



# A Study of Muscular Objective Tinnitus Caused by the Eustachian Tube

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## Abstract

Objective tinnitus that originates in muscles can be heard by others as well as by the patient. Although there have been many reports of objective tinnitus, each report has been limited to a small number of cases that have varied from one another, with some being accompanied by such findings as voluntary and/or involuntary movement of the soft palate and eardrum, as well by blinking, and the etiology has remained unclear. We analyzed 16 cases of objective tinnitus synchronous with the opening and closing of the eustachian tube. The voluntary and involuntary movements of the soft palate and eardrum were consistent with the findings in previous reports. The 16 cases included 11 cases of patulous eustachian tube and in 10 of them the patient voluntarily induced tinnitus to prevent the symptoms of a patulous eustachian tube. These patients created an opportunity to close the patulous eustachian tube by repeating opening and closing. The sound of the opening and closing of the eustachian tube became an objective tinnitus. The tinnitus was heard only voluntarily in seven cases and voluntarily and involuntarily in nine cases; one of patients was tentatively diagnosed with middle ear myoclonus and another was diagnosed with pharyngolaryngeal myoclonus. Patulous eustachian tube was first described as one of the causes of objective tinnitus. We speculated that the soft palate and eardrum movements were initially voluntary, but that some of them became involuntarily. If this involuntary movement is seen at the time of examination, it may be diagnosed as myoclonus. Psychological factors may be involved in the transitions from voluntary to involuntary, but further research will be necessary to assess this possibility.

## Keywords

- ▶ patulous eustachian tube
- ▶ middle ear myoclonus
- ▶ palatal myoclonus

## Introduction

Objective tinnitus is defined as ringing in the ears that can be heard by both the individual and another person, and it is classified into muscular, vascular, and other types.<sup>1</sup> Objective tinnitus was first reported in Japan by Kubo in 1903,<sup>2</sup>

after which several cases have been reported. Besides muscular objective tinnitus, which develops centrally, objective tinnitus has been associated with soft palate myoclonus,<sup>3–6</sup> middle ear myoclonus presenting buckling of the eardrum,<sup>4,7</sup> and pharyngolaryngeal myoclonus.<sup>8</sup> Patients who voluntarily perform soft palate vibrations,<sup>9,10</sup> patients who voluntarily

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buckle the eardrum,<sup>11</sup> patients without soft palatal movements or eardrum buckling,<sup>1,12</sup> and patients with no history of facial palsy who develop objective tinnitus due to blinking<sup>13</sup> have been reported. However, these reports were all case reports consisting of a few patients, and the underlying cause has not been elucidated. The most interesting unresolved issues include determining whether the difference is due to a different pathology or a phenotype that changed from a single pathology. In this study, we examined patients in whom the sound was thought to arise from the eustachian tube, and we report signs that can be used to elucidate the onset mechanism.

### Patients and Methods

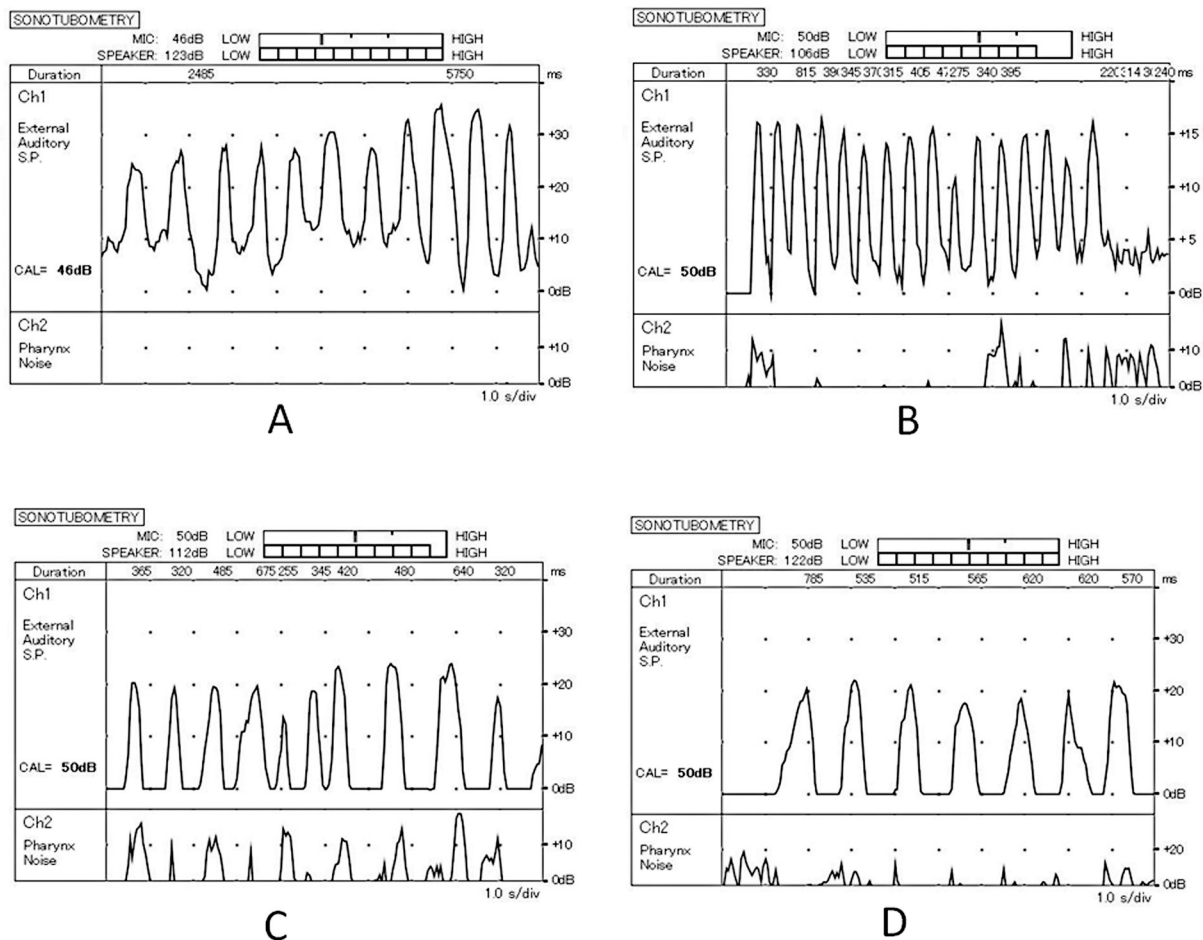
We included 16 patients who were examined at our hospital and presented with objective tinnitus, together with opening and closing of the eustachian tube that was consistent with tinnitus on sonotubometry (the measurement results of four typical cases is presented in ►Fig. 1). The sample included 4 men and 12 women aged 10 to 69 years, including 3 patients in their teens, 4 in their 20s, 3 in their 30s, 3 in their 40s, 1 in their 50s, and 2 in their 60s. Several examiners confirmed the diagnosis of objective tinnitus using an otoscope. JK-05A (D

type; Rion Co., Ltd.) was used for the eustachian tube function test. In patients with patulous eustachian tubes, the diagnosis was determined based on the Diagnostic Criteria of Patulous Eustachian Tubes proposed in 2016.<sup>14,15</sup>

### Results

►Table 1 summarizes the findings and progress of each patient. The chief complaints were ear fullness, autophony, hearing respiratory sounds, earache, etc., in 12 patients and tinnitus (expressed as burbling, crackling, and clicking sounds) in 4 patients. The chief complaint was unilateral in 14 patients and bilateral in 2. However, the onset of tinnitus was unilateral in nine patients and bilateral in seven. The side of the chief complaint and tinnitus were inconsistent in two patients.

Concurrent ear diseases detected in the 16 patients included patulous eustachian tube in 10 patients and sniff-type patulous eustachian tube in 1 patient. Patient 14, who had pharyngolaryngeal myoclonus, had test results that corresponded to those of patients with a definite patulous eustachian tube, and 12 of the 16 patients had test results that corresponded to those of patients with a definite patulous eustachian tube. One patient presented with pars



**Fig. 1** Sonotubometry findings of 4 typical patients among the 16 patients. Measurements were taken while tinnitus was induced. Each wave form represents opening and closing of the eustachian tube. (A) Patient 2; (B) patient 3; (C) patient 4; and (D) patient 13.

**Table 1** The progress and findings of each patient

Patient	Age (y)	Gender	Chief complaint	Side	Ear complications	Test	Progress and tinnitus trigger	Eardrum	Hearing disturbance	Acoustic method	Soft palate and voluntary movement	Voluntary/involuntary	Treatment
1	23	F	Bilateral 1, 2, 3, 5	Bilateral	Bilateral patulous eustachian tubes	○	Middle ear myoclonus 4 y prior, and symptoms avoided by inducing tinnitus	Normal	Mild	12	Small, eardrum, myoclonus	Both	Kobayashi plug, ineffective
2	24	F	Left 1, 2, 3	Left	Left patulous eustachian tube	○	Ear fullness noticed for several months, and symptoms avoided by inducing tinnitus	Normal	Normal	12	Large	Both	Follow-up observation, unchanged
3	27	M	Left 1	Left	Left patulous eustachian tube	○	1 mo of onset, and symptoms avoided by inducing tinnitus	Normal	Normal	16	Large	Both	Pharmacotherapy, effective
4	18	M	Left 1, 2	Left	Left patulous eustachian tube	○	3 mo of onset, and symptoms avoided by inducing tinnitus	Normal	Normal	12	Large	Both	Kobayashi plug, effective
5	40	F	Right 1, 2, 3	Right	Right patulous eustachian tube	○	6 mo of onset, and symptoms avoided by inducing tinnitus	Normal	Normal	10	Large, pursing of the lips	Voluntary	
6	20	M	Right 1, 2, 3	Left	Right patulous eustachian tube	○	6 y of onset, presently, symptoms avoided by inducing tinnitus, and tinnitus in contralateral side	Normal	Normal	10	Small, eardrum	Both	Contralateral Kobayashi plug, effective
7	69	M	Left 2	Bilateral	Left patulous eustachian tube	○	Symptoms avoided by inducing tinnitus since adolescence	Normal	Normal	10	Small	Voluntary	Follow-up observation, unchanged
8	46	F	Left 1, 2	Right	Left patulous eustachian tube	○	1 y of onset, and symptoms avoided by inducing tinnitus	Normal	Moderate	6	Large, opening and closing of the mouth	Voluntary	Pharmacotherapy, ineffective
9	52	F	Right 4	Right	Right patulous eustachian tube	○	1 mo of onset, and symptoms avoided by inducing tinnitus	Normal	Moderate	8	Large	Both	Treatment at exacerbation, effective
10	38	F	Right 1	Right	Right patulous eustachian tube	○	Opening and closing, and closure irregular since childhood, and symptoms avoided by inducing tinnitus	Normal	Normal	10	Small	Voluntary	Follow-up observation, unchanged
11	35	F	Right 2	Bilateral	Right patulous eustachian tube (sniffing)	○	Eustachian tube closed by sniffing and opened	Concave	Normal	14	Large	Both	Instructed to stop sniffing, effective

(Continued)

**Table 1** (Continued)

Patient	Age (y)	Gender	Chief complaint	Side	Ear complications	Test	Progress and tinnitus trigger	Eardrum	Hearing disturbance	Acoustic method	Soft palate and voluntary movement	Voluntary/involuntary	Treatment
12	47	F	Right 2	Bilateral	Right eustachian tube dysfunction	○	Eustachian tube closed by sniffing and opened by inducing tinnitus since adolescence	Cholesteatoma	Mild	12	Large eardrum	Voluntary	Instructed to stop sniffing, effective
13	34	F	Left 1, 2	Bilateral	Left eustachian tube dysfunction	○	1 y of onset, and ear fullness avoided by inducing tinnitus	Normal	Normal	13	Small, blinking, facial movements	Voluntary	Tympanic ventilation tube, effective
14	63	F	Left 4, 5	Left	Left sensorineural hearing loss	○	2 y of onset, discomfort avoided, pharyngolaryngeal myoclonus	Normal	Mild	10	Small larynx, myoclonus	Both	Follow-up observation, unchanged
15	10	F	Bilateral 4	Bilateral	Nothing	○	3 mo of onset, and trigger unknown	Normal	Normal	8	Large, blinking	Voluntary	Follow-up observation, unchanged
16	17	F	Right 4	Bilateral	Nothing	○	5 days of onset, and trigger unknown	Normal	Normal	10	Large	Both	Follow-up observation, unchanged

Note: Chief complaint: 1, autophony; 2, ear fullness; 3, one's respiratory sound listening; 4, tinnitus; and 5, earache.  
 Certainty: ○ = patient with test findings of a patient with definite patulous eustachian tube according to the patulous eustachian tube diagnostic criteria proposed in 2016.  
 Voluntary/involuntary: voluntary = voluntary tinnitus; both = with tinnitus even when involuntary.  
 Acoustic method: number of times the eustachian tube was opened and closed in a 10-second period.  
 Soft palate and other movements: large = large up and down movements of the soft palate; small = small slight movements of the hard palate.

**Table 2** Concurrent ear disease

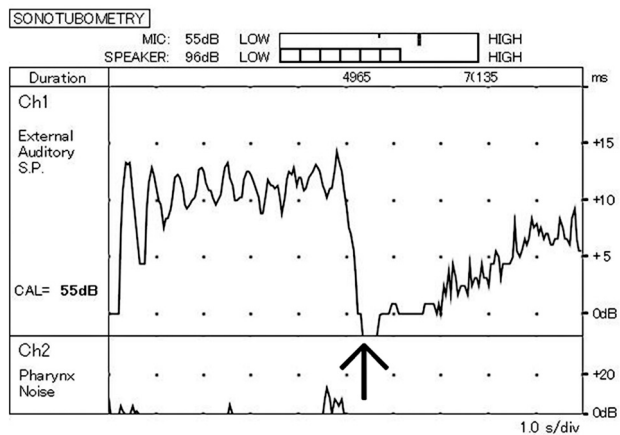
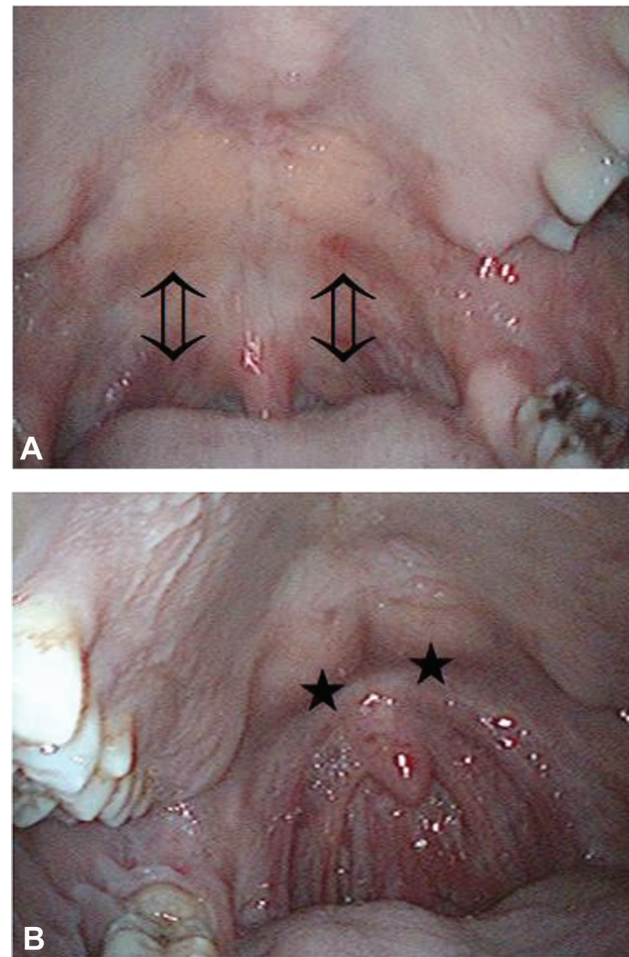
Patulous eustachian tube	11 patients
Acute sensorineural hearing loss (pharyngolaryngeal myoclonus)	1 patient
(The 12 cases above are actual patients with patulous eustachian tubes on testing)	
Eustachian tube dysfunction	1 patient
Cholesteatoma (sniffing habit)	1 patient
Not observed	2 patients

**Table 3** Opportunity to induce tinnitus in patients with patulous eustachian tube

Patulous eustachian tube (Tinnitus was induced to avoid symptoms)	10 patients
Patulous eustachian tube (sniffing-type) (The patient had the habit of closing the eustachian tube by sniffing and opening it by inducing tinnitus)	1 patient

flaccida cholesteatoma with a sniffing habit without findings of a patulous eustachian tube, one patient presented with eustachian tube dysfunction causing negative pressure of the eardrum, and two patients presented with no specific ear disease (►Table 2).

Patient 11 had undergone regulation of eustachian tube opening and closing since childhood and visited the hospital because she could no longer close the eustachian tube adequately, and patient 12 had cholesteatoma with a sniffing habit; both these patients could close the eustachian tube by sniffing and open it by inducing tinnitus. Additionally, among the cases of patulous eustachian tube in patients 1 to 11, it was discovered that 10 patients, excluding the patient with the sniff-type patulous eustachian tube, induced tinnitus to avoid symptoms caused by a patulous eustachian tube (►Table 3). ►Fig. 2 shows the sonotubometry results in a patient who had closed the eustachian tube by inducing

**Fig. 2** Sonotubometry findings of patient 10 while inducing tinnitus. Eustachian tube closure to induce tinnitus intentionally several times is indicated by (†).**Fig. 3** (A, B) Finding of the soft palate when tinnitus is induced. The large up and down movements (‡) presented in image A were observed in nine patients, and small, slight movements of the hard palate in image B (★) were observed in seven patients.

tinnitus. Patient 13 experienced slight negative pressure on the eardrum (confirmed by tympanogram), and she avoided discomfort by inducing tinnitus. She stated that she was irritated by inadvertent tinnitus, and a tympanic membrane ventilation tube was successfully placed. Patient 14 was always conscious of discomfort caused by acute left-sided sensorineural hearing loss, which was neurotic, for which she consulted the Department of Psychiatry. Subsequently, tinnitus developed, and pharyngolaryngeal myoclonus was observed on some occasions. Based on sonotubometry findings, the chief complaints were tinnitus and earache; however, a patulous eustachian tube might have preceded these complaints. Patient 1 also had a history of regular rhythmic buckling of the eardrum and had been diagnosed with middle ear myoclonus; however, myoclonus was not observed during examination at our hospital. Furthermore, the two patients with myoclonus underwent head magnetic resonance imaging; however, there were no specific findings in either patient.

The eardrum findings revealed a concave eardrum in patient 11 and pars flaccida cholesteatoma in patient 12. There was no evidence of eardrum recession in the other patients. The auditory acuity was within the normal range in

**Table 4** Other movements associated with tinnitus

Buckling of the eardrum	3 patients
Blinking	1 patient
Blinking with facial movements	1 patient
Opening and closing the mouth	1 patient
Pursing the lips	1 patient
Pharyngolaryngeal movements	1 patient

**Table 5** Voluntary and involuntary tinnitus

Voluntary only	7 patients
With involuntary times	9 patients (temporary myoclonus in 2 patients)

11 patients, 2 patients had mild hearing loss, and 3 patients had moderate hearing loss. The number of times the eustachian tube opened and closed over a 10-second period using sonotubometry was approximately 6 to 16 times. Soft palatal movements included up and down movements in nine patients (►Fig. 3A) and slight, small movements in the hard palate in seven patients (►Fig. 3B). Three patients had eardrum buckling, including two with rhythmic buckling of the eardrum and one with buckling of the eardrum as middle ear myoclonus. We observed blinking as a tinnitus-induced movement in one patient, blinking with facial movements in one patient (the two patients with blinking had no history of facial palsy and could induce tinnitus even without blinking), mouth opening and closing in one patient, pursing of the lips in one patient, and pharyngolaryngeal movements in one patient (temporary pharyngolaryngeal myoclonus) (►Table 4).

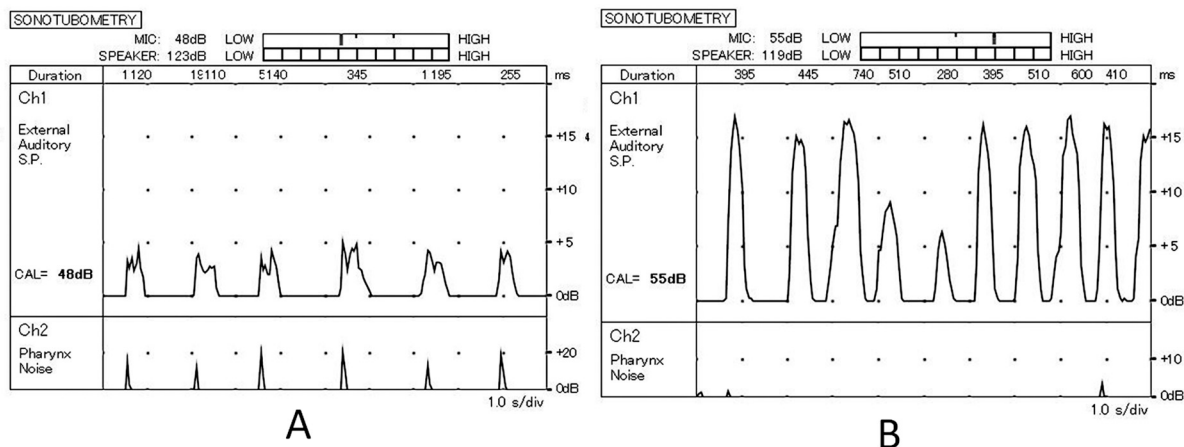
Tinnitus was only induced voluntarily in seven patients and was audible with involuntary movements in nine patients (►Table 5). Patient 14, who had pharyngolaryngeal myoclonus, could voluntarily induce tinnitus when myoclonus was not observed (►Fig. 4).

In tinnitus arising in the eustachian tube, treatment was performed for each eustachian tube condition. Patients whose etiology was unknown were followed up, with the expectation of spontaneous recovery.

### Discussion

The eustachian tube is a potential source of sound in objective tinnitus of muscular origin.<sup>9,10,16</sup> The sound is assumed to be produced by luminal changes when opening and closing the eustachian tube. The opening and closing of the eustachian tube can be detected using sonotubometry,<sup>17,18</sup> and to date, the same results as those shown in ►Fig. 1 have been found using the acoustic method.<sup>4,5</sup> Therefore, we examined patients in whom opening and closing of the eustachian tube coinciding with objective tinnitus could be recorded using sonotubometry as objective tinnitus of muscular origin caused by the eustachian tube. We obtained various results that are consistent with previous results.<sup>1,3-13</sup> The findings included various soft palate movements (►Fig. 3), eardrum movements, voluntary movements, and myoclonus (►Table 5). Therefore, while objective tinnitus of muscular origin has been reported previously, it was widely assumed in the reports that the opening and closing of the eustachian tube coinciding with tinnitus could be involved in the underlying pathology.

The subjects ranged in age from their teens to their 60s. Objective tinnitus of muscular origin has been reported in children younger than 10 years, and thus, it is considered to be a disease that can occur at any age. Many patients reported symptoms of the patulous eustachian tube as their chief complaint; however, some patients presented tinnitus arising secondary to the symptoms as the chief complaint. Tinnitus had developed in patients 7 and 10 since childhood and adolescence, respectively. Furthermore, two patients (patients 11 and 12) who had a sniffing habit for a long time were diagnosed with a sniff-type patulous eustachian tube and pars flaccida cholesteatoma with a sniffing habit, respectively. Similar to these two patients, patients who had adjusted the eustachian tube by inducing tinnitus were assumed to have



**Fig. 4** (A) Opening and closing in myoclonus and (B) voluntary opening and closing in patient 14 measured using the acoustic method.

congenital eustachian tube dysfunction. Patients 7, 10, and 11 were thought to have visited the hospital after being unable to close the eustachian tube as desired due to age-related changes in the flexibility of the eustachian tube.

Ward et al<sup>19</sup> reported that 14% of patients with a patulous eustachian tube complained of tinnitus expressed as crackling and rumbling, while 31% had anxiety neurosis and complications from tonic contraction of the tensor veli palatini muscle. Eleven patients had a definite patulous eustachian tube, and some with pharyngolaryngeal myoclonus also presented test findings of a definite patulous eustachian tube in this study. Patients with a patulous eustachian tube are generally aware that they can avoid symptoms by lowering their heads, applying pressure on the neck region, and sniffing. Similarly, it appeared that opening and closing the eustachian tube can be performed to avoid the symptoms of a patulous eustachian tube, and it was found that 10 of the 11 patients diagnosed with a patulous eustachian tube attempted to avoid symptoms and were able to achieve this by inducing tinnitus. Such patients could have closed the eustachian tube by repeatedly opening and closing an open eustachian tube (→ Fig. 2).

Among patients who voluntarily induced tinnitus, patients 5 and 13 were always very conscious of themselves as they induced tinnitus to avoid symptoms. Patient 12 noted that when she became tense, she inadvertently experienced clicking sounds. In this study, more than 50% of the patients voluntarily induced tinnitus and heard tinnitus involuntarily. Furthermore, some patients changed their chief complaint to involuntary tinnitus (patients 9, 14, and 16). Patient 9 had a child attending the Department of Psychiatry, and she noted that when her child's psychiatric condition worsened, her tinnitus worsened. If involuntary induction of tinnitus occurs during consultations, it may aid in the diagnosis of myoclonus. Patient 1 had previously been diagnosed with middle ear myoclonus; however, it was not observed during a medical examination at our hospital. Tinnitus, however, can occur involuntarily. During the medical examination, opening and closing of the glottis, as well as rhythmic movements of the neck and soft palate, were observed in patient 14, allowing for the diagnosis of pharyngolaryngeal myoclonus. Patient 14 had consulted the Department of Psychiatry for discomfort and tinnitus. She underwent tenotomy of the ossicular muscle; however, it was ineffective.

Emphasis is placed on organic lesions in the Guillain-Mollaret triangle as the central cause of soft palate myoclonus<sup>20</sup>; however, in functional myoclonus, common causes are said to involve neurosis, hysteria, and ticks.<sup>10</sup> Frequent avoidance behavior from the voluntary patulous eustachian tube is thought to cause muscle stress as a result of voluntarily moving muscles that are usually involuntary, as well as increased frequency of muscle contraction. Sustained muscle tension and other factors can readily lead to a convulsive state and are thought to cause involuntary contraction. It was assumed that as these mental factors accumulate, the involuntary movement would become remarkable. Involuntary soft palate movements and buckling of the eardrum observed during medical examinations are diagnosed as myoc-

lonus. Therefore, it is thought that a patulous eustachian tube causes symptoms in some patients with soft palate myoclonus and middle ear myoclonus. Patients with soft palate myoclonus who are mentally stable and have developed voluntary movement have been reported.<sup>8</sup> Furthermore, psychiatric mental factors may be involved in the development of involuntary movements. In patients with a patulous eustachian tube, myoclonic movements were reported to be observed in the soft palate.<sup>21</sup>

The test findings of the patulous eustachian tube were not recorded for patient 13. The symptoms were alleviated with the placement of a tympanic ventilation tube, and therefore, eustachian tube dysfunction was diagnosed. Patient 14 presented findings of a patulous eustachian tube on a eustachian function test. Thus, the discomfort experienced could be considered as ear fullness caused by the patulous eustachian tube; however, if the ear discomfort was caused by acute sensorineural hearing loss, it shows that the mechanism causing muscular objective tinnitus with the sound arising in the eustachian tube does not involve only a patulous eustachian tube. The cause of the triggers in patients 15 and 16 are unclear.

The number of times the eustachian tube is opened and closed in a 10-second period, as confirmed using sonotubometry, is thought to be associated with the technical skill and the number of years of opening and closing the eustachian tube. There were patients with rhythmic up/down movements of the soft palate and limited or small movements of the soft palate (→ Fig. 3), as well as patients with slight movements that could be overlooked. If these findings are interpreted as no movement, as found in the literature, then all movements correspond to findings of the soft palate in patients with objective tinnitus reported to date.<sup>1,3-6,9,10,12</sup>

Buckling of the eardrum was observed in three patients. It has been reported that apart from the eustachian tube, the ossicular muscle can cause muscular objective tinnitus. Buckling of the eardrum in the myoclonus is considered to be a movement of the tensor tympani muscle; however, based on our present results, in middle ear myoclonus, it is thought that the tensor veli palatini muscle is simultaneously contracted. This could involve some common features: the dominant nerve of both muscles is the third branch of the trigeminal nerve, both muscles are attached to the cartilage of the eustachian tube, and both the tensor veli palatini and tensor tympani muscles act to open the eustachian tube.<sup>22</sup> There have been reports of rhythmic buckling of the eardrum in patients with soft palate myoclonus.<sup>8</sup> We thought that the opening and closing of the eustachian tube should be verified in middle ear myoclonus when considering sectioning the tendon of the tensor tympani muscle.

Objective tinnitus arising simultaneously with blinking in patients with no history of facial palsy has been reported.<sup>14</sup> However, in the two patients in whom blinking was observed in our study, the fact that tinnitus was induced without blinking<sup>23</sup> and that it was thought that there were cases of facial movements, movement of the corners of the mouth, and mouth opening and closing (→ Table 4) led us to believe that there were individual differences that were not in the adjustment of the facial nerves and trigeminal nerve but in the accompanying movements, which appeared in the process of

learning to close the eustachian tube to induce tinnitus, including stimulating movements to voluntarily move the tensor veli palatini muscle, the size of the soft palate movements, and the presence or absence of eardrum buckling.

Most reports of muscular objective tinnitus only included a small sample, and the cause of onset was difficult to elucidate. However, in the present study, upon examining patients who presented with opening and closing of the eustachian tube that corresponded to tinnitus on sonotubometry, we observed findings consistent with those reported previously. It is suggested that the behavior is initiated to avoid symptoms of the patulous eustachian tube and eustachian tube dysfunction as a pathology of muscular objective tinnitus. We presume that the behavior of repeatedly opening and closing the eustachian tube created an opportunity to close. Furthermore, a possible cause of myoclonus is thought to involve a series of conditions, whereby some factors such as psychiatric factors in addition to such evasive behavior, depending on the patient, lead to evasive behaviors that occur unnoticeably, even when involuntary, and when such behaviors become remarkable, they are diagnosed as myoclonus. We believe that the pathology will become clearer by evaluating more patients, and if patulous eustachian tube is diagnosed, by considering whether tinnitus is expressed as crackling or burbling sounds, and if middle ear myoclonus or soft palate myoclonus is observed, by determining whether or not the concurrent patulous eustachian tube is observed. The treatment methods include treating the objective tinnitus, for instances, caused by the eustachian tube; however, regarding the treatment method for patients with a chief complaint of tinnitus and when the cause is temporarily attributed to myoclonus, the question as to whether such a shift can be prevented by treating the eustachian tube are topics to be addressed in future.

## Conclusion

We examined 16 patients with muscular objective tinnitus in whom the sound was thought to be caused by opening and closing of the eustachian tube. All the patients were able to voluntarily induce tinnitus, which was recorded using sonotubometry. Eleven patients had a patulous eustachian tube and a sniffing habit, and most of the patients had eustachian tube dysfunction. Muscular objective tinnitus was inferred to be partially caused by voluntary movements to avoid the symptoms of a patulous eustachian tube by repeatedly opening and closing the eustachian tube to create opportunities to close it. Soft palate movements associated with tinnitus, buckling of the eardrum, and accompanying blinking have also been reported to date, and the appearance of such variations was attributed to individual differences in the learning process of eustachian tube opening and closing. Some movements started as voluntary movements and subsequently became involuntary, and some patients were diagnosed with myoclonus.

### Conflict of Interest

None declared.

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