

Analysis of the Presence, Location and Morphometry of the «Alveolar Antral Artery» by Cone-Beam Computed Tomography in Chilean Adults

Análisis de la Presencia, Ubicación y Morfometría de la Arteria Alvéolo-Antral por Tomografía Computarizada de Haz Cónico en Adultos Chilenos

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SUMMARY: The posterior superior alveolar artery is responsible for the vascularisation of the mucous which covers the posterior wall of the maxillary sinus, pulp and the periodontal tissues of upper molars. The collateral rami of the infraorbital artery irrigate the mucous of the anterior and lateral walls of the maxillary sinus, as well as the pulp and periodontal tissue of the upper anterior teeth and upper premolars. Both these arteries present intraosseous and extraosseous rami which form an anastomosis in the anterior and lateral walls of the maxillary sinus, called the alveolar antral artery (AAA). The aim of this study was to analyse the presence, location and morphometry of the AAA in a Chilean population, considering sex, side and age, using Cone-Beam computed tomography (CBCT). Forty-two CBCT examinations of Chilean adults were evaluated to analyse the presence, location (extraosseous, intraosseous or subperiosteal) and diameter (<1mm, 1-2 mm, 2-3 mm, >3 mm) of the AAA and the distance from the AAA to the amelocemental limit of the upper second premolar (2PM), permanent upper first molar (1M) and permanent upper second molar (2M) by sex and age range. Pearson's chi-squared test, Student's t-test, ANOVA and Pearson's correlation coefficient were applied, using a significance threshold of 5 %. AAA was found in 75 sides (89.3 %), 38 on the right side (90.5 %) and 37 on the left (88.09 %); extraosseous location was most common. More than 80 % of the arteries presented a diameter between 1 and 2 mm, with no important differences between sexes or age ranges. In younger individuals, the artery was located closer to the vestibular amelocemental limit than in older individuals. Carrying out a proper treatment plan which includes imagenological analysis before surgical procedures is essential to avoid possible haemorrhagic events in the region.

KEY WORDS: Alveolar antral artery; Cone-beam computed tomography; Anastomosis; Posterior superior alveolar artery; Infraorbital artery; Anatomy.

INTRODUCTION

The posterior superior alveolar artery (PSAA) is responsible for the vascularisation of the mucous which covers the posterior wall of the maxillary sinus, pulp and periodontal tissues of upper molars. The collateral rami of the infraorbital artery (IOA) irrigate the mucous of the anterior and lateral walls of the maxillary sinus, as well as the pulp and periodontal

tissue of the upper anterior teeth and upper premolars (Alves & Cândido, 2016). Both these arteries present intraosseous and extraosseous rami which form an anastomosis in the anterior and lateral walls of the maxillary sinus, called the alveolar antral artery (AAA) (Kang *et al.* 2013; Alves & Cândido). This anastomosis is at risk of lesions and can restrict

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the dimensions of the bone window during any procedure in the region, such as elevation of the maxillary sinus floor (Mardinger *et al.*, 2007; Rysz *et al.*, 2014). One possible intraoperative complication of elevation of the maxillary sinus floor with lateral approach is the occurrence of a haemorrhagic event due to lesion of the AAA (Stacchi *et al.*, 2017). Lesion of the AAA can cause intense bleeding, obscuring the surgeon's view, and can lead to accidental perforation of the sinus membrane (Ella *et al.*, 2008). Bleeding due to transection of small-diameter arteries during surgical procedures does not normally cause serious problems, and can be controlled easily with electrocauterization (Maridati *et al.*, 2014). With large-diameter arteries, however, it is more difficult to establish haemostasis, as well as increasing the risk of accidental perforation of the sinus membrane (Maridati *et al.*). Complications during surgery to elevate the maxillary sinus floor can cause a higher implant failure rate (Khoury, 1999), reduced bone formation (Nolan *et al.*, 2014) and reduced stabilisation of particulate graft material due to perforation of the membrane (Wallace *et al.*, 2012). It is essential to avoid complications during procedures in the region of the lateral wall of the maxillary sinus, to obtain a higher success rate in treatment; anatomical knowledge of the AAA and proper pre-operative evaluation by X-ray are therefore essential to reduce the risk of complications during surgical procedures. The AAA is always present in the wall of the maxillary sinus, however its location, diameter and distance from the alveolar crest can vary (Maridati *et al.*). The aim of this study was therefore to analyse the presence, location and morphometry of the AAA in Chilean individuals, considering sex, side and age, using Cone Beam computed tomography (CBCT).

MATERIAL AND METHOD

A descriptive, retrospective, observational cross-sectional study was carried out. The sample was non-probabilistic, by convenience. We examined all the CBCT images taken between May and October 2019 as part of the diagnosis and/or treatment planning of patients who attended the Teaching Clinic of Universidad de La Frontera, Temuco, Chile. All the patients involved in this study signed an informed consent which stated their free right to participate in the study or not, with no influence on their dental treatment. The study was approved by the Scientific Ethics Committee of Universidad de La Frontera, No. 067-19.

CBCT examinations of Chilean adults of both sexes were included. Examinations were excluded in which fractures and/or surgery of the maxillary sinus were observed which might affect the interpretation of the tomographies, and images containing congenital anomalies associated with the maxillary bone.

The presence of the AAA was analysed in the anterior and lateral walls of the maxillary sinus using coronal sections. All the measurements were carried out by a previously calibrated researcher; intra-observer analysis was performed. The location of the AAA was classified as intraosseous (Fig. 1A), below the membrane (Fig. 1B) and on the outer cortex of the lateral sinus wall, following Güncü *et al.* (2011). The location of the AAA was analysed by sex, side and age range.

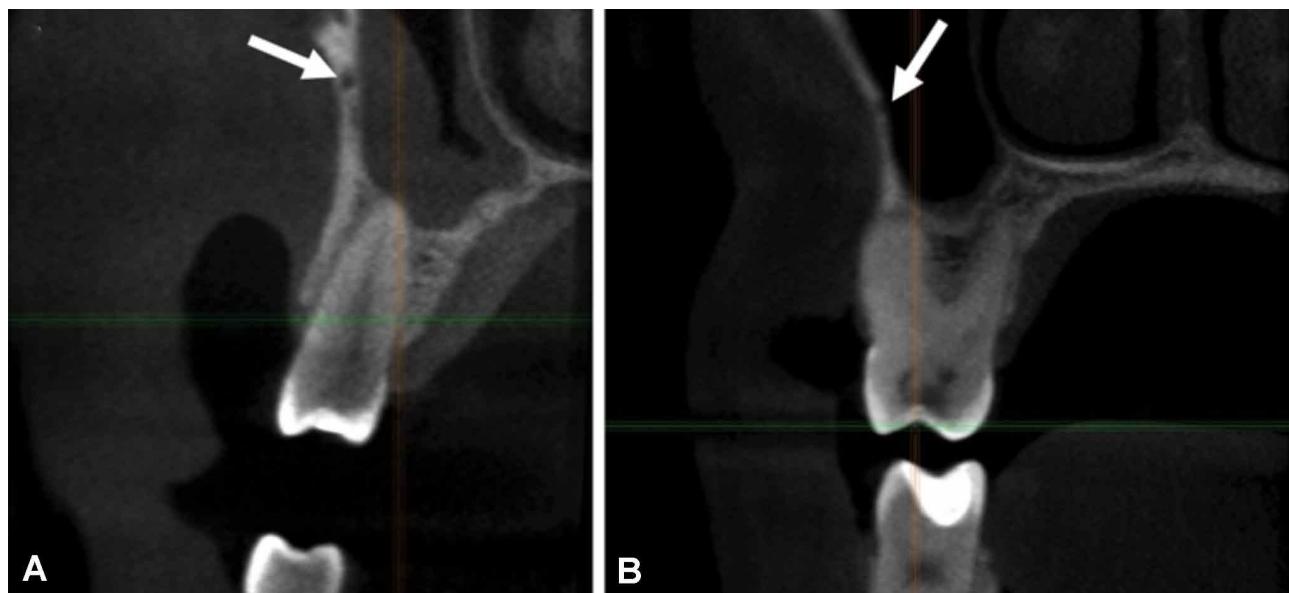


Fig. 1. Coronal section in CBCT. A. Intraosseous AAA (arrow) at the level of the right second premolar. B. Sub-periosteal AAA (arrow) at the level of the right permanent upper first molar.

The diameter of the AAA was analysed by sex, side and age range. The diameter was classified as <1mm, between 1 and 2 mm, between 2 and 3 mm and >3 mm, as proposed by Mardinger *et al.* The association between the diameter and location of the AAA and the association between sides were analysed for the variables location and diameter of the AAA. For analysis by age range, the sample was divided into the following ranges: 18-28 years; 29-39 years; 40-49 years; > 50 years.

We also determined the distance from the AAA to the vestibular amelocemental limit in the following regions: upper second premolar (AAA-2PM), permanent upper first molar (AAA-1M) and permanent upper second molar (AAA-2M) (Fig. 2).

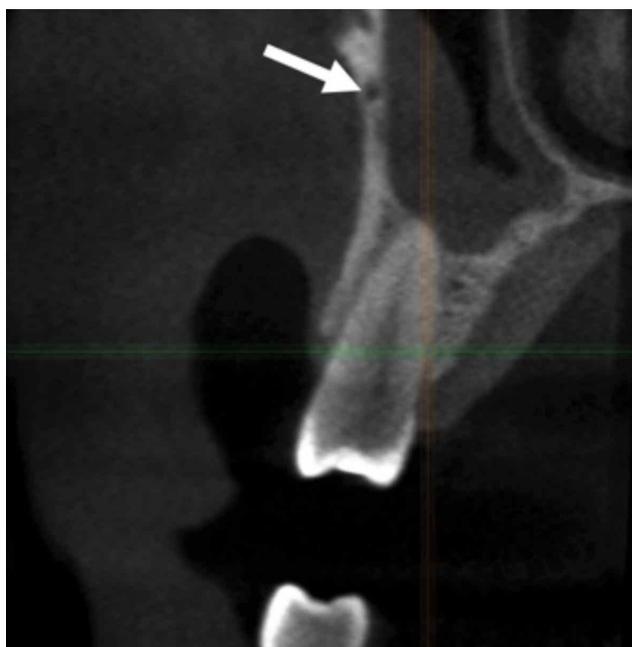


Fig. 2. Coronal section in CBCT showing the measurement from the AAA to the vestibular amelocemental limit in the right upper second premolar.

The CBCT examinations were carried out with a PAX Zenith 3D Tomograph (Vatech Co., Gyeonggi-Do, Korea), FOV 12 x 9 cm. / 8 x 6 cm. The images were taken at 120 kV, 10 mA, with exposure time of 24 seconds. The measurements of the images were calculated with the Ez3D Plus software (E-WOO Technology Co, Ltd. Korea), with voxel size 0.2 mm. (12 x 9 cm) / 0.12 mm. (8 x 6 cm).

Statistical analysis. The intraclass correlation coefficient (ICC) and the kappa test were used for intra-observer analysis. The association was classified as poor (0.0), slight (0.01-0.20), regular (0.21-0.40), moderate (0.41-0.60), substantial (0.61-0.80) and almost perfect (0.81-1.00).

Levene's test was applied to test homogeneity of variances and the Kolmogorov-Smirnov test to analyse the normality of the data. Pearson's chi-squared test was used for qualitative variables: comparison of presence between sides, sexes and age ranges. The strength of association between the variables was evaluated by the Phi coefficient (ϕ). The strength of association was interpreted as suggested by Cohen (1988), being classified as small (0.10), medium (0.30), large (0.50) or very large (≥ 0.70). Student's t-test for dependent samples was used for analysis between sides and Student's t-test for independent samples for analysis between sexes. One-way ANOVA was used for analysis between age ranges. Pearson's correlation coefficient was used to analyse the relation between left and right sides for the distances (AAA-2PM, AAA-1M, AAA-2M) and for the diameter of the AAA. The age-diameter ratio was also analysed. Pearson's correlation was classified as nil ($r=0$), very low ($0 < r < 0.2$), low ($0.2 < r < 0.4$), moderate ($0.4 < r < 0.6$), high ($0.6 < r < 0.8$), very high ($0.8 < r < 1$) and perfect ($r=1$). GraphPad Prism software was used for the figures. SPSS software v. 22.0 was used for statistical analysis, with a significance threshold of 5 %.

RESULTS

The intra-observer analysis presented an almost perfect concordance index (> 0.8) in all the analyses. Forty-two CBCT examinations were used (84 maxillary sinuses) of patients aged between 18 and 61 years (mean 29.05 years, $SD=13.04$ years), 15 women (35.7 %) and 27 men (64.3 %).

Presence of AAA. AAA was found in 75 sinuses (89.3 %): 38 on the right side (90.5 %) and 37 on the left (88.09 %). No differences in the presence of AAA were found between sides ($p=0.124$). AAA was present in 90 % of women and 88.9 % of men, with no statistically significant difference in presence of AAA between sexes ($p=0.875$).

Location of the AAA. In the 2PM region we observed that the highest number of AAA were located on the outer cortex of the lateral sinus wall (57.3 %), followed by intraosseous (33.3 %) and below the membrane (9.3 %) (Fig. 3). In the 1M region we observed that the highest number of AAA were located on the outer cortex of the lateral sinus wall (49.3 %), followed by intraosseous (27.4 %) and below the membrane (23.3 %) (Fig. 3). In the 2M region we observed that the highest number of AAA were located on the outer cortex of the lateral sinus wall (45.3 %), followed by below the membrane (32 %) and intraosseous (22.7 %) (Fig. 3).

In the analysis between sexes, statistically significant differences were observed only in the 2M region, with a

small strength of association ($p=0.036$, Phi coefficient=0.297). We observed that among males the most common location of the AAA is on the outer cortex of the lateral sinus wall (56.3 %), followed by below the membrane (27.1 %) and intraosseous (16.7 %); among females, below the membrane is most common (40.7 %), followed by intraosseous (33.3 %) and on the outer cortex of the lateral sinus wall (25.9 %) (Fig. 4).

The location of the AAA presented no statistically significant differences between sides and age ranges.

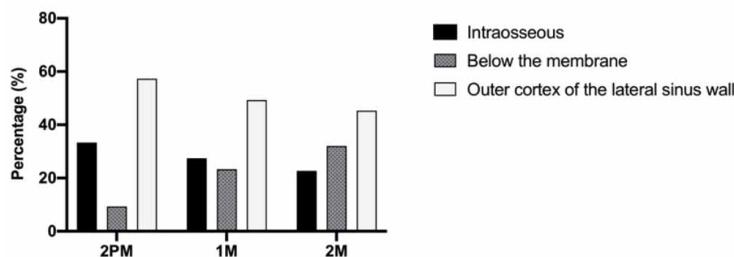


Fig. 3. Location of the AAA (percentage) in the region of 2PM, 1M and 2M.

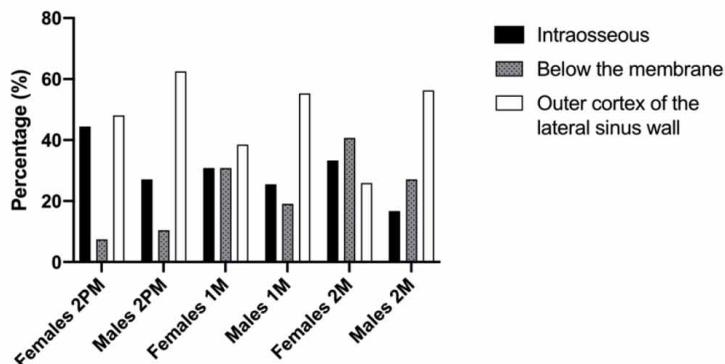


Fig. 4. Location of the AAA (percentage), by sex.

Diameter of the AAA. The mean diameter of the AAA was 1.16 mm (SD=0.30 mm) in the 2PM region; 1.28 mm (SD=0.39 mm) in the 1M region, and of 1.30 mm (SD=0.31 mm) in the 2M region. We observed that the diameter of the AAA on the left side was significantly greater than on the right side in the 1PM, 1M and 2M regions ($p<0.000$) (Fig. 5).

The diameter of the AAA in the 2PM region was smaller than 1mm in 15.6 % of cases and between 1 and 2 mm in 84.4 %. The diameter of the AAA in the 1M region was smaller than 1mm in 13.5 % of cases, between 1 and 2 mm in 83.8 % and between 2 and 3 mm in 2.7 %. The diameter of the AAA in the 2M region was smaller than 1mm in 12.2 % of cases, between 1 and 2 mm in 82.9 % and between 2 and 3 mm in 4.9 %.

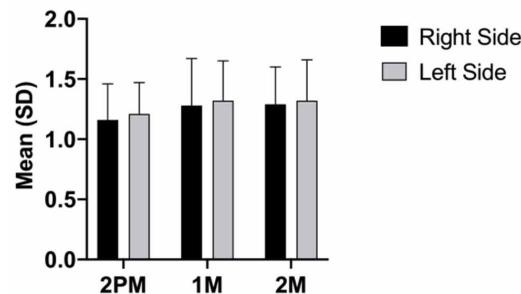


Fig. 5. Mean and standard deviation (SD), in millimetres, found for the diameter of the AAA in the region of the second premolar, first molar and second molar, by side.

Table I shows the correlation between sides for the diameters of the AAA; a very high, significant positive correlation is observed in the 2M region and a high significant positive correlation in the 2PM and 1M regions.

No statistically significant differences were found between sexes for the diameter, except in the 2M region (right side), where the mean value was greater in men (1.60 mm, SD=0.32 mm) than in women (1.20 mm, SD=0.20 mm) ($p=0.006$).

No statistically significant differences in any variable were observed in the analysis of the diameter of the AAA by age range.

In the analysis between age and diameter of the AAA we observed that the diameter in the 1M region (right side) presented a low significant negative correlation. No statistically significant differences were found for the other variables (Table II).

Distance to the AAA. The mean distances were: 22.15 mm (SD=3.38 mm) for AAA-2PM; 18.33 mm (SD=3.80 mm) for AAA-1M and 17.34 mm (SD=4.13 mm) for AAA-2M.

In the analysis of distance by age, we observed a moderate significant positive correlation for AAA-2M (right side) and a low significant positive correlation for AAA-2M (left side) and AAA-1M (both sides). No significant correlation was found for AAA-2PM (Table III).

In the analysis between sides we observed that the mean values for AAA-2PM, AAA-1M and AAA-2M were significantly higher on the right side than the left ($p<0.000$) (Fig. 6).

Table I. Pearson's correlation coefficient (rho) and p value between left and right sides.

Analysis	Distance AAA-2PM	Distance AAA-1M	Distance AAA-2M	Diameter 2PM region	Diameter 1M region	Diameter 2M region
rho	0.950	0.987	0.981	0.734	0.727	0.863
p-value	0.000*	0.000*	0.000*	0.000*	0.001*	0.000*

* statistically significant difference.

Table II. Pearson's correlation coefficient (rho) and p value between age and diameter of the AAA in the region of the second molar, first molar and second premolar.

	Right Side			Left Side		
	Diameter 2PM region	Diameter 1M region	Diameter 2M region	Diameter 2PM region	Diameter 1M region	Diameter 2M region
rho	-0.147	-0.322	-0.257	-0.254	-0.020	-0.166
p-value	0.385	0.043*	0.105	0.161	0.912	0.328

* statistically significant difference.

Table III. Pearson's correlation coefficient (rho) and p value between age and distances, by side.

	Right Side			Left Side		
	Distance AAA-2PM	Distance AAA-1M	Distance AAA-2M	Distance AAA-2PM	Distance AAA-1M	Distance AAA-2M
rho	0.234	0.398	0.413	0.275	0.373	0.360
p-value	0.198	0.015*	0.000*	0.128	0.023*	0.022*

* statistically significant difference.

Table I shows the correlation between sides for AAA-2PM, AAA-1M and AAA-2M, with a very high significant positive correlation for all the distances.

Between sexes, only AAA-2PM (right side) presented statistically significant differences; the mean values for this distance were higher in women (22.81 mm, SD=2.87 mm) than in men (19.67mm, SD=2.89 mm) (p=0.049).

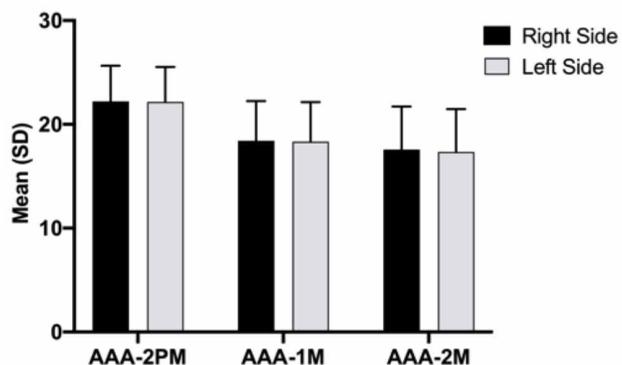


Fig. 6. Mean and standard deviation (SD), in millimetres, found for the AAA-2PM, AAA-1M and AAA-2M distances, by side.

Between age ranges we observed a statistically significant difference only for AAA-2M between individuals of 18-28 years vs. 40-49 years. On the right side the distance was smaller for the 18-28 years group (16.61 mm, SD=1.70 mm) than the 40-49 years group (16.52 mm, SD=4.07 mm) (p=0.027). A similar finding was recorded on the left side,

where the distance was significantly smaller for the 18-28 years group (16.52 mm, SD=4.07 mm) than the 40-49 years group (23.11 mm, SD=2.62 mm) (p=0.035).

DISCUSSION

During surgical procedures like horizontal osteotomy of the maxilla, Le Fort I fracture treatment and Caldwell-Luc surgeries, as well as elevation of the maxillary sinus floor, there is a potential risk of bleeding from the rami of the maxillary artery (Shahidi *et al.*, 2016); it is therefore important to have detailed anatomical knowledge of the region. One of the principal intraoperative complications that occur during elevation of the sinus floor with lateral approach is bleeding due to lesions of the AAA (Stacchi *et al.*). The AAA is always present in the lateral wall of the maxillary sinus (Rosano *et al.*, 2011) and the bleeding caused by accidental lesion can occur during opening of the lateral window (Stacchi *et al.*). Complications during surgical procedures, such as lesion of the AAA and perforation of the sinus membrane, have a negative impact on the clinical results, reducing implant survival rate and diminishing the formation of new bone in the region (Stacchi *et al.*).

In the present study we analysed the presence, location and diameter of the AAA, using CBCT, in Chilean individuals. We identified the AAA in 89.3 % of the sinuses

analysed, similar to the findings of Ilgüy *et al.* (2013) in a Turkish population who also reported identifying the AAA in 89.3 % of patients. Note that studies in cadavers report that the AAA can be observed in 100 % of the sinuses analysed (Solar *et al.*, 1999; Traxler *et al.*, 1999; Rosano *et al.*, 2009). Because the calibre of the AAA is often very small, it cannot always be observed in CT and CBCT images (Mardinger *et al.*). Other studies analysing the presence of AAA using CT scans or CBCT report rates of between 60.3 % in a Thai population (San Aung *et al.*, 2017) and 64.5 % (Güncü *et al.*) for a Turkish population, 55 % for an Israeli population (Mardinger *et al.*) and 52.9 % for a North American population (Elian *et al.*, 2005), all lower than in our investigation.

Cruz Ibañez *et al.* (2016) studied the distance from the alveolar antral canal to the cervical region of the tooth, finding distances of 17.35 mm for 2PM, 16.96 mm for 1M and 18.75 mm for 2M. San Aung *et al.* reported the distance from the AAA to the alveolar crest, finding 15.93 mm (SD=3.57 mm) for the 2M region, 15.82 mm (SD=4.09 mm) for the 1M region and 20.35 mm (SD=4.74 mm) for the 2PM region. Rysz *et al.* also reported the distance from the AAA to the alveolar crest, finding 19.91 mm for the 2M region, 15.99 mm for the 1M region and 16.52 mm for the 2PM region. Mardinger *et al.*, in their study in an Israeli population, also analysed the distance from the AAA to the alveolar crest, finding 19.05 mm (SD=4.60 mm) for the 2PM region, 16.92 mm (SD=4.45 mm) for the 1M region and 18.88 mm (SD=3.86 mm) for the 2M region. In the present study we analysed the distance from the AAA to the vestibular amelocemental limit; in the 2PM region, the AAA was more distant than in other regions, with a mean of 22.20 mm for the right side and 22.15 mm for the left side. In the 2M region, the AAA was located closer to the vestibular amelocemental limit than in the other regions, 17.56 mm for the right side and 17.34 mm for the left. In our study we also observed that the distance from the AAA to the amelocemental limit tends to increase with increasing age; in other words, the artery is further from the amelocemental limit in older than younger individuals.

The location of the AAA varies over its course, and all three variations (intraosseous, below the membrane, on the outer cortex of the lateral sinus wall) can be found in the lateral wall of the same maxillary sinus. In the present study, the AAA presented the highest percentage of locations on the outer cortex of the lateral sinus wall in the 2PM, 1M and 2M regions; the location below the membrane (intrasinus) presented the lowest percentage. Different findings were reported by Güncü *et al.* and Ilgüy *et al.*, who reported the majority of the AAA in an intraosseous location and less than 6 % on the outer cortex of the lateral

sinus wall. In our study we did not find a marked sexual difference in the location of the AAA; in the 2M region the location on the outer cortex of the lateral sinus wall was more common in males (56.3 %) than in females (25.9 %), while below the membrane was more common in females (40.7 %) than in males (27.1 %). Ilgüy *et al.* also reported differences between sexes, finding that intraosseous AAA was more prevalent in males (74.4 %) than in females (66.4 %), and location on the outer cortex of the lateral sinus wall was also more prevalent in males (10 %) than in females (1.9 %).

In the present study the mean value of the calibre of the AAA was between 1 and 2 mm in more than 80 % of the cases analysed; it was smaller than 1 mm in between 12.2 % and 15.6 %, and between 2 and 3 mm in between 2.7 % and 4.9 % of the cases, depending on the region analysed (2PM, 1M, 2M). No AAA was found with calibre greater than 3 mm. Güncü *et al.* also reported that the majority of AAA presented a calibre between 1 and 2 mm, and only 12.3 % were larger than 2 mm. Our findings disagree with Güncü *et al.* who reported that they found statistically significant differences in the calibre of the AAA between sexes but not between sides. In our study we found differences between sexes only in the right side in the 2M region, where the diameter was larger in men than in women; and a larger diameter on the left side than on the right. Mardinger *et al.*, in their study in Israelis, reported that the diameter of the canal was smaller than 1 mm in 26 % of cases, between 1 and 2 mm in 22.1 % of cases and between 2 and 3 mm in 7.0 % of cases. Kang *et al.* reported that only 37.8 % of the AAA presented a diameter greater than 1 mm and Ilgüy *et al.* found 31.1 % of AAA with diameter greater than 1 mm. Elian *et al.* suggested that an AAA with diameter less than 0.5 mm would not produce important bleeding; Mardinger *et al.* and Rosano *et al.* (2011) considered that damage to a small-calibre artery (<2 mm) does not affect the execution of the surgical procedure. In a systematic review, Stacchi *et al.* found only 0.4 % haemorrhagic events in 542 sinus floor elevations with lateral approach using rotating or ultrasound instruments. In the same systematic review the authors observed that the majority of the studies reporting haemorrhagic events indicated that the event was not significant during the antrostomy (Stacchi *et al.*). It may be noted that lesion of the AAA during sinus surgery may cause abundant bleeding, and that it is important to preserve the integrity of the anastomosis of the PSAA and IOA in order to support the neoangiogenesis of the bone graft, improving the formation of regenerated tissue (Solar *et al.*). It is therefore important to analyse the region and plan the procedure carefully in order to avoid complications during surgery.

CONCLUSIONS. In the present study, the AAA was identified by CBCT in 89.3 % of the sinuses analysed, most frequently in an extraosseous location. More than 80 % of the arteries presented a diameter between 1 and 2 mm, with no important differences between sexes and age ranges. The distance from the AAA to the vestibular amelocemental limit generally increases proportionally on both sides, and there is no marked effect of sex. In younger individuals, the artery is located closer to the amelocemental limit than in older people. Based on our findings we suggest that a proper treatment plan should be prepared, including imagenological analysis, before surgical procedures to avoid possible haemorrhagic events in the region.

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RESUMEN: Arteria alveolar superior posterior es responsable de la vascularización de la mucosa que recubre la pared posterior del seno maxilar, la pulpa y el tejido peridontal en el que se insertan los molares superiores. Las ramas colaterales de la arteria infraorbitaria irrigan la mucosa de las paredes anterior y lateral del seno maxilar, así como la pulpa y el periodonto de los dientes anteriores superiores y los premolares superiores. Ambas arterias presentan ramas intraóseas y extraóseas que forman una anastomosis en las paredes anterior y lateral del seno maxilar, denominada arteria alvéolo antral (AAA). El objetivo de este estudio fue analizar la presencia, localización y morfometría del AAA en una población chilena, considerando sexo, lado y edad, mediante tomografía computarizada Cone-Beam (CBCT). Se evaluaron 42 exámenes CBCT de adultos chilenos para analizar la presencia, ubicación (extraósea, intraósea o subperióstica) y diámetro (<1 mm, 1-2 mm, 2-3 mm, > 3 mm) del AAA, y la distancia del AAA al límite amelocemental del segundo premolar superior (2PM), primer molar superior permanente (1M) y segundo molar superior permanente (2M) por sexo y rango de edad. Se aplicaron la prueba de chi-cuadrado de Pearson, la prueba t de Student, ANOVA y el coeficiente de correlación de Pearson, utilizando un umbral de significancia del 5 %. Se encontró AAA en 75 lados (89,3 %), 38 del lado derecho (90,5 %) y 37 del lado izquierdo (88,09 %); la localización extraósea fue la más común. Más del 80 % de las arterias presentaban un diámetro entre 1 y 2 mm, sin diferencias importantes entre sexos ni rangos de edad. En individuos más jóvenes, la arteria se ubicó más cerca del límite amelocemental vestibular que en individuos mayores. La realización de un adecuado plan de tratamiento que incluya análisis imagenológico antes de los procedimientos quirúrgicos es fundamental para evitar posibles eventos hemorrágicos en la región.

PALABRAS CLAVE: Arteria alvéolo antral; Tomografía computarizada de haz cónico; Anastomosis, Arteria alveolar superior posterior; Arteria infraorbitaria; Anatomía.

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