Prevalence and Characteristics of Articular Eminence Pneumatization: A Cone-Beam Computed Tomographic Study

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Abstract

Purpose The temporal bone represents a variety of pneumatization patterns with clinical significance for planning surgical procedures in this area. The purpose of the present study was to assess the prevalence and characteristics of the glenoid fossa and articular eminence pneumatization and to classify the pattern of pneumatization using CBCT images.

Methods CBCT images of 327 patients (654 temporal bones) were evaluated to determine pneumatized articular eminence prevalence and characteristics. Gender, age, laterality, type and grade of pneumatization were recorded for the left and right sides. Chi-square test was used to evaluate the relationship between pneumatized articular tubercle and gender, grade and type.

Results PAT was identified in 251 (76.7%) patients of whom 139 (55.4%) were male and 112 (44.6%) were female with a mean age of 30.31 ± 10.32 years. Bilateral PAT occurred in 175 (69.7%) patients. Three hundred and ninety-six (93%) of areas were multilacunar, and 30 (7%) were unilacunar. Of 654 areas, 228 (34.8%) had grade 0, 299 (45.7%), grade 1, 92 (14.1%), grade 2 and 35 (5.4%), grade 3. No statistically significant correlation was found between prevalence of pneumatization, gender, type and grade.

Conclusion The present study emphasized the need to assess PAT before surgical intervention of TMJ. CBCT provides reliable and accurate information to determine the characteristics, the exact extension of pneumatization and its relationship to the adjacent structures. The preoperative temporal bone CBCT is a crucial component of the evaluation of PAT in patients candidate for surgical intervention of TMJ.

Keywords Pneumatization · Cone-beam computed tomography · Articular eminence · Temporomandibular joint

Introduction

Pneumatization is defined as the presence of air filled cavities in the bone [1–3]. The functional implications of temporal bone pneumatization are resonance minimization of the skull, reception of sound and function as an air reservoir of the middle ear [4]. Pneumatization of articular eminence which appears similar to mastoid air cells has been described first by Tyndall and Matteson as an asymptomatic radiolucent defect without any expansion or cortical destruction in the zygomatic process of temporal bone and articular eminence that does not extend beyond the zygomaticotemporal suture [5]. The existence of these air cavities near temporomandibular joint (TMJ) can be considered as a possible complicating factor during surgical procedures of TMJ and articular eminence [3, 6–12]. Furthermore, these pneumatizations may facilitate the spread of inflammation, tumors, infection, fractures or any other pathological processes into the joints because of reducing the bony resistance [1, 3, 7, 9, 12]. Otitis media and mastoiditis may extend into the joint through these air

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cells and may cause TMJ ankyloses consequently [1]. Moreover, during surgical intervention of the condyle and articular eminence, inadvertent penetration may occur which may lead to dural tear and cerebrospinal fluid leakage [13].

Different imaging modalities have been used for evaluating pneumatized articular tubercle (PAT) in previous studies [1, 8, 14, 15]. Two-dimensional (2D) radiographs have certain shortcomings [7]. Cone-beam computed tomography (CBCT), a new developed imaging technique, provides detailed images of maxillofacial region with high resolution and without magnifications or distortions [7, 13, 16]. Few studies have been conducted on the prevalence and classifications of PAT using CBCT [1, 7, 9, 13]. Therefore, the purpose of the present study was to determine the prevalence and pattern of distribution of PAT regarding to age, gender, laterality and grade of pneumatization.

Materials and Methods

The present study was approved by the institutional ethical committee. CBCT images of a total of 327 patients (177 males and 150 females) with a mean age of 30.51 ± 10.04 years (ranging from 7 to 65) who were referred to a private oral and maxillofacial radiology center for various reasons were evaluated. The patients with the history of trauma and/or surgical intervention in the TMJ and/or craniofacial abnormalities were not included in the study.

The CBCT images were obtained by the same clinician using New Tom VGi with a field of view of 15×15 cm, 110 kv, 3 mA and exposure time of 3.8 s. The presence of pneumatization was determined on the sagittal views by going through the scenes interactively. CBCT images with evidence of bony destruction or sclerosis, fluid retention and any pathologies or fractures in the glenoid fossa and articular eminence were excluded from the study.

All CBCT images were examined concomitantly by two researchers who were blind to the patients' age and gender. Pneumatization was identified on both sides as a well-defined radiolucent defect in the articular eminence and roof of the glenoid fossa, posterior to the zygomaticotemporal suture, as described by Tyndall and Matteson [5]. Patients' age and gender were recorded for all patients. In patients with pneumatization, the lacunarity, grade and laterality of PAT were also recorded. The pneumatization was classified into unilacunar and multilacunar. According to Tyndall and Matteson, unilacunar pneumatization has a single well-defined radiolucent small cavity and the multilacunar type has numerous small cavities. The degree of pneumatization on each side, left and right, was classified into 4 grades

Fig. 1 Sagittal CBCT images of pneumatized articular eminence. **a** Unilocular, **b** multilocular

according to the grading system presented by Al-Faleh and Ekram [17]. It was classified as grade 0 (pneumatization limited to the mastoid process), grade 1 (pneumatization between the mastoid process and the glenoid fossa), grade 2 (pneumatization between the deepest point of the glenoid fossa and the tip of the articular eminence) and grade 3 (pneumatization extending beyond the crest of the articular eminence) (Fig. 1).

The data were analyzed with SPSS software version 18 (SPSS Inc., Chicago, IL, USA). Chi-square test was used to compare the differences in pneumatization in regard to gender, type and grade. P value less than 0.05 was considered statistically significant (Fig. 2).

Results

We studied 654 temporal bones of 327 patients. Pneumatization was found in 251 out of 327 patients (76.7%) with a range of 9–65 years (mean age 30.31 ± 10.32). Of these patients, 139 (55.4%) were male and 112 (44.6%) were female. However, there was no significant difference in the prevalence of PAT between males and females. The pneumatization of 76 (30.3%) patients was unilateral with 35 on the left side and 41 on the right side, and in 175 (69.7%) patients, the pneumatization was bilateral. It was found that while 30 cases (7%) of pneumatization were

Fig. 2 Sagittal CBCT images different grades of pneumatized articular eminence. **a** grade 0, **b** grade 1, **c** grade 3, **d** grade 4

Table 1 Distribution of PAT according to gender, lacunarity and laterality

Gender	Lacunarity		Laterality		
	Unilacunar	Multilacunar	Unilateral		Bilateral
			L	R	
Male	15 (3.5%)	214 (50.3%)	24 (9.5%)	25 (10%)	90 (35.9%)
Female	15 (3.5%)	182 (42.7%)	11 (4.4%)	16 (6.4%)	85 (33.8%)
Total	30 (7%)	396 (93%)	35 (13.9%)	41 (16.4%)	175 (69.7%)

unilacunar, 396 cases (93%) were multilacunar. Table 1 represents the prevalence of pneumatization regarding to laterality and lacunarity. No statistically significant differences in the prevalence of PAT with respect to gender ($p = 0.794$) and lacunarity ($p = 0.783$) were found. Table 2 shows the distribution of various grades of pneumatization regarding to age, gender and lacunarity. The highest prevalence of PAT was that of grade 1, and the least incidence was that of grade 3. No significant relationship was found between the grade of pneumatization and gender (p value = 0.522). There was significant correlation between the grade of PAT and lacunarity (p value = 0.015). The multilacunar and unilacunar type of PAT was

significantly lower in patients with grade 3 than patients with grade 1 and 2.

Discussion

The present study provided information about the prevalence and extension of temporal bone pneumatization in the TMJ. Various imaging modalities have been proposed previously for the diagnosis of temporal bone pneumatization including plain film radiographs [3, 5, 8, 14, 17–20], CT [6, 10, 11, 21] and CBCT [1, 7, 9, 13]. Traditionally, 2D radiographs such as panoramic radiography,

Table 2 Distribution of gender, lacunarity and age between the PAT grade groups

Grade	1	2	3
<i>Gender</i>			
Male	159 (37.3%)	48 (11.3%)	22 (5.1%)
Female	140 (32.9%)	44 (10.3%)	13 (3.1%)
<i>Lacunarity</i>			
Unilacunar	28 (6.6%)	2 (5%)	0 (0%)
Multilacunar	271 (63.6%)	90 (21.1%)	35 (8.2%)
Age (years)	9–65 (mean: 30.26 ± 10.26)	13–57 (mean: 30.29 ± 9)	14–58 (mean: 30.8 ± 12.87)
Total	299 (70.2%)	92 (21.6%)	35 (8.2%)

transorbital radiography, submentovertical and reverse towns were employed for evaluating temporal bone pneumatization. However, these radiographs have inherent limitations, which compromise the diagnostic accuracy of these modalities because of inadequate visualization of PAT [3, 5, 8, 15]. Conventional radiographs provide 2D images which are subjected to superimposition of the skull base and zygomatic process on the TMJ [6, 7, 9, 16]. Three-dimensional (3D) images are considered as the gold standard for the evaluations of pneumatized air spaces of the skull [22]. 3D radiographs present the PAT without superimposition of surrounding structures. Furthermore, the medial portion of the articular eminence is not visible in panoramic radiographs and could be detectable only on 3D images [6, 16, 23]. Magnetic resonance imaging (MRI) is considered as a method of choice for the assessment of soft tissue [10, 14]. CBCT images provide high-quality images of temporal bone with higher spatial resolution, lower image artifacts, shorter scanning time and lower exposure [8, 13]. The resolution of CT allows air cavities as small as 2 mm to be differentiated from bone marrow. However, submillimeter resolution is provided in CBCT images [21]. Therefore, CBCT was used in the present study.

Although PAT is considered as a rare normal variation, the incidence of this phenomenon in the present study (76.7%) was more than that demonstrated in many previous studies. The prevalence of PAT, based on panoramic radiographs, has been reported to be between 1 and 6.2% in previous investigations [3, 7, 8, 18]. The diversity in the results of previous studies which used conventional radiographs might be due to the difficulties in visualization of the PAT because of its complex anatomy and superimposition of surrounding structures. However, the researches which assessed this phenomenon on CBCT images reported the frequency of 8% [16], 21.3% [7] and 65.8% [1]. The higher rate of prevalence of PAT reported by the mentioned studies may be associated with the use of CBCT images which increases the perceptibility of air cell detection. The

wide variation in the prevalence of PAT in studies which used the same detection method (CBCT) may be due to the difference in the sample size and the racial variation of the patients studied.

The findings of this investigation, consistent with almost all previous studies, showed no significant difference between males and females in the prevalence of PAT [6–9, 15, 24]. This finding is rational since this phenomenon is not sex linked. Only the study by Ilguy et al. [1] demonstrated significantly higher PAT in females than males. In the present study, a higher male prevalence of PAT with a sex ratio of 1.1:1 was found which was compatible with some researches [2, 6, 8, 9, 11, 12, 17, 19]. However, other studies reported a female preponderance with different sex ratios [1, 6, 14, 18].

It has been hypothesized that accessory air cell pneumatization starts after puberty [10]. In contrast to this statement, we detected PAT in a 9-year-old patient. In accordance with our results, some previous studies (Orhan et al. [18], Hofman et al. [24], Yavuz et al. [8]) reported PAT in sub-adult patients. The mean age of patients with PAT was 30.31 years old, which was very close to previous reports by Tyndall and Matesson [5], Miloglu et al. [16] and Yavuz et al. [8].

In the present study, like the results of most previous studies [2, 14, 18, 19], there was no correlation between pneumatization and laterality. In contrast to our findings, Laderia et al. [7] reported a significant correlation between pneumatization and laterality with a higher frequency on the left side. In this study, a much higher prevalence of multilacunar type of PAT was found, which was in agreement with the findings of Ilguy et al. [1], Laderia et al. [7] and Orhan et al. [2]. In contrast to our findings, most previous studies determined equal distribution of types of pneumatization (unilacunar and multilacunar) [3, 16, 18, 22]. The higher incidence of multilacunar type in this study might be related to the use of CBCT images, providing more clear images of classification of type of PAT. Most previous reports demonstrated a high incidence of unilateral PAT with an average

unilateral to bilateral ratio of 2:5:1. However, the present study showed a higher prevalence of bilateral cases which was in agreement with the study conducted by Ilguy et al. [1]. The ratio of bilateral to unilateral PAT was 1:8:1 in the present study.

There is wide variability in the extent of temporal bone pneumatization, ranging from complete acellularity to strong pneumatization which is governed by both genetic and environmental factors [19]. PAT is limited to the glenoid fossa in some patients, and in others it extends anteriorly to the articular eminence [22]. Previous studies used different specific anatomic landmarks as reference points for the classification of pneumatization patterns of temporal bone [6, 9, 13, 17]. The patterns of extension of pneumatization were divided into four groups according to the classification method of Al-Faleh and Ekram [17]. According to this grading system, only grades 2 and 3 of PAT were considered as an indicator of pneumatization of articular eminence because only in these 2 grades, the anterior mastoid air cells extended further in the articular eminence and zygomatic process. In the present study, 19.5% of the detected PATs were classified as grade 2 and 3 of pneumatization which is very close to the findings of Demirel et al. [9] who reported 18% of pneumatization as grade 2 and 3. The incidence of air cells extending anterior to the articular eminence crest (grade 3) was infrequent (5.4%). Al-Faleh and Ekram [17] reported that the prevalence of grade 2 and 3 was 21 and 4.9%, respectively. Zamaninaser et al. [19] reported the incidence of grade 2 and 3 of pneumatization only since they used panoramic radiographs which could not show the posterior part of glenoid fossa because of superimposition [19]. In this study, we found no significant correlation between pneumatization grade, age and gender. Similarly, no statistical relevance between grade and sex was declared in the study performed by Demirel et al. [9]. However, we found significant correlation between grade of pneumatization and lacunarity. The multilacunar and unilacunar type of PAT was significantly lower in patients with grade 3 than in patients with grade 1 and 2.

Although no treatment is necessary for PAT, the presence of PAT has been considered as a potential complicating factor for surgical procedures involving the mandibular condyle and the temporal bone [5, 6, 10, 12]. The roof of the glenoid fossa becomes more fragile and weakened in cases of PAT. Carter et al. [15] have pointed out that articular eminectomy is absolutely contraindicated in patients with large degree of PAT. Inadvertent penetration may also occur during surgical procedures which may consequently result in dural tear, cerebrospinal fluid leakage and intracranial infection or hemorrhage [6]. Moreover, the fractures of the skull may extend through these spaces and release air into the glenoid fossa [10].

Conclusion

The frequency of PAT in the present study was higher than previous studies. CBCT provides reliable and accurate information to determine the characteristics, the exact extension of pneumatization and its relationship to the adjacent structures. CBCT should be applied prior to the surgical manipulation of the joint in patients with PAT for accurate visualization and classification of the temporal bone pneumatization.

Compliance with Ethical Standards

Conflict of interest All authors declare that they had no conflict of interest.

Animal and Human Rights This article does not contain any studies with human participants or animals performed by any of the authors.

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