장근의 자발적 수축 (voluntary eardrum movement)은 다양한 귀질환의 원인으로 여겨지고 있다. 따라서 고막긴장근이 씹기근육과 공동수축을 하는 것은 턱관절장애 관련 귀질환을 이해하는 데 중요한 현상이다. 본 연구는 기존의 문헌을 바탕으로 귀와 씹기계통의 계통발생학적 연관성을 고찰하고, 고막긴장근과 씹기구조의 계통발생학적 연관성이 턱관절장애 관련 귀질환에 중요한 역할을 할 것이라는 가설을 제시하고자 한다.

등자근 (stapedius muscle)이 청각반사 (acoustic reflex)와 관련되어 소리전달조절 역할을 하는 것과는 달리, 고막긴장근은 청각반사와는 별개로 수축하는 것으로 알려져 있다. 이는 고막긴장근이 삼차신경감각핵 (trigeminal sensory nucleus)에서 들어온 고유감각에 의해 조절되기 때문으로 여겨진다. 계통해부학적으로 포유류의 망치뼈, 모루뼈 및 등자뼈를 포함한 가운데귀 구조는 포유류가 아닌 턱뼈 척추동물 (non-mammlian jawed vertebrate)과는 달리 씹기에는 관여하지 않는다. 포유류가 아닌 턱뼈 척추동물에서 포유류로의 진화과정에서 이러한 기능적 분리가 이루어졌으나, 포유류에서 고막긴장근과 씹기근육의 신경연결은 일부 남아 있다. 따라서 이러한 계통발생학적 흔적은 귀-씹기계통의 병적 연관성과 관련이 있다고 볼 수 있다. 본 연구는 이러한 계통발생학적 배경을 바탕으로 씹기근육의 비정상적 수축 시 고막긴장근이 귀-씹기계통 계통발생학적 흔적을 통해 과도한 공동수축을 일으켜 다양한 귀의 이상질환이 나타날 수 있다는 가설을 제시한다.

찾아보기 낱말: 고막긴장근, 씹기근육, 턱관절장애, 턱관절장애 관련 귀질환, 계통발생학

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