

Prevalence of Zygomatic Air Cell Defects in the Tunisian Population: A Retrospective Study

Prévalence des cellules pneumatiques zygomatiques dans la population tunisienne : Etude rétrospective

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ABSTRACT

Objectives: Zygomatic Air Cell Defect (ZACD) is an anatomical variation that may complicate surgical procedures involving the temporomandibular joint. This retrospective study aimed to determine the prevalence, location, and morphological characteristics of ZACD in a Tunisian population and to compare the findings with previously reported data.

Methods: A total of 3,988 digital panoramic radiographs from patients aged 4–94 years were independently assessed by three oral and maxillofacial radiologists. Demographic characteristics, ZACD laterality (unilateral/bilateral), and morphology (unilocular/multilocular) were recorded. Statistical analysis was performed using the Chi-Squared test, and the results were contextualized through a comprehensive literature review.

Results: ZACD was detected in 2.28% of cases, with a mean age of 37.4 years (range: 7–67). Most cases were unilateral (69/92), predominantly on the left side, while bilateral involvement was noted in 23 patients. Unilocular (56.5%) and multilocular (43.5%) patterns were almost equally distributed. No significant associations were observed between ZACD presence and patients' age, sex, laterality, or locularity.

Conclusion: The prevalence of ZACD in the Tunisian population is comparable to that of other populations, but it tends to occur in younger individuals. Recognizing ZACD on panoramic radiographs is clinically relevant, as its presence may pose challenges during surgical or endoscopic procedures of the temporomandibular joint. Awareness of this variation can therefore help clinicians anticipate potential complications and improve preoperative planning.

Keywords: Cone-Beam Computed Tomography; Radiography, Panoramic; Retrospective Studies; Temporomandibular Joint

RÉSUMÉ

Objectifs : Les cellules pneumatiques zygomatiques (ZACDs) sont des variantes anatomiques pouvant compliquer les interventions chirurgicales impliquant l'articulation temporo-mandibulaire. Cette étude rétrospective visait à déterminer la prévalence, la localisation et les caractéristiques morphologiques des ZACDs dans une population tunisienne, et à comparer les résultats avec les données publiées.

Méthodes : Un total de 3 988 radiographies panoramiques numériques, provenant de patients âgés de 4 à 94 ans, a été évalué de manière indépendante par trois radiologues oraux et maxillo-faciaux. Les caractéristiques démographiques, la latéralité des ZACD (unilatérale/bilatérale) et la morphologie (uniloculaire/multiloculaire) ont été enregistrées. L'analyse statistique a été réalisée à l'aide du test du Chi², et les résultats ont été interprétés dans le contexte d'une revue de littérature exhaustive.

Résultats : Les ZACDs ont été détectés dans 2,28 % des cas, avec un âge moyen de 37,4 ans (extrêmes : 7–67). La majorité des cas était unilatérale (69/92), prédominant du côté gauche, tandis qu'une atteinte bilatérale a été observée chez 23 patients. Les morphologies uniloculaire (56,5 %) et multiloculaire (43,5 %) étaient presque également réparties. Aucune association significative n'a été observée entre la présence de ZACD et l'âge, le sexe, la latéralité ou le type de localité des patients.

Conclusion : La prévalence des ZACDs dans la population tunisienne est comparable à celle d'autres populations, mais ces anomalies semblent plus fréquentes chez les sujets jeunes. La reconnaissance des ZACDs sur les radiographies panoramiques présente un intérêt clinique, car leur présence peut compliquer les procédures chirurgicales ou endoscopiques de l'articulation temporo-mandibulaire. La connaissance de cette variation anatomique permet donc aux cliniciens d'anticiper d'éventuelles complications et d'améliorer la planification préopératoire.

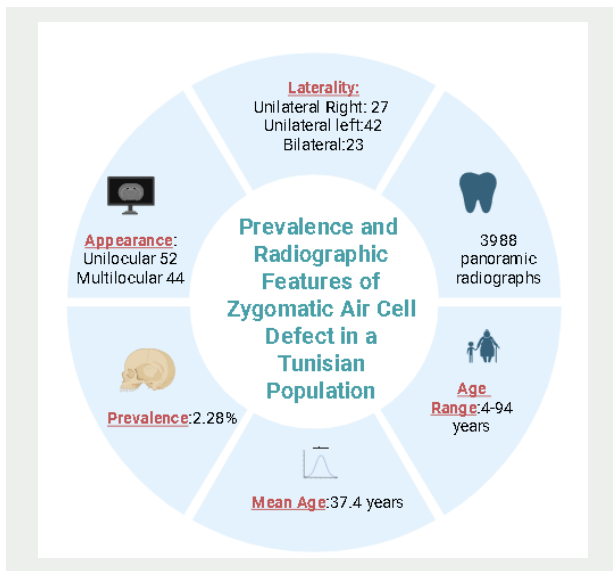
Mots-clés : Articulation temporo-mandibulaire (ATM), Radiographie panoramique, Tomographie volumique à faisceau conique (CBCT), Études rétrospectives

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INTRODUCTION

Pneumatization is defined as “the development of air cell-like cavities in bone” (1). In addition to the main paranasal sinuses, accessory air cells can develop in various regions of the skull, including the temporal bone. Temporal bone pneumatization involves five regions: the middle ear, mastoid process, perilyabyrinthine bone, petrous apex, and accessory region (1). The process of mastoid pneumatization begins around the 33rd week of embryonic development and it continuous until approximately 8-9 years of age (2). This process can also extend anteriorly to the level of the zygomatic arch and the articular eminence (3). It was in 1985 that the term “Pneumatized Articular Tubercle” (PAT) or “eminence” was first coined by Tyndall and Matteson (4). In his research, Gunnel cited Tremble as the first to report on PAT in 1934, with a specific focus on studying the anatomical pathways through which infections could disseminate in the temporal bone (5). Carter et al. later redefined this entity as the Zygomatic Air Cell Defect (ZACD) (1). It was then that ZACD was defined as “an asymmetric radiolucent defect in the zygomatic process of the temporal bone with the appearance similar to mastoid air cells” having common characteristics, including “the extension of the defect anteriorly as far as the articular tubercle but not beyond the zygomaticotemporal suture and no enlargement or cortical destruction of the zygoma”(4).

The recognition of ZACDs on radiographs is clinically relevant, not only because they may contraindicate procedures such as eminoplasty or eminectomy, but also due to their potential role in trauma and infection. In pediatric patients, large defects may represent weak areas predisposing to fractures or serve as pathways for the spread of infections such as otitis media, with possible extension to the skull base. Radiologically, ZACDs can also mimic a variety of pathological entities including cysts, vascular malformations, eosinophilic granuloma, or early fibrous dysplasia and emphasizing the need for accurate differential diagnosis. Their early detection, particularly

in younger patients presenting with TMJ disorders or requiring corrective surgery, is therefore crucial for preventing complications and optimizing treatment planning (6,7)

Despite the clinical implications of ZACD, its prevalence and characteristics appear to vary across populations. Cranial morphology itself shows wide inter-population variability (8), which could affect the distribution of such defects. However, studies on ZACD remain scarce, and data from North African or Tunisian populations are lacking. Furthermore, most available studies have focused primarily on adults, whereas the present work encompasses a broader age range, including children from as young as four years old.

Therefore, this study was designed to determine the prevalence and features of ZACDs in a defined group of Tunisian subjects, with a particular focus on their dominant location and morphological type.

METHODS

Study design and ethical considerations

This retrospective cross-sectional study was conducted in compliance with the principles outlined in the Declaration of Helsinki. Ethical approval was obtained from the Institutional Review Board (IRB) at the Faculty of Medicine of Monastir (IORG 0009738 N°172 OMB 0990-0279) on 12 April 2024. The rights of the participants were protected, and written informed consent was obtained from all subjects prior to inclusion.

Study population and recruitment

A total of 4,025 routine panoramic radiographs taken between January 2014 and December 2020 were retrieved from the archives of the Departments of Oral Medicine and Radiology. After applying the eligibility criteria, 3,988 radiographs were assessed. Radiographs were included if they belonged to patients referred for routine dental care or diagnostic purposes, such as caries detection, dental pain, missing or extra teeth, mixed dentition analysis, periodontal disease, third molar assessment, restorative and prosthodontic evaluations, orthodontic planning, or temporomandibular joint (TMJ) assessment. Radiographs in which the zygomatic arch region was not clearly visible due to anatomical or technical limitations were excluded. The sampling technique employed was non-probability convenience sampling, as all eligible panoramic radiographs available during the study period were included without random selection.

Radiographic examination

All panoramic images were obtained using the Sirona Sidexis Orthophos XG panoramic unit (Sirona Dental Systems GmbH, Fabrikstr. 31, D-64625 Bensheim, Germany; Model No. 5952168, Serial No. D3352) operating at 60–75 kVp, 10 mA, and 16 s. A complementary metal-oxide-semiconductor (CMOS) direct digitizing sensor was

RESULTS

used. Radiographs were processed and standardized using the SIDEXIS XG 2.5 software (Sirona Dental Systems GmbH).

Image analysis

All radiographs were independently and simultaneously reviewed by three experienced oral and maxillofacial radiologists under optimal viewing conditions. Zygomatic air cell defects (ZACDs) were recorded only when an indisputable, well-defined unilocular or multilocular radiolucency of the zygomatic arch or articular eminence was observed, without extension across the zygomaticotemporal suture.

Diagnostic criteria

Unilocular pneumatized articular temporal bone (PAT) was defined as a single oval radiolucent defect with well-defined bony borders (Fig.1), while multilocular PAT was characterized by multiple small radiolucent cavities (Fig.2).

Statistical analysis

Collected data were categorized according to age, sex, location (unilateral/bilateral), and locularity (unilocular/multilocular). Statistical comparisons were performed using Pearson's chi-squared test. A p-value < 0.05 was considered statistically significant. All analyses and graphical representations were conducted using GraphPad Prism 8.0.2 (GraphPad Software, LLC, San Diego, CA, USA).

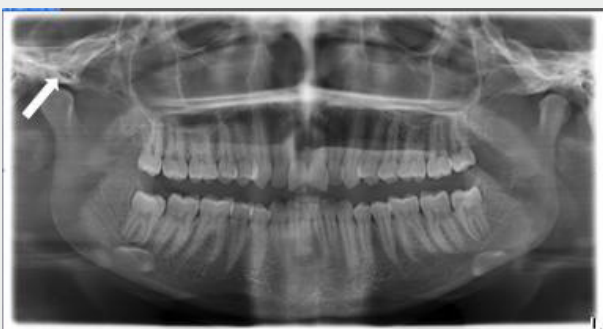


Figure 1. Panoramic radiograph showing right Unilocular Zygomatic Air Cell Defect. The white arrow shows right unilocular zygomatic air cell defect on the panoramic radiograph



Figure 2. Panoramic radiograph showing right Multilocular Zygomatic Air Cell Defect. The black arrow shows right multilocular zygomatic air cell defect on the panoramic radiograph

Among the 3988 patients, the mean age was 39.3 years (SD 18.3), with an age range from 4 to 94 years. The study included the radiographs of 1632 males (41%) and 2356 females (59%). The mean age for the male patients was 42.3 years (SD 19.0), extending from 4 to 94 years, whereas the mean age of the female patients was 37.2 years (SD 17.5), spanning from 5 to 94 years.

Of the 3988 panoramic radiographs assessed, Zygomatic Air Cell Defect (ZACD) was identified in 92 subjects, with a prevalence of 2.28%. The radiographs were categorized by age in decades, with a mean age of 37.4 years across all the subjects. Most ZACDs were noted in individuals aged 20 to 29 years. The youngest subject with ZACD was 7 years old while the oldest was 67 years old.

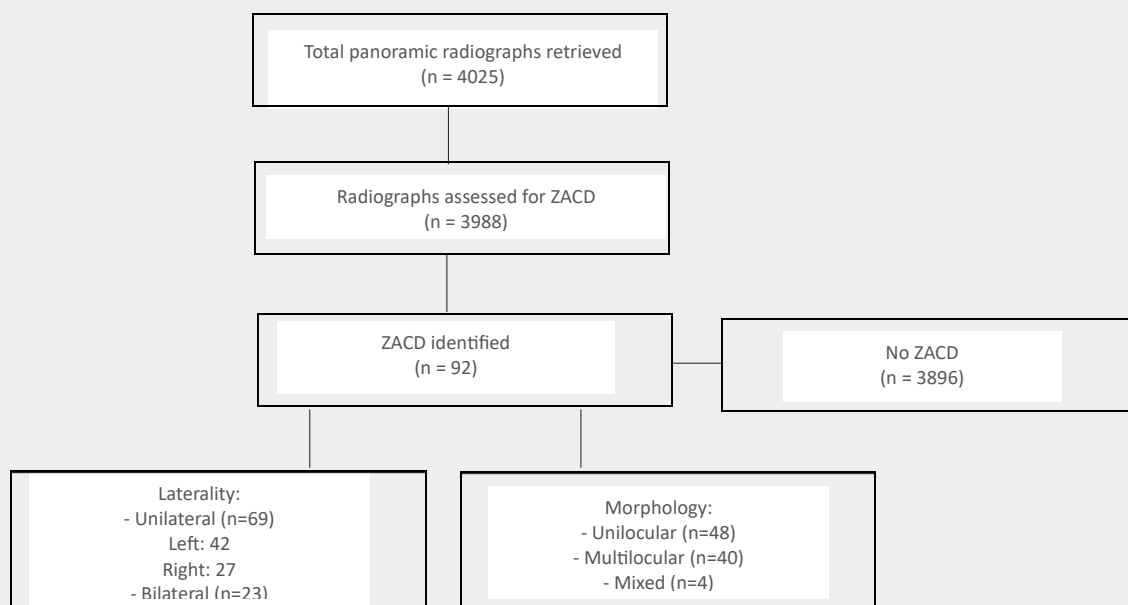
Out of the 92 ZACDs identified in the present study, 44 occurred in males and 48 in females, 69 were unilateral, and 23 were bilateral. With regard to locularity, 48 were unilocular, 40 multilocular, and 4 having unilocular appearance on one side and multilocular appearance on the other side. Among the 69 unilateral ZACDs, 32 were noted in males and 37 in females. Out of the 23 bilateral ZACDs, 12 were found in males and 11 in females. In the group of 48 unilocular cases, 21 were noted in males and 27 in females. Out of the 40 multilocular cases, 21 were found in males and 19 in females. For the unilateral variant, 42 were located on the left side and 27 on the right side. No statistically significant differences were noted regarding age ($p = 0.624$), sex ($p = 0.452$), laterality ($p = 0.207$), or locularity ($p = 0.602$). Table 1 summarizes the variations of ZACDs with respect to sex, locularity, and laterality. Table 2 presents the variations with regard to age.

Table 1. Characteristics of PAT: locularity, laterality, and sex in the present study.

Sex	Locularity		Laterality		
	Unilocular	Multilocular	Bilateral		
			Unilateral		
			Right	Left	
Males	21	21	9	23	12
Females	27	19	18	19	11
Total	48	40	27	42	23

Table 2. Characteristics of pneumatized articular eminence : locularity, laterality, and age in the present study.

Age group (years)	Number	Unilateral		Bilateral	Unilocular	Multilocular
		Left	Right			
(1-9)	2	1	1	0	1	1
(10-19)	10	5	2	3	7	3
(20-29)	31	14	6	11	18	15
(30-39)	12	5	4	3	3	9
(40-49)	11	4	5	2	8	4
(50-59)	13	7	5	1	9	4
(60-69)	11	5	1	5	5	7
(70-79)	2	1	1	0	1	1
(80-94)	0	0	0	0	0	0



Discussion

This study, based on a large sample of 3,988 panoramic radiographs, established an overall prevalence of Zygomatic Air Cell Defects (ZACDs) of 2.28%. No statistically significant difference was noted between males and females. Most ZACDs were unilateral (unilateral-to-bilateral ratio of 3:1), more frequently located on the left side, and predominantly unilocular (52 unilocular vs. 44 multilocular). The most affected age group was around the fourth decade of life (mean age 37.4 years), although ZACDs were observed across a broad age range, from 7 to 67 years.

The observed prevalence aligns with previous reports by Tyndall and Matteson, Khojastepour et al., Kishore et al., and Srikanth et al., as well as studies reporting rates around 1.5% (Kathikaya et al., Kaugars et al., Carter et al., Orhan et al., Yavuz et al.) (4–6,9–14). However, it is slightly lower than values reported by Abbas et al. (3.6%) Zamaninaser et al. (6.2%) and Ndiaye et al. (1,3,15). Such variation in the prevalence of ZACDs may be attributed to the differences in the sample sizes, the studied populations, and the methodological approaches across studies. Overall, however, most of the literature, including the present study, supports the notion that ZACDs are relatively uncommon.

Gupta et al. offered two possible explanations for this consistently low prevalence: first, the actual number of ZACDs may be very limited due to the wide variability in accessory air cells of the temporal bone; and second, their detection on panoramic radiographs is particularly challenging because of superimposition of adjacent anatomical structures (16).

This diagnostic limitation is further highlighted when comparing imaging modalities. While panoramic radiographs typically yield low prevalence estimates, CBCT studies have reported much higher rates, ranging from 14.1% to 76.7% (Table 4). This discrepancy likely reflects CBCT's superior diagnostic accuracy, free from

the superimposition of adjacent structures inherent to panoramic imaging (1,16). Similarly, Zadavec et al. reported a sensitivity of 0.45 and a specificity of 0.98 when comparing panoramic radiography to MRI, underscoring this limitation (21). Additionally, in their study, Milogu et al. noted that only Computed Tomography (CT) could effectively visualize the medial portion of the articular eminence which remains inaccessible to panoramic imaging (1). Despite these limitations, panoramic radiographs continue to represent the most accessible and cost-effective tool for the initial detection of ZACDs, since they usually allow visualization of the posterior part of the zygomatic arch (18,3).

Interestingly, when focusing on symptomatic populations, Gupta et al. investigated patients presenting with TMJ pain or dysfunction of the masticatory muscles (19). Although their study included a relatively small sample (70 patients), they reported a ZACD prevalence of 30.0%, which is considerably higher than the rates observed in general population studies. This finding raises the possibility of a potential association between ZACDs and TMJ-related symptoms, warranting further research in this direction.

No sex predilection was found in the present study, consistent with the findings of Abbas et al., Tyndall and Matteson, Srikanth et al., Carter et al., Orhan et al., and Yavuz et al. (1,4,9,12–14). However, some authors have reported a male predominance (Patil et al., Park et al., Karandeep Singh) (10,20,21), while others described a female predominance (Zamaninaser et al., Orhan et al., Miloglu et al.) (3,13,22). Such discrepancies may result from imbalanced sample ratios or biological factors related to the timing of pneumatization onset during puberty (1). In females experiencing puberty at an earlier age, pneumatization processes are biologically more advanced than in males of equivalent age. Consequently, the prevalence of ZACDs may appear higher or more easily detectable in females. Overall, this issue remains debated, and no definitive conclusion can be drawn.

The mean age of 37.4 years is in line with some previous studies (4,5,9,13) but lower than others (11-12,23), likely reflecting demographic differences in the studied populations. Notably, identification of a ZACD in a 7-year-old patient, consistent with other reports (7,14,23,24), challenges the notion that pneumatization is radiographically evident only after puberty. While it has been suggested that accessory air cells start developing after puberty and reach full expression a few years later (13), the presence of ZACDs in children indicates that pneumatization may begin earlier, but only becomes visible once sufficiently advanced. Therefore, further investigations using high-resolution CT or CBCT in pediatric populations are needed better understand the timing and progression of pneumatization in the articular eminence (3).

In the present analysis, most of ZACDs occurred unilaterally (unilateral to bilateral ratio was 3:1), which is consistent with most of the previous studies conducted on panoramic radiography (4-6,10,9,12-14) and CBCT (25-26).

A high proportion of ZACDs was noted on the left side, which is consistent with the findings of Kishore et al. and Hofmann et al.(6,23).However, in their studies, Patil et al.(10) and Carter et al. (12) noted a higher occurrence of ZACDs on the right side, and Park et al (20) reported equal distribution on both sides. In the present study, most of the unilateral ZACDs occurred in males, which is in accordance with the findings reported by Kishore et al .,Srikanth et al and Patil K et al.,. (6,9-10). The cited literature did not explicitly specify the factors influencing unilateral or bilateral PAT.

A review of the previously published studies revealed variability in the locality of ZACDs. Among the 92 ZACDs, 52 were unilocular and 44 were multilocular, indicating that the unilocular type is more prevalent. Similar findings have been reported in other studies (1,4-6). Nevertheless, other studies conducted on panoramic radiography have shown a predominance of the multilocular type (3,10,9,13-14).The most drastic divergence was 103 multilocular vs 30 unilocular ZACDs (18).

Such differences could be attributed to the discrepancies in the sample sizes as well as the inter-observer variability in determining the types of ZACDs, especially when using panoramic radiographs. Moreover, Ladeira et al. demonstrated a significantly increased occurrence of the multilocular type (98.7%) based on CBCT images. This contrast was due to the limitations of panoramic radiography in accurately assessing both the prevalence and the type of pneumatisation (1, 27).

The main strength of this study is its large sample size (n=3,988), providing substantial statistical power for evaluating a relatively rare condition. The use of panoramic radiography as a first-line, widely accessible modality allowed efficient screening of a large population, which would be less feasible and more costly with CBCT. The main limitations are inherent to panoramic imaging, including superimposition of anatomical structures, which likely leads to underestimation of ZACD prevalence, as consistently shown in CBCT studies (1,16-17). Differences

in classification of ZACDs as unilocular or multilocular may also result from inter-observer variability and the two-dimensional nature of panoramic radiographs compared to CBCT (1,27).

ZACDs are clinically significant because they represent sites of minimal bone resistance, potentially facilitating the spread of tumors, infections, or inflammatory processes deep into the bone. They may reduce bone volume and resistance, increasing the risk of fractures, resorption, or TMJ ankylosis (25). Preoperative radiological assessment of pneumatization in the articular tubercle and glenoid fossa is therefore essential. Surgeons should take caution during procedures such as eminectomy, eminoplasty, or miniplate insertion, as ZACDs can complicate surgery and risk accidental penetration through the defect, dura mater rupture, or cerebrospinal fluid leakage (10,25,28). Consequently, these procedures may be contraindicated when ZACDs are identified preoperatively (10,28).

Differential diagnoses of round radiolucent lesions that may occur in this region, including aneurysmal bone cysts, vascular malformations, eosinophilic granuloma, central hemangioma, chondroblastoma, metastatic lesions, early stages of fibrous dysplasia and central giant cell tumors, must also be considered. All these lesions could be at the origin of some clinical symptoms, such as pain and swelling over the zygoma, facial asymmetry, and radiographic osteolysis. They are different from "asymptomatic pneumatization that appears radiographically as non-expansive and non-destructive well-defined defects"(9).

In conclusion, this large-scale study confirms the low prevalence of ZACDs in the Tunisian population, in line with previous reports, but also reveals a higher occurrence in younger individuals, a finding that adds a novel perspective to existing literature. The clear delineation of their radiographic characteristics underlines the importance of distinguishing ZACDs from pathological lesions. While patients with TMJ disorders were excluded, the high prevalence reported in symptomatic groups calls for further research to explore a possible association with TMJ pain, challenging the traditional view of ZACDs as entirely asymptomatic entities. For radiologists and surgeons, recognizing this anatomical variation remains essential to ensure accurate diagnosis, avoid unnecessary procedures, and prevent potential complications.

Table 3. Summary of the reported prevalence of pneumatized articular eminence (Panoramic Radiography analysis)

Authors	Study sample size	Cases with PAT N	Prevalence (%)	Males N (%)	Females N (%)	Unilocular/ Multilocular	Unilateral/ Bilateral	Mean Age	Country
Tyndall and Matteson (4) (1985)	1061	28	2.6	13 (46.6)	15 (53.6)	17/16	23/5	32.5	United States
Kaugars et al.(11) (1986)	784	8	1.02	1 (12.5)	7 (87.5)	Not reported	4/4	50.5	United States
Carter et al.(12) Meta analysis (1999)	4759	76	1.7	34 (44.7)	42 (55.3)	Not reported	59/17	49.6	
Orhan et al. (13) (2005)	1006	19	1.8	7 (36)	12 (64)	10/16	12/7	36.6	Turkey
Yavuz et al. (14) (2008)	8107	83	1.03	42 (51)	41 (49)	44/66	56/27	26.9	Turkey
Srikanth HS et al. (9) (2010)	600	15	2.5	7 (46.6)	8 (53.3)	2/13	9/6	34.12	South indian
Kathikaya Patil et al.(10) (2011)	7755	141	1.82	91 (64.5)	50 (35.4)	45/96	107/34	36.19	India
Asieh Zamaninaser et al.(3) (2012)	2600	94	3.6	35 (37.2)	59 (62.8)	45/70	70/24	33.2	Esfahanian population
Shokri et al.(1) (2013)	1563	98	6.2	33 (33.6)	65 (66.4)	52/46	64/34	22.8	Iran
Khojastepour et al.(5) (2015)	3098	46	2.1	23 (36)	41 (64)	49/39	40/24	35.1	Iran
Kishore et al.(6) (2015)	2500	63	2.5	38	25	49/14	44/19	37.4	North indian Senegal
Ndiyae et al. (15) (2021)	444	35	7.8	17 (48)	18 (51)	14/19	16/21	35.4	
Aldhelai et al.(7) (2024)	1653	462	27.9	212 (45.9)	250 (54.1)	235/131	207/255	11.91	Saudi Arabia Yemen
Aldhelai et al.(7) (2024)	1516	440	29	186 (42.3)	254 (57.7)	194/178	213/227	8.70	
Present study (2023)	3988	92	2.28	44 (47.8)	48 (52.2)	52/44	69/23	39.3	Tunisia

Table 4. Summary of the reported prevalence of pneumatized articular eminence (Recent Cone Beam CT analysis).

Authors	Country	Study sample size	Cases with PAT (number)	Prevalence (%)	Males/Females	Unilateral/ Bilateral
Khojastepour et al. (29) (2017)	Iran	327	251	76.7%	139/112	76/175
Buyuk et al.(26) (2018)	Turkey	1000	391	39.1%	423/577	215/176
Borahan et al. (25) (2018)	Turkey	300	98	32%	55/43	56/42
Adisen and Misirlioglu (25) (2018)	Turkey	276	39	14.1%	17/22	22/17
Shekhawat et al.(25) (2020)	India	106	50	56%	24/26	44/14
ElBeshlawy (30) (2020)	Egypt	210	136	19.1%	20/20	20/20

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