Original Article

# Cephalometric Characteristics in Skulls with Artificial Deformation in a Pre-Columbian Civilization of the Peruvian Andes (Chavin Civilization 900 B.C. to 200 B.C.)

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**Abstract**

**Objective:** To evaluate the cephalometric characteristics of skulls with and without artificial deformation in a pre-Columbian civilization of the Peruvian Andes (Chavin civilization 900 B.C. to 200 B.C.). **Materials and Methods:** The study was observational, analytical, retrospective, and comparative in design. The image analysis unit was radiological with cephalometric measurement. The sample consisted of occipito-frontal dry skulls of the Chavín culture ($n = 40$) with and without artifical deformation, which underwent cephalometric radiography for analysis. **Results:** The measurements of skull base size, anterior cranial base size, posterior cranial base size, posterior cranial base size, and cranial deflection were greater in the deformed than the non-deformed skulls (95.1 ± 6.6 vs. 92.3 ± 6.2 mm, 61.5 ± 3.6 vs. 61.4 ± 3.6 mm, 39.8 ± 3.4 vs. 38.1 ± 3.5 mm, 136 ± 26.9 vs. 135.0 ± 5.6 mm, and 35.7 ± 31.8 vs. 28.2 ± 14.6 mm, respectively). Significant differences were only found in the posterior cranial base size measurements between deformed and nondeformed skulls ($P = 0.008$). When comparing the characteristics of the skulls, significant differences were only found between the position of the posterior nasal spine and the maxilla size of the deformed versus the non-deformed skulls ($P < 0.05$). **Conclusions:** It is concluded that there are differences in the size, position, and inclination of the craniofacial structures between the artificially deformed skulls and the skulls that have not been artificially deformed by the old Chavin civilization.

**Keywords:** *Cephalometric, deformation, pre-Columbian, skulls*

## Introduction

Artificial cranial deformation (ACD) or intentional deformation of the skull was a widespread practice in the pre-Columbian cultures of ancient Peru. This consisted of the placement of tablets tied around the skull at an early age to achieve a different skull shape for establishing aesthetic differences from childhood, with this being a differentiating indicator of social position or religion. Neither can the possibility that these practices were carried out with the intention of achieving mass control be ruled out. An interesting question has always been whether these deformations induced important changes in the maxillofacial

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structures. This is particularly important since it would provide knowledge for the study of maxillofacial orthopedics based on pre-Columbian ancestral knowledge.[1-5]

The ACD was a widespread practice in many villages in Peru and around the world. Indeed, in many cases, although these villages had no geographical or cultural connections, this practice was performed with amazing similarity. The ACD is defined as the modification of the natural shape of the skull through the application of force on the skull during the growth stage.[1-4] Although these cranial deformations were able to modify the shape of the skull, it remains unclear whether they induced changes in the facial structures, in particular the base of the cranium, and the nasomaxillary complex and the maxilla itself.[6-9]

Ethnicity should be understood as common characteristics that define the identity of a person with a group, such as: biological, cultural, linguistic, ideological, historical, and national features. A common biological aspect is an important trait that defines a group such as, for example, facial aspects or modifications made to facial structures, similar to what occurs in some African tribes that deform their ears or lips to establish their ethnic identity. These ethnicity markers are powerful representations that are not only used to define but also used to control and maintain group identity. Likewise, artificial cranial modification may have been used to identify ethnic populations, as demonstrated by Andean bio-archaeological studies.[10-14]

Thus, the purpose of this study was to compare the cephalometric characteristics of skulls with and without artificial deformation from a pre-Columbian civilization of the Peruvian Andes (Chavin civilization 900 B.C. to 200 B.C.)

## Materials and Methods

### Design and sample size

The study was observational, analytical, retrospective, and comparative in design. Radiological images and cephalometric measurements were made. The sample was made up of occipito-frontal dry skulls of the Chavín culture ($n = 40$) with and without artificial deformation, which had undergone X-ray study. For cephalometric analysis, non-deformed skulls were used for comparison. We analyzed the craniofacial structures in the cephalometric radiographies of dry skulls obtained [Figure 1] from the *Museo Arqueologico de Ancash "Augusto Soriano Infante"* located in the Region of Ancash, Peru with coordinates 9°31′49.27″S, 77° 31′46.4″W.

### Allocation

The following groups were formed:

Group 1: Deformed and non-deformed skulls in which the skull base size, posterior cranial base size, anterior cranial base size, inclination of the posterior cranial base, and cranial deflection were measured.

Group 2: Deformed and non-deformed skulls in which the anteroposterior position of the cheekbone, vertical position of the cheekbone, and cheekbone tilt were measured.

Group 3: Deformed and non-deformed skulls in which the position of the posterior nasal spine, the position of the anterior nasal spine, maxilla size,

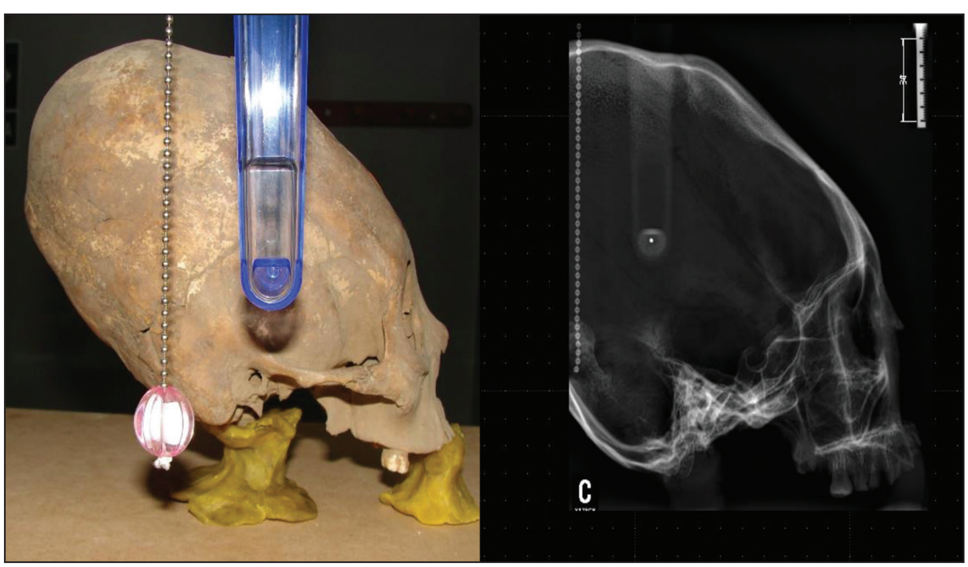


**Figure 1:** Plotting and measurement of the size, position, and inclination of the base structures of deformed skulls

maxilla inclination, anterior vertical growth of the maxilla complex, posterior vertical growth of the complex maxillary, and anterior dentoalveolar position were measured.

Inclusion criteria:

- Adult dry skulls with artificial deformation of the fronto-occipital region.
- Adult dry skulls of Chavin origin
- No damage to the cranial base, nasomaxillary and dentoalveolar region
- No history of deforming disease
- With permanent dentition

Exclusion criteria

- From any other pre-Colombian culture.
- Damage to the cranial base, nasomaxillary or dentoalveolar region.
- Infant skulls

### Procedure

Digital cephalometric radiographs were taken for collecting and comparing the cephalometric measurements of all the dry artificially deformed and non-deformed skulls included in the study [Figures 2–4]. PaX-I digital cephalometric equipment (Vatech) was used to obtain panoramic images. A platform was added to support the skulls so that they were positioned in a Frankfort horizontal plane parallel to the floor and in strict profile. Each radiographic image was made with a 64 kVp and 23 mA shot. The radiographs were then stored in a digital file and evaluated to ensure that they met the sample selection criteria. Each radiograph was scaled, and modified Burstone, Legan, and Ricketts analysis points and lines were digitally traced for investigation with LibreCAD software.

### Calibration of cephalometric measures

The cephalometric analysis was based on Burstone and Leagan, Bjork, Steiner, and Rickets analyses. Researcher training and validation in the location of the points and lines, as well as the measurements of the LibreCad software program were carried out with an orthodontist specialist in cephalometry from the Faculty of Dentistry of the *Universidad Nacional Mayor de San Marcos* [Figures 3 and 4]. To determine the level of agreement, the intraclass correlation index was applied to a sample of 25 radiographs, obtaining a value of 0.99 ($P < 0.001$), which indicated a very good level of agreement.

### Statistical analysis

With the linear and angular data obtained, a database was developed with the Stata® 15 software. For the statistical analyses, the Shapiro-Wilk test was used to determine normal distribution of the variables, and the Levene test was used to establish equality of the variances. For the variables with a normal distribution,

**Figure 2:** Skull base: The deformed skulls presented a larger total cranial base and with a greater angulation between the anterior and posterior cranial base (red); however, the lengths of the latter do not have significant differences (blue)

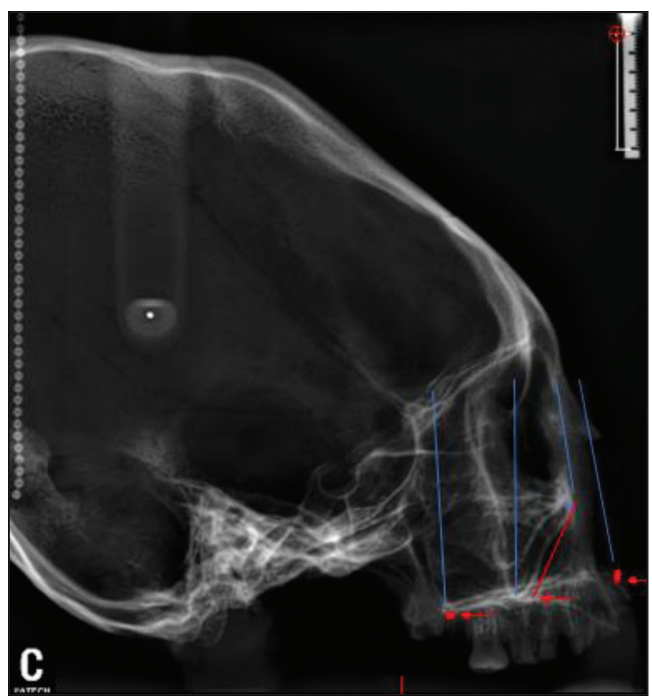

**Figure 3:** Nasomaxillary complex: The structures of the naso-malar complex, such as the anterior nasal spine, posterior nasal spine, and the base of the cheekbone, have a more distal position (red). The vertical height of all points does not vary (blue)

the Student's *t*-test was used for independent samples; in the groups without a normal distribution, Mann-Whitney U test was used. In both cases, a $P$ value of <0.05 was considered statistically significant.

## Results

The measurements of skull base size, anterior cranial base size, and cranial base size deflection of the deformed skulls were greater than the non-deformed skulls (95.1 ± 6.6 vs. 92.3 ± 6.2 mm; 61.5 ± 3.6 vs. 61.4 ± 3.6 mm; 136 ± 26.9 vs. 135 ± 5.6 mm and 35.7 ± 31.8 vs. 28.2 ± 14.6 mm, respectively). Significant differences were only found in the posterior cranial base size measurements between deformed and non-deformed skulls (39.8 ± 3.4 vs. 38.1 ± 3.5 mm; $P = 0.008$) [Table 1].

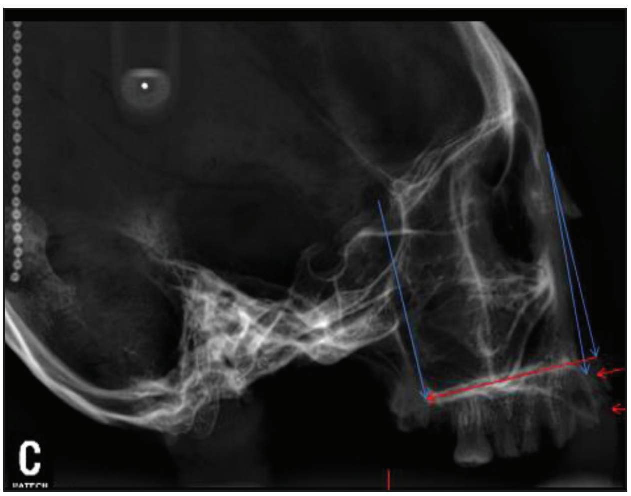


**Figure 4:** Maxillary complex: The size of the maxilla is greater in deformed skulls and its position is more distal than in undeformed skulls. The anterior dentoalveolar process is more distal in deformed skulls. None of the structures is different in vertical positioning, and this includes the inclination of the palatal plane

The anteroposterior position of the cheekbone of the deformed skulls was notably higher compared with the non-deformed skulls (35.7 ± 2.5 mm vs. 6.9. ± 3.0 mm, respectively). The vertical position of the cheekbone was also higher in the deformed versus the non-deformed skulls (28.7 ± 2.4 mm vs. 27.2 ± 4.3 mm, respectively). However, the non-deformed skulls showed the highest cheekbone tilt measurements compared with the deformed skulls (57.2 ± 5.6 mm vs. 46.7 ± 6.8, respectively). Finally, no significant differences were found in any of the three measurements in relation to size, position, or inclination ($P > 0.05$) [Table 2].

The measurements of position of the anterior nasal spine, position of the posterior nasal spine, maxilla inclination, posterior vertical growth of the complex maxillary, and anterior dentoalveolar position were lower in deformed compared with non-deformed skulls (88.4 ± 4.8 vs. 91.0 ± 4.1 mm; 43.8 ± 2.8 vs. 47.2 ± 2.3 mm; 0.5 ± 4.0 vs. 1.6 ± 3.1 mm; 44.0 ± 3.7 vs. 45.3 ± 3.4 mm; and 2.4 ± 4.8 vs. 4.8 ± 3.6 mm, respectively). All the groups presented normal distribution except for the anterior vertical growth of the maxilla complex. Therefore, significant differences were only found between the position of the posterior nasal spine and the maxilla size of deformed versus non-deformed skulls ($P < 0.05$) [Table 3].

## Discussion

Similar to other cultures in the world, the Chavín culture practiced ACD. The reasons that they did this are not the subject of the present investigation, but they

**Table 1: Description of the results of the position, size, and inclination of the skull base structures in deformed and non-deformed skulls**

| | Type of skull | Mean | SD | P* | P |
|---|---|---|---|---|---|
| Skull base size | Non-deformed | 92.3 | 6.2 | 0.937 | 0.597** |
| | Deformed | 95.1 | 6.6 | 0.141 | |
| Anterior cranial base size | Non-deformed | 61.4 | 3.6 | 0.444 | 0.927** |
| | Deformed | 61.5 | 3.6 | 0.29 | |
| Posterior cranial base size | Non-deformed | 38.1 | 3.5 | 0.478 | 0.977** |
| | Deformed | 39.8 | 3.4 | 0.938 | |
| Inclination of the posterior cranial base | Non-deformed | 135 | 5.6 | 0.478 | 0.008+ |
| | Deformed | 136 | 26.9 | 0.001 | |
| Cranial deflection | Non-deformed | 28.2 | 14.6 | 0.001 | 0.273+ |
| | Deformed | 35.7 | 31.8 | 0.001 | |

Level of significance ($P < 0.05$)

SD = standard deviation

*Shapiro-Wilk test

**Student's *t*-test

+Mann-Whitney U test

**Table 2: Presentation of the results of the size, position and inclination of the structures of the naso-malar complex in deformed and non-deformed skulls**

| | Type of skull | Mean | SD | *P** | *P* |
|---|---|---|---|---|---|
| Anteroposterior position of the cheekbone | Non-deformed | 6.9 | 3.0 | 0.007 | 0.482⁺ |
| | Deformed | 35.7 | 2.5 | 0.618 | |
| Vertical position of the cheekbone | Non-deformed | 27.2 | 4.3 | 0.001 | 0.224⁺ |
| | Deformed | 28.7 | 2.4 | 0.906 | |
| Cheekbone tilt | Non-deformed | 57.2 | 5.6 | 0.050 | 0.401** |
| | Deformed | 46.7 | 6.8 | 0.050 | |

Level of significance ($P < 0.05$)

SD = standard deviation

*Shapiro-Wilk test

**Student's *t*-test

⁺Mann-Whitney U test

**Table 3: Evaluation of the maxillary and dentoalaveolar component of deformed and non-deformed skulls of the ancient Chavin civilization of Peru**

| | Type of skull | Mean | SD | *P** | *P* |
|---|---|---|---|---|---|
| Position of the anterior nasal spine | Non-deformed | 91.0 | 4.1 | 0.152 | 0.075** |
| | Deformed | 88.4 | 4.8 | 0.983 | |
| Position of the posterior nasal spine | Non-deformed | 47.2 | 2.3 | 0.465 | 0.001** |
| | Deformed | 43.8 | 2.8 | 0.217 | |
| Maxilla size | Non-deformed | 43.0 | 4.9 | 0.464 | 0.022** |
| | Deformed | 46.3 | 3.7 | 0.191 | |
| Maxilla inclination | Non-deformed | 1.6 | 3.1 | 0.14 | 0.324** |
| | Deformed | 0.5 | 4 | 0.992 | |
| Anterior vertical growth of the maxilla complex | Non-deformed | 47.1 | 4.6 | 0.020 | 0.665⁺ |
| | Deformed | 47.5 | 3.9 | 0.430 | |
| Posterior vertical growth of the complex Maxillary | Non-deformed | 45.3 | 3.4 | 0.069 | 0.265** |
| | Deformed | 44.0 | 3.7 | 0.308 | |
| Anterior dentoalveolar position | Non-deformed | 4.8 | 3.6 | 0.858 | 0.689** |
| | Deformed | 2.4 | 4.8 | 0.426 | |

Level of significance ($P < 0.05$)

SD = standard deviation

*Shapiro-Wilk test

**Student's *t*-test

⁺Mann-Whitney U test

are important in relation to the time at which it was performed. According to the information collected, the procedure was performed immediately after the child was born, with splints being attached to the frontal and the occipital regions of the skull by tissues and cords for a period of 8 to 12 months.[13] This fronto-occipital technique reveals the importance of this procedure for this culture. The way in which the force was applied determined a type of skull that was clearly different from other unmodified skulls. The shell was projected upward and backward, giving the appearance of a domed cone. Undoubtedly, the functional matrix, in this case, the brain, was forced to grow in the direction of least resistance, causing a powerful vector that stretched the fontanelles and incipient sutures to an upward and backward growth that ultimately shaped the flat bones of the skull. The effect on the shell is evident and is well described in the literature. However, little is known about the effect that it had on the structures of the skull base and facial regions.[6,10] Despite metric studies,[15] the effects of this skull deformation, especially on internal structures, have not been measured in detail. For this reason, this study aimed at evaluating these effects by using digital cephalometric radiography and a software that is able to perform measurements with a 1:1 ratio.

At birth, the synchondrosis is very open and contains all the genetic information for the development of the skull base. When the ancient Chavines applied ACD, they introduced a powerful vector onto the base of the skull. According to our findings, this vector was able to modify the size and inclination of the skull base. No significant differences were observed in the size of the anterior cranial base and the posterior cranial base between deformed and non-deformed skulls, but the total cranial base seemed larger in deformed skulls. The same occurs with the inclination of the cranial base, which was greater in deformed than in non-deformed skulls. Therefore, the cranial base is deformed by ACD causing platybasia, with an increase in the length of the total cranial base, that is consistent with the findings of other studies.[4,14,15]

With this evidence, it could be conjectured that the ACD vector was capable of causing a vertical projection of the sphenoid, since the point seals represent the "sella turcica," and this is where the angle between the anterior and posterior cranial base is evident. If the lengths of the cranial bases do not change but the angulation does, this indicates the presence of a force that presses the sella that opens the angle and enlarges the total cranial base. With this information, we should expect that cranial deflection would be less in deformed skulls than in non-deformed skulls. However, our evidence indicates that there were no differences between the two groups, which can be explained by the Frankfort horizontal plane, including the orbital point that is part of the face as a point before the margin used to orient the skull and, as is known, the face has a low development and is sustained through the years, far from the first year where ACD develops slowly and progressively over time after ACD has been performed. It has been shown that ACD produces changes in the cranial base and that its behavior is very similar in the different types of cranial deformation, despite skulls presenting dissimilar shapes and elongations. This, however, has been refuted by Moss *et al*.,[15] who found that involvement of the cranial base is directly related to the type of cranial deformation.

Another study is that carried out by McNeill *et al*.,[16] who found no differences in the angle of the skull base in nations of the Pacific Northwest coast that practiced fronto-occipital modification and annular modification. Their results suggested that both styles of ACD demonstrated platybasia, which contradicts the outcomes of Moss *et al.*[15] Furthermore, in their study on ancient Peruvian skulls, Bjork *et al.*[17] showed that the cranial modification would have shortened the measurements of the cranial bases and stated that the side with the greatest asymmetry had the greatest amount of change. However, Schendel *et al.*[18] found no differences in skull base angles between modified and unmodified Hawaiian skulls. However, according to the study by Anton,[19] who evaluated skulls of a Peruvian sample with annular and fronto-occipital modification, platybasia was found in both modified skulls. This coincides with the study by Cheverud *et al*.,[20] who analyzed skulls with frontal-occipital cranial modification in samples from Ancón in Peru and Songish groups from the Pacific Northwest coast. They observed that although both groups practiced ACD with similar techniques, different modifying devices were used.

On the other hand, Kohn *et al.*[21] conducted an investigation of intentionally deformed ring-style skulls from the Kwakiutl and Nootka nations on the Pacific Northwest coast. Despite these two populations living in very close territories and maintaining the same style of modification, the modification devices were different, which could partially explain the differences obtained, especially in the skull base. The Kwakiutl skull exhibited an increase in size in an anterior–posterior direction, but a reduction in size in the lateral and medial superior–inferior directions. However, there were no significant changes in the dimensions of the skull base among the Nootka skulls. These results are in agreement with those described by Bjork *et al*.,[17] who demonstrated facial and mandibular changes in a Peruvian sample of skulls with frontal-occipital deformation and, similar to the changes observed at the base of the skull, these metrics were more exaggerated on the side with the largest asymmetry.

The impact of the results of this study is important, because it shows that the face and skull are closely related in the growth and developmental processes. The brain acts as a functional matrix that molds the shell, and of course, the base of the skull, although they have different growth structures. The shell grows from sutures, whereas the base of the skull grows from synchondrosis. The expansive growth of the brain gives rise to a rounded, lobular structure of the skull. The growth vectors go in all directions and certainly provide secondary growth vectors to the bones of the face. However, the main limitation of this study is that synchondroses have their own growth since they are primary cartilages that grow throughout childhood and adolescence, closing completely at the age of 22 years, as occurs with sphenooccipital synchondrosis. This endochondral growth provides the base of the skull with growth that affects the direction and magnitude of growth of the facial bones, in particular the nasomaxillary complex and the maxilla itself. The ACD practiced by many people around the world and, in particular, by the ancient Peruvians has been reported by many anthropological investigations, and it is generally studied from a morphological, physical point of view and rarely from a radiographic and cephalometric point of view. Another limitation is that this study only evaluated a sagittal cephalometric view that only shows the degree of involvement of the sagittal structures at the base of the skull, nasomaxillary complex, and maxilla, regardless of the overlapping bones. Orthodontic cephalometry can measure changes and establish differences between groups, since standards have been established in human populations, thus allowing comparisons to be made. Nonetheless, one of the strengths of this study for correctly evaluating these variations or characteristics is the inclusion of a control group of non-deformed skulls from very similar periods and from the same culture and with the same type of deformation.

Finally, this study shows that the ACD practiced by the ancient Chavines was primarily occipito-frontal and that this procedure was practiced in children, generally within the first year of life, a time at which the main features of the direction of facial growth are defined. Knowing how these attachments placed on the skull of growing individuals are capable of affecting not only the shape but also the magnitude of growth is an area of particular interest to dental surgeons who are specialized in orthodontics and maxillary orthopedics. This knowledge allows visualization and quantification of the facial and maxillary effects and is of interest in dentistry, because devices are placed on the face, skull, or neck to apply point forces on the teeth to redirect maxillofacial growth in patients with malocclusions and skeletal abnormalities. Our findings allow better understanding of the behavior of facial structures subjected to the orthopedic action of devices placed at an early age and how to apply these devices both in the diagnosis and in the treatment of skeletal disorders in patients with malocclusions. On the other hand, the results of this study expand the theoretical bases of the ACD technique, specifically in Andean civilizations, to better understand existing historical–cultural models; in addition, they provide insights into the biological impact of this procedure on facial structures.

## Conclusions

According to the results and limitations of this study, it is concluded that artificially deformed skulls show differences in the position, size, and inclination of craniofacial structures compared with the non-deformed skulls of the ancient Peruvian Chavines. Further, deformed skulls have a larger total cranial base and a greater angle between the posterior and anterior cranial base, whereas the lengths of the latter do not present significant differences. Finally, the size of the maxilla is greater in deformed skulls and its position is more distal than in non-deformed skulls. The anterior dentoalveolar process is more protruded in deformed skulls. However, none of the structures is different in vertical positioning, and this includes the inclination of the palatal plane.

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None to declare.

### Conflicts of interest

None to declare.

### Author contributions

Study conception (FPV, RT, ADS), data collection (FPV, RT, AL), data acquisition and analysis (FPV, AL, FMT, ADS, FPV), data interpretation (FPV, DB, AL, FMT), and article writing (FMT, FPV, RT, ADS, DB).

### Ethical policy and institutional review board statement

Not applicable.

### Patient declaration of consent

Not applicable.

### Data availability statement

The data that support the study results are available from the author (Dr. Fernando Perez, e-mail: lperezv@unmsm.edu.pe) on request.

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