

Relationship between the degree of mastoid pneumatization and the presence of persistent foramen of Huschke

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Abstract. The aim of this study was to determine the relationship between the degree of mastoid pneumatization and the presence of persistent foramen of Huschke (FH). Temporal computed tomography images of 714 patients (1428 ears) who applied to the Otorhinolaryngology Department of Karabuk University Training and Research Hospital between January 2016 and June 2018 were retrospectively analysed. We compared the mastoid pneumatization levels of 95 patients (74 females, 21 males, mean age 53.18 ± 15.09 years) who had persistent FH and 135 patients (103 females, 32 males, mean age 54.29 ± 15.82 years) with no FH who had similar age and gender. FH was found to be unilateral (right: 23, left: 45) in 68 (71.5%) out of 95 patients with FH, and FH was bilateral in 27 (28.4%) patients. The degree of mastoid pneumatization of the patients with FH was significantly higher than the patients without FH ($p = 0.015$). The degree of pneumatization of the mastoid bone may lead to persistent FH by affecting the ossification process of the tympanic segment, which has a close anatomical relationship with it.

Key words: computed tomography; external auditory canal; Huschke; foramen tympanicum; mastoid pneumatization; temporomandibular joint.

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Persistent Foramen Huschke (FH) is the dehiscence in the bone lamella that separates the external auditory canal (EAC) and the temporomandibular joint (TMJ). This bone lamella is formed by the tym-

panic segment of the temporal bone. FH, which is also known as foramen tympanicum, is considered an anatomical variation of the tympanic segment¹. FH, which is formed during the development of the

EAC, gets considerably smaller as the tympanic plate is ossified. The ossification process continues after birth and FH closes at around 5 years of age. When bone fusion is not complete, FH remains persis-

tent. Genetic factors may play a role in persisting FH, but there are also factors affecting ossification of the tympanic bone after birth. Maxillofacial and tympanic bone continues to develop after birth and is shaped according to the pressure effect of actions such as mastication, deglutition and respiration².

The preoperative determination of the presence of FH is of great importance for physicians who perform ear and TMJ surgery. During TMJ arthroscopy, endoscopes with a diameter less than 3 mm may result in tympanic membrane perforation, incus, malleus, and facial nerve damage by passing through this foramen^{3,4}. Ear tumors may spread to the infratemporal region through this foramen. In addition, TMJ may cause otologic symptoms as herniated to the EAC from this foramen^{5,6}.

The pneumatization process of the mastoid bone begins in the last weeks before birth and continues to develop after birth until puberty. Although it varies between individuals, the pneumatization process is completed approximately at 15 years of age in men and at about 10 years of age in women⁷. Considering the location of the mastoid bone, pneumatization of the mastoid bone may affect the development of other temporal bone segments or vice versa.

While genetic and developmental factors are accused, the aetiology of FH is not definite. To the best of our knowledge, the relationship between the degree of pneumatization of the mastoid bone and the presence of persistent FH has not been previously investigated. The purpose of this study was to determine whether there is a relationship between the degree of mastoid pneumatization and the presence of persistent FH.

Materials and Methods

Patient selection

omography images of 714 patients (1428 ears) over 15 years of age who had undergone high-resolution temporal tomography (HRCT) imaging for various reasons such as tinnitus, dizziness, otalgia, and hearing loss in the otorhinolaryngology outpatient clinic between January 2016 and June 2018 were retrospectively analysed. The patients who underwent ear or TMJ surgery, temporal or maxillofacial fractures, cholesteatoma, and congenital anomalies were excluded from the study. Ninety-five patients (74 women, 21 men, mean age 53.18 ± 15.09 years) who had persistent FH and 135 patients (103 females, 32 males, mean age 54.29 ± 15.82 years) with similar age and gender characteristics who had no FH were included in the study. Age and sex distribution of both groups were compared. The mastoid pneumatization degrees were compared according to sex and age. The mastoid pneumatization degrees were compared in patients with and without persistent FH. Ethical approval for the study was obtained from the ethics committee of our institution (2018-3/4). The study was performed in accordance with principles of Helsinki Declaration.

Computed tomography imaging and analysis of images

HRCT was performed using Toshiba Alexion ADV (Toshiba Medical Systems, Otowara, Japan) 120 kVp, 150 mAs, high-resolution, 0.5-mm slice thickness, 256×256 matrix and 210-mm field of view. Coronal and sagittal reformats of the images on the axial plane were created

by the three-dimensional feature of the imaging program Akgun PACS viewer version 3 B (Akgun Software, Ankara, Turkey) for all patients.

All images were examined by an expert radiologist. In the axial tomography images, bone dehiscence in the anterior wall of EAC was considered as the presence of FH (Fig. 1A). The presence of FH was confirmed by examining the sagittal (Fig. 1B) and coronal (Fig. 1C) sections. The FH localization was determined (right, left, bilateral). The classification of the degree of pneumatization of the mastoid bone was based on the method where Han et al.⁸ used the sigmoid sinus as the reference structure. According to this method, in the axial section where the malleoincudal complex is seen as an ice-cream-cone shape in the temporal tomography, three lines were drawn at the most anterior, the most lateral aspect and the most posterior points of the sigmoid sinus and extending anterolaterally at 45 degrees. The patients were divided into four groups according to the degree of pneumatization. The pneumatization degrees were evaluated as group 1 (hypo-pneumatized) if they were located in the anteromedial of the line passing through the most anterior point of the sigmoid sinus; as group 2 (moderate-pneumatized) if they extended to the lines passing through the most anterior and the most lateral points of the sigmoid sinus; as group 3 (good-pneumatized) if they extended to the lines passing through the most lateral and the most posterior points of the sigmoid sinus; and as group 4 (hyper-pneumatized) if they extended posterolateral to the line passing through the most posterior point of the sigmoid sinus (Fig. 2). Han et al.⁸ compared these four groups, which were formed when

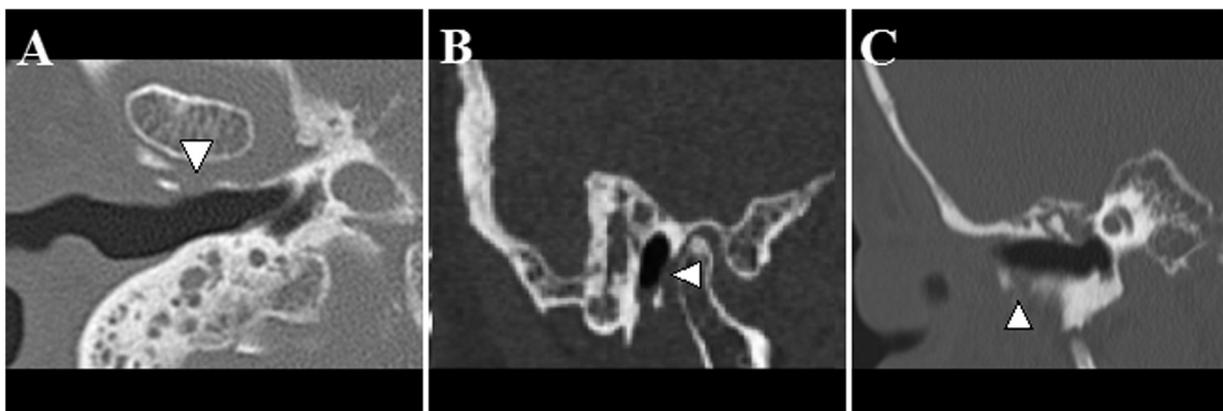


Fig. 1. Computed tomography imaging of the temporal bone. (A) Axial section, (B) sagittal section, (C) coronal section (the arrowheads indicate the presence of the foramen of Huschke).

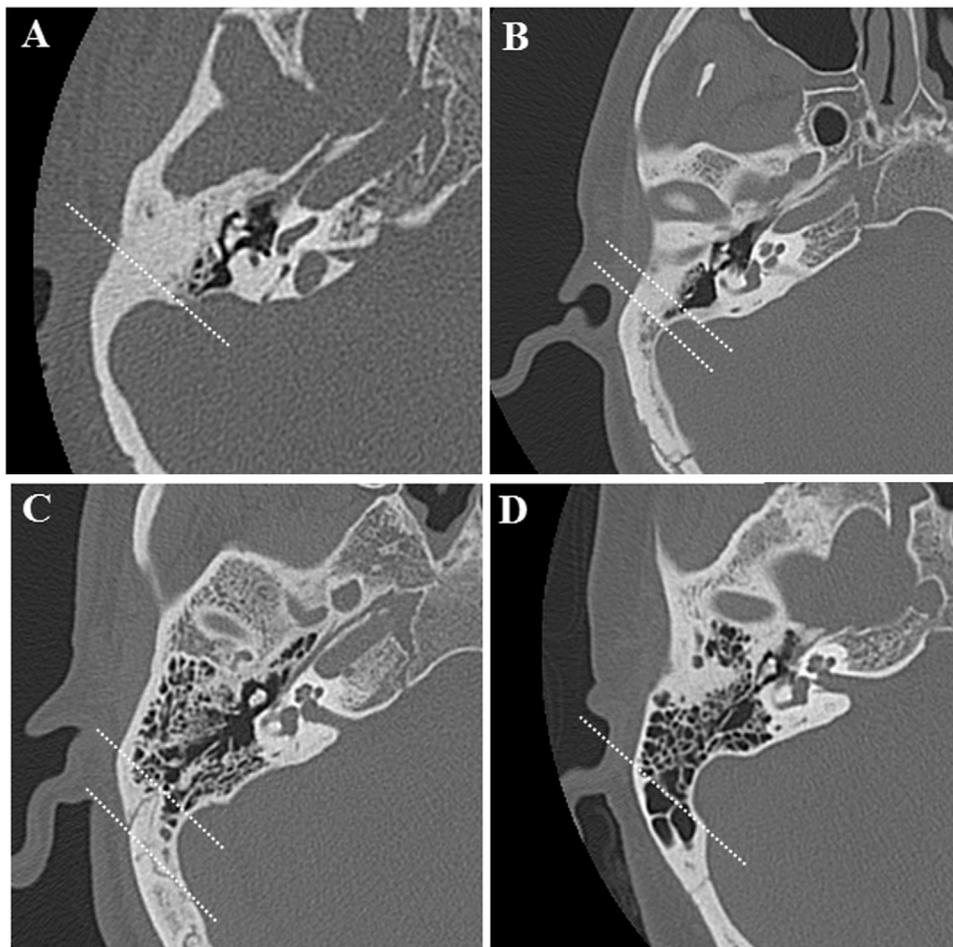


Fig. 2. Grouping of pneumatization in relation to the sigmoid sinus. (A) Group 1 (hypo-pneumatization group): if pneumatized cells were located in the anteromedial of the line passing through the most anterior point of the sigmoid sinus. (B) Group 2 (moderate pneumatization group): if pneumatized cells extended to the lines passing through the most anterior and the most lateral points of the sigmoid sinus. (C) Group 3 (good pneumatization group): if pneumatized cells extended to the lines passing through the most lateral and the most posterior points of the sigmoid sinus. (D) Group 4 (hyper-pneumatization group): If pneumatized cells extended posterolateral of the line passing through the most posterior point of the sigmoid sinus.

they considered the sigmoid sinus as a reference structure, with the volumetric measurements of mastoid pneumatization and found that this classification correlated with volumetric measurements.

Statistical Analysis

We used IBM SPSS Statistics for Windows, version 21.0 (IBM Corp., Armonk, NY, USA) to perform our analyses. For the descriptive statistics, the values of frequency, percentage, mean, standard deviation (SD), median, minimum, and maximum were presented. The *t*-test was used to compare age distribution between patients with and without FH, and Pearson's χ^2 -test was used to compare sex distribution. Pearson's χ^2 -test was used for the relationship between sex and degree of pneumatization. One-way analysis of variance (ANOVA) test was used for the relationship between

age and pneumatization degree, and the Tukey test was used as the post hoc test. Pearson's χ^2 -test was used for the relationship between the degree of pneumatization and the presence of FH.

Results

Of the 714 patients, 95 (13.3%) had persistent FH. Out of 95 patients with FH, 68 (9.5%) had FH unilaterally (right: 23, left: 45) and 27 (3.8%) had FH bilaterally. There was no significant difference in age ($p = 0.549$) and gender ($p = 0.777$) distribution in patients with and without persistent FH. Age and sex distribution of the patients are given in Table 1. There was no significant difference in both sex and age with degrees of pneumatization on both the right and left sides. The degree of mastoid pneumatization of the patients with FH was

significantly higher than the patients without FH ($p = 0.015$). So, as the degree of pneumatization increased, the presence of FH increased significantly. The relationship between the degree of pneumatization and presence of FH is given in Table 2.

Discussion

In this study, we investigated the relationship between the degree of mastoid pneumatization and the presence of persistent FH. We compared the degrees of mastoid pneumatization in patients with and without persistent FH. We found that mastoid pneumatization was significantly higher in patients with persistent FH compared to non-FH patients.

The FH is located at the anteroinferior aspect of the EAC, posteromedial to the TMJ. Computed tomography and dry skull studies have been performed for FH prev-

Table 1. Age and sex distribution of patients.

	Presence of FH	No FH	<i>p</i>
Age			0.549 ^a
Mean ± SD	53.18 ± 15.09	54.28 ± 15.82	
Min-max	15-89	15-94	
Sex			0.777 ^b
Female	74 (41.80%)	103 (58.19%)	
Male	21 (39.62%)	32 (60.37%)	

FH, foramen of Huschke; SD, standard deviation.

^a*t*-test.

^bPearson's χ^2 test.

Table 2. The relationship between the degree of pneumatization of the mastoid bone and the presence of Foramen of Huschke.

Degree of mastoid pneumatization	Presence of FH		No FH		<i>p</i>
	<i>n</i>	%	<i>n</i>	%	
1	21	17.07	99	29.37	0.015 ^a
2	22	17.88	72	21.36	
3	32	26.01	74	21.95	
4	48	39.02	92	27.29	
Total	123	100	337	100	

FH, Foramen of Huschke.

^aPearson's χ^2 test.

alence and rates of FH between 1.5% and 38.2% have been reported in these studies^{1,9-12}. In our study, this rate was found to be 13.3%. These differences may be due to inclusion criteria of patients, racial and genetic characteristics of patients, or thickness of the section of the tomography used in imaging. Although prevalence studies on the presence of FH have been performed, the factors affecting the ossification process of these foramina have not been elucidated.

Whether there is a relationship between age and FH incidence has been investigated in a number of studies¹⁰⁻¹². Afghari et al.¹⁰ did not find a relationship between age and persistent FH incidence in the study they conducted. Hashimoto et al.¹¹, in their dry skull study, found that the incidence of persistent FH decreased significantly after 10 years of age and they argued that the foramen continues to close after childhood. Ertugrul and Keskin¹² found that the prevalence of persistent FH increased significantly with aging, and argued that the presence of persistent FH could be not only congenital but also acquired. They stated that increased osteolysis with aging and repeated chewing movements over the years may cause thinning of the anterior wall of EAC and subsequent reopening of closed FH. In studies investigating the relationship between gender and the incidence of persistent FH, it has been reported that persistent FH is more common in females¹²⁻¹⁴. The more frequent occurrence in females is attributed to the differ-

ences in growth and development of bone structures between two genders^{1,10,13}.

During the embryological development of the tympanic ring, EAC prevents migration of the ectodermal tissue into the middle ear. In the mechanism of congenital cholesteatoma formation, a theory has been suggested that migration of EAC ectodermal tissue can not be stopped by the tympanic ring as a result of a developmental anomaly in the tympanic ring¹⁵. In the same way, the bone fusion defect that occurs as a result of an anomaly during the embryological development of the tympanic bone may also be effective in persisting FH.

The degree of mastoid pneumatization varies between individuals. Two theories have been proposed for this difference between individuals. The first theory is that the degree of mastoid pneumatization is genetically determined. According to this theory, low mastoid pneumatization degree is thought to prepare the ground for middle-ear pathologies. According to the second theory, normal middle ear mucosa is required for a natural mastoid pneumatization process. According to this theory, increased middle ear pathologies during childhood cause a low mastoid pneumatization degree. Some researchers have investigated the relationship between genetic diseases and the degree of mastoid pneumatization. Sade et al.¹⁶ found that patients with otosclerosis had more mastoid pneumatization than the healthy control group and their finding supports the first theory. In many studies, it has been

found that an inflammatory process in the middle ear was associated with a low degree of mastoid pneumatization. It has been observed that mastoid pneumatization decreased in patients with otitis media with effusion, chronic otitis media, and cholesteatoma^{17,18}. Shim et al.¹⁹ found that the degree of mastoid pneumatization was significantly lower in patients with superior semicircular canal dehiscence than patients with temporal bone fracture or otosclerosis. Given these two theories, adjacent structures may influence the degree of mastoid pneumatization or vice versa. Considering the location of the mastoid bone, the degree of mastoid pneumatization is also likely to affect bone fusion in the tympanic bone. To our knowledge, the relationship between the degree of pneumatization of the mastoid bone and the presence of persistent FH has not been previously investigated.

The fusion in the tympanic bone may also be genetically determined, as in the theory that the mastoid bone pneumatization is genetically determined. However, considering that the mastoid bone pneumatization and the fusion in the tympanic bone continue after birth and they have a close anatomical relationship, it is possible that these two temporal bone segments affect each other.

The limitation of this study was that a computerized volumetric measurement of the degree of mastoid pneumatization could not be performed. In addition, because the people whose temporal computed tomography images were evaluated were the patients who applied to the otorhinolaryngology department, the results could not fully reflect the general population.

In conclusion, the present study is thus the first to analyse the relationship between the degree of mastoid pneumatization and the presence of FH. We found that the degree of mastoid pneumatization was significantly higher in patients with persistent FH compared with those who did not have persistent FH. The degree of mastoid pneumatization and whether or not FH will be closed by ossification may be genetically determined. However, when it is considered that the mastoid segment and the tympanic segment are two adjacent structures of the temporal bone and the two bone segments continue to develop after birth, the pneumatization of the mastoid bone may affect the ossification of the tympanic bone and thus the presence of FH, or vice versa.

Funding

This study received no funding.

Competing Interests

There is no conflict of interest in this study.

Ethical Approval

The study was approved by our Institutional Ethical Committee (2018-3/4).

Patient Consent

We obtained written informed consent from the patients.

References

- Lacout A, Marsot-Dupuch K, Smoker WR, Lasjaunias P. Foramen tympanicum, or foramen of huschke: pathologic cases and anatomical CT study. *Am J Neuroradiol* 2005;**26**(6):1317–23.
- Mao JJ, Nah HD. Growth and development: hereditary and mechanical modulations. *Am J Orthod Dentofacial Orthop* 2004;**125**(6):676–89.
- Herzog S, Fiese R. Persistent foramen of Huschke: possible risk factor for otologic complications after arthroscopy of the temporomandibular joint. *Oral Surg Oral Med Oral Pathol* 1989;**68**(3):267–70.
- Applebaum EL, Berg LF, Kumar A, Mafee MF. Otologic complications following temporomandibular joint arthroscopy. *Ann Otol Rhinol Laryngol* 1988;**97**(6):675–9.
- Moriyama M, Kodama S, Suzuki M. Spontaneous temporomandibular joint herniation into the external auditory canal: a case report and review of the literature. *Laryngoscope* 2005;**115**(12):2174–7.
- Ertugrul S. Rare cause of tinnitus: Spontaneous temporomandibular joint herniation into the external auditory canal. *J Craniofac Surg* 2018;**29**(5):521–2.
- Lee DH, Jun BC, Kim DG, Junk MK, Yeo SW. Volume variation of mastoid pneumatization in different age groups: a study by three-dimensional reconstruction based on computed tomography images. *Surg Radiol Anat* 2005;**27**(1):37–42.
- Han SJ, Song MH, Kim J, Lee WS, Lee HK. Classification of temporal bone pneumatization based on sigmoid sinus using computed tomography. *Clin Radiol* 2007;**62**(11):1110–8.
- Bhanu PS, Sankar KD. Incidence of Foramen of Huschke in South Andhra Population of India. *J Clin Diagn Res* 2016;**10**(6):AC01–3. <http://dx.doi.org/10.7860/JCDR/2016/18735.8031>.
- Afghari P, Ghaffari R, Sohailpour S. Anatomical assessment of foramen tympanicum using cone beam computed tomography images. *Dental Hypotheses* 2016;**7**(3):107–11.
- Hashimoto T, Ojiri H, Kawai Y. The foramen of Huschke: age and gender specific features after childhood. *Int J Oral Maxillofac Surg* 2011;**40**(7):743–6.
- Ertugrul S, Keskin NK. Relationship of age to foramen of Huschke and investigation of the development of spontaneous temporomandibular joint herniation. *Int J Oral Maxillofac Surg* 2018;(September (8)). <http://dx.doi.org/10.1016/j.ijom.2018.08.011>. [Epub ahead of print].
- Deniz Y, Geduk G, Zengin AZ. Examination of foramen tympanicum: cone-beam computed tomography anatomical study. *Folia Morphol (Warsz)* 2018;**77**(2):335–9.
- Akbulut N, Kursun S, Aksoy S, Kurt H, Orhan K. Evaluation of foramen tympanicum using cone-beam computed tomography in orthodontic malocclusions. *J Craniofac Surg* 2014;**25**(2):106–9.
- Kenji A. Role of the tympanic ring in the pathogenesis of congenital cholesteatoma. *Laryngoscope* 1983;**93**(9):1140–6.
- Sade J, Shatz A, Kremer S, Levit I. Mastoid pneumatization in otosclerosis. *Ann Otol Rhinol Laryngol* 1989;**98**(6):451–4.
- Csakanyi Z, Katona G, Josvai E, Mohos F, Sziklai I. Volume and surface of the mastoid cell system in otitis media with effusion in children: a case-control study by three-dimensional reconstruction of computed tomographic images. *Otol Neurotol* 2011;**32**:64–70.
- Iino Y, Imamura Y, Hiraishi M, Yabe T, Suzuki J. Mastoid pneumatization in children with congenital cholesteatoma: an aspect of the formation of open-type and closed type cholesteatoma. *Laryngoscope* 1998;**108**(7):1071–6.
- Shim BS, Kang BC, Kim CH, Kim TS, Park HJ. Superior canal dehiscence patients have smaller mastoid volume than age- and sex-matched otosclerosis and temporal bone fracture patients. *Korean J Audiol* 2012;**16**:120–3.

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