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Clinical Paper
TMJ Disorders

Relationship of age to foramen of Huschke and investigation of the development of spontaneous temporomandibular joint herniation

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Abstract. The aim of this study was to determine the prevalence, localization, and width of the foramen of Huschke (FH) and the relationship between age and FH. Another aim was to investigate the development of spontaneous temporomandibular joint (TMJ) herniation. This was a retrospective review of high-resolution computed tomography images of the temporal bone of 1025 patients. The prevalence of FH and the axial and sagittal diameters of the foramen were evaluated. Cases were found in which the TMJ had herniated through FH into the EAC. FH was detected in 137 (13.4%) of 1025 patients. The prevalence of FH was higher in females (18.4%) than in males (6.6%) ($P < 0.001$). The presence of FH increased with age ($P = 0.005$). Herniation of the TMJ through FH into the EAC was seen in four patients (0.4%), and 2.9% of patients with FH detected had TMJ herniation into the EAC. As well as being congenital, FH can also be senile; the prevalence may increase with age. Herniation of the TMJ through FH into the EAC is very rare; this was observed in 0.4% of all patients and 2.9% of patients with FH detected.

Key words: external auditory canal; foramen of Huschke; herniation; high-resolution computed tomography; temporomandibular joint.

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The external auditory canal (EAC) and temporomandibular joint (TMJ) are separated by a bony wall, which is formed by the tympanic segment of the temporal bone. The foramen of Huschke (FH), also called foramen tympanicum, is an anatomical variation of this tympanic segment. It is located at the antero-inferior aspect of the EAC, posteromedial to the TMJ[1,2].

Ossification of the EAC begins with the fusion of two prominences originating from the anterior and posterior portions of the tympanic ring. This fusion is not fully completed at birth. The FH gets smaller in size as the tympanic plate ossifies and closes around 5 years of age. When the bone fusion is not complete, the FH persists. The retrodiscal soft tissues of the TMJ may herniate through this bony dehiscence into the EAC. TMJ herniation into the EAC may cause otological symptoms of otalgia, ear discharge, tinnitus, hearing loss, and sense of fullness in the ear[3–6].

Preoperative detection of the FH variant is a great advance for clinicians, especially those who perform ear and TMJ surgery. During TMJ arthroscopy, endoscopes smaller than 3 mm in diameter may cause tympanic membrane perforation, incus dislocation, and facial nerve tympanic segment damage by penetrating into the foramen[7,8]. There may also be salivary gland fistula[9] or spread of the tumour from the ear into the infratemporal fossa.

Very few computed tomography (CT) studies have been performed because persistent FH is rare and most patients do not present symptoms[1,2,5,10–12]. In particular, spontaneous herniation of the TMJ through FH is extremely rare. This study aimed to determine the prevalence, localization, and diameter of FH in high-resolution computed tomography (HRCT) images obtained from a large series of 1025 patients. It was also aimed to determine the relationship of age and sex to FH and investigate the clinical and radiological findings of cases in which the TMJ has herniated spontaneously through this foramen into the EAC.

Materials and methods

Patient selection

This was a retrospective review of 2050 HRCT images of the temporal bone from 1025 patients who were suffering from hearing loss, vertigo, tinnitus, otitis media, and otalgia and who were admitted to the otolaryngology outpatient clinic between April 2015 and October 2017. In some cases, although temporal CT images were obtained, the aim of the CT was unclear . These patients were also included in the study. Patients with congenital anomalies, previous ear or TMJ surgery, cholesteatoma, temporal, cranial, or mandibular fractures, and patients younger than 5 years of age were excluded from the study. Technically unsuitable HRCT images were also excluded from the study.

Computed tomography imaging

HRCT was performed using a Toshiba Alexion ADV scanner (Toshiba Medical Systems, Otawara, Tochigi, Japan) with settings of 120 kVp, 150 mAs, high resolution, 0.5 mm slice thickness, 256 × 256 matrix, and 210 mm field of view. For all patients, coronal and sagittal reformatted images in the axial plane were created using the 3D feature of the imaging program Akgun Pacsviewer version 3B (Akgun Software, Ankara, Turkey).

Imaging analysis

All HRCT images were examined independently by two specialists, one an otolaryngologist and the other a radiology specialist, and the presence of persistent FH was investigated. In axial sections, the presence of bony dehiscence on the anterior wall of the EAC was considered as an FH entity. The presence of the FH was confirmed in sagittal and coronal plane images. The prevalence and localization (unilateral, bilateral) of FH was determined. The distance of FH to the tympanic membrane, the EAC anterior wall thickness, and the axial and sagittal diameters of FH were calculated using the distance toolbar in the tomography imaging program. The tympanic membrane was detected on axial images. The distance from the junction of the tympanic membrane to the anterior EAC wall, to the medial margin of the FH, was recorded as the distance of the tympanic membrane to FH. The largest axial widths in the axial and sagittal planes were recorded as the diameters in the axial and sagittal planes, respectively. In patients without FH, the thickness of the thinnest site of the EAC anterior wall was measured and considered as the EAC anterior wall thickness. It was also determined whether the TMJ had herniated through FH into the EAC. In the axial and sagittal sections, TMJ herniation was considered to be the protrusion of retrodiscal soft tissue density into the EAC through the dehiscence.

When there was inconsistency between the two investigators regarding the presence or absence of the FH, the case was reassessed by the two authors together until consensus was reached. The correlation between the measurements recorded by the two study investigators was examined statistically . The mean values of the measurements (the distance of FH to the tympanic membrane, the thickness of the EAC anterior wall, and the diameter of FH in the axial and sagittal planes) made by the two study authors were obtained and used in the analysis .

The presence of FH and the incidence of bilateral FH were compared between the sexes. The presence of FH was analyzed according to age divided into decades . The presence of FH according to the side (right and left) was also assessed . The diameters of FH in the axial and sagittal planes were compared between the sexes. The thickness of the EAC was examined in relation to sex and age.

Statistical analysis

For the descriptive statistics, the frequency, percentage, mean, standard deviation (SD), median, minimum, and maximum values were recorded. The distribution of variables was assessed using the Kolmogorov–Smirnov test. The groups were compared using the χ^2 test for categorical variables (with small numbers per cell, Fisher's exact test was used). The independent samples *t*-test was used for the analysis of quantitative data. The correlation between numerical variables was examined by Spearman correlation test. The level of statistical significance was established at a *P*-value of <0.05. SPSS version 18.0 software (SPSS Inc., Chicago, IL, USA) was used to perform the analyses.

Ethics statement

The working protocol was prepared in accordance with the principles set out in the Declaration of Helsinki. The study was approved by the institutional ethics committee.

Results

Of the 1025 patients included in this study, 588 were female (57.4%) and 437 were male (42.6%). The mean age of female patients was 47.9 ± 17.72 years (range 9–94 years) and of male patients was 46.8 ± 17.65 years (range 6–88 years). There was no significant difference in age distribution between the sexes ($P = 0.342$).

There was an inconsistency between the two authors in terms of FH presence in five patients. These patients were reassessed by the two authors together to reach a

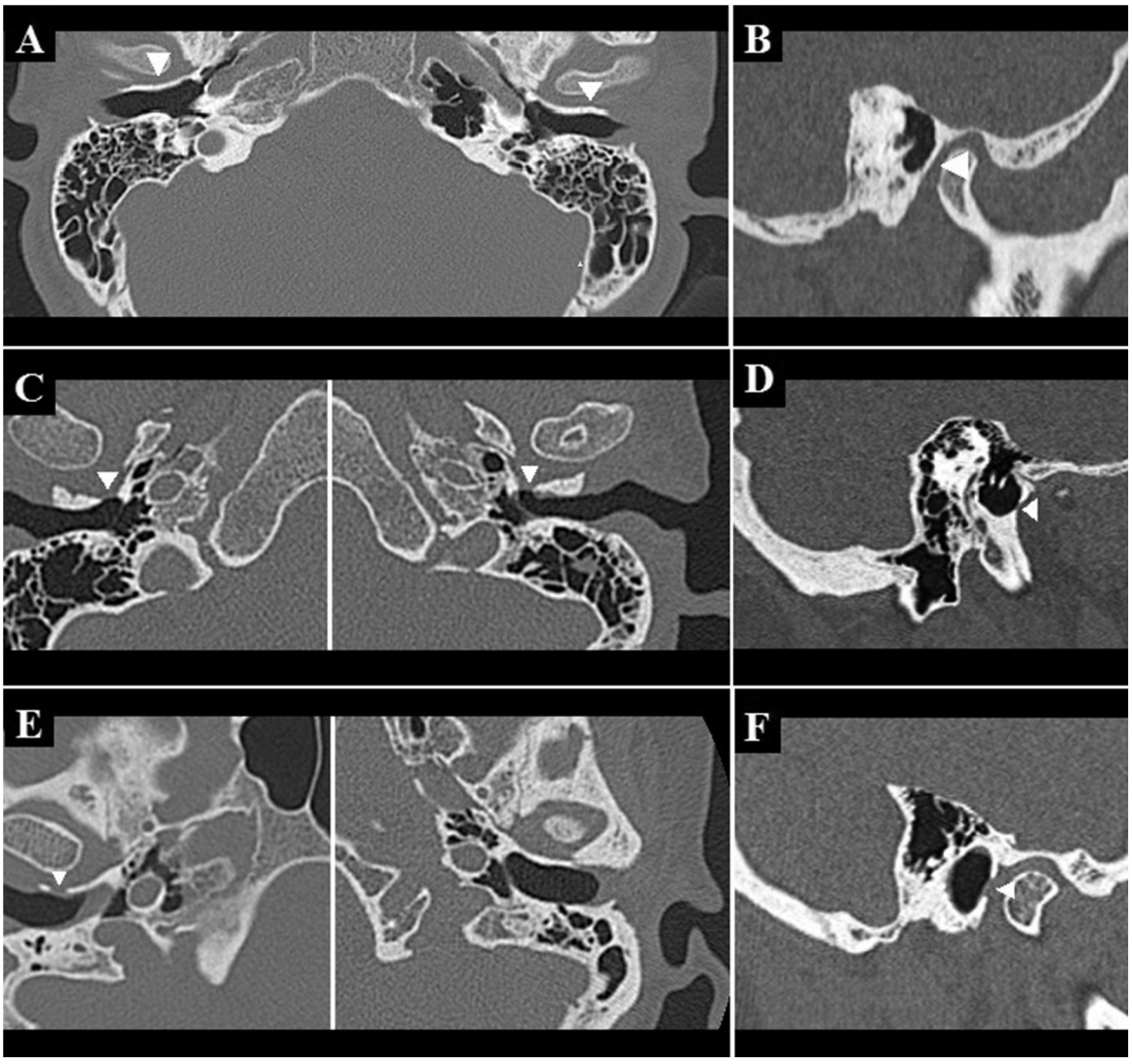

Fig. 1. HRCT imaging of the temporal bone. A patient without FH: (A) axial plane; (B) sagittal plane. A patient with bilateral FH: (C) axial plane; (D) sagittal plane. A patient with unilateral FH (on the right side): (E) axial plane; (F) sagittal plane.

consensus on the presence or absence of FH. As a final decision, three patients had FH and two patients were considered to have a thin bone lamella. Correlation between the two investigators' measurements was tested with the correlation test; the measurements were found to be consistent ($P < 0.001$) . Example HRCT images from a patient without FH, a patient with bilateral FH, and a patient with unilateral FH are given in Fig. 1 .

FH was detected in 137 (13.4%) of the 1025 patients. The incidence of FH was calculated to be 5.6% . Unilateral FH (Fig. 1E, F) was present in 95 patients (69.3% of those with FH; 9.3% of the total study population) and bilateral FH (Fig. 1C, D) was present in 42 patients (30.7% of those with FH; 4.1% of the total study population) . FH was detected in 179 (8.7%) of 2050 temporal HRCTs. The prevalence of FH was found to be higher in female subjects than in male subjects ($P < 0.001$). The more frequent bilateral involvement in females was significant ($P < 0.001$) (Table 1).

The mean age was found to be significantly higher in patients with FH (mean 52.9 ± 15.5 years) than in patients without FH (mean 46.6 ± 17.8 years) ($P < 0.001$). Correlations between the

Table 1. Prevalence of foramen of Huschke and localization according to sex .

	Male		Female		Total	
	n	%	*n*	%	*n*	%
FH						
No FH	408	93.4	480	81.6	888	86.6
Presence of FH	29	6.6	108	18.4[a]	137	13.4
Location						
Right	11	2.5	23	3.9[a]	34	3.3
Left	14	3.2	47	8.0[a]	61	6.0
Bilateral	4	0.9	38	6.5[a]	42	4.1
Total	437	100	588	100	1025	100

FH, foramen of Huschke.
[a] Statistically significant ($P < 0.001$).

Table 2. Correlations between the presence of foramen of Huschke and age .

Age (years)	No FH		Presence of FH		Total		*P*-value
	n	%	*n*	%	*n*	%	
6–20	53	6.0	2	1.5	55	5.4	0.005
21–30	119	13.4	7	5.1	126	12.3	
31–40	147	16.6	22	16.1	169	16.5	
41–50	177	19.9	25	18.2	202	19.7	
51–60	170	19.1	31	22.6	201	19.6	
61–70	118	13.3	29	21.2	147	14.3	
≥70	104	11.7	21	15.3	125	12.2	
Total	888	100	137	100	1025	100	

FH, foramen of Huschke.

Table 3. Size of foramen of Huschke according to sex and plane mm.

	Male			Female			Total			
	n	Mean	SD	*n*	Mean	SD	*n*	Mean	Range	SD
Right axial	15	1.81	0.44	61	2.10	0.61	76	2.04	0.98–3.78	0.58
Right sagittal	15	1.66	0.50	61	2.21[a]	0.74	76	2.10	0.81–3.86	0.72
Left axial	18	1.93	0.43	85	2.06	0.75	103	2.03	0.85–6.40	0.70
Left sagittal	18	1.94	0.62	85	2.30	0.76	103	2.24	1.08–5.26	0.74

FH, foramen of Huschke; SD, standard deviation.
[a] Statistically significant ($P = 0.008$).

presence of FH and age are given in Table 2. The presence of FH increased with age ($P = 0.005$). FH was found on the right side of 76 (42.5%) temporal bones and on the left side of 103 (57.5%) temporal bones (Table 3). The presence of FH on the left side (10.0%) was significantly higher than that on the right side (7.4%) ($P < 0.001$). In patients with FH, the distance of FH to the tympanic membrane was 1.42 ± 0.98 mm (range 0.49–8.04 mm) on the right side and 1.83 ± 1.19 mm (range 0.63–7.30 mm) on the left side.

When the shape of foramens was examined, they were seen to be round or oval shaped. Axial and sagittal diameters were equal in some patients, while in others there were differences between the two diameters. The mean size in the axial plane was 2.04 ± 0.65 (range 0.85–6.40) and the mean size in the sagittal plane was 2.18 ± 0.74 (range 0.81–5.26 mm). The distributions of the axial and sagittal plane dimensions of FH by sex are given in Table 3. The right sagittal diameters were significantly higher in females than in males ($P = 0.008$) and the size was always larger in females regardless of the side and plane differences.

In patients without FH, the thickness of the anterior wall of EAC was significantly lower in females (mean 1.13 ± 0.26 mm on the right, 1.14 ± 0.27 mm on the left) than in males (mean 1.20 ± 0.31 mm on the right and 1.23 ± 0.31 mm on the left). The thickness of the anterior wall of EAC decreased significantly with age on both sides ($P < 0.001$). The correlations between the thickness of the anterior wall of the EAC and age are given in Table 4.

Spontaneous herniation of the TMJ through FH into the EAC (Fig. 2) was seen in four patients (Table 5). These four patients who had spontaneous herniation of the TMJ into the EAC consisted of 0.4% of all patients, 0.7% of female patients, 2.9% of patients diagnosed with FH, and 3.7% of female patients diagnosed with FH. Two of the four patients (50%) with detected herniation were over 60 years of age. The FH axial (mean 3.96 ± 1.74) and sagittal (mean 3.60 ± 1.14) diameters of the four patients with herniation were larger than the axial (mean 1.99 ± 0.55) and sagittal (mean 2.17 ± 0.73 mm) diameters of the patients without herniation. In patients with herniation, the most common symptom was otalgia. Fullness of the ear and tinnitus were other symptoms. The patients did not undergo surgery as their daily lives were not affected much by their complaints . Three patients with otalgia benefitted from analgesic treatment, but there was no change in their complaints of ear fullness or tinnitus on follow-up .

Table 4. Correlations between the thickness of the anterior wall of the external auditory canal and age.

Age (years)	*n*	Right EAC		Left EAC		*P*-value
		Mean	SD	Mean	SD	
6–20	55	1.19	0.36	1.25	0.40	<0.001
21–30	126	1.16	0.35	1.17	0.37	
31–40	169	1.06	0.38	1.02	0.45	
41–50	202	1.09	0.39	1.06	0.42	
51–60	201	1.01	0.42	1.01	0.45	
61–70	147	1.03	0.45	1.05	0.48	
≥70	125	0.97	0.41	0.97	0.47	
Total	1025	1.06	0.40	1.05	0.44	

EAC, external auditory canal, SD, standard deviation.

Discussion

Persistent FH is the result of an ossification and fusion defect on the antero-inferior wall of the EAC. The reported prevalence of FH is between 1.5% and 22.7% in tomography studies[1,2,5,10–12], and between 7.2% and 38.2% in osteological studies[12–15]. The prevalence of FH in the present study was 13.4%. Tozoglu et al.[2] reported unilateral FH in 11.6% and bilateral FH in 6.3% of patients. Deniz et al.[10] reported unilateral FH in 9% and bilateral FH in 2.5% of patients. Unilateral FH was found in 9.3% of patients and bilateral FH in 4.1% of patients in the present study. In a study in which the prevalence of FH was found to be 1.5%[5], the CT slice thickness was 1 mm and patients with cholesteatoma and trauma were included in the patient group . In the current study, the CT used was more sensitive, with a slice thickness of 0.5 mm. In addition, patients with trauma and cholesteatoma were excluded from the study. It is believed that these differences in FH prevalence may be due to the group of patients included in the study, racial and genetic factors, procedural and measurement differences in tomography studies, and possible erroneous measurements in osteological studies due to the fragility of the bones.

Tozoglu et al.[2] reported FH on the right side in 15.5% of patients and on the left side in 7.2%. Deniz et al.[10] detected right-side FH in 4% of patients and left-side FH in 7.5%, and Akbulut et al.[11] detected FH on the right in 17.8% of patients and on the left in 14%. In the present study, FH was found on the right side in 7.4% of the patients and on the left side in 10.0% of the patients. While Tozoglu et al.[2] and Akbulut et al.[11] found FH to be significantly more common on the right side, the

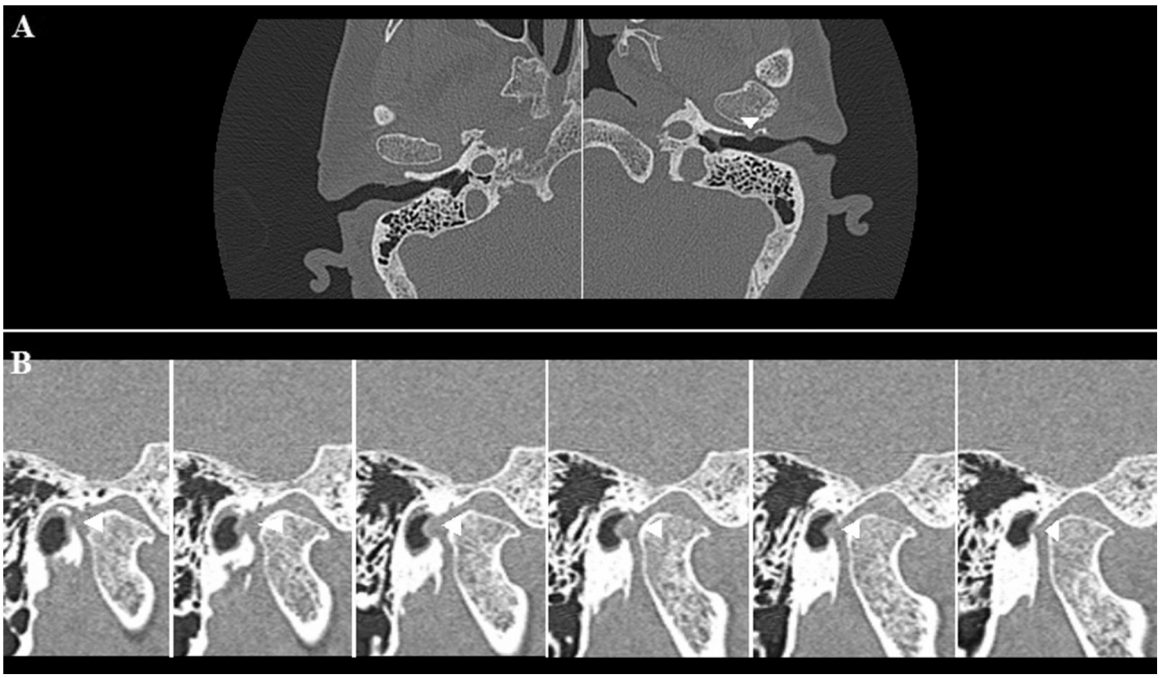

Fig. 2. HRCT imaging of the temporal bone showing spontaneous temporomandibular joint herniation into the external auditory canal through foramen of Huschke: (A) axial plane; (B) sagittal plane.

results of the present study, similar to those of the study by Deniz et al.[10], found FH to be significantly more common on the left side .

When the association between sex and FH was examined, it was found that in some studies FH was seen at a significantly higher level in females and in some studies FH was seen in females but not at a significantly higher level[10–12]. In the present study, FH was detected in 18.4% of female patients and 6.6% of male patients and the prevalence of FH was significantly higher in females. It was also found that the presence of more bilateral FH in females was also significant. EAC anterior wall thickness was also measured in the anatomical region of FH in patients who did not have FH. In females, the EAC anterior wall thickness was significantly lower on both the right and left than in males. The more frequent occurrence of persistent FH in females may be due to differences between the two sexes in terms of growth and development of the bones[1,10,12]. In this study, it was found that the EAC anterior wall thickness decreased significantly and FH frequency increased significantly with age. It is hypothesized that FH can be not only congenital but also senile. This study appears to be unique in showing that the prevalence of FH increases with age. Afghari et al.[12] found no association between age and the incidence of FH in their study. Hashimoto et al.[16], in a dry skull study, found that the incidence of FH declined significantly after age 10 years. They argued that the foramen continues to close after childhood. However, their study may have been subject to errors, since it was a dry skull study and false-positive results may have been obtained due to the fragility of the bones.

In this study, the mean diameter of FH in the axial plane was 2.04 ± 0.65 and in the sagittal plane was 2.18 ± 0.74 mm. The dimensions in females were generally higher than those in males, regardless of plane or side . Sagittal diameters were larger in some studies than in the present study[10,12], whereas axial diameters were larger in others[1,2,11].

In a study by Lacout et al.[1], the distance of FH to the tympanic membrane was found to be 1 mm on average (range 0–2.2 mm). In this study, the distance of the foramen to the tympanic membrane was found to be 1.42 ± 0.98 mm (range 0.49–8.04 mm) on the right and 1.83 ± 11.9 mm (range 0.63–7.30 mm) on the left. It was determined that FH could be further away from the tympanic membrane.

Park et al.[5] reported that the TMJ was spontaneously herniated into the EAC in four patients (0.4%), and findings in these four patients were reported as otalgia, otorrhoea, hearing loss, tinnitus, and aural fullness. In this study of 1025 patients, there was spontaneous herniation of the TMJ into the EAC in four female patients (0.4%). Patients in whom herniation was detected had complaints of otalgia, tinnitus, and aural fullness. In the study by Park et al.[5], 27% of patients with a patent FH were reported to have spontaneous herniation of the TMJ into the EAC, compared to 2.9% in the present study. However, Park et al.[5] reported that small-diameter FHs may have been missed because the CT slice thickness was 1 mm . In the present study, small FHs were detectable with a slice thickness of 0.5 mm, and spontaneous herniation was much lower than the rate originally reported by Park

Table 5. Characteristics of patients with spontaneous temporomandibular joint herniation into the external auditory canal.

Patient	Age (years)	Sex	Side	Axial diameter	Sagittal diameter	Distance to the TM	Symptom
1	63	F	L	6.40	5.26	6.30	O, T
2	47	F	R	3.78	3.16	3.34	O
3	73	F	R	3.37	2.69	1.07	AF
4	38	F	L	2.30	3.28	1.21	AF, O

TM, tympanic membrane; F, female; L, left; R, right; O, otalgia; T, tinnitus; AF, aural fullness.

et al.[5]. Furthermore, the patients who developed herniation were found to have larger axial and sagittal diameters of FH than the patients without herniation. The risk of herniation increases as the diameter of the foramen increases. In these cases, what is really herniated is the retrodiscal soft tissue, not the TMJ itself. The protrusion that occurs when the mouth is closed and disappears when the mouth is opened on the anterior wall of the EAC on otoscopic examination is typical for the TMJ herniation into the EAC. Eighty percent of herniation cases reported in the literature are over 50 years of age.[17]. In this study, 50% of patients with herniation detected were over 60 years old. This suggests that after years of repeated chewing, the TMJ may herniate into the EAC, either due to foramen expansion or softening of the connective tissue.

In symptomatic cases, the bone defect should be closed to prevent TMJ herniation into the EAC. Two different procedures are defined. The first is the pre-auricular approach based on TMJ exposure and the second is the endaural approach based on the exposure of the anterior wall of the tympanic bone[4,18,19]. Tragal cartilage, polypropylene, and titanium mesh can be used to close the defect[4,5,18]. The four cases with herniation in this study refused surgery because they stated that their complaints did not negatively affect their daily lives. The patients were instructed not to chew foods on the affected side. It was observed that the complaints of otalgia were alleviated with analgesic treatment, but that the complaints of aural fullness and tinnitus continued .

The limitations of this study include its retrospective design and the fact that osteoporosis, osteopenia, and calcium metabolism disorders were not screened in the patients. The increased prevalence of FH in women and with age suggests that osteoporosis may have influenced the elucidation of the EAC anterior wall, the formation of the foramen, or the expansion of an existing foramen. There is a need for prospective studies to explore the association between osteoporosis and FH. In addition, these prevalence rates may be higher than those in the general population secondary to the reason for evaluation in an otolaryngology clinic.

In conclusion, this study appears to be unique in showing that the prevalence of FH increases with age. Herniation of the TMJ into the EAC is very rare and was observed in 0.4% of all patients and in 2.9% of patients in whom the FH was detected. The foramen site is the thinnest region of the EAC anterior wall, and recurrent chewing movements of the mandible with age may lead to erosion of the thin EAC bony wall that closes FH. FH can be not only congenital but also senile.

Radiologists and clinicians dealing with TMJ and ear surgery should be particularly alert to this variation. Without preoperative detection, otological complications may develop during TMJ arthroscopy.

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Competing interests

There is no conflict of interest in this study.

Ethical approval

The study was approved by the institutional ethics committee (2017-10/1).

Patient consent

Written informed consent was obtained from the patients.

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