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Research Report

Evaluation of the relationship between pneumatization of mastoid process, articular eminence and glenoid fossa on CBCT

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ABSTRACT

Background: *Pneumatization refers to air-filled spaces within the bone. The studies about articular tubercle/eminence pneumatization were only few in numbers with unclear information regarding the data on pneumatization in this region. PAT may become predisposed to the spread of inflammatory processes along the temporomandibular joint. Traumatic occlusion, one of the triggers of the TMJ inflammatory process, can occur during conservative dentistry treatment which requires the attention of a dentist to avoid TMJ disorder.* ***Purpose:*** *This study aimed to evaluate the prevalence, characteristics and relationships of mastoid process pneumatization (MPP), articular tubercle/eminence pneumatization (PAT), and glenoid fossa pneumatization (PGF) in one population in Turkey by using cone-beam computed tomography (CBCT).* ***Methods:*** *In total, 739 of CBCT images were examined retrospectively. The prevalences of the pneumatization by age, gender, laterality and locularity were detected. Independent t-test and the chi-square test for the significance of differences between variables.* ***Results:*** *Apneumatic type MPP was detected in 3.1% of cases, partial pneumatic type MPP in 33.6%, pneumatic type MPP in 63.3% of cases. PGF was detected in 28.0% of the sides and PAT in 23.7% of cases. There was no statistically significant relationship found between the presence of PAT and PGF with gender and age ($p>0.05$). In 45 cases with a pneumatic type MPP, PGF was not observed in any of them, while no PAT was determined in 44 (97.8%) of 45 cases. Pneumatic type mastoid was detected in 309 (92.8%) of 333 cases with multilocular PGF and in 89 (82.4%) of 108 cases with unilocular PGF. There was a statistically significant relationship found between MPP and PAT with PGF types ($p<0.05$).* ***Conclusion:*** *It is necessary to detect these air gaps before TMJ surgery to prevent complications during and after the operation. It will be more accurate if PAT and PGF are assessed on 3D technics than on 2D radiographs. Relationship between MPP pneumatization degree and PAT and PGF can help for understanding the features and functions of PAT and PGF***,** *it has been considered useful to also determine the prevalence and characteristics of PAT in a population of traumatic patients of occlusion treatment and to examine the possible relationship between traumatic types of occlusions and pneumatized articular eminence.*

Keywords: *Pneumatization; mastoid process; articular tubercle; glenoid fossa; cone-beam computed tomography*

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INTRODUCTION

The mastoid process of the temporal bone is the most pneumatic bone in the neck and head area. So far, many studies on mastoid process pneumatization (MPP) have been done. MPP is reported to have similar functions to paranasal sinuses, such as to protect the skull from external influences and reducing skull mass.[1,2] Several studies investigating the extent of mastoid aeration in patients with temporal bone fractures have suggested that the pneumatic cells within the temporal bone act as shock absorbers during traumatic events, thereby lowering the likelihood of fractures.[3,4] Although it has not been confirmed yet, it is accepted by many authors that there may be a correlation between some ear diseases such as chronic otitis and secretory otitis, and MPP.[4–6] It is known that these air cells facilitate the spread of inflammation, fracture, tumor and various pathologies. For this reason, it is substantial to define their existence before operation in this way the required precautions can be taken before surgery and the optimal surgical procedures can be performed.[5]

Pneumatized articular eminence/tubercle (PAT) was first described in 1985 by Tyndall and Matteson as accessory air cells that develop in the root of the zygomatic arch and the articular tubercle of the temporal bone, resembling air cells found in ethmoid bone and the mastoid process.[7] If the pneumatization is identified on a radiograph, it is usually referred to as PAT or pneumatization of the

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glenoid fossa (PGF)depending on the location.[8] Both PAT and PGF appear as asymptomatic radiolucent defects in the process of zygomatic of the temporal bone, alike in appearance to mastoid air cells. There is a possibility of these pneumatization to extend to the articular eminence but do not surpass the zygomaticotemporal suture, nor do they cause cortical destruction or expansion of the zygoma.[7,9–11] PAT may take part in the spread inflammatory processes within the temporomandibular joint. Traumatic occlusion is one of the factors that can trigger TMJ disorders. Occlusion refers to the process of closing or being closed, together with the static relationship between the biting or chewing surfaces of the maxillary and mandibular teeth or their substitutes. However, when assessing or recording occlusion, both dynamic and static interactions within the masticatory system are generally considered together. Essentially, occlusion encompasses the relationship between the movements of the mandible and opposing chewing surfaces of the teeth and, which are influenced by the temporomandibular joint and associated orofacial muscles. Thus, occlusion involves a complex interaction of anatomical and physiological factors. Proper occlusal adjustment is essential to restore normal function and maintain balance within the masticatory system. Such dysfunction can also be expressed in the form of disorders affecting the masticatory muscles or the temporomandibular joint (TMJ). Dental occlusion plays a pivotal role in the function of the masticatory system, influencing mandibular posture at rest, mandibular movement, swallowing, mastication, the loads applied to the TMJ, and the trajectories involved during maximal intercuspal occlusion. The TMJ and dental occlusion are connected by nature, "for better or for worse," although a direct correlation between all TMJ disorders and occlusion remains a topic of debate.

During dental examinations, PGF and PAT can be observed on panoramic radiographs. However, panoramic radiographs, which are commonly used in dentistry, have some limitations, such as producing only two-dimensional imaging, causing image magnifications, and being unable to prevent superimposition. [12,13]. While computed tomography (CT) devices, can get control of the drawbacks of traditional projections by offering three-dimensional imaging, their use in dentistry is limited due to high radiation exposure, high cost, and the lengthy time required for image acquisition. One of the main benefits of cone beam computed tomography (CBCT), developed in the early 1990s, is its ability to expose patients to a lower radiation dose compared to CT, thanks to the use of a low-energy fixed anode tube.[14] The aim of this study is to analyze the distribution of pneumatization types of mastoid process, glenoid fossa and articular tubercle by gender and age in one population in Turkey with CBCT and also to investigate the relationship between MPP, PAT and PGF.

MATERIALS AND METHODS

Ethics Committee of Gaziantep University Clinical Research on 20.06.2018 approved this research with approval number 2018/105. The research involved a retrospective analysis of CBCT images from patients who are in the age of 18 and older who visited the Gaziantep University, Faculty of Dentistry, Department of Dentomaxillofacial Radiology between 2015 and 2018 for various reasons. The pneumatization of the mastoid process, glenoid fossa, and articular eminence was examined in these images. CBCT images were acquired from the Planmeca ProMax 3D Mid (Planmeca Oy, Helsinki, Finland) device with 16x9 and 16x16 cm FOV, and 90 kVp, 12 mA, 14-27 sec irradiation parameters. Images configured with a 0.4 mm^3 voxel resolution with the Planmeca Romexis Viewer (Helsinki, Finland) program were analyzed on the UltraSharp LED TFT 24-inch monitor (Dell, Dell Inc. Round Rock, TX, USA).

CBCT images of 18-year-old patients and older were covered in the study, provided they had no lesions, defects, pathologies, jaw fractures, prior surgical procedures in the examined area, or systemic and genetic diseases that could influence the study. Low resolution images, incomplete visualization of the examined region, or artifacts caused by the patient or the device were excluded.

CBCT images from 739 patients aged 18 to 88 years were analyzed. The temporal bone regions examined for pneumatization, comprising glenoid fossa, the mastoid process, and articular eminence, were assessed using multiplanar images acquired from axial, sagittal, and coronal planes for both the right and left sides.

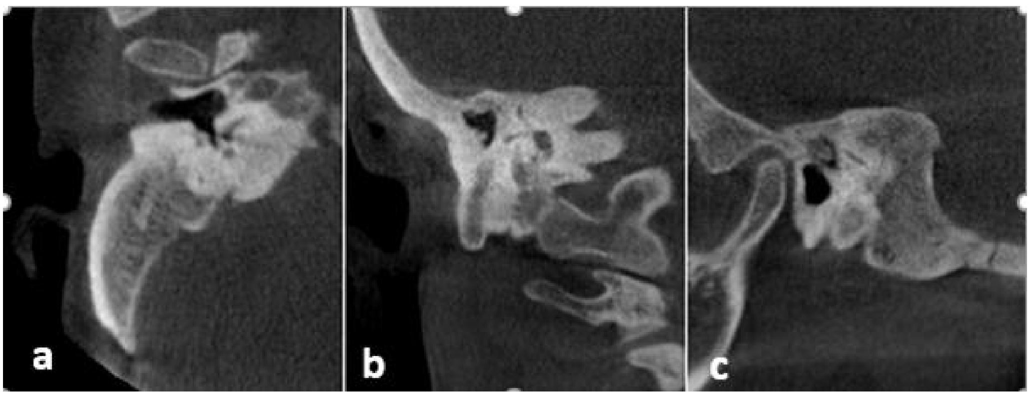

Figure 1. The images of CBCT of apneumatic mastoid process in axial (a), coronal (b) and sagittal (c)sections.

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MPP in the images was categorized based on air cell density as apneumatic (Figure 1), partially pneumatic (Figure 2), and pneumatic (Figure 3), with its distribution analyzed by age and gender. Additionally, radiolucent formations resembling mastoid air cells, which did not expand beyond the zygomaticotemporal suture or cause cortical defects and expansion in the zygoma, were examined in articular eminence regions and the glenoid fossa.

PAT was considered as one classification of a radiolucent image if it was located in the articular eminence region, and as PGF if it was situated in the roof of the glenoid fossa. Meanwhile, the unilocular type was categorized as a single, well-defined, rounded radiolucent defect. Whereas, multiple radiolucent cavities were classified as the multilocular type of pneumatization. Cases of unilocular/multilocular PGF (Figure 4) and unilocular/multilocular PAT (Figure 5) were documented by analyzing the images. Additionally, the correlation between PAT and PGF, which are considered as the enlarge od mastoid air cells, and MPP was also examined.

The re-evaluation of the 20% images was held by the observer after two weeks to assess intra-observer consistency. The agreement in radiographic evaluations was measure by using the kappa test. In determining the data if it is conformed to a normal distribution, he Kolmogorov-Smirnov was applied to the process. An independent t-test was conducted to seek the difference of variables between the two groups, while chi-square test was used to analyze the relationships between categorical variables. The SPSS for Windows version 22.0 (Armonk, NY: IBM) was performed in the process of statistical analyses, with a significance level stood at $p < 0.05$.

RESULTS

The assessment of CBCT images demonstrated excellent intra-observer agreement (kappa = 0.92). In this study, a total of 739 CBCT images (1478 sides) from 336 female patients (45.5%) and 403 male patients (54.5%) were analyzed. The age of the cases ranged from 18 to 88 years, with a mean age of 43.66 ± 15.73 years (44.62 ± 15.52 in females and 42.51 ± 15.93 in males).

Distribution the types of MPP, PGF and PAT by gender on both sides (right and left) is shown in Table 1. The most followed type was recorded as pneumatic type mastoid

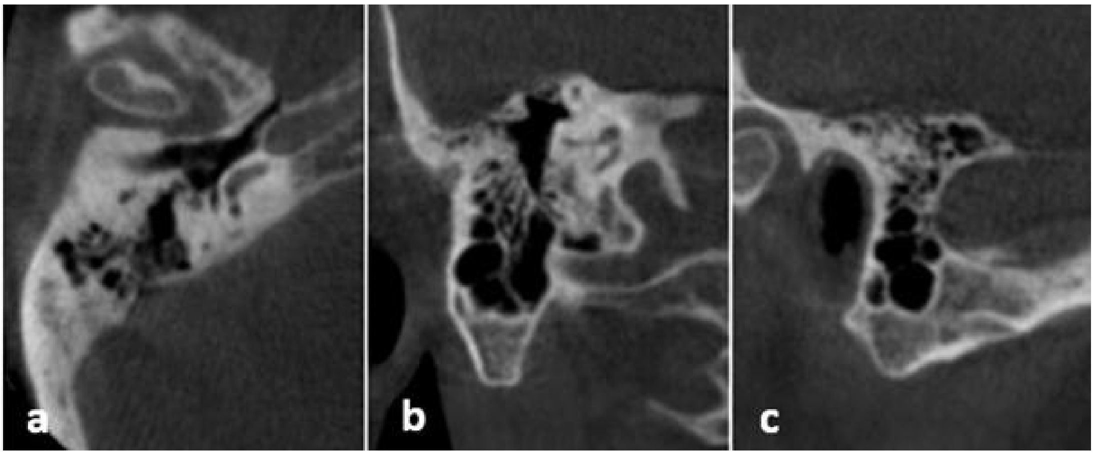

Figure 2. The images of CBCT of partial pneumatic mastoid process in axial (a), coronal (b) and sagittal (c)sections.

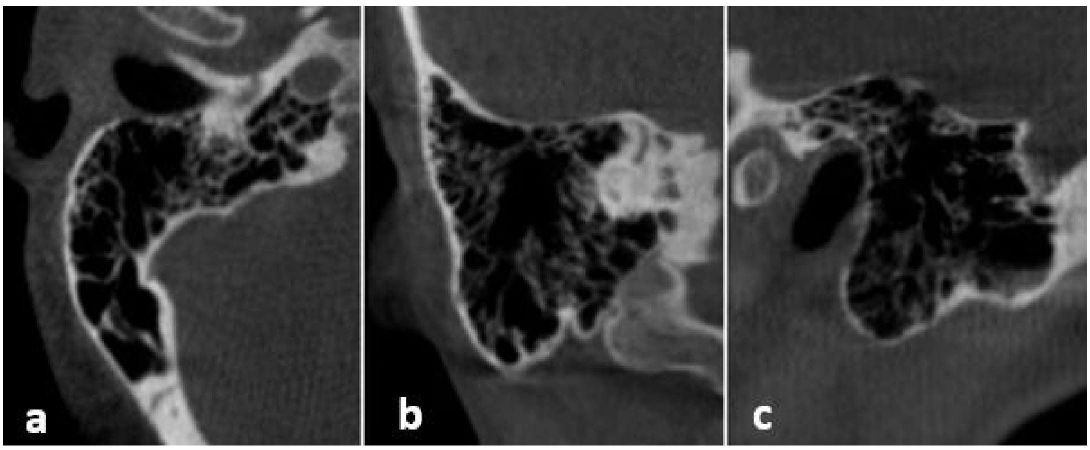

Figure 3. The images of CBCT of pneumatic mastoid process in axial (a), coronal (b) and sagittal (c) sections.

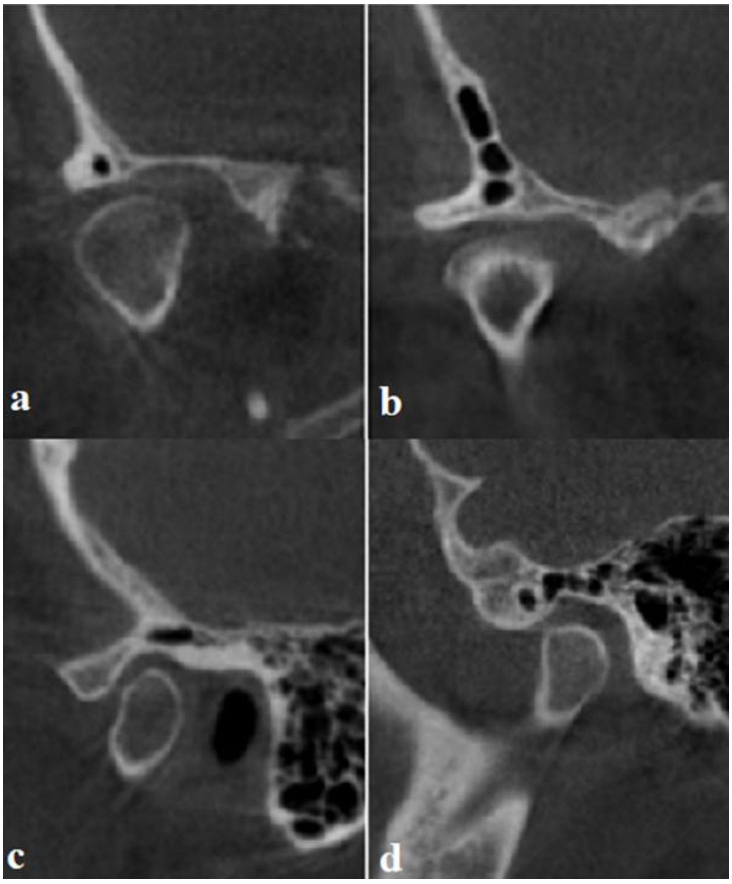

Figure 4. In CBCT sagittal sections; unilocular (a) / multilocular (b) PGF image and in CBCT coronal sections; unilocular (c) / multilocular (d) PGF image.

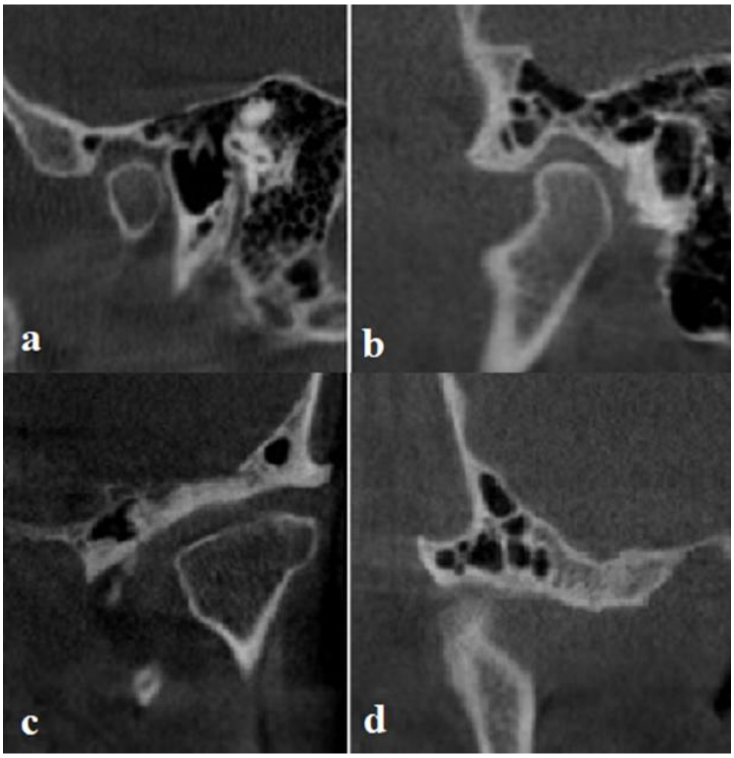

Figure 5. In CBCT sagittal sections; unilocular (a) / multilocular (b) PAT image and in CBCT coronal sections; unilocular (c) / multilocular (d) PAT image.

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Table 1. Distribution of MPP, PGF and PAT types by gender on both sides (right and left)

MPP	RIGHT				LEFT			
	Male n (%)	Female n (%)	Total n (%)	p	Male n (%)	Female n (%)	Total n (%)	p
Apneumatic	12 (1.6)	12 (1.6)	24 (3.2)	0.119	12 (1.6)	9 (1.2)	21 (2.8)	0.212
Partial Pneumatic	145 (19.6)	97 (13.1)	242 (32.7)		150 (20.3)	105 (14.2)	255 (34.5)	
Pneumatic	246 (33.3)	227 (30.7)	473 (64.0)		241 (32.6)	222 (30.0)	463 (62.7)	
Total	403 (54.5)	336 (45.5)	739 (100.0)		403 (54.5)	336 (45.5)	739 (100.0)	
PGF	RIGHT				LEFT			
	Male n (%)	Female n (%)	Total n (%)	p	Male n (%)	Female n (%)	Total n (%)	p
Multilocular	84 (11.4)	69 (9.3)	153 (20.7)	0.449	93 (12.6)	87 (11.8)	180 (24.4)	0.651
Unilocular	25 (3.4)	29 (3.9)	54 (7.3)		29 (3.9)	25 (3.4)	54 (7.3)	
Absent	294 (39.8)	238 (32.2)	532 (72.0)		281 (38.0)	224 (30.3)	505 (68.3)	
Total	403 (54.5)	336 (45.5)	739 (100.0)		403 (54.5)	336 (45.5)	739 (100.0)	
PAT	RIGHT				LEFT			
	Male n (%)	Female n (%)	Total n (%)	p	Male n (%)	Female n (%)	Total n (%)	p
Multilocular	60 (8.1)	58 (7.8)	118 (16.0)	0.679	65 (8.8)	66 (8.9)	131 (17.7)	0.414
Unilocular	24 (3.2)	19 (2.6)	43 (5.8)		23 (3.1)	21 (2.8)	44 (6.0)	
Absent	319 (43.2)	259 (35.0)	578 (78.2)		315 (42.6)	249 (33.7)	564 (76.3)	
Total	403 (54.5)	336 (45.5)	73 (100.0)		403 (54.5)	336 (45.5)	739 (100.0)	

Table 2. Descriptive characteristics of PAT and PGF based on the distribution of gender

	PGF				PAT			
	Male n (%)	Female n (%)	Total n (%)	p	Male n (%)	Female n (%)	Total n (%)	p
Present	137 (18.5)	160 (21.7)	297 (40.2)	0.279	112 (15.2)	126 (17.1)	238 (32.2)	0.162
Absent	199 (26.9)	243 (32.9)	442 (59.8)		224 (30.3)	277 (37.5)	501 (68.7)	
Unilocular	54 (12.2)	54 (12.2)	108 (24.5)	0.592	40 (11.9)	47 (14.0)	87 (25.9)	0.511
Multilocular	156 (35.8)	177 (39.7)	333 (75.5)		124 (36.9)	125 (37.2)	249 (74.1)	
Unilateral	64 (21.5)	89 (30.0)	153 (48.5)	0.295	60 (17.9)	80 (23.8)	140 (58.8)	0.249
Bilateral	73 (24.6)	71 (23.9)	144 (51.5)		52 (15.5)	46 (13.7)	98 (41.2)	
Unilateral Right	25 (16.3)	38 (24.9)	63 (41.2)	0.457	25 (17.9)	38 (27.1)	63 (45.0)	0.353
Unilateral Left	39 (25.5)	51 (33.3)	90 (58.8)		35 (25.0)	42 (30.0)	77 (55.0)	

Table 3. Descriptive characteristics of PAT and PGF based on the average age (mean) of the cases

	PGF		PAT	
	Total (Mean±SD)	p	Total (Mean±SD)	p
Present	42.51±15.94	0.031*	41.97±14.37	0.017*
Absent	44.99±16.67		44.47±16.30	
Unilocular	38.59±13.46	0.001*	38.51±15.56	0.001*
Multilocular	42.31±14.10		42.93±12.60	
Unilateral	42.53±14.04	0.016*	42.40±16.19	0.133
Bilateral	40.80±14.01		41.35±11.34	
Unilateral Right	42.52±14.21	0.327	41.00±15.69	0.324
Unilateral Left	42.53±14.00		43.55±16.59	

Table 4. The relationship between MPP and PAT and PGF types

		MPP				
		Apneumatic n (%)	Partial pneumatic n (%)	Pneumatic n (%)	Total n (%)	p
PGF	Multilocular	0 (0.0)	24 (7.2)	309 (92.8)	333 (100.0)	0.001*
	Unilocular	0 (0.0)	19 (17.6)	89 (82.4)	108 (100.0)	
	Absent	45 (4.3)	454 (43.8)	538 (51.9)	1037(100.0)	
PAT	Multilocular	1 (0.4)	44 (17.7)	204 (81.9)	249 (100.0)	0.001*
	Unilocular	0 (0.0)	21 (24.1)	66 (75.9)	87 (100.0)	
	Absent	44 (3.9)	432 (37.8)	666 (58.3)	1142 (100.0)	

Table 5. Relationship between PAT and PGF types

		PGF				
		Multilocular n (%)	Unilocular n (%)	Absent n (%)	Total n (%)	p
PAT	Multilocular	159(63.9)	20(8.0)	70(28.1)	249(100.0)	0.001*
	Unilocular	22(25.3)	15(17.2)	50(57.5)	87(100.0)	
	Absent	152(13.3)	73(6.4)	917(80.3)	1142(100.0)	

process in both sides and genders. Pneumatic type MPP was seen in 246 (33.3%) men and 337 (30.7%) women on the right side and in 241 (33.3%) men and 222 (30.7%) women on the left side. No significant correlation was found between MPP types and gender ($p>0.05$).

PGF was observed in 207 (28.0%) cases, including 153 (20.7%) multilocular and 54 (7.3%) unilocular. On the left side, PGF was determined in a total of 234 (31.7%) cases, including 180 (24.4%) multilocular and 54 (7.3%) unilocular. On the right side, PGF was detected in a total of 261 (21.8%) cases, including 118 (16.0%) multilocular and 43 (5.8%) unilocular. PAT was observed in a total of 175 (23.7%) cases on the left side, including 131 (17.7%) multilocular and 44 (6.0%) unilocular. PAT was followed in a total of 157 (21.8%) cases on the right side, including 118 (16.0%) multilocular and 43 (5.8%) unilocular. No statistically significant relationship was found between PAT and PGF types and gender ($p>0.05$).

The descriptive features of PAT and PGF by gender distribution is presented in Table 2. Among the 739 cases, PGF was identified in 297 (40.2%) cases, while PAT was observed in 238 (32.2%) cases. There was no significant correlation between gender and the presence of PAT or PGF ($p > 0.05$). Of the detected PGFs, 153 (48.5%) were unilateral, and 144 (51.5%) were bilateral. Similarly, among the identified PAT cases, 140 (58.8%) were unilateral, and 98 (41.2%) were bilateral. No significant correlation was found between gender and whether the cases were unilateral or bilateral. Regarding the laterality of unilateral cases, 63 (41.2%) of unilateral PGFs were located on the right side, while 90 (58.8%) were on the left side. For unilateral PAT, 63 (45.0%) cases were on the right side, whereas 77 (55.0%) were on the left. The presence of unilateral PAT and PGF on either the right or left side did not show a great difference ($p > 0.05$).

The relationship between the mean age of the cases and the descriptive characteristics of PAT and PGF is presented in Table 3. The mean age of cases with PGF was 42.51 ± 15.94, while for those without PGF, it was 44.99 ± 16.67. A significant association was found between the presence of PGF and mean age ($p < 0.05$). The mean age of cases with unilocular PGF (38.59 ± 13.46) was significantly lower than that of patients with multilocular PGF (42.31 ± 14.10) ($p < 0.05$). Similarly, the mean age of patients with bilateral PGF (40.80 ± 14.01) was notably lower than that of patients with unilateral PGF (42.53 ± 14.04) ($p < 0.05$). Regarding PAT, the mean age of patients with PAT (41.97 ± 14.37) was significantly lower than those without PAT (44.47 ± 16.30) ($p < 0.05$). Additionally, the difference in mean age between cases with unilocular PAT (38.51 ± 15.56) and multilocular PAT (42.93 ± 12.60) was statistically remarkably ($p < 0.05$). However, no significant relationship was found between the unilateral or bilateral presence of PAT and mean age ($p > 0.05$).

The relationships between MPP, PAT and PGF types are shown in Table 4. In 45 cases with apneumatic type MPP, PGF was not observed in any of them, while no PAT was determined in 44 (97.8%) of the 45 cases. Pneumatic type mastoid was detected in 309 (92.8%) of 333 cases with multilocular PGF and 89 (82.4%) of 108 cases with unilocular PGF. Pneumatic type mastoid was found in 204 (81.9%) of 249 cases with multilocular PAT and 66 (75.9%) of 87 cases with unilocular PAT. There was a notable relationship found between MPP, PAT and PGF types ($p <0.05$).

The correlation between PAT and PGF types is presented in Table 5. Among the 917 cases without PGF, PAT was not observed in 81.5% of them. PGF was identified in 179 (71.9%) out of 249 patients with multilocular PAT and in 37 (42.5%) out of 87 patients with unilocular PAT. A great significant association was found between PGF and PAT ($p < 0.05$).

DISCUSSION

The MPP in temporal bone has functions such as reducing skull mass, protecting the skull from external influences and reducing the incidence of fractures by absorbing the impact during a traumatic event.[1,2,4] It is thought that PAT and PGF are also extensions of MPP and have similar features and functions related to MPP.[7] Knowing the properties of PAT and PGF and their relationship with MPP is important for us to have more information about the functions and benefits of these structures. However, although there are many studies about MPP in the literature, there are not enough studies about PAT and PGF. In our study, the prevalence and characteristic features of PAT and PGF were evaluated by CBCT and examined according to age and gender. It was also investigated whether there is a relation between MPP and PAT and PGF. According to what we know, this study is the first study to assess the correlation between MPP, PAT and PGF.

There have been many studies about MPP. In a study where evaluated the relationship between Bell paralysis and MPP, found that there was no great difference between the pneumatization volumes of patients with Bell paralysis and healthy patients.[15] Apuhan et al.[16] was suggested that there was no developmental relationship between the volume of adenoid tissue and the volume of mastoid air cells in their study. Gencer et al.[17] investigated the effect of nasal septum deviation on MPP and they stated that the mastoid cell volume tended to be larger on the contralateral side of the deviation. Hindi et al.[18] assessed whether there is a relation between ethmoid and sphenoid sinus and MPP. They concluded that while there was a positive relationship between sphenoid sinus volume and MPP, no correlation was found between the ethmoid sinus and MPP.

The MPP system has been classified as pneumatic, partial pneumatic, apneumatic in this study and the rates were determined as 63.4% pneumatic, 33.6% partial pneumatic and 3.0% apneumatic type MPP. Resorlu et al.[19] stated these that as 59.3% pneumatic, 23.4% partial pneumatic and 17.3% apneumatic type. Baklacı et al.[20] reported pneumatic type as 31.2%, partial pneumatic type as 42.6% and apneumatic type as 26.2%. Toros et al.[21]

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found that 36.7% were pneumatic type, 27.6% were partial pneumatic type and 35.7% were apneumatic type.

Kang et al.[4] classified the MPP as poor, medium, good and very good according to the number of pneumatic air cells in their studies in which they evaluated the effect of the degree of MPP on temporal bone fractures. Of the examined mastoid processes were 5.6% weak pneumatic, 25.9% medium pneumatic, 25.9% good pneumatic and 42.6% very good pneumatic. Ertugrul et al.[22] noted that poor pneumatic type was 26.1%, medium pneumatic type 20.4%, good pneumatic type 23.1%, very good pneumatic type 30.4%. Similar to our results, Resorlu et al.[19] and Kang et al.[4] concluded that the most common type was the pneumatic type and the least observed type was apneumatic type. In the studies of Toros et al.[21], Baklacı et al.[20] and Ertuğrul et al.[22], The apneumatic type was reported at higher rates in previous studies compared to this one. These variations in results are likely attributed to differences in classification systems and imaging techniques employed.

In this study, PGF was identified in 40.2% of cases, while PAT was observed in 32.2% of cases. Consistent with our findings, Groell and Fleismann[23], Ladeira et al.[8], Shamshad et al.[24], Buyuk et al.[25], and Salli et al.[26] also reported a higher prevalence of PGF compared to PAT (Table 6). The similarity in results across studies may be attributed to the anatomical proximity of the glenoid fossa to the mastoid process compared to the articular eminence. Given the significant association between MPP and both PAT and PGF, along with findings from previous research, it can be suggested that PAT and PGF may represent extensions of mastoid air cells. However, further studies are necessary to explore this topic in greater detail. A clearer understanding of this relationship will assist researchers to identify the functions and potential advantages of pneumatization in other anatomical areas.

Studies utilizing panoramic radiography have reported the prevalence of PAT to range between 1.03% and 3.42%, whereas studies using CT and CBCT have indicated a prevalence of 8% to 51.8%. In the current study, the prevalence of PAT appeared to be 32.2%, in accordance with the findings of CBCT investigations. Given the results of this study and the significant differences in prevalence observed between two-dimensional and three-dimensional imaging techniques in the literature, it can be inferred that plain radiographs are inadequate for detecting pneumatization. Groell and Fleischmann[23] pointed out that deeper structures, such as the glenoid fossa and the medial portion of the articular eminence, may not be seen on panoramic radiographs, making CT a more reliable diagnostic tool. Jadhav et al.[27] highlighted that CBCT, due to its higher spatial resolution, surpasses CT in analyzing air and bone gaps where high contrast resolution is not essential. Laderia et al.[8] emphasized the superior diagnostic value of CBCT over panoramic radiography for evaluating air spaces within the temporal bone. Likewise, Ilguy et al.[28] reported that CBCT provides precisely and reliable results to determine the exact location of air cells, the type of pneumatization, and its relationship with adjacent structures.

Articular eminence of the temporal bone is an anatomical structure which can be clearly assessed on panoramic radiography. Nevertheless, since the glenoid fossa in the temporal bone cannot be seen in panoramic radiography and CBCT technique relatively is a new imaging modality, very limited number of studies have been done on PGF. In the literature, the prevalence of PGF notified by Groell and Fleischmann[23], Salli et al.[26], Ladeira et al.[8], Buyuk et al.[25], Ilguy et al.[28], Mosavat and Ahmadi[29] were 51%, 47.1%, 38.3%, 29.6%, 11.7% and 5.9%, respectively. In our study, PGF was observed in 40.2% of the cases. This variability in results may be due to population size, ethnicity, experience of observers, and different technical features of the devices used in the studies.

Mosavat and Ahmadi[29] (2.5:1) and Ilguy et al.[8] (1.3:1) reported a higher prevalence of unilateral PGFs compared to bilateral PGFs. However, studies conducted by Salli et al.[26] (32.3% unilateral, 67.7% bilateral), Ladeira et al.[8] (42.5% unilateral, 57.5% bilateral), and Shamshad et al.[24] (36.5% unilateral, 63.5% bilateral) indicated a higher occurrence of bilateral PGFs. In the present study, the distribution of unilateral and bilateral PGF cases was nearly equal, with 51.5% being unilateral and 48.5% bilateral.

Among the unilateral PGF cases identified in this study, 63 (41.2%) were located on the right side, while 90 (58.8%) were on the left side ($p<0.001$). This finding aligns with the results of Ladeira et al.[8] (29% on the right side, 70% on the left side), Salli et al.[26] (38.2% on the right side, 61.8% on the left side), and Buyuk et al.[25] (38.6% on the right side, 61.4% on the left side). The predominance on the left side is believed to be associated with etiological factors contributing to the development of pneumatization.[1,8] In this regard, Allam[9] proposed several factors that may influence growth patterns, including mucosal conditions, heredity, growth center development in the bone, eustachian tube function, and concurrent infections, though the exact etiology remains uncertain.

Table 6. Studies investigating the prevalence of PAT and PGF using CBCT

	N	Prevalence of PGF %	Prevalence of PAT %
Groell ve Fleismann (1999)	100	51.0	12.0
Ladeira et al. (2013)	658	38.3	38.3
Ilguy et al. (2015)	111	11.7	51.8
Shamshad et al (2018)	100	52.0	12.0
Buyuk et al. (2018)	1000	29.6	28.4
Salli et al. (2019)	1000	47.1	14.7
Current study	739	40.2	32.2

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Numerous studies in the literature [8,25,26,30-35] have reported a higher prevalence of unilateral PAT cases compared to bilateral PAT cases, whereas a few studies [28,36] have indicated a greater occurrence of bilateral PAT cases than unilateral ones. In the current study, the unilateral-to-bilateral PAT ratio was 1.1:1, with no statistical significance. Furthermore, among the unilateral PAT cases identified, 63 (45.0%) were on the right side, while 77 (55.0%) were on the left side, with no significant difference observed between the two sides. Similarly, studies conducted by Shokri et al.[34], Yavuz et al.[32], Carter et al.[31], and Hofmann et al.[37] also found no significant variation in PAT rates between both sides (right and left). However, Orhan et al.[38] reported that unilateral PAT cases were more frequently observed on the right side than on the left. Conversely, research by Ladeira et al.[8], Salli et al.[26], Buyuk et al.[25], and Kaugars et al.[39] indicated that unilateral PAT cases were more commonly detected on the left side than on the right. The literature does not identify any predisposing factor that determines whether PAT occurs unilaterally or bilaterally. Similarly, no specific factor has been noted that would explain the dominance of unilateral PAT cases on either the right or left side. However, considering the significant relationship between MPP and PAT found in this study, it can be suggested that variations between both sides (right and left) may be influenced by a history of disease or previous surgical procedures affecting MPP.

The relationship of MPP with septal deviation has been previously reported.[17] Considering that there is a relationship between PAT/PGF and MPP, it can be assumed that existing septal deviations may be one of the etiological factors in detecting unilateral or bilateral cases. However, further studies are needed in this subject.

PAT may become predisposed to the spread of inflammatory processes along the temporomandibular joint. Malocclusion can lead to temporomandibular joint (TMJ) syndrome. Traumatic occlusion is one of the conditions that can trigger TMJ disorder. Occlusion is always involved to a certain extent in daily dental treatments. During a restorative treatment, sudden occlusal changes can occur with amalgam or composite resins that can lead to an excessive bite, overbite or underbite. If they are not tolerated, these changes in occlusion can lead to ineffective sensorimotor regulation. When the occlusal alignment is interrupted, so are the abilities of the manducatory apparatus, which is harmful to the various structures include PAT. Patients with conservative dentistry treatment which often involves tooth filling also can contribute to occlusion disorders in the teeth which can last a long time without realizing it, resulting in TMJ syndrome. Patients sometimes ignore the presence of traumatic occlusion and the body adapts in the long term but this has an impact on TMJ health. Hence, it has been considered useful to also determine the prevalence and characteristics of PAT in a population of traumatic patients of occlusion treatment and to examine the possible relationship between traumatic types of occlusions and pneumatized articular eminence.

The limitation of this study was the lack of data on the systemic patient disease because of the retrospective nature of the study. In future researches, MRI or CBCT may be used in evaluating the relationship between TMJ diseases and pneumatization. In addition, multi-center studies can be conducted in different populations by increasing the sample size and relationship between traumatic occlusion types and pneumatized articular eminence.

The relationship between MPP degree and presence of PAT and PGF may be important in understanding the features and functions of PAT and PGF. Since PAT and PGF can be one of ways of the spreading of inflammation, fractures, tumors and various pathologies, these pneumatic cavities should be detected before TMJ surgery to prevent complications during and after the operation. CBCT is an ideal method for observing air spaces within bone. It has been considered useful to also determine the prevalence and characteristics of PAT in a population of traumatic patients of occlusion treatment and to examine the possible relationship between traumatic types of occlusions and pneumatized articular eminence.

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