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ARTICLE

MANDIBULAR ANGLE MORPHOLOGY IN OPEN BITE SUBJECTS ACCORDING TO THE SKELETAL RELATIONSHIP: A CBCT SHORT REPORT.

Morfología del ángulo mandibular en sujetos con mordida abierta de acuerdo a la relación esquelética: un informe breve en CBCT.

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ABSTRACT:

Aim: The purpose of this research was to three-dimensionally evaluate the mandibular angle morphology in open bite subjects with different sagittal skeletal relationships.

Material and Methods: Cone beam computed tomography (CBCT) images of 26 subjects (12 men and 14 women) with anterior open bite were evaluated. The sample included 3 groups categorized by their sagittal skeletal relationship (based on ANB angle and anteroposterior dysplasia indicator (APDI)): Class I (n=9), Class II (n=6) and Class III (n=11). The total gonial angle, upper gonial angle, lower gonial angle, intergonial width, interantegonial width and antegonial notch depth were measured. ANOVA and Tukey tests were used for intergroup comparison. The Kruskal Wallis test was also used when necessary. In addition, the Pearson correlation coefficient was calculated to evaluate significant correlations between overbite and antegonial notch depth with gonial angle, Frankfurt mandibular plane angle (FMA) and the palatal plane-mandibular plane (PP-MP).

Results: A significant difference was only found on the upper gonial angle between Class II and Class III (p=0.047). The upper gonial angle showed greater values (48°±3°) with the mandibular branch toward backward in Class III subjects and lower values (42.42°±4.39°) with the mandibular ramus leaning forward in subjects with Class II skeletal relationship. Besides, only a statistically significant correlation was found between overbite and the lower gonial angle (r=-0.418, p=0.034).

Conclusion: Mandibular angle morphology is similar in anterior open bite subjects with different sagittal skeletal relationships, except for the upper gonial angle which is increased in Class III and decreased in Class II subjects with open bite. Lower gonial angle is negatively correlated with overbite. This difference should be considered by orthodontists when planning their treatments.

KEYWORDS:

Mandible; open bite; cone-beam computed tomography; cephalometry; malocclusion; humans.

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RESUMEN:

Objetivo: El propósito de esta investigación fue evaluar tridimensionalmente la morfología del ángulo mandibular en sujetos de mordida abierta con diferentes relaciones esqueléticas sagitales.

Material y Métodos: Se evaluaron imágenes de tomografía computarizada de haz cónico (CBCT) de 26 sujetos (12 hombres y 14 mujeres) con mordida abierta anterior. La muestra incluyó 3 grupos categorizados por su relación esquelética sagital (según el ángulo ANB y el indicador de displasia anteroposterior (APDI)): Clase I (n=9), Clase II (n=6) y Clase III (n=11). Se midieron el ángulo goniaco total, el ángulo goniaco superior, el ángulo goniaco inferior, el ancho intergonial, el ancho interantegonial y la profundidad de la entalladura antegonial. Se utilizaron las pruebas ANOVA y Tukey para la comparación intergrupal. La prueba de Kruskal Wallis también se utilizó cuando fue necesario. Además, se calculó el coeficiente de correlación de Pearson para evaluar correlaciones significativas entre la sobremordida y la profundidad de la entalladura antegonial con el ángulo goniaco, el ángulo del plano mandibular de Frankfurt (FMA) y el plano palatino-plano mandibular (PP-MP).

Resultados: Solo se encontró una diferencia significativa en el ángulo goniaco superior entre la Clase II y la Clase III (p=0.047). El ángulo gonial superior mostró valores mayores (48°±3°) con la rama mandibular hacia atrás en sujetos Clase III y valores más bajos (42,42°±4,39°) con la rama mandibular inclinada hacia adelante en sujetos con Clase II esquelética relación. Además, solo se encontró una correlación estadísticamente significativa entre la sobremordida y el ángulo goniaco inferior (r= -0,418, p= 0,034).

Conclusión: La morfología del ángulo mandibular es similar en sujetos con mordida abierta anterior con diferentes relaciones esqueléticas sagitales, excepto por el ángulo goniaco superior que aumenta en la Clase III y disminuye en sujetos de Clase II con mordida abierta. El ángulo gonial inferior se correlaciona negativamente con la sobremordida. Los ortodoncistas deben considerar esta diferencia al planificar sus tratamientos.

PALABRAS CLAVE:

Mandíbula; mordida abierta; tomografía computarizada de haz cónico; cefalometría; maloclusión; humanos.

INTRODUCTION.

Anterior open bite is one of the most difficult dentofacial deformities to treat. Its complexity is attributed to a combination of skeletal, dento-alveolar and functional factors and related habits.[1-6] The etiology of anterior open bite is currently considered to be multifactorial, and its incidence varies between 1.5% and 11% and among races and dental age.[1,6,7-11]

Many open bite subjects have obtuse gonial angles, due to mandibular clockwise rotation, excessive lower anterior facial height and decreased posterior facial height.[12]

However, other etiological factors have been described, such as supraeruption of posterior teeth or an increase in posterior dentoalveolar vertical growth resulting in a downward and backward rotation of the mandible.[1-3,5]

For several years, the vertical facial pattern was considered the main etiological factor for the development of anterior open bite and the main cause of instability during and after treatment.

Nonetheless, the open bite condition is not necessarily associated with an hyperdivergent pattern and not all hyperdivergent subjects have this type of malocclusion. Hyperdivergent subjects can present a normal overbite or even an excessive overbite, while subjects with normal vertical patterns can present an anterior open bite, and thus, a vertical growth pattern is not the only cause of anterior open bite.[1,10] However, associations between the vertical growth pattern and a high gonial angle, and a deep antegonial notch have been reported.[9]

There are no three-dimensional (3D) studies evaluating the mandibular angle morphology in

anterior open bite subjects. In most studies these evaluations were performed in different facial types and with two-dimensional (2D) lateral or frontal radiographs.[12-15] However, these methods may present some limitations due to image superimposition and the difficulty of structure evaluation. Therefore, further studies in different biotopes are needed on the open bite.

The knowledge of the etiology of open bite will significantly alter orthodontic treatment planning and biomechanics, with counterclockwise rotation of the mandible being performed when necessary. The present study can shed light on whether the behavior of the gonial angle on the 3 axes of space in open bite subjects differs according to each skeletal relationship. If there is any difference, it should be considered by orthodontists.

Therefore, the purpose of this study was to evaluate mandibular angle morphology in the three planes of space in open bite subjects with different sagittal skeletal relationships using cone beam computed tomography (CBCT).

MATERIALS AND METHODS.

The present study was approved by the Ethics Committee of the School of Dentistry, of the Científica del Sur University, in Lima, Peru (Protocol 000226).

Written informed consent was obtained from the patients who agreed to take part in the study.

Sample size

The sample included 26 pretreatment CBCT (12 males, 14 females) of open bite subjects aged 18 to 55 years old who attended a private radiological diagnostic center from 2010 to 2017 and met the selection criteria.

It should be noted that this center takes approximately 20 scans per day, for a total of 4800 CBCTs per year.

On the other hand, it is important to mention that the Cone Beam Computed Tomography (CBCT) was performed for clinical reasons unrelated to the research, and was not specifically performed for the present study.

Selection criteria

The selection criteria were CBCTs of subjects of both sexes aged between 18 and 55 years. Individuals with anterior open bite and high quality CBCTs that met the acquisition parameters were selected. Subjects with previous orthognathic surgery, orthodontic treatment, mandibular pathology, or systemic diseases or syndromes were excluded.

The sample was divided into 3 groups according to the sagittal skeletal relationship (A point, nasion and B point (ANB) and anteroposterior dysplasia indicator (APDI)):

Class I (n=9), Class II (n=6) and Class III (n=11). ANB is the angle used to assess the skeletal relationship between points A and B in degrees.[2]

APDI is the anterior-posterior dysplasia indicator to assess the skeletal relationship and is obtained from the algebraic sum of the angles N–Pg–FH (facial plane) plus/minus the facial angle AB plane (this is positive when point B is ahead of point A and is negative when point A is ahead of point B) and plus/minus the angle FH–PP (palatal plane) (this is negative when PP is tilted upward and positive when tilted downward) (Table 1).

When the two methods to diagnose the sagittal skeletal facial growth pattern (ANB and APDI) did not coincide, a decision was made based on radiographic evaluation and clinical judgment, including analysis of the bone profile, soft profile convexity and overjet.

Image acquisition

CBCT images were taken with a Picasso Master 3D (Vatech, Hwaseong, South Korea, with 8 mA and 90 kV) with the patient seated, correctly positioned with maximum dental intercuspation without chin positioner.

Subsequently, CBCT images were processed with Real Scan 2.0 software, using multiplanar reconstruction in coronal, axial and sagittal views, trans axial and tangential views and evaluation by 3D volume reconstruction, with a flat panel detector 25 cm x 20 cm, 30 cm x 30 cm.

The 20 cm x 19 cm field of view includes areas of interest with dimensions of 672 x 672 x 496

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pixels (510 MB) and a resolution of 0.3 mm x 0.3 mm x 0.3 mm.

Training, calibration and error study

The researcher was trained and underwent an evaluation of reliability by an oral and maxillofacial radiologist with over 10 years of experience. Intra-examiner reliability was assessed using the intra-class correlation coefficient (ICC) obtaining values greater than 0.9 in all measurements.

All measurements were performed with a 30-day interval between the two measurements. In addition, the Dahlberg formula was used to assess any error of measurement, obtaining values less than 1 ° or 0.5 mm in all measured variables.

Measurement of variables

All measurements were performed in 3D volumetric CBCT-synthesized cephalograms. Gonial angle and antegonial notch measure-ments were performed on both sides. Right side values were only used because of the absence of statistically significant differences or a high correlation between the two sides. (Table 2). The following measurements made:

Overbite

Vertical distance in mm between the incisal edge of the maxillary and mandibular central incisor, perpendicular to the occlusal plane (Po-Or).[16]

Gonial Angle

Angular measurement formed by the mandibular plane (Go-Me) and the mandibular ramus plane (Ar-Go) seen in the sagittal plane (Figure 1).[17]

Upper Gonial Angle

Angular measurement formed by the tangent of the mandibular ramus plane (Ar-Go) and a line from the gonial angle to the nasion point (Go-Na). (Figure 1).[17]

Lower Gonial Angle

Angular measurement formed by the Go-Na line and the mandibular plane (Go-Me). (Figure 1).[17]

Antegonial Notch Depth

Vertical linear measurement in mm from a tangent line to the most concave surface of the antegonial notch to a tangent line to the inferior border of the mandibular body. (Figure 2).

Intergonial Width

Linear measurement in mm between the right and left gonion point seen in the coronal plane. (Figure 3).

Interantegonial Width

Linear measurement in mm between the right and left antegonion point seen in the coronal plane. (Figure 3).

Statistical analyses

All statistical analyses were performed using SPSS software for Windows (version 22; IBM SPSS, Chicago, Illinois). Normality of the data dis-tribution was evaluated by the Shapiro-Wilk test. Analysis of variance (ANOVA) and Tukey test or Kruskal Wallis and Mann-Whitney U tests were used for intergroup comparisons.

To compare whether the measure of gonial angle is related to gender or side, the t-test was applied. Additionally, the Pearson correlation coefficient was calculated to evaluate significant correlations between overbite and antegonial notch depth with gonial angle, FMA and PP-MP. Statistical significance was set at $p<0.05$ for all tests.

RESULTS.

The initial sample characteristics including skeletal relationship, gender, age (years), overbite (mm), ANB (°) and APDI (°) are shown in Table 3. Descriptive statistics of the outcome variables are shown in Table 4. A significant difference was only found in the measure of the upper gonial angle between Class II and III (p=0.007).

The upper gonial angle showed greater values (48°±3°) with the mandibular branch toward backward in Class III subjects and lower values (42.42°±4.39°) with the mandibular ramus leaning forward in subjects with Class II skeletal relationship. No significant differences were found in any of the other measurements.

No significant correlations were found among the variables studied, except for the correlation between overbite and the maxilla-mandibular hyperdivergency (PP-MP) (r=-0.525, p=0.006) and the correlation between overbite and the lower gonial angle (r=0.418, p=0.034) (Table 5).

Figure 1. Angular measurements of total gonial angle (TGA), upper gonial angle (UGA) and lower gonial angle (LGA).

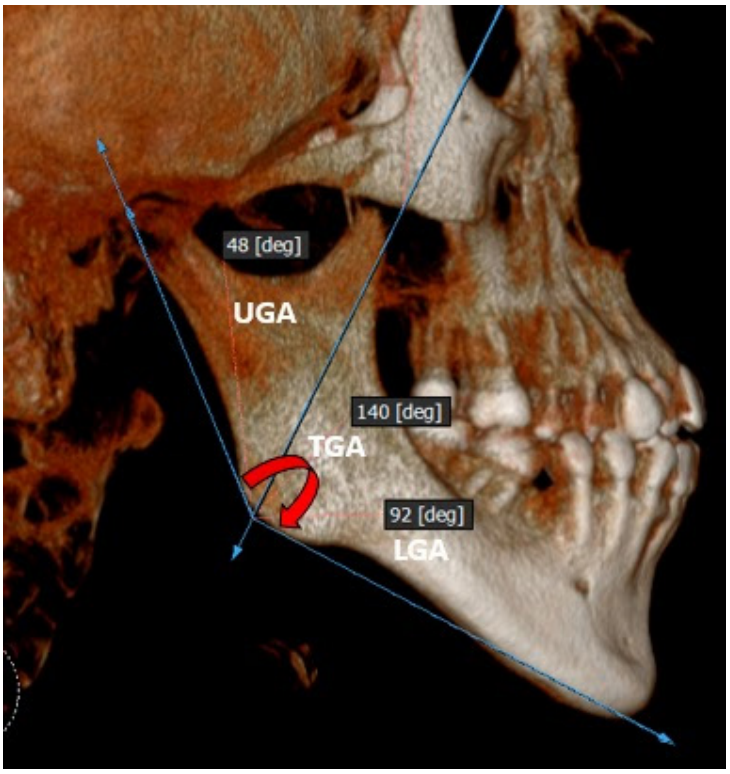

Figure 2. Evaluation of the antegonial notch depth for the open bite cases.

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Figure 3. Evaluation of the intergonial and interantegonial width in the evaluated sample.

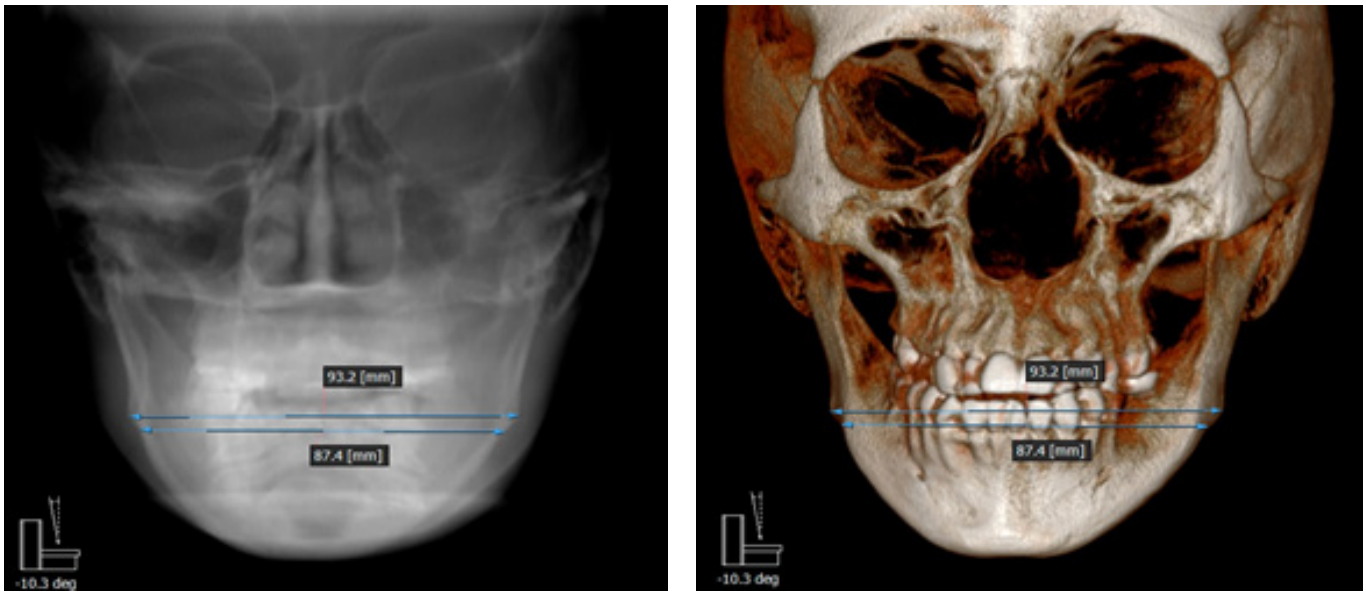

Table 1. Methods to diagnose the sagittal skeletal relationship.

Malocclusion	ANB	APDI
Class I	0 a 4°	80° +-3
Class II	> 4°	<77°
Class III	< 0°	>83°

ANB: A point, nasion, B point. APDI: Anteroposterior Dysplasia Indicator.

Table 2. Comparison of the goniac angle between sides and sex.

Side	N	Mean	SD	*p* (paired t-test)
Right	26	125.00	8.21	0.923
Left	26	125.04	7.89	

	Male (12)		Female (14)		
Side	Mean	SD	Mean	SD	*p* (independent t-test)
Right	126.83	9.19	123.43	7.24	0.300
Left	126.5	9.27	123.79	6.58	0.401

SD: Standard Deviation.

Table 3. Initial sample characteristics including skeletal relationship, gender, age (years), overbite (mm), ANB (°) and APDI (°).

Skeletal relationship	Male	Female	Total	Age Mean (SD)	Overbite Mean (SD)	ANB Mean (SD)	APDI Mean (SD)
Class I	4	5	9	36.33[a] (13.49)	-1.93 (1.45)	3.95[a] (1.89)	82.46[a] (1.67)
Class II	1	5	6	37.17[a] (16.92)	-2.81 (2.74)	6.57[b] (0.93)	77.38[b] (4.59)
Class III	7	4	11	25.09[b] (6.99)	-2.65 (2.18)	-2.91[c] (4.17)	102.11[c] (5.44)

Different letters indicate a significant difference ($p< 0.05$) based on an independent *t*-test. **SD:** Standard Deviation. **APDI angle:** anteroposterior dysplasia indicator. **ANB angle:** A point, nasion, B point.

Table 4. Measurements of goniac and antegonial characteristics according to the skeletal relationship.

Goniac and antegonial measurements	Class I		Class II		Class III		
	Mean	SD	Mean	SD	Mean	SD	*p*-value
Total Goniac Angle	123.56[a]	11.58	122[a]	4.89	127.82[a]	5.78	0.320
Upper Goniac Angle	45.69[ab]	3.76	42.42[a]	4.39	48.00[a]	3.26	0.047
Lower Goniac Angle	77.87[a]	8.98	79.58[a]	3.53	79.82[a]	4.99	0.780
Antegonial Notch Depth	2.14[a]	1.13	2.78[a]	1.33	1.96[a]	0.49	0.480
Intergonial Width	95[a]	6.16	94.10[a]	8.24	93.45[a]	4.97	0.860
Interantegonial Width	86.20[a]	4.38	83.82[a]	5.05	86.59[a]	3.55	0.420

Different letters indicate statistically significant differences; statistically significant at $p<0.05$; SD: Standard Deviation

Table 5. Pearson correlation coefficient to evaluate the mandibular angle morphology and overbite (mm).

Measurement	Overbite		
	N	R	*p*-value
Total Goniac Angle	26	-0.159	0.438
Upper Goniac Angle	26	0.313	0.119
Lower Goniac Angle	26	-0.418	0.034
Antegonial Notch Depth	26	0.243	0.232
Intergonial Width	26	0.136	0.508
Interantegonial Width	26	0.031	0.882
Frankfort Mandibular Angle	26	-0.236	0.245
Palatal Plane and Mandibular Plane	26	-0.525	0.006*

*: Significant

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DISCUSSION.

Open bite is one of the most difficult dentofacial deformities to treat. The success of orthodontic treatment usually requires careful evaluation of etiological factors.[1-5] The etiology of anterior open bite is multifactorial, and many theories have been proposed, including genetic, anatomical and environmental factors.[1,6,9-11] Classifying open bite as skeletal or dental is challenging, which is why many clinicians prefer classification according to the etiology.[6] Its treatment is highly variable because of the difficulty in determining the causes, making a diagnosis and establishing potential relapse after orthodontic treatment.[18]

As mandibular hyperdivergency of the gonial angle is one of the main features of open bite, clarifying not only the sagittal behavior but also each skeletal relationship in 3D will help to establish its influence on the development of anterior open bite and establish possible therapeutic approaches. This study takes advantage of the latest technological tools in diagnostic imaging, such as CBCT, to clarify important aspects of the management of this entity.

The present study clarifies one of the questions related to skeletal mandibular transverse behavior, using measures of intergonial and interantegonial width. In the absence of significant differences, our findings confirm the limited influence that hyperdivergency has on mandibular width in any skeletal relationship with anterior open bite, with the mean values being useful as reference measures.

More studies should be carried out using the 3D tool to corroborate our findings, obtaining volumetric measurements in addition to linear and angular measurements, to take advantage of the 3D tool in a more efficient way. Moshiri *et al*.,[19] Kumar*et al*.,[20] and Cattaneo *et al*.,[21] assessed the reliability, accuracy and precision of linear and angular measurements by comparing CBCT-synthetized cephalograms with conventional lateral radiographs. They concluded that there is a high reliability and that CBCT-synthetized cephalograms can adequately replace conventional radiographs, since there were no significant differences in these measurements.

Replacing conventional radiography by 3D images and their derivative applications seems to be an inevitable trend. In the present study, all measurements were made with 3D volumetric CBCT-synthetized cephalograms in order to evaluate the morphology of the mandibular angle in 3 dimensions.

No significant differences were found between males and females indicating the absence of sexual dimorphism. These results are consistent with those reported by Mangla *et al*.,[12] who concluded that the gonial angle and FMA were significantly higher in the hyperdivergent group without sexual dimorphism.

For many years, the vertical facial pattern was considered the main factor for anterior open bite, relating a high gonial angle with this condition. Acuña *et al*.,[15] concluded that skeletal open bite has a direct relationship with the vertical behavior of the bony bases and can be considered the origin of this type of malocclusion.

Mangla *et al*.,[12] found that the gonial angle was significantly increased in the hyperdivergent group of their study sample. Similarly, many researchers such as Trouten *et al*.,[5] Nahoum *et al*.,[14] Siriwat *et al*.,[22] Schendel *et al*.,[23] Opdebeeck *et al*.,[24] Subtelny *et al*.,[25] and Fields *et al*.,[26] have indicated that an obtuse gonial angle is associated with a skeletal open bite, while a decreased gonial angle is associated with a deep bite, leading to the development of the present study.

In our study we found that the mean gonial angle was 123.56° and 122° for the Class I and II groups, respectively, with both values being slightly lower than the standard value proposed by Bjork (130° ± 5°), showing that not all patients with anterior open bite have a high or obtuse gonial angle.

Furthermore, in the Class III group, the mean gonial angle was 127.82°, indicating a normal value, and this was because the average of the upper gonial angle was found to be decreased and the mean of the lower gonial angle was increased, offsetting these values and producing an adequate mandibular growth for this group. When performing the ANOVA test for total gonial angle and lower

gonial angle, no significant differences were found among the groups. A significant difference was found in the upper gonial angle between Classes II and III, probably due to the different growth pattern characteristics of each malocclusion.

Siriwat *et al.*,[22] reported that the upper gonial angle reflects the horizontal vector of facial growth. The significant difference found in this study in this angle between Classes II and III is a manifestation of the behavior of the mandibular ramus in open bite subjects. No significant difference was found when analy-zing the association between gonial angle and overbite (p=0.438), and with no significant correla-tion (r=-0.159), suggesting that an increased gonial angle does not increase overbite. On the other hand, when we analyzed the association between the measurement of overbite according to the skeletal relationship, no significant differences were found, showing that regardless of whether the subject is classified as Class I, II or III, negative overbite of different magnitudes may be observed. Similarly, no significant correlations were found for the upper gonial angle, antegonial notch depth, intergonial width, interantegonial and FMA with overbite.

However, a significant correlation (r= -0.418, p= 0.034) was found between the lower gonial angle and overbite. Overbite becomes more negative while the lower gonial angle increases. It was also found that maxillomandibular hyperdivergency (PP-MP) influences overbite (r=-0.525, p=0.006). While the angle formed by the palatine plane and mandibular plane increases, overbite becomes more negative, suggesting that maxillomandibular factors (PP-MP) have more influence than intra-mandibular factors (gonial angle).

Mangla *et al.*,[12] studied antegonial notch depth and reported 1.09 for men and 1.11 for women in the control group and values of 1.67 for men and 2.03 for women in the hyperdivergent group. Their results do not agree with those of the present study, mainly because we studied their behavior in three skeletal relationships while the previous study sample was not characterized in this way, providing further strength to our findings.We therefore conclude that there are no significant differences in the depth of the antegonial notch among different skeletal relationships in patients with anterior open bite.

Finally, the main clinical contribution of this research was to inform orthodontists that, in general, the total gonial angle is not a variable with a significant direct correlation to the severity of an anterior open bite. This knowledge is a key point for clinicians who should take into account when ma-king compensations for open bite malocclusions, which will probably be successful at the expense of molar intrusions that will produce mandibular rotations to improve these malocclusions.

Therefore, we emphasized that a high gonial angle is not necessary, the main factor predisposing an anterior open bite. Other etiological factors are involved such as dentoalveolar and functional factors or the presence of habits.

One of the limitations of the present short report study was the small sample size which may be explained by the absence of similar reports in the literature, the lack of databases and lastly because of the low prevalence of anterior open bite.[1,6] For this reason, the results of the present investigation cannot be generalized to all individuals with open bite. Another limitation is the lack of homogeneity in the distribution of skeletal class groups found in the analysis of the distribution of the sample.

However, it is of note that the sample consisted of all CBCT scans of subjects with anterior open bite attending a radiological reference center in the city of Lima from 2010 to 2017. On the other hand, the present investigation is limited by the lack of a control group. Likewise, the absence of clinical evaluation or having access to the patient's clinical history were another limitation, since we could not consider muscular pathologies as the cause of changes in the morphology of the gonial angle. Therefore, the findings must be evaluated within these limitations.

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CONCLUSION.

Mandibular angle morphology is similar regardless of the skeletal relationship in subjects with anterior open bite, except in the upper gonial angle that is increased in Class III and decreased in Class II.

There is no sexual dimorphism nor differences in mandibular morphology according to side. No significant correlation was found among the total gonial angle, the upper gonial angle, antegonial notch depth, intergonial width or interantegonial width with overbite. A lower gonial angle and PP-PM are the only measures of mandibular morphology that affect overbite.

Conflict of interests:

The authors do not have any financial interests or commercial associations to disclose.

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Authors' contributions:

All authors have read and approved the final manuscript content, write-up of the manuscript and have contributed significantly in the study:

Laquihuanaco G: Conceived the study design, carried out the data collection analysis and write-up of the manuscript.

Rodríguez-Cárdenas Y: Participated in the study design, write-up of the manuscript.

Ruíz-Mora G and Meneses-López A: Contributed to the study design and helped to draft the manuscript.

Arriola-Guillén L: Performed the statistical analysis and helped to write-up the manuscript.

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