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Article

Dimension and morphology of the mandibular condyle in Class I patients in cone beam computed tomography.

Dimensión y morfología del cóndilo mandibular en pacientes de Clase I en tomografía computarizada de haz cónico.

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Abstract: To evaluate the anterior-posterior (A-P)/medial-lateral (M-L) dimension, and morphology of the mandibular condyle in patients aged 18 to 65 years with Class I skeletal pattern on Cone Beam Computed Tomography scans (CBCTs). **Materials and Methods:** Seventy one CBCTs were evaluated using RealScan 2.0 software. The dimension was determined by points A (most anterior in the sagittal plane), P (most posterior in the sagittal plane), M (most interior in the coronal plane), L (most exterior in the coronal plane). The morphology of the condyle was evaluated in two coronal and sagittal planes, being classified as: round, flat, convex or mixed. The size of the condyle was analyzed by descriptive statistics and the morphology by frequency distribution. For the bivariate analysis, the Student's t-test was applied. **Results:** Measurements were obtained for the A-P diameter of the right condyle (RC) (8.72mm ± 1.25mm) and the left condylar (LC) (8.50mm ± 1.50mm), the M-L diameter of the RC (19.24mm ± 2.03mm) and the LC (18.97mm ± 1.87mm). There were significant differences in the male M-L dimension of the LC compared to the female (p=0.002). The most prevalent morphology of RC (35.21) and IQ (23.94) in the coronal plane was round. . **Conclusion:** The A-P dimension of the right and left condyle is similar in both genders; however, there are differences in the M-L dimension of the left male condyle. The most prevalent morphology of the right and left condyle was round in the sagittal plane with the exception of the coronal plane.

Keywords: Mandibular condyle; cone-beam computed tomography; temporomandibular joint; prevalence; humans; mandible.

Resumen: Evaluar la dimensión antero- posterior (A-P)/medio-lateral (M–L), y la morfología del cóndilo mandibular en pacientes de 18 a 65 años con patrón esquelético Clase I en tomografías computarizadas Cone Beam. **Material y Métodos:** 71 tomografías fueron evaluadas mediante el software RealScan 2.0. La dimensión fue determinada por los puntos A (más anterior en el plano sagital), P (más posterior en el plano sagital), M (más interno en el plano coronal), L (más externo en plano coronal). Se evaluó la morfología del cóndilo en dos planos coronal y sagital, clasificándose en: redonda, aplanada, convexa y mixta. La dimensión del cóndilo fue analizada por estadística descriptiva y la morfología mediante distribución de frecuencias. Para el análisis bivariado, se aplicó la prueba de t de Student. **Resultado:** Se obtuvieron las medidas del diámetro A-P del cóndilo derecho (CD) (8,72mm ± 1,25mm) y el izquierdo (CI) (8,50mm ± 1,50mm), el diámetro M-L del CD (19,24mm ± 2,03mm) y el CI (18,97mm ± 1,87mm). Hubo diferencias significativas en la dimensión M-L del CI del sexo

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masculino en comparación al femenino (p=0.002). La morfología más prevalente del CD (35,21) y CI (23,94) en plano coronal fue de tipo redonda. **Conclusión:** La dimensión A-P del cóndilo derecho e izquierdo es similar en ambos sexos; sin embargo, existen diferencias en la dimensión M-L del cóndilo izquierdo del sexo masculino. La morfología del cóndilo derecho e izquierdo más prevalente fue la redonda en plano sagital a excepción del plano coronal.

Palabras Clave: *Cóndilo mandibular; tomografía computarizada de haz cónico; articulación temporomandibular; prevalencia; humanos; mandíbula.*

INTRODUCTION.

The occlusion skeletal pattern is the relationship between the maxilla and the mandible in an anterior-posterior profile.[1] It is classified into three different classes (Class I, Class II and Class III), with more than 50% of the general population classified as having a Class I skeletal pattern, representing an ideal and optimal maxillomandibular skeletal relationship.[2] Patients with Class I skeletal pattern, despite representing the ideal, may present pathologies in the mandibular condyle. These pathologies affect condylar dimension and mor-phology and trigger signs and symptoms such as muscle pain, joint click, facial asymmetry and limited mouth opening, thus affecting function and mastication.[3] Despite this, there is little updated information on the actual dimensions of the mandibular condyle in Peruvian patients with Class I skeletal pattern, which leads to establish initial parameters of normality in this population.

The evaluation of the mandibular condyle dimensions has been reported since 1968 with the Moffett study, which reports considerable differences in the size of the condyle between the existing human groups. This means that the temporomandibular joint can be altered in response to attrition or loss of teeth during an individual's lifetime.[4]

In 1983, Hinton conducted a study on dry human skulls from an American population. This study determined that the average size of the mandibular condyle in the medial-lateral plane is 26.8mm and in the anteroposterior diameter is 18.2mm.[5] Rey *et al.*,[6] evaluated the three-dimensional morphology of the mandibular condyle with cone-beam computed tomography in a Mexican population. They found that the median-lateral diameter measurement of the condyle was 21.8mm in men and 18.7mm in women.

However, with regard to the anteroposterior diameter, an average measurement of 10.1mm in men and 9.8mm in women was found. Thirdly, Hedge *et al.*,[7] in 2013, determined through a systematic review that the dimensions of the mandibular condyle in humans averages 21mm in the medial-lateral diameter and 9mm in the anteroposterior diameter, which are currently considered normal characteristics.

Another important parameter of study is condylar morphology, which depends on the mastication and phonation functions performed by each individual throughout their life. According to Moss theory, function makes form and form favors function, so we consider that an adequate condylar structure is required to maintain proper function.[8]

Many authors have studied the classification of the shape of mandibular condylar shape classification.[10-13] Yale *et al.*[9] described the condylar morphology in human skulls in an American population and determined the anteroposterior classification (convex, flattened, angled and rounded shape). With advancing technology, studies of condylar morphology began to be carried out with computed tomography such as those performed by Christiansen *et al.*,[10] and Raustia *et al.*[11] Then, Cotecchia *et al.*,[12] made a classification simplifying the criteria following the compilation of all the previous studies and classified the mandibular condyle as round, flat, angled and mixed type in the lateral and posterior view.

Currently, 3D images – from Cone Beam Computed Tomography (CBCT) - are an effective complementary method for the study of the mandibular condyle. The CBCT is an instrument used for diagnosis and accurately reproduces anatomical structures both at normality and their pathological variations. Also, the development of software that allows making cuts in different planes and obtaining more specific measures without distortion allows for obtaining reliable and true data.[13-14]

Findings of the dimension and morphology of the mandibular condyle will allow us to establish a pattern of normality in a population, as well as to make an early diagnosis of temporomandibular pathologies. Therefore, the aim of the study is to evaluate the dimension and morphology of the mandibular condyle in Peruvian patients aged 18 to 65 years with Class I skeletal pattern from Cone Beam Computed Tomography data.

MATERIALS AND METHODS.

The design was descriptive and retrospective and the analysis unit consists of a Cone Beam computed tomography (CBCT) from an imaging center (January and July 2017, Lima – Peru). The initial sample size was 59 CBCT (statistical software Epidat® version 4.2, α 95% and precision 0.20) through the estimation of a mean (SD 0.78).[6] However, a total of 71 CBCTs were collected for convenience (26 male and 45 female). The inclusion criteria were CBCTs of 18-65 year old patients of both sexes with Class I skeletal pattern with bilateral molar contacts and who have completed their growth stage.

Exclusion criteria were tomographies from patients with facial trauma, dentofacial deformities associated with syndromes, total edentulous patients and patients with a record of surgical treatment in the face area. Independent variants were morphology and condylar dimension, and dependent variants were Class I skeletal pattern and sex This report was approved by the Ethics Committee of the Universidad Peruana de Ciencias Aplicadas (CEI/152–12-1). All patients provided signed informed consent, and confidentiality of the information was maintained by coding clinical records and CBCT.

Techniques and procedures

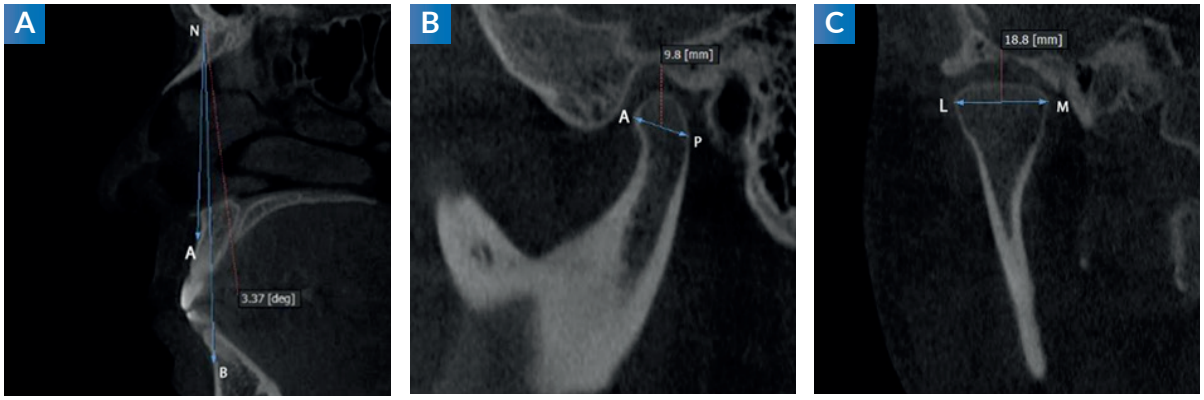
The mandibular condyle dimension (A-P and M-L) and the anterior-posterior profile (Steiner-Class I analysis) was performed with RealScan 2.0 software (PointNix, Korea) (Figure 1). The determination of the anterior-posterior dimension (A-P) in mm was performed in the sagittal plane by projecting a line from the most prominent anterior point of the condyle (Point A) to the most prominent posterior point of it (Point P).

The determination of the medial-lateral dimension (M-L) in mm was performed in the coronal plane with the projection of a line from the most prominent internal point of the condyle (Point M) to the most prominent external point of it (Point L).[15]

Furthermore, the mandibular condyle morphology was identified and visually compared with the classification made by Cotecchia *et al.*,[12] in the two planes, both sagittal and coronal, being classified as flat, round, convex and mixed in each plane (Figure 2).

Data of the mandibular condylar dimension were analyzed by means of descriptive statistics: mean, median, standard deviation, minimum and maximum and those of the condylar morphology by means of frequency distribution (%-Microsoft Excel©). For the bivariate analysis between dimension and sex variables, the Student's t-test was applied (Microsoft Excel©/ Stata® version 12.0).

Figure 1. Anatomical points viewed at the CBCT.



A: ANB points to evaluate the Class I skeletal pattern.
B: Sagittal view in which point A and point P are located.
C: Coronal view in which point M and point L are located. (CBCT Image - Database).

Figure 2. Classification of the morphology of the condyle in the coronal and sagittal plane according to Cotecchia *et al.*[13]

Classification	Description
Round	A circular curvature predominates.
Angled	An acute angle of the curvature predominates.
Flat	A flattened profile predominates.
Mixed	Combination of the above-mentioned shapes or irregulars.

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Table 1. Descriptive statistics of the anterior - posterior and medial - lateral dimension of the right and left mandibular condyle in patients with Class I skeletal pattern.

	Dimension	Mean	Median	S.D.	Minimum	Maximum
Right Condyle	Anterior- Posterior Diameter	8.72mm	8.70mm	1.25	6.00	12.00
Right Condyle	Medium - Lateral Diameter	19.24mm	18.90mm	2.03	14.50	24.80
Left Condyle	Anterior- Posterior Diameter	8.50mm	8.50mm	1.50	5.40	12.90
Left Condyle	Medium – Lateral Diameter	18.97mm	18.70mm	1.87	14.80	23.00

S.D: Standard deviation.

Table 2. Descriptive statistics of the coronal and sagittal morphology of the right and left mandibular condyle in patients with Class I skeletal pattern.

Condyle	Plane	Morphology	n	(%)
Right Condyle	Coronal	Round	25	(35.21)
		Flat	22	(30.99)
		Angled	16	(22.54)
		Mixed	8	(11.27)
Right Condyle	Sagittal	Round	28	(39.44)
		Flat	23	(33.39)
		Angled	14	(19.72)
		Mixed	6	(8.45)
Left Condyle	Coronal	Round	17	(23.94)
		Flat	22	(30.99)
		Angled	12	(16.90)
		Mixed	20	(28.17)
Left Condyle	Sagittal	Rounded	26	(36.62)
		Flat	23	(32.39)
		Angled	16	(22.54)
		Mixed	6	(8.45)

n: Absolute frequency. **%:** Relative frequency.

Table 3. Comparison between the mean of the A-P and M-L dimension of the right and left condyle according to the gender.

Condyle	Dimension	Sex	Mean*	S.D.	*p*-value
Right	Anterior-Posterior	Male	8.97mm	1.51	0.285***
		Female	8.57mm	1.06	
Right	Medium-Lateral	Male	19.85mm	2.12	0.052**
		Female	18.88mm	1.91	
Left	Anterior-Posterior	Male	8.73mm	1.76	0.343**
		Female	8.38mm	1.32	
Left	Medium-Lateral	Male	19.83mm	1.70	0.002**
		Female	18.48mm	1.80	

*: Measurement in mm. **: Student's t-test. ***: Student's t-test for unequal variances. **p-value:**Statistical significance level, ($p<0.05$).
S.D: Standard deviation.

RESULTS.

In the 71 CBCTs evaluated, it was found that the A-P diameter of the right condyle had a mean of 8.72mm ± 1.25mm and 8.50mm ± 1.50mm for the left condyle. Similarly, the M-L diameter of the right condyle had a mean of 19.24mm ± 2.03mm and 18.97mm ± 1.87mm for the left condyle. (Table 1)

Regarding the morphology of the mandibular condyle, it was found that in the coronal plane the most frequent morphology for the right condyle was round (35.21%), flat (30.99%), angled (22.54%) and mixed (11.27%); for the left condyle it was: round (23.94%), flat (30.99%), angled

(16.90%) and mixed (28.17%). In the sagittal plane, the most frequent morphology for the right condyle was found to be round (39.44%), flat (33.39%), angled (19.72%) and mixed (8.45%); for the left condyle, it was round (36.62%) flat (32.39%), angled (22.54%) and mixed (8.45%). (Table 2)

A comparison between the dimension obtained from the mandibular condyle and the gender found a significant difference (p=0.002) in the length of the left condyle in the M-L plane in male gender. (Table 3)

DISCUSSION.

The aim of the study is to evaluate the dimension and morphology of the mandibular condyle in Peruvian patients aged 18 to 65 years with Class I skeletal pattern in 71 CBCT scans. There is a clear difference in the M-L dimension of the left condyle males (greater than 1.00mm). On the other hand, there was no significant difference between the A-P dimensions in both sexes. Furthermore, the most frequent shape in the right and left condyle was the round type in both planes, except for the left condyle in the coronal plane, where the most frequent was the flat type.

In this study, CBCT was chosen as its 3D digital development improves significantly the true replication of anatomical structures, location and precise measurement in comparison with traditional 2D images. This is because CBCT avoids the superposition of adjacent structures and provides high resolution images, showing detailed anatomical structures. In addition, the software enables multiplane recons-tructions, axial, sagittal and coronal cuts, image reduction or enlargement, among other options.[13-14]

At present, there are several studies that use CBCT for the analysis of the mandibular condyle, taking into account the characteristics of this instrument. In 2014, Patel *et al.*,[16] used CBCT for the diagnosis of bone defects in the mandibular condyle.

In 2015 in India, Manjula *et al.*,[17] used CBCT to observe the condylar position in the glenoid cavity due to its accuracy. Also, Sacucci *et al.*,[18] studied condylar volume in patients with different skeletal patterns in CBCT. Recent studies, such as Bertram *et al.*,[19] in 2017, evaluated condylar erosion related to posterior tooth loss using CBCT. On the other hand, Garcia-Sanz *et al.*,[20] conducted a study to verify the accuracy of the CBCT in volumetric and linear measurements of the mandibular condyle, and they concluded that it is a specific and reliable technique for the clinical diagnosis of this bone structure.

Although the dimension and morphology of the mandibular condyle is related to functionality, it is also related to ethnicity and geographical location. As for South America, in 2009 Fialho *et al.*,[21] conducted a study in 30 Brazilian patients in order to investigate the dimension and position of the right and left condyle in individuals with Class I malocclusion. They found a mean A-P diameter of 9.30mm ± 1.08mm for the right side and 9.39mm ± 1.28mm for the left side. For the M-L diameter, they found a mean of 20.62mm ± 1.87mm for the right side and 20.57mm ± 1.93mm for the left side.

The results are in agreement with the data described in the present study. On the other hand, Park *et al.*,[22] analyzed 60 CBCTs in 2014 of adult patients in Korea, and evaluated morphology and dimension of the mandibular condyle according to vertical facial profiles, such as hypodivergent, normodivergent and hyperdivergent. In the normodivergent group it was found that the round was the most common and its dimension had a mean of 7.21mm ± 1.16mm in the A-P diameter and a mean of 19.40mm ±2.79mm in the M-L diameter.

Park *et al.*,[22] A-P dimension value is below the range found in the present study (8.50mm-8.72mm). This difference is probably due to differences in lifestyle, diet and food diversity in the region. The most frequent morphology in this study was round. According to Moss' functional matrix hypothesis, the shape of the bones depends on the functional matrix which includes the muscles, ligaments, nerves, soft tissues and teeth.[8] This means that the shape of the condyle can vary according to the function of the surrounding components. In the ideal Class I skeletal pattern, one would expect the shape of the condyle to be round and symmetrical,[12] because the functional matrix of the condyle is balanced in performing its functions properly. However, the condylar structure may vary due to some alteration in its function caused by a pathology that appears throughout an individual's lifetime.[23]

In relation to sex, the difference found in the left M-L dimension of the condyle in males is possibly due to inherent variations between the two sexes. According to biological anthropology studies, bone characteristics and measurements are different between the sexes.[22-23] The length and weight of the bones (femur, pelvis and skull) is greater in males than in females.

On the other hand, Class I skeletal pattern patients may develop some disorder at the mandibular condyle level during their lifetime due to tooth loss, systemic

diseases, trauma and hormonal factors.[24-25] Depending on the severity, surgical intervention of the condyle may be indicated, which would entail the planning and design of a condylar prosthesis to restore its function.[26]

However, there are studies published reporting high failure rates due to inappropriate design, lack of biomechanical principles and poor knowledge of orthopedic literature.[27,28] Therefore, it is important to understand the appropriate morphology and dimension of the structure to be replaced as well as to ensure that it complies with the most important feature pointed out by Mercuri, functionality. However, the controversy is focused on choosing the prosthesis design that achieves the best functional measures.[29]

This question will be solved when reliable models with functional parameters in normal or pathological states are obtained based on literature or research studies of the different populations.[30]

Certain limitations were placed on this study, including the number of variables associated with the dimension and morphology of the mandibular condyle, such as the condylar space in the glenoid cavity and the condylar position. The age of the patients and the functionality can also be associated. Selection criteria were another limitation, as they made the choice and sample size difficult. Previous studies performed condyle measurements on human skeletons.[4,5,21]

However, this may have biases or limitations. The effect of high temperatures or erosion could increase the margin of error in the measurements.[30] Currently, the use of CBCT would be recommended because of its accuracy in the analysis of these structures.

The evaluation of the dimension and morphology of the mandibular condyle with a higher number of samples (larger population, different geographical regions) will allow to corroborate the measurements obtained and to establish a normal range of values of populations or regions for an adequate diagnosis and treatment planning.

CONCLUSION.

The A-P dimension of the right and left condyle is similar in both genders. However, there are differences in the M-L dimension of the left condyle males. The most prevalent morphology of the right and left condyle was round in the sagittal plane, except for the coronal plane.

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