



## VOLUMETRIC ANALYSIS OF THE ARTICULAR EMINENCE PNEUMATIZATION USING CONE-BEAM COMPUTED TOMOGRAPHY

### ABSTRACT





**Objectives:** To assess tomographic features of articular eminence pneumatization (AEP) using cone beam computed tomography (CBCT).

**Materials and Methods:** To evaluate 659 CBCTs (500 women and 159 men) of the Oral and Maxillofacial Radiology service of Universidad Peruana Cayetano Heredia Dental Clinic, between 2014 – 2015. The age group was between 7 to 79 years-old. The classification of Al Faleh and Ibrahim was also used to assess the degree of pneumatization, and the statistical analysis was performed using the chi-square test.

**Results:** The frequency of AEP was 76.2% (502 cases). The highest frequency was found for grade 0 and 2, the highest frequency was found in the 6th decade of life and great predominance was found for the female sex. However, no statically significant differences were found with respect to the gender.

**Conclusions:** AEP prevalence was 76.2% and CBCT became the gold-standard that allows an adequate evaluation of this anatomical variant.

**Keywords:** Cone-beam computed tomography, temporal bone, temporomandibular joint, zygoma.

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## INTRODUCTION

In recent years Cone Beam Computed Tomography (CBCT) has been used with great frequency in the evaluation of bony structures of the skull. The image detail, the short examination time, the low cost and the lower exposure to radiation compared to conventional computed tomography (CT) has made it become the gold standard for the proper evaluation of the skull.<sup>1</sup>

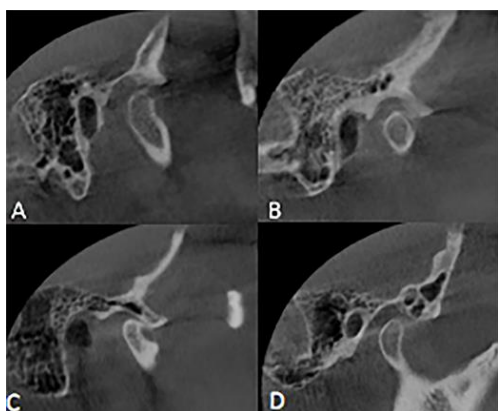
The pneumatization process can be defined as a development of air within the bone cavities and can occur in numerous locations in the skull including the temporal bone.<sup>2</sup> The mastoid antrum is the first cell of the mastoid air system to develop around the 4th and 5th month of intrauterine life. The pneumatization process begins around the 7 months of intrauterine life. During the post-natal development, the epithelium of the mastoid portion expands and begins its development 1 to 2 years after birth.<sup>3,4</sup> Some authors, among them Groell and Fleischman<sup>5</sup>, reported that articular eminence pneumatization (AEP) occurs through a sub-epithelial bone resorption process. The complete pneumatization of mastoid cells can be divided into 3 stages: infantile stage, from birth to 2 years of age; the transitional stage, from 2 to 5 years; and the adult stage, after 5 years.<sup>2</sup> The AEP can be in relation to the middle ear, the Eustachian tube and the mastoid structure, depending on the degree there may be repercussions in the cholesteatoma processes, chronic otitis and even in pathological or surgical procedures such as mastoidectomy.<sup>6</sup> Another entity associated with the AEP is the middle-ear barotrauma, this entity is defined as the damage of the middle ear tissues where the Eustachian tube does not allow the entry of air into this structure producing a pressure difference between the middle ear and the surrounding environment. Uzun *et al.*<sup>7</sup> reported an inverse relationship between the size of pneumatization and risk of symptomatic middle ear barotrauma in sport scuba divers. This indicates that people with AEP are protected against a barotrauma since the mastoid cells act as shock absorbers before sudden changes in pressure.

Panoramic radiography and other conventional projections of the skull do not provide adequate visualization of the posterior aspect of the zygomatic arch due to the superposition of structures. These disadvantages have been overcome now, cone-beam CT (CBCT) has a great field of applications in dentistry, including preoperative implant planning, third molar imaging, temporomandibular joint (TMJ) evaluation, orthodontic treatment planning, and craniofacial anomaly estimation. In comparison to computed tomography (CT) they are cheaper and incur a lower radiation dose. Recently, a higher prevalence of temporal bone pneumatization around TMJ has been reported using CT.<sup>8</sup>

Within the radiographic features, AEP appears as radiolucent images of defined limits and of similar shape and size to the mastoid pneumatization (MP) air cells. These cells can appear unilaterally or bilaterally and present a unilocular or multilocular radiographic pattern. Also, they do not produce expansion or symptomatology, important characteristics to be able to rule out some pathologies such as an eosinophilic granuloma, hemangiomas or solitary bone cysts at this level.<sup>9</sup> Several studies have classified the AEP, among them Han *et al.*<sup>10</sup> and Yamakami *et al.*<sup>11</sup> However, few were made using CBCT. Recently, Shamshad *et al.*<sup>12</sup> reported a prevalence of 52% in India. In 2014, Nascimento *et al.*<sup>13</sup> found a frequency of 3.3% in Brazil and Demirel *et al.*<sup>14</sup> reported 67.6% in Turkey. In 2013, Delibasi *et al.*<sup>15</sup> described 2.54% and Ladeira *et al.*<sup>1</sup> found 21.3% in Brazil. The pneumatization pattern can affect any surgical procedures involving the skull base region. Pneumatization of the articular eminence is a challenging entity for TMJ surgery and spread of infections in this region. Practitioners who are dealing with TMJ surgery and pathology should need detailed information about this anatomical variation since it may cause serious complications. The aim of this study was to classify articular eminence pneumatization in adults using CBCT data sets in a peruvian population.

## MATERIALS AND METHODS

We designed a descriptive, transversal and retrospective study. This study used CBCT images of patients who were referred to the Oral and Maxillofacial Radiology Service at Universidad Peruana Cayetano Heredia, between February 2014 and December 2015. The study protocol (17.12.2014), was approved by the Institutional Ethics Committee of the Universidad Peruana Cayetano Heredia (CIE-UPCH). Selection criteria for patients (6 to 79 years of age) included images with field of view in which the right and left MP were adequately seen. Cases displaying cystic or tumoral pathologies in the temporal bone or maxillofacial fracture history were excluded from the study. The variables that were taken into account were age, gender, laterality (unilateral, bilateral), sides (right or left) and degree of pneumatization. Guidelines were drawn perpendicular to the axis of the condyle on axial views, and cross-sectional reconstructions were made perpendicular to these lines with 1-mm slice thicknesses and 1-mm slice intervals. Axial and sagittal sections were also used. For the degree of pneumatization, the Al Faleh and Ibrahim<sup>16</sup> classification was used, which is conformed by 4 grades (0 to 3): grade 0 = pneumatization limited to the MP, grade 1 = pneumatization between the MP to the deepest part of the glenoid fossa, grade 2 = pneumatization between the deepest part of the glenoid fossa and the tip of the articular eminence and grade 3 = pneumatization extending beyond the crest of the articular eminence (Figure 1).



**Figure 1.** Example of AEP (sagittal view) showing the degree of pneumatization based on Al Faleh and Ibrahim<sup>16</sup> classification. (A) Grade 0. (B) Grade 1. (C) Grade 2. (D) Grade 3.

The principal investigator was trained and calibrated by an oral and maxillofacial radiologist with more than 10 years of experience. This calibration was performed on 15 CBCT scans (Siemens, Germany). All the scans were acquired on a Galileos unit (Siemens, Germany) operating from 10mA to 42Ma and 85Kv according to each patient, all the images were exported on a Lenovo H61 compatible computer and were evaluated through the Galaxis 1.7.2 software. The inter-observer Kappa was 0.82 and 0.9 for the intra-observer agreement. 20 CBCTs were evaluated per day on an inter-day basis in a dimmed room at a distance of 60 cm from the diagnostic viewing screen, with low ambient light and maximum of 2 hours per day. The digital images were analyzed on a 21-inch screen, with a resolution of 1600x900 pixels and 32-bit color depth.

### Statistical methods

The collected data was statistically analyzed using SPSS ver.23 for Windows (IBM SPSS, Chicago, Illinois, USA). Frequency distribution tables were used for the variables sex, laterality, side and degree of pneumatization. For the bivariate analysis, the Chi-Square Test and the Yates-corrected Chi-square Test were used for the case of sex because it was a non-homogeneous sample. The study had a confidence level of 95% and  $p < 0.05$ .

## RESULTS

The study population consisted of 659 CBCTs. There were 159 male patients and 500 female patients. The prevalence of AEP for the female gender was 58.3% (384 CBCTs) and for the male gender 17.9% with 118 CBCTs. Overall, 445 cases (33.8%) had grade 0 pneumatization, 371 cases (28.1%) had grade 1, 432 cases (32.8%) had grade 2, and 70 cases (5.3%) had grade 3. Regarding the AEP grade by gender, the highest prevalence was grade 0 followed by grade 2 for both genders. There was no significant relationship between the grade of pneumatization and sex ( $p=0.82$ ) (Table 1).

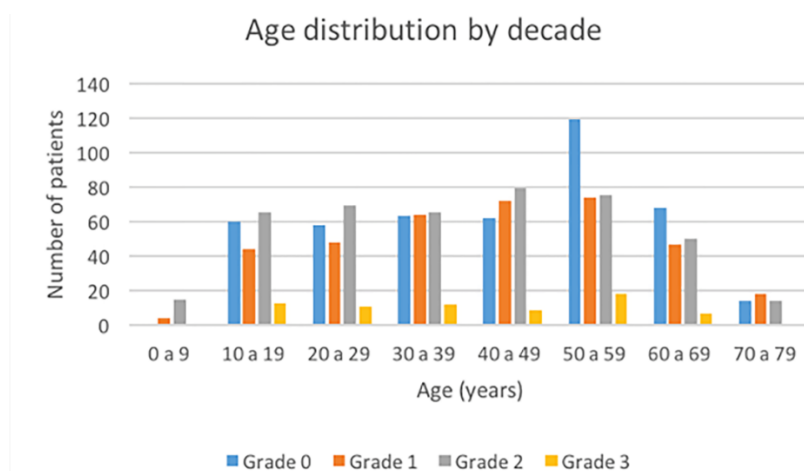
**Table 1.** Distribution of AEP groups and sex groups

Sex	Pneumatization grade							
	Grade 0		Grade 1		Grade 2		Grade 3	
	n	%	n	%	n	%	n	%
Male	114	8.6	85	6.4	103	7.8	16	1.2
Female	331	25.1	286	21.7	329	25.0	54	4.1
<b>TOTAL</b>	<b>445</b>	<b>33.8</b>	<b>371</b>	<b>28.1</b>	<b>432</b>	<b>32.8</b>	<b>70</b>	<b>5.3</b>

*Yates-corrected Chi-square Test (p=0.51).*

For the AEP grade and the age group, the highest prevalence was on the 50-59 years-old group for

grade 0. For grade 2, the 40-49 years-old group had the highest prevalence (figure 2).

**Figure 2.** Frequency distribution of the AEP in relation to the age.

With respect to the side and frequency of the AEP grade, the most prevalent grade for the right side was grade 0. For the left side, grade 2 was the

one with the highest prevalence. A statistically significant difference was found between the AEP grade and the side (Table 3).

**Table 3.** Distribution of AEP groups and side

Side	Pneumatization grade							
	Grade 0		Grade 1		Grade 2		Grade 3	
	n	%	n	%	n	%	n	%
Right	252	19.1	182	13.8	192	14.6	33	2.5
Left	193	14.6	189	14.3	240	18.2	37	2.8
<b>TOTAL</b>	<b>445</b>	<b>33.8</b>	<b>371</b>	<b>28.1</b>	<b>432</b>	<b>32.8</b>	<b>70</b>	<b>5.3</b>

*Chi-Square Test (p<0.01).*

In relation to laterality, grade 2 was the most prevalent grade found in bilateral cases. For

unilateral cases, the highest prevalence was in grade 0 (Table 2).

**Table 2.** Distribution of laterality between the pneumatization groups

Laterality	Pneumatization grade							
	Grade 0		Grade 1		Grade 2		Grade 3	
	n	%	n	%	n	%	n	%
Absent	157	100.0	0	0.0	0	0.0	0	0.0
Unilateral	128	49.6	84	32.6	40	15.5	6	2.3
Bilateral	3	0.4	287	38.5	392	52.5	64	8.6

Chi-Square Test ( $p < 0.01$ ).

## DISCUSSION

The present study is one of the few studies available in South America and the first in our country using CBCT. This technique allows to evaluate and detect the AEP more precisely.<sup>13</sup> The frequency of the AEP in the present study was 76.2% (502 cases) of 659 revised CBCTs. This result is similar to the one published by Demirel *et al.*<sup>14</sup> with a frequency of 67.6% (169 cases) of 250 revised CBCTs and to the study reported by Khojastepour *et al.*<sup>17</sup> with a prevalence of 76.7% (251 cases) of 327 CBCT patients. On the other hand, a lower frequency of 6.47% (39 cases) was reported in the turkey population.<sup>9</sup> Furthermore, Ladeira *et al.*<sup>1</sup> and Delibasi *et al.*<sup>15</sup> found 21.3% (140 cases) and 2.54% (21 cases) respectively in Brazil. Recently, Şallı *et al.*<sup>18</sup> reported a prevalence of 14.7% (147 cases) of 1000 cases in a Turkish population.

Regarding studies using CT, Groell and Fleischmann (9) found a frequency of 12% (12 cases) in Austria, and Bronoosh *et al.*<sup>19</sup> found 9.55% (43 cases) in Iran. Also, Al Faleh and Ibrahim<sup>16</sup> found 34% (102 cases) using conventional tomograms in Egypt. Only one study has reported a higher prevalence using CT (69% of 100 cases) in India.<sup>12</sup> Moreover, using panoramic radiography Shokri *et al.*<sup>20</sup> and Khojastepour *et al.*<sup>8</sup> found a frequency of 6.2% (98 cases) and 2.1% (64 cases) respectively in Iran using panoramic radiography. In India, Kishore *et al.*<sup>21</sup> and Patil *et al.*<sup>22</sup> found similar frequencies of 2.5% (63 cases) and 1.82% (141 cases) respectively. Orhan *et al.*<sup>2</sup> reported a similar frequency of 1.88% (19 cases) to the ones reported by Hofmman *et al.*<sup>23</sup> with a frequency of 2.38% (20 cases) and of 1.85% (20 cases) respectively in

Germany (Table 4). We have noticed that this anatomical variant increases its frequency when evaluated through CBCT. The improvement of the image and the advance on the techniques can contribute to an adequate evaluation. Therefore, the frequency of AEP can be increased.

Our study showed a greater predilection of AEP on females. Nevertheless, there was no statistically significant difference. Similar results were reported by other authors.<sup>6,16,23-25</sup> On the other hand, Ladeira *et al.*<sup>1</sup> found a slight predilection for the male gender with respect to the total of patients with AEP evaluated with CBCT. Some authors attribute a higher prevalence on the female sex because pneumatization begins with maturation, for this reason girls are chronologically and biologically older than children. Another theory may be due to the random recruitment performed at the time of the study.

Our findings detected more cases with AEP in the sixth decade of life with an age range of 7 to 79 years-old. In the present study, there was a statistically significant difference. Ladeira *et al.*<sup>1</sup> found a similar result. This may be due to the main indication for taking CBCT, since most of the patients in the clinic are referred by the implantology area. Another theory according to Orhan *et al.*<sup>2</sup> is that accessory air cells begin their pneumatization after puberty and end their development several years later, even in the adult stage.

Regarding the AEP localization, most studies found that there is a greater predilection for the left side, as reported in the present study where we found a statistically significant difference. However, other studies such as that of Patil *et al.*<sup>22</sup>,

Bronoosh *et al.*<sup>19</sup> and Carter *et al.*<sup>24</sup> found a greater predilection for the right side (Table 4).

**Table 4.** Percentages of articular eminence pneumatization from previous studies by sex, age, side and laterality

Author	Year	Country	Sex				Age range (Years)	Most frequent age group (Years)	N° of cases by side				Imaging Technique
			Female	%	Male	%			Right	Left	Unilateral	Bilateral	
Şalih <i>et al.</i> <sup>18</sup>	2020	Turkey	253	51.8	235	48.2	16-77	--	149	88	237	381	CBCT
Khojastepour <i>et al.</i> <sup>17</sup>	2018	Iran	112	44.6	139	55.4	9 - 65	---	41	35	76	175	CBCT
Shamshad <i>et al.</i> <sup>12</sup>	2017	India	48	48	52	52	18 - 65	---	14	17	31	38	CT
Kishore <i>et al.</i> <sup>21</sup>	2015	India	----	----	----	----	19 - 78	29 - 38	36	46	44	19	PAN
Demirel <i>et al.</i> <sup>14</sup>	2014	Turkey	179	55.5	159	44.5	----	----	----	----	----	----	----
Bronoosh <i>et al.</i> <sup>19</sup>	2014	Iran	----	----	----	----	----	----	32	30	24	19	CT
Khojastepour <i>et al.</i> <sup>8</sup>	2014	Iran	41	64	23	36	19 - 69	19 - 29	----	----	----	----	PAN
Shokri <i>et al.</i> <sup>19</sup>	2013	Iran	65	66.4	33	33.6	8 - 60	11 - 20	30	34	64	34	PAN
Ladeira <i>et al.</i> <sup>1</sup>	2013	Brasil	75	37	129	63	11 - 85	50 -59	94	110	76	64	CBCT
Patil <i>et al.</i> <sup>22</sup>	2012	India	----	----	----	----	19 - 75	19 - 28	96	79	107	34	PAN
Miloglu <i>et al.</i> <sup>9</sup>	2010	Turkey	25	54	14	46	----	----	12	21	23	16	PAN
Al Faleh <i>et al.</i> <sup>16</sup>	2005	Egypt	54	52.9	48	47.1	----	----	86	89	----	----	Conventional CT
Orhan <i>et al.</i> <sup>2</sup>	2005	Turkey	12	63.1	7	36.9	11 - 29	20 - 29	----	----	----	----	PAN
Hofmman <i>et al.</i> <sup>22</sup>	2001	Germany	11	55	9	45	7 - 87	20 - 29	----	----	----	----	PAN
Carter <i>et al.</i> <sup>23</sup>	1999	USA	20	50	20	50	17 - 83	60 - 69	25	23	32	8	PAN

CBCT: Cone-beam CT, PAN: Panoramic radiography, CT: Computed tomography

Moreover, with respect to laterality a higher prevalence was found for unilateral presentations on CT, panoramic radiography and CBCT. However, Nascimento *et al.*<sup>13</sup> found a higher prevalence of bilateral presentations. Our study found a similar result, this can be due to the same time of development of both temporal bones. In the present study, a statistically significant difference was found with respect to AEP with regard to laterality (Table 4).

Finally, based on Al Faleh and Ibrahim<sup>16</sup> mastoid cells classification, the highest prevalence was for grades 0 and grade 2. With respect to the gender, females with grade 0 had the highest prevalence. However, no statistically significant differences were found. Statistically significant differences were found regarding the age group, the sixth and fifth decade of life were the most prevalent. Finally, the left side and a bilateral presentation were the most prevalent, with grade 2

in a predominant occurrence. A statistically significant difference was also found.

It is very important to know the degree of pneumatization that mastoid cells can present. This can allow us to relate, prevent or rule out pathologies associated with the temporal bone at this level. An adequate diagnosis and also the possibility of being participants in a multidisciplinary management with other areas of medicine may benefit the patient.

## CONCLUSIONS

In conclusion, AEP pneumatization was found in 76.2% of the patients, the highest prevalence of AEP was found in grades 0 and 2, and our results were consistent with previous studies using cone-beam CT. Knowing the degree of AEP pneumatization is important because we can prevent or rule out pathologies associated with the temporal bone at this level. Further studies using

cone-beam CT including greater numbers of patients may be useful to define the frequency of this entity and its relationship with other variables.

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