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Cone-beam computed tomographic study of the persistent foramen tympanicum according to age, sex, and skeletal patterns

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Abstract

This cross-sectional study evaluated the influence of prevalence, laterality and diameter of persistent foramen tympanicum (PFT) in cone beam computed tomographic (CBCT) scans of adult patients with different sagittal skeletal patterns, sex and age. CBCT of 510 patients were assessed for the presence of PFT. Skeletal pattern, age and sex of the affected patients were recorded, as well as laterality and diameter of PFT. Differences were tested using the one-way ANOVA, chi squared and paired-*t* tests, at α=5%. A total of 49 (9.7%) patients presented with PFT; 36 (73.5%) were women ($p<0.01$) aging from 31-50 years ($p>0.05$), with Class III skeletal pattern ($p>0.05$). The unilateral/bilateral ratio was 3.9:1 ($p<0.01$). No correlation was found between the PFT diameters with sex and age, but differences were found between the classes, with the largest diameters in Class II individuals ($p=0.046$). The prevalence of PFT in CBCT scans was 9.7%, with women being more affected, with unilateral defects in most cases. Skeletal patterns did not have significant effects on PFT prevalence, although PFT diameter varied among classes, with higher measures in Class II individuals.

Keywords: Anatomy; ear canal; temporomandibular joint; cone beam computed tomography

Introduction

The persistent foramen tympanicum (PFT), also known as foramen of Huschke, is a developmental defect in the tympanic segment of the temporal bone,[1–4] located at the antero-inferior aspect of the external auditory canal (EAC), posteromedial to the temporomandibular joint (TMJ).[1,2,4–7] EAC ossification begins with the fusion of two prominences originating from the anterior and posterior aspects of the tympanic ring.[1,2] It is known that this fusion process is not completed at birth and that the foramen tympanicum becomes smaller in size as the tympanic plate ossifies, closing at around five years of age. [1] However, there are several reports of foramen tympanicum persistence in adults.[1,2,6]

Although most PFT are asymptomatic,[3] their persistence may be related to several clinical complications, since they may facilitate the spread of infections and neoplastic processes from the ear into the infratemporal fossa,[1,4] and lead to herniation of TMJ retrodiscal soft tissues into the EAC.[1,3,5–7] Additionally, salivary fistulas, otalgia, external otitis, and otorrhea originating in the parotid or synovial fluid of the TMJ have been reported.[1,2,5,6,8–10]

PFT may represent a complication factor in TMJ arthroscopy and arthrocentesis,[3,6,11] since endoscopes may cause tympanic membrane trauma[12] or perforation,[1] hearing loss,[12] incus displacement, bone fractures,[1] facial paralysis,[12] and facial nerve tympanic segment injury[1] by

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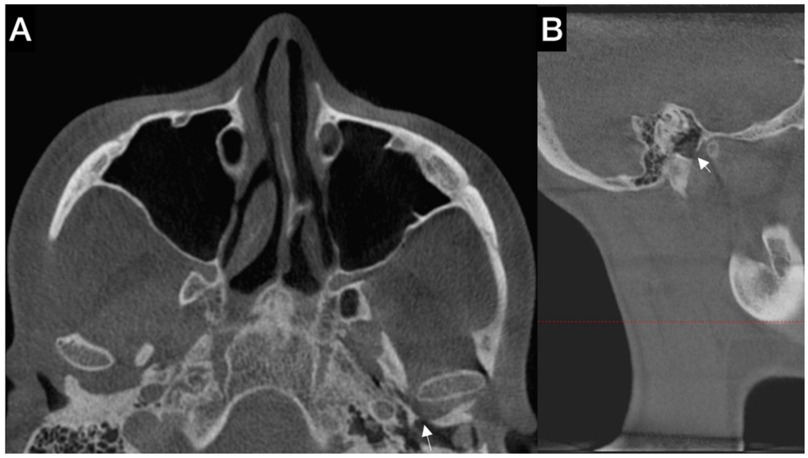

Fig. 1. Cone-beam computed tomographic imaging of the temporal bone. Persistent foramen tympanicum (dehiscence on the anterior wall of the external auditory canal) in the right side identified in the axial reconstruction (A) and confirmed in the sagittal reconstruction (B).

Fig. 2. Measurement of persistent foramen tympanicum (in millimetres) in axial (A) and sagittal (B) reconstructions.

penetrating into the foramen. Thus, clinicians should be aware of these alterations[3] and this knowledge is helpful for diagnosis and treatment planning in this region.

The prevalence of PFT is uncertain[13] and some factors such as sex, age, ethnicity, and skeletal facial discrepancies are associated.[2,6,7,13] Because cone beam CT (CBCT) allows the visualisation of bone components of ear and TMJ without superimposition, this technology has been indicated as the method of choice for assessing this region.[14,15] Thus, the aim of this study is to evaluate the prevalence, localisation and diameter of PFT regarding the sagittal skeletal pattern, age, and sex by means of CBCT scans. The null hypothesis stated that there were no significant differences in the prevalence of PFT on the basis of skeletal patterns, sex, or age.

Material and methods

After ethics approval (CAAE #55110916.5.0000.0104), this cross-sectional study was developed according to STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) initiative.[16] It was carried out according to the principles described in the Declaration of Helsinki.

CBCT scans of 510 patients (207 men, 303 women) were selected from a Brazilian population who underwent examination for several reasons at the Oral Radiology Clinic at LIPC/UEM between February 2014 and July 2018. All exams that represented the ear region and the TMJ bilaterally, at maximum intercuspation, were included. In addition, only the exams in which the skeletal pattern could be defined were selected (large FOV- field of view). Exclusion criteria were patients less than 18 years of age, with history of surgery in the TMJ region, facial trauma, orthognathic surgery, congenital craniofacial syndrome, orofacial pain, or maxillofacial pathologies.

The scans were obtained in the Next Generation® i-Cat equipment (Imaging Sciences International), with 120 Kvp, 3-8 mA, and a 0.3 mm isometric voxel. The same radiologist performed all CBCT exams and had full access to the patients' clinical records. The ANB angles' measurements were performed using Dolphin Imaging software version 11.95 (Dolphin Imaging & Management Solutions, Patterson

Dental Supply) by an experienced orthodontist and patients were classified according to the skeletal discrepancy in class I (0° < ANB <4°, n = 190), class II (ANB ≥ 4°, n = 169) and class III (ANB ≤ 0°, n = 151).[17]

The exams were then independently assessed by two external and calibrated observers (radiologists, both with 12 years of experience with CBCT) in a quiet and dark room, using the scanners' dedicated software (i-CAT Vision, version 1.9.3, Imaging Sciences International Inc). When differences were found, a consensus was reached with a third blinded external observer. The right and left regions of each patient were evaluated from reconstructed axial slices and, when a PFT was identified, the confirmation was performed in the sagittal reconstructions (1 mm thickness). The presence of a bony dehiscence on the anterior wall of the EAC was considered as a PFT[1] (Fig. 1). Image-processing tools were used to adjust the level of the images to ensure optimal visualisation and software tools such as zoom; filter and contrast could be used. Three-dimensional rendering images were used when necessary.

The laterality (unilateral or bilateral) and the diameter of each PFT were also determined. The axial and sagittal diameters of PFT were measured using the distance toolbar (Fig. 2).

Statistical analysis

The frequency of PFT was correlated with sex, age, and laterality using the paired *t*-test. PFT measurements were compared using the ANOVA one-way test and the correlation with the mean diameter and skeletal pattern was performed using the chi squared test of independence. Cohen's Kappa test was used to assess intra- and inter-observer variability in evaluating the persistence of the foramen and the intraclass correlation coefficient (ICC) tested the intra- and inter-observer reliability for measurements and repeated exams. The significance level was set at p<0.05. All statistical procedures were computed with SPSS version 17.0.1 (SPSS Inc).

Results

Kappa value for intra- and inter-observer agreement was perfect (1.00). The variables presented excellent concordance, with replicability at a significance level of 5% (ICC>0.90).[18]

Overall, 49 (9.7%) patients presented with PFT; 13 (26.5%) men and 36 (73.5%) women, with a sex ratio of 1:2.8 (p<0.01). We found a unilateral/bilateral ratio of 3.9:1, with 39 (79.6%) and 10 (20.4%) patients with unilateral and bilateral PFT, respectively (p<0.01). Of the unilateral cases, 32 (82%) were on the left side and 7 (18%) on the right side.

The age of the individuals with PFT ranged from 18 to 88 years, with the highest frequency between 31 to 50 years (46.94%), although statistically significant differences were not found (p>0.05) (Table 1).

Table 1
Distribution of persistent foramen tympanicum according to age. Data are no. (%).

Age	Men	Women	Total
18-30	6 (46.14)	9 (25.0)	15 (30.61)
31-50	3 (23.08)	20 (55.6)	23 (46.94)
51-70	2 (15.39)	6 (16.7)	8 (16.33)
71-90	2 (15.39)	1 (2.8)	3 (6.12)
Total	13 (100)	36 (100)	49 (100)

Table 2
Mean diameter (mm) of persistent foramen tympanicum according to sex. Data are mean (SD) unless otherwise stated.

Side/MPR	Men	Women	p value
Right axial	2.08 (0.52)	2.55 (0.67)	0.151
Right sagittal	2.07 (0.53)	2.50 (0.59)	0.146
Left axial	2.41 (0.72)	2.69 (0.66)	0.286
Left sagittal	2.37 (0.46)	2.62 (0.67)	0.320

MPR: multiplanar reconstruction.

Table 3
Mean diameter (mm) of persistent foramen tympanicum according to skeletal pattern. Data are mean (SD) unless otherwise stated.

MPR	Class I	Class II	Class III	p value
Axial	2.33 (0.54)^{a}	2.93 (0.66)^{b}	2.52 (0.70)^{ab}	0.046*
Sagittal	2.38 (0.55)	2.80 (0.76)	2.44 (0.57)	0.147

Different letters indicate a significant difference (*p < 0.05).
MPR: multiplanar reconstruction.

PFT diameter varied from 1.37-4.07mm and 1.2-3.71mm in sagittal and axial reconstructions, respectively. No statistically significant differences in PFT mean diameters were found when sexes were compared (p>0.05), although the largest measurements were found in women (Table 2). Also, no correlation was found between the PFT diameters and the age (p>0.05).

Among patients with PFT, 15 (30.6%) were classified as Class I, 12 (24.5%) Class II and 22 (44.9%) Class III, with no statistically significant difference in the prevalence of PFT between them (p>0.05). However, when the axial PFT diameters were compared, statistically significant differences were found between the classes, with the largest diameters in the Class II group (p=0.046) (Table 3).

Discussion

Several studies evaluated the presence of the foramen tympanicum through macroscopic inspection of macerated skulls, with a prevalence varying from 4.4%[19] to 46.0%.[20] Using helical CT, some authors[1] found a value of 13.4%. In CBCT studies, the literature reports a prevalence varying between 2.27%,[21] 16.6%,[22] 17.9%[5] and 22.7%,[6] with a maximum sample of 303 patients.[21] The prevalence in the present investigation was 9.7% in a sample of 510 patients. CBCT provides relatively high-resolution and allows multiplanar reconstructions, eliminating superposition of anatomical structures at a reasonably accessible scan cost, reduced acquisition time, and lower radiation doses when compared to helical CT.[6,21] This technology is considered the gold-standard imaging method for evaluation of bone components of the TMJ and the tympanic region.[21]

We agree with Hashimoto et al[2] that ethnicity may be one factor that affects the prevalence of PFT, since the process of membranous ossification of the skull exhibits variability between races.[23] Particular nutritional habits, environmental and socioeconomic conditions may influence the variations in facial morphology of each population.[20] Available studies include Japanese,[2] South-Korean,[13] Indian,[3] Iranian[19] and Turkish[1,4,6] populations. Another study[21] also investigated a Brazilian population, whose peculiarity is to be widely miscegenated, with European, African, Eastern, and Indigenous ancestry. This ethnic heterogeneity can be helpful in the external validation of our results.

As well as previously described,[5,6,24] the PFT in axial and sagittal reconstructions showed an oval shape, since the diameters in both planes were slightly different.[6] We found a higher prevalence of unilateral PFT (3.9:1), corroborating most studies,[5,6,22] in which unilateral/bilateral ratio varied from 1.85:1,[5] 1.47:1[6] and 3.15:1.[22] Conversely, Lima et al[21] found a higher prevalence of bilateral PFT (1:2.5). The authors attribute this difference to the resolution of the CBCT equipment. However, we used the same equipment with a similar voxel size (0.3 mm) and, for this reason, we do not believe that this parameter could affect the capacity of identifying the PFT, resulting in the difference between the results. Likewise, we cannot infer that the considerably larger sample size of our study influenced the different results.

We found the highest frequency of PFT between 18-30 and 31-50 years, with a prevalence of 30.61% and 46.94%, respectively, although no statistically significant difference was found. Hashimoto et al[2] found that 26.7% of PFT occurred in their youngest group (10-19 years). They stated that the regression of the foramen continues after childhood, and that the PFT can close over time.[2] Based on our observations that the prevalence of PFT declined dramatically in patients over 50 years of age, we agree with this statement. The study by Ertugrul and Keskin[1] appears to be unique in showing that the prevalence of PFT increases with age and the authors speculate whether osteoporosis or other diseases may have influenced the results.

Women were more affected (73.5%), corroborating most of the studies.[1,2,4,5,21] This female predominance may be based on differences in growth and development of bone structures between sexes.[4,24] However, some investigations did not find significant differences between sexes.[4,6] We also found the largest PFT diameters in women, as well as demonstrated by Akbulut et al.[6]

Class III individuals showed the highest number of PFT (44.9%), although no statistically significant differences were found in the prevalence of alteration among skeletal patterns. We found only one study that also investigated the PFT in patients with malocclusions,[6] in which Class II patients were more affected (38.09%), also without statistically significant differences between classes. Both studies agreed when PFT diameters were compared, with higher measures found in Class II subjects with statistically significant level. These results are significant, since they may be caused by the position of the condyle and retrodiscal tissue of the TMJ.[6] Several patterns of mandibular growth induce differences in the distribution of tension along the TMJ and the glenoid fossa responds significantly to environmental changes.[25] The postero-superior condylar position in the glenoid fossa can press the retrodiscal tissue through the functional movements (chewing, speech, and breathing), leading to the foramen enlargement.[6,26]

In individuals with Class II and III skeletal patterns a significantly higher prevalence of degenerative joint disease and/or signs and symptoms of temporomandibular disorders has been suggested[27] and TMJ procedures are more frequently indicated in these individuals.[28] Hence, the presence of a PFT might be considered as a potential complicating factor for clinical and surgical procedures in the temporal bone region, emphasising the importance of recognising this alteration in imaging exams. For example, the connection into EAC during arthroscopy or arthrography can result in otological complications,[11,12] and in cases where the condyle is clinically in the EAC, the health of the condyle is likely compromised.[26] Other complications include pain, dysfunction,[4] external otitis,[8] and salivary fistulas.[9,10] However, because PFT is rare and most patients are asymptomatic, its presence may be neglected. In addition, in clinical routine, PFT image can be misinterpreted and this communication can be misdiagnosed as a bone fracture.[12] In symptomatic cases, the surgical repair of PFT using tragal cartilage graft, polyethylene, polypropylene or titanium mesh, and pedunculated temporoparietal fascia flap via a preauricular approach[26] may be proposed, considering the potential complications of this alteration.

The limitations of this study include its retrospective design. Some clinical factors such as hormonal (menopause, pregnancy) and bone (osteopoenia, osteoporosis, calcium metabolism abnormalities) disorders could not be screened in the patients. Prospective studies are needed to investigate these associations.

In conclusion, CBCT is a valuable tool to determine the presence and the diameter of PFT. The higher frequency of this complication was found in women between 31 to 50 years. The defect was unilateral in most cases. The largest foramens were found in Class II patients. Radiologists, clinicians, and surgeons should be aware of these anomalies and this knowledge is helpful in interpreting imaging for diagnosis and treatment planning purposes in this region.

Conflict of interest

We have no conflicts of interest.

Ethics statement/confirmation of patients' permission

Ethics approval: CAAE #55110916.5.0000.0104. Patients' permission not applicable.

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