RESEARCH

Pneumatization of the articular eminence on cone beam computed tomography: prevalence, characteristics and a review of the literature

O Miloglu*, AB Yilmaz, E Yildirim and HM Akgul

Department of Oral Diagnosis and Radiology, Faculty of Dentistry, Ataturk University, Erzurum, Turkey

Objectives: The aim of this study was to determine the prevalence and characteristics of pneumatized articular eminence (PAT) by cone beam CT (CBCT) and to present a review of the PAT literature.

Methods: A retrospective study was performed using sagittal and coronal CBCT images of 514 patients in the Department of Oral and Maxillofacial Radiology, Ataturk University, Turkey. Age and gender were recorded for all patients and, for the cases of PAT, laterality and types were also recorded. The χ^2 test was used.

Results: Of the 514 patients, 41 (8.0%) had PAT, of whom 25 were female (61.0%) and 16 were male (39.0%). This difference was not statistically significant ($P > 0.05$). The age range of the patients with PAT was 15–62 years (mean 30.6 ± 11.4). Of the 41 patients, 31 (75.6%) had unilateral and 10 (24.4%) had bilateral PAT. 17 (41.5%) PATs were unilocular and 24 (58.5%) were multilocular.

Conclusions: It is possible that PAT is a more frequent condition than is commonly perceived. In differential diagnosis of suspected cases or in cases for which surgical treatment is planned, panoramic radiographs should be supplemented with CBCT.

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Introduction

Pneumatization refers to the development of air-filled cavities in bone. Tremble¹ reported the distribution of air cells in the temporal bone. Ten locations where accessory air cells could be found within the temporal bone were identified, including one area in the zygomatic process of the temporal bone.^{1,2} Tyndall and Matteson³ indicated that the pneumatized articular eminence (PAT) of the temporal bone has been identified as an asymptomatic radiolucent defect in the zygomatic process of the temporal bone with an appearance similar to mastoid air cells. Carter et al⁴ re-emphasized the occurrence of this phenomenon and named these air cells as zygomatic air cell defects in a similar fashion.

Air cells in the articular eminence of the temporal bone can be visible on panoramic radiographs and there are many case reports and prevalence studies on PAT, based on the use of these radiographies, in the current literature.^{3–22} Panoramic radiographs were considered the initial method to check for these defects because panoramic radiography is more advantageous than CT for visualization of the articular eminence owing to the low cost and radiation dose. However, since CT is not subjected to superimposition it exceeds the diagnostic accuracy of panoramic radiographs in the evaluation of temporal air spaces. Moreover, a less superficially located region, such as the medial portion of the articular eminence, may only be visible on CT. To our knowledge, a systematic study of the prevalence of PAT using cone beam CT (CBCT) has not previously been performed. In this study, we have attempted to determine the prevalence and characteristics

*Correspondence to: Assistant Professor Ozkan Miloglu, Department of Oral Diagnosis and Radiology, Faculty of Dentistry, Ataturk University, 25240, Erzurum, Turkey; E-mail: omiloglu@hotmail.com

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of PAT in an oral diagnosis and radiology clinic population using CBCT, and to present a review of the PAT literature.

Literature review

A detailed search of the reported literature was conducted using the Pubmed database for the years 1976 to 2009. The search strategy used the keywords “pneumatized articular eminence”, “pneumatized articular tubercle”, “zygomatic air cell defect”, “air cells”, “zygomatic arch” and “zygomatic process”. The citation lists from the included references were subsequently examined in an attempt to identify additional reports and a hand search was performed to find letters to the editor and opinion letters in the journals (Tables 1 and 2).

Materials and methods

We designed a retrospective cohort study composed of tomography images of 514 patients who presented to the Oral Diagnosis and Radiology service at the Ataturk University Dentistry Faculty between March 2008 and September 2009. Patients had been scanned with CBCT (NewTom FP QR-DVT 9000, 110 kVp, 15 mA, 36 s scan time, 5.4 s typical X-ray emission time, 17 cm diameter–13 cm height scan volume, Verona, Italy). Cases in which the zygomatic arch was not adequately seen for technical or anatomical reasons and the cases that had maxillofacial fracture history were not included in this study. On one of the axial views, the long axis of the examined condyle was traced, and the software generated lateral and frontal cross-sectional reconstructions perpendicular and parallel to the long axis of the condyle, respectively. The thickness of the image slices was 1 mm and the distance between slices was 1 mm for both lateral and frontal reconstructions. Images were reviewed on a digital imaging workstation. The images were examined by two investigators (one professor and one postgraduate dentomaxillofacial radiologist) at the same time. To check for the diagnostic reproducibility of the interreliability of the two investigators, 10% of the

radiographs assigned by them were randomly examined each day for three consecutive days. Examination of results using the Wilcoxon matched pairs signed-rank test showed no statistically significant differences between the two observers, indicating diagnostic reproducibility. In addition, 10% of the remaining radiographs were selected at random and re-evaluated twice by the same examiners 6 weeks after the first evaluation. Intraexaminer reproducibility was found to be 96% and 90%, respectively. Pneumatization of articular eminence was determined on both sides.

The age and gender were recorded for all patients and, for the cases of PAT, laterality and type were also noted. Diagnosis of PAT on the images was done only if unequivocal pneumatization of the articular eminence could be seen or if the defect was located in the articular eminence posterior to the zygomaticotemporal suture as a well-defined uni- or multilocular radiolucency. PAT was classified as unilocular or multilocular as in the study by Tyndall and Matteson.³ Unilocular PAT was identified as a single radiolucent oval defect with well-defined bony borders. Multilocular PAT was identified as numerous radiolucent small cavities.

The variables were analysed using the Statistical Package for Social Sciences (SPSS 11.5; Chicago, IL) program. The χ^2 test was used to determine potential differences in the distribution of lesions when stratified by gender. A *P*-value of < 0.05 was considered statistically significant.

Results

The average age of the 514 patients who were included in this study was 33.4 (SD 14.0) years and the age range was 4–85 years. There were 298 females (58.0%) and 216 males (42.0%) in the study population. The mean age of the females was 31.8 (SD 14.3) years with a range of 7–82 years while the mean age of the males was 35.7 (SD 13.3) years with a range of 4–85 years. The gender and age distribution of the study population is presented Table 3.

41 (8.0%) of 514 individuals had PAT, of whom 25 (61.0%) were females and 16 (39.0%) were males. The ages of the patients ranged from 5 to 62 years (mean 30.6 ± 11.4 years). Mean age was 29.1 years for females and 33.0 years for males. 31 cases (75.6%) had unilateral and 10 (24.4%) had bilateral PAT. Of the 31 unilateral

Table 1 Prevalence of pneumatized articular eminence in the literature

Author and year	Sample sizes	Number of cases	Gender		Age range (years)	Laterality		Review source	Prevalence (%)
			F	M		Unilateral	Bilateral		
Tyndall and Matteson, ³ 1985	1061	28	15	13	15–74	23	5	Panoramic	2.6
Kaugars <i>et al</i> , ¹⁴ 1986	784	8	7	1	32–69	4	4	Panoramic	1.0
Carter <i>et al</i> , ⁴ 1999	2734	40	20	20	17–83	32	8	Panoramic	1.5
Hofmann <i>et al</i> , ¹⁰ 2001	1084	20	11	9	7–87	16	4	Panoramic	1.8
Orhan <i>et al</i> , ⁷ 2005	1006	19	12	7	11–90	12	7	Panoramic	1.88
Orhan <i>et al</i> , ⁶ 2006	1049	17	8	9	7–16	10	7	Panoramic	1.62
Yavuz <i>et al</i> , ⁵ 2009	8107	83	41	42	10–75	56	27	Panoramic	1.03
Present series, 2010	514	41	25	16	4–85	31	10	CT	8.0

F, female; M, male

Table 2 Published case reports of pneumatized articular eminence in the literature

Author	n	Gender		Age	Laterality
		F	M		
Roser <i>et al</i> ²²	1	F		19	L
Kulikowski <i>et al</i> ²¹	1		M	19	R
Sewerin <i>et al</i> ²⁰	NA	NA		NA	NA
Kraut ¹⁷	1	NA		NA	L
Yuroska ¹⁶	1	F		18	L & R
Lindenmuth and Clark ¹⁹	1	F		23	R
Piette ¹⁵	1		M	15	L
	1		M	31	L
	1	F		29	L & R
Tyndall and Matteson ¹⁸	1		M	33	L & R
	1		M	22	R
	1	F		24	L
Randzio <i>et al</i> ¹³	1	NA		NA	NA
Deluke ¹²	1		M	16	L
Hasnaini ¹¹	1		M	18	L & R
Koudstaal and van der Wal ⁹	1	F		67	L
Stooper <i>et al</i> ⁸	1	F		53	R

F, female; M, male; L, left; R, right; NA, not available

cases, 14 (45.2%) were on the left and 17 (54.8%) were on the right side. 17 (41.5%) of the PATs were unilocular type, 24 (58.5%) were multilocular type (Table 3). The youngest patient with PAT was a 15-year-old female. Figures 1–3 show several PAT examples in different images.

Discussion

The classification of temporal bone pneumatization is complex. It can be divided into five regions, which in turn are subdivided into areas. The primary regions consist of the middle ear, mastoid (squamosmastoid), perilabyrinthine, petrous apex and accessory. The squamosmastoid region comprises two key areas of pneumatization, the mastoid antrum (including the central tract) and the periantral area. The tegmental periantral cells lie superior to the mastoid antrum and may pass upward into the squamosmastoid region or extend into the zygomatic arch producing the PAT.^{4,23}

Table 3 Details of detected pneumatized articular eminence (PAT) cases in present study

		n	PAT lesions	Prevalence (%)	χ^2	P-value
Gender	Female	298	25	8.4	0.16	0.7
	Male	216	16	7.4		
Age (years)	4–20	104	5	4.8		
	21–40	286	30	10.5		
	41–60	106	5	4.7		
	61–87	18	1	5.6		
Laterality	Unilateral		31	75.6		
	Bilateral		10	24.4		
Type	Unilocular		17	41.5		
	Multilocular		24	58.5		
	Total	514	41	8.0		

L, left; R, right

Figure 1 Bilateral pneumatized articular eminence example

The anatomical relationship of PAT to mastoid air cells is interesting. Perhaps PAT can be thought of as extensions of the mastoid air cells similar to extensions of the paranasal sinuses. Dentists are aware of alveolar and tuberosity extensions of the maxillary sinuses and the occasional extension of the sphenoid sinus superiorly into the dorsum sellae.³

There have been only a few studies on PATs in the literature. The prevalence of this phenomenon has been reported to be between 1.0% and 2.6%.^{3–7,10,14} All of the current studies were carried out on panoramic radiographs. The use of conventional panoramic radiographs to screen for PAT is expedient because the radiographs are obtained during routine examination of many patients. Conventional panoramic radiographs, however, have inherent problems, including a wide focal zone and superimposition of adjacent structures. High-resolution CT is considered the method of choice for the assessment of bony structures and air spaces in the base of the skull. Since CBCT is not subject to superimposition, it exceeds the diagnostic accuracy of panoramic radiographs in the evaluation of temporal air spaces. Although the air cells adjacent to the temporomandibular joint (TMJ) may be visible on panoramic radiographs, a less superficially located

Figure 2 Unilocular and multilocular pneumatized articular eminence examples

Figure 3 Coronal and three-dimensional images of pneumatized articular eminence. Arrow indicates an area of pneumatization

region such as the medial portion of the articular eminence may be visible on only CT.^{23,24} Therefore, CBCT images were used to ensure high accuracy in this prevalence study of PAT. In our study, the prevalence of PAT was detected as 8.0%, and this rate was higher than suggested in literature. Groell and Fleischmann²⁴ detected an articular eminence with air spaces in 12 of 100 patients who had undergone high-resolution axial CT.

Current reports in the literature reveal an average female-to-male ratio of 1.1:1. The female-to-male ratio in the present study was found to be 1.6:1. However, the difference between females and males was not statistically significant and this was consistent with the literature. The mean age of patients with PAT found by Carter *et al*,⁴ Kaugars *et al*,¹⁴ Yavuz *et al*,⁵ Hoffmann *et al*¹⁰ and Orhan *et al*⁷ was 49.6, 45.9, 30.0, 43.2 and 36.6 years, respectively. The mean age was 30.6 years in the present study, similar to that found by Tyndall and Matteson's³ (32.5 years), owing to the young adult population in both investigations. The age range of patients with PAT was wide (4–85 years), similar to Carter *et al*⁴ (4–93 years), Yavuz *et al*⁵ (10–75 years), Hoffmann *et al*¹⁰ (7–87 years), Orhan *et al*⁷ (11–90 years) and Tyndall and Matteson³ (15–74 years). However, Kaugars *et al*'s¹⁴ series was relatively more constricted (32–69 years). In our study, the youngest patient reported with PAT was 15 years old. Hollingshead²⁵ pointed out that the accessory air cells begin to pneumatize after puberty and achieve full size after several years, as is the case with proper mastoid air cells. In contrast to this statement, Hoffman *et al*,¹⁰ Orhan *et al*⁷ and Yavuz *et al*⁵ detected cases of PAT in patients aged 7, 11 and 10 years and therefore before the second half of the second decade of life. Orhan *et al*⁶ found PAT in 9 patients before puberty with a mean age of 8.8 years and an age range of 7–11 years. Pneumatization of accessory air cells had begun before puberty, which is in contrast with general opinion.

A current literature review revealed that the unilateral to bilateral ratio was 2.5:1. In the present study, a ratio of 3:1 was observed, which is close to that reported in the literature. Tyndall and Matteson³ found

15 multilocular and 17 unilocular PAT cases, Orhan *et al*⁷ reported 16 multilocular and 10 unilocular PAT cases, and Yavuz *et al*⁵ detected 66 multilocular and 44 unilocular PAT cases in their series. In our study, we found that 17 (41.5%) of PATs were unilocular and 24 (58.5%) of PATs were multilocular.

PAT must be differentiated from other radiolucencies within the zygomatic arch, including aneurysmal bone cyst, haemangioma, giant cell tumour, eosinophilic granuloma, fibrous dysplasia and metastatic tumour deposits.^{3,4,7,10,14,18,26} PAT can be detected incidentally on radiographs as an asymptomatic radiolucency with non-expansile characteristics. All of the other entities in the differential diagnosis have been reported to be characterized by painful enlargement of the cheek and seen radiographically as expansile, destructive lesions. CT images can be considered where there is a differential diagnosis of suspected cases.

PAT is important because it facilitates the spread of various pathological processes into the joint such as tumours, inflammation or fractures owing to minimal resistance. The presence of air in the TMJ has been shown to be associated with acute temporal bone fracture,²⁷ and surgical procedures of the temporal bone affected by PAT can be complicated.^{7,24,27–29} During any TMJ surgery in patients with PAT, perforation can occur owing to firm dissection or forceful flap retraction. The treatment of some TMJ dysfunction requires fossa-eminence prostheses to correct the effects of the pathology. When these are placed between the condyle and skull base, perforation may occur because of the screws.^{5,30} Therefore, CT must be performed to determine exact size and the relationship to adjacent tissue of PAT cases detected in the panoramic radiographs before TMJ surgery.

Treatment of PAT is unnecessary. If pneumatization without any ipsilateral symptomatology is seen in the articular eminence coincidentally, it should be kept under observation. The presence of PAT can be a contraindication for performing eminoplasty or eminectomy to treat recurrent chronic mandibular dislocation.^{4,5,7,14,17,19,21} Lindenmuth and Clark¹⁹ indicated that such surgical considerations dictate that an

awareness of pneumatization of the articular eminence be part of our anatomical knowledge.

In conclusion, our results suggest that the prevalence of PAT is higher than has been previously believed. Diagnosis of this anomaly has become incidental, since it does not present any clinical symptoms. Such prevalence studies, particularly from developing countries, will provide useful information to understand better the

nature and different clinical features of uncommon entities.

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