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NOTE / *NOTE*

Variations in the Thickness of the Cranial Vault in a Deformed Skull from Pre-Hispanic Ancón (Peru)

Variations de l'épaisseur de la voûte crânienne d'un crâne déformé préhispanique d'Ancón (Pérou)

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Abstract A medical tomodensitometric study (TDM) was performed on a dry skull from the necropolis of Ancón in Peru. The skull, housed at the Muséum national d'histoire naturelle in Paris, displays an anteroposterior, brachycephalic, oblique, asymmetric, and bilobar deformation. TDM permitted 3-D reconstructions of the skull, endocranium, and vault thickness. The external surface displayed deformation and asymmetry in the bone structures and the endocranium demonstrated deformation and asymmetry in the brain lobes and superficial structures. The TDM demonstration of abnormal variations and pronounced asymmetry in the thickness of the vault strongly suggested that the deformation was *ante mortem*. The 3-D TDM reconstructions also helped to reconstruct the device used to deform the head.

Keywords Tomodensitometry · Skull · Intentional deformation · Brachycephaly · Bilobar · Peru

Résumé Une étude tomodensitométrique (TDM) médicale a été réalisée sur un crâne sec de la nécropole d'Ancón au Pérou. Le crâne est conservé au Muséum national d'histoire naturelle à Paris. Il présente une déformation antéropostérieure, brachycéphale, oblique, asymétrique et bilobée. La TDM a permis la réalisation de reconstructions 3D du crâne, de l'endocrâne et de l'épaisseur de voûte. La surface externe montrait la déformation et l'asymétrie des structures osseuses. L'endocrâne montrait la déformation et l'asymétrie des lobes cérébraux, et les structures superficielles. La mise en évidence par TDM de variations anormales et d'une asymétrie marquée de l'épaisseur de voûte suggérait fortement que la déformation était ante mortem. De plus, les reconstructions 3D ont pu aider à la reconstitution de l'appareil déformateur.

Mots clés Tomodensitométrie · Crâne · Déformation intentionnelle · Brachycéphalie · Bilobé · Pérou

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Introduction

A medical TDM study was performed on a deformed, brachycephalic, asymmetrical, bilobar Huaura-type skull from Ancón (Peru). This type of deformation is not specific to, but is associated with, the region of ancient Ancón, Lima, and Chancay. Many other types of cranial deformation, either brachycephalic or dolichocephalic, were performed in pre-Hispanic Peru. Ancón, Lima, and Chancay are close to each other: Ancón is located on the central coast of Peru, 40 km northwest of Lima, and Chancay is near the sea 20 km northwest of Ancón. The Ancón necropolis contained non deformed and deformed skulls, many of which were deformed intentionally in a bilobar fashion. The Chancay people (1200–1470) produced ceramic figures of bilobar heads, which suggests that this type of deformation was widely performed in this part of the central coast from the 12th to the 15th centuries [1,2].

The aim of the study was to display the expected deformation of the brain, and demonstrate the variations in the thickness of the vault as previously described in intentionally deformed skulls [3]. Based on the assumption that thinning of the cranial vault could be demonstrated in regions subjected to increased pressure, the hypothesis was that abnormal variations in vault thickness might confirm that the deformation was intentional, and help to determine the design and placing of the device used to produce the skull deformation in infancy and childhood.

Materials

Skull n° 22580, with mandible, came from Ancón (Peru), and has been housed since 1889 at the Muséum national d'Histoire naturelle (MNHN) in Paris. The archaeological context was not described, and for reasons of museum curating, no dating technique was applied. The morphological features of the skull have been described elsewhere [4].

Briefly, the skull displayed an anteroposterior, oblique, Huaura-type intentional deformation [1]. The skull was markedly asymmetrical, and deformed in a bilobar fashion with two prominent asymmetrical parietal humps, a medial sagittal posterior depression located at and above lambda and a transverse depression along the posterior side of the coronal suture. The left parietal hump was higher and further forward than the right one. The facial features were also asymmetrical. The orbital bones were situated further forward and lower on the left side than on the right side. The deformation was characterized by three-way flattening: anteroposterior (frontal, occipital), lateral (temporal and parietal) on each side, and from above. A so-called Inca bone was present. Two parietal *foramina* and an occipital fossa could be considered as normal anatomical features.

The classic morphological features for estimating sex and age were analysed. Our interpretation was cautious, and bias due to deformation was taken into account, especially as regards the degree of closing of sutures. Nonetheless, the gracile features of the bones, including the mandible, strongly suggested the female type, as well as the muscle attachments, which were small. Dental wear suggested that the skull belonged to a middle-aged adult, who had most probably died at the age of 45 [5–9]. The endocranial volume of the skull was equal to 1,340 cm^3, which is in the normal range for the ethnic group, probable sex, and probable age at death [10].

Methods

A standard medical TDM was performed at the Department of Radiology of the R. Poincaré University Hospital in Garches, France. The settings were: tension 120 kwp, X-ray tube current 265, voxel size 0.47 mm, voxel number 512 × 512 × 459.

The TDM study followed a protocol derived from those defined by Antoine Balzeau at the MNHN [11–14]. In order to quantify the thickness of the cranial vault, the boundary (threshold) between the bone and the surrounding air on each side of the vault was identified using the half-maximum height (HMH) technique [15].

The skull (cranium and mandible) was reconstructed in 3-D as the external surface. The endocranium was reconstructed in 3-D as the internal surface. The distance between the outer skull and the endocranium was displayed as a 3-D reconstruction of the vault thickness. Thresholding procedures, 3-D volume rendering, 3-D topographic mapping and illustration acquisition were performed with Avizo 7 (Mercury Computer Systems).

Results

The 3-D TDM reconstructions of the skull allowed both internal and external visualization of the deformation and asymmetry of the bone structures (Fig. 1 a to e). The 3-D TDM reconstructions of the endocranium demonstrated deformation of the brain lobes and the asymmetry of the parietal and occipital lobes. The 3-D reconstructions also permitted an analysis of the surface structures: venous sinuses, middle meningeal veins and arachnoid (Pacchionian) granulations (Fig. 1 a' to e').

The bone thickness of the vault varied between 1.6 mm and 9.6 mm, measuring 6.0 mm at bregma and lambda and 9.6 mm at the internal occipital protuberance, which was the thickest area of the vault. The maximum thickness of the parietal humps was 6.3 mm on the left side and 5.4 mm on the right side.

The 3-D TDM reconstructions of the thickness of the vault bones revealed presumably normal and presumably abnormal variations. Thicker areas were related to the frontal crest (which is internal and sagittal); the upper frontal bone; the sagittal area from bregma to the occipital protuberance; a very short sagittal occipital line below the protuberance; occipital transverse lines from the protuberance on each side; along the lambdoid suture; V-shaped central areas of the lateral parietal bones increasing in thickness to the parietal humps; and parietal humps.

The upper frontal bone, parietal humps and V-shaped central areas of the lateral parietal bones were asymmetrically thicker. Their thickening was more pronounced on the left side. The asymmetry of the variations in thickness was more marked at the location of the parietal bones than at the location of the frontal bone.

Thinner areas were related to the supra-orbital areas of the frontal bone; the posterior side of the coronal suture; arachnoid granulations, the upper sagittal sinus within a short posterior segment; parasagittal areas of the posterior and, to a lesser extent, anterior upper parietal bones; the occipital bone above and below transverse occipital lines; middle

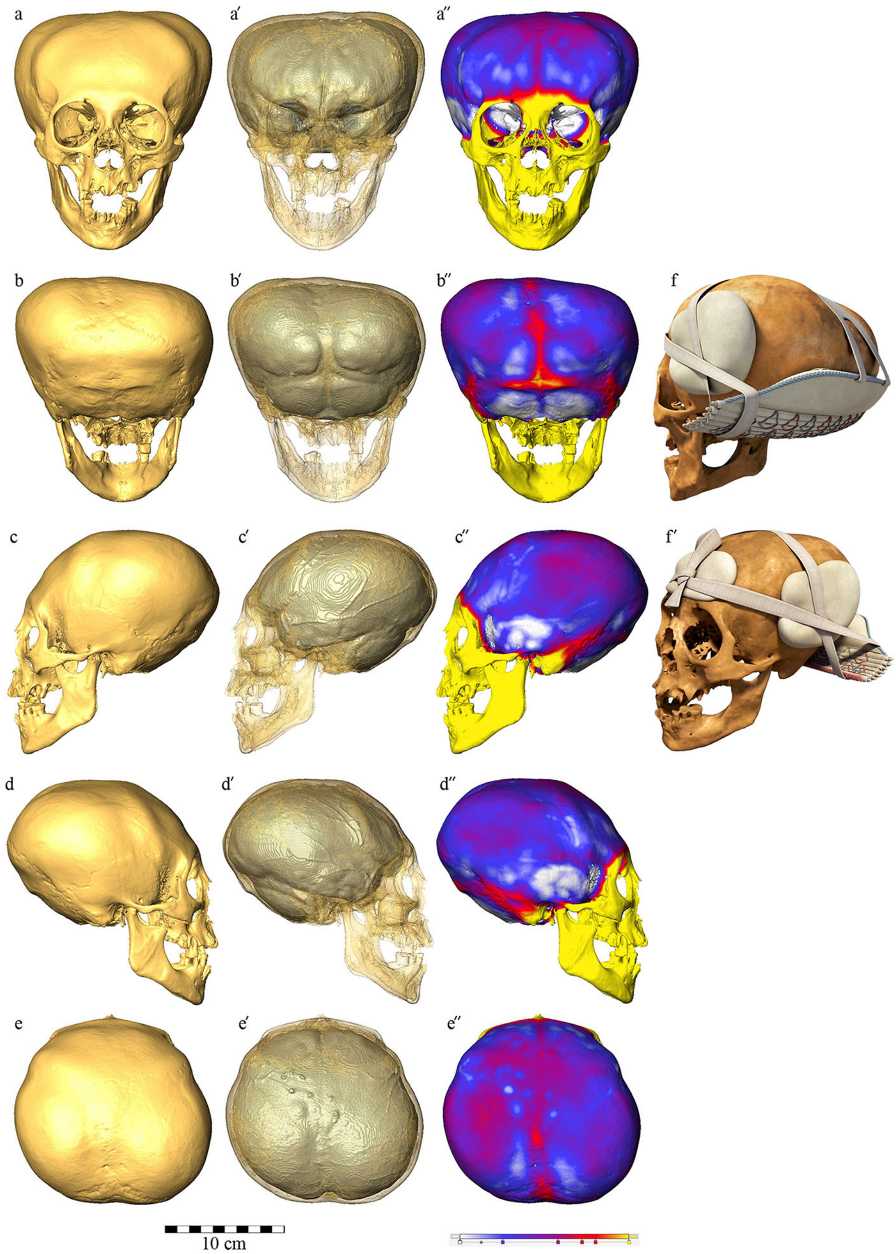

Fig. 1 3-D tomodensitometry reconstructions of skull n° 22580, positioned along the Frankfurt horizontal line. (a-a'') Anterior view. (b-b'') Posterior view. (c-c'') Left profile. (d-d'') Right profile. (e-e'') Upper view. (a-e) External surface. (a'–e') Endocranium with skull visualised in transparency. (a''-e'') Thickness of the vault (2 to 10 mm colour scale, increasing from white to yellow). The cranium and mandible display female-type morphological features. The cranial deformation is brachycephalic, obliquely oriented, bilobar and asymmetrical. Variations in cranial bone thickness are due to external and internal structures, and are markedly asymmetrical. (f, f') 3-D tomodensitometry reconstructions of skull n° 22580 with virtual 3D reconstruction of a deforming device. ©Mac Guff/Muséum national d'histoire naturelle (2014). (f) Posterior and left lateral view. (f') Anterior and left lateral view / *Reconstructions tomodensitométriques 3D du crâne (avec mandibule) n° 22580, orienté selon l'horizontale de Francfort. (a-a'') Vue antérieure. (b-b'') Vue postérieure. (c-c'') Profil gauche. (d-d'') Profil droit. (e-e'') Vue supérieure. (a-e) Surface externe. (a'–e') Endocrâne avec crâne visualisé en transparence. (a''-e'') Épaisseur de voûte (échelle de couleur 2 à 10 mm, du blanc au jaune). Les caractéristiques morphologiques du crâne et de la mandibule sont de type féminin. La déformation crânienne est brachycéphale, oblique, bilobée et asymétrique. Les variations d'épaisseur de la voûte sont dues à des structures externes et internes et sont fortement asymétriques. (f, f') Reconstitution tomodensitométrique 3D du crâne n° 22580 avec reconstitution infographique 3D d'un appareil déformateur. ©société Mac Guff/Muséum national d'histoire naturelle (2014). (f) Vue postérolatérale gauche, (f') Vue antérolatérale gauche.*

meningeal veins; temporal squama; lateral parietal bones except for their thicker V-shaped central part.

As regards the thickness of the vault, presumably abnormal findings were the pronounced asymmetry, the thinning of the parasagittal posterior part of the parietal bones and the lack of regular occipital thickening anteroposteriorly towards the external occipital protuberance (Fig. 1 a" to e").

We were able to reconstruct a deforming device with reference to the literature [1] and to the TDM features of the skull (Fig. 1 f and f').

Discussion

The reconstruction of a well-preserved inner skull made it possible to study the cerebral lobes and surface structures such as the upper sagittal, transverse and sigmoid sinuses, meningeal veins and arachnoid granulations. The general orientation of the middle meningeal system is normally oblique. This system has a predominant anterior ramus consisting of the bregmatic and obelic meningeal branches. The ramifications are numerous and linked by a number of anastomoses that form a covering pattern [13]. The endocranium of the skull analysed showed deformation of the brain, asymmetry of the parietal and occipital lobes and surface structures, with no noticeable abnormality other than deformation and asymmetry.

Thickness values may vary according to methodological procedures, external and/or internal cranial structures, pathological, traumatic, and taphonomic alterations, and the state of preservation of the bones. The spatial resolution limitations of the HMH methodology overestimate thickness values when the areas measured are very thin [11].

The main anatomical structures that influence the bone thickness of the cranial vault are the frontal crest, endocranial imprints (venous sinuses, middle meningeal veins, arachnoid granulations) and occipital superstructures [13,14]. The deformed skull from Ancón display variations related to all these structures.

In anatomically modern *Homo sapiens*, the pattern of distribution of cranial bone thickness can vary with individuals, but the thinner areas of the upper vault generally correspond to the area of the parietal bones located laterally to the midsagittal plane and in the anterior third of the bone, which is thinner than the posterior part [14]. Compared to normal anatomical variations of the vault thickness [11,14,16], the pronounced asymmetry of the parietal bones and the marked thinning of the parasagittal posterior part of the parietal bones suggested pressure exerted from above by a head-deforming device, while the lack of regular occipital thickening anteroposteriorly towards the external occipital protuberance suggested pressure exerted from behind by a head-deforming device.

In intentional anteroposterior deformations from Bolivia, the topographic mapping of vault thickness constantly demonstrated frontal bone thinning. The thinning of the bones of the vault due to external compression was accompanied by thickening elsewhere, and affected the three layers of the vault [3]. In the anteroposterior deformation analysed, abnormal thinning was demonstrated in the parasagittal posterior part of the parietal bones, which might have resulted from external compression in infancy against the thrust of the growing brain. A striking feature of the thickness of the vault was the pronounced asymmetry mainly in the parietal bones. The skull and face are normally slightly asymmetric [13], but the asymmetry of the skull analysed was so marked in the bone structures, cranial vault measurements and cranial vault thickness that it appeared to be beyond any possibility of natural individual variation.

Intentional (artificial) cranial deformations must be distinguished from non-intentional deformations [17,18]. It can be possible to recreate the type, placing and extension of the deforming device from the shape of the skull, abnormal flattened areas, grooves and crests. The bilobar shape and the strong asymmetry of the skull from Ancón clearly suggests an intentional *ante mortem* deformation. The TDM demonstration of abnormal variations in the vault thickness further suggested that the deformation was *ante mortem*. The 3-D TDM reconstructions also helped to reconstruct the head-deforming device, which was probably complex, made of bands and cushions exerting pressure anteroposteriorly, laterally and from above [1,4].

Conclusion

The medical TDM and Avizo study of a deformed skull with intentional brachycephalic, bilobar and asymmetrical deformation demonstrated variations in the thickness of the vault, which further suggested that the deformation was intentional, and also helped to reproduce the head-deforming device.

The diploe might be thinned by external compression more easily than internal and external tables in deformations related to external (presumably intentional) pressure. High-resolution micro-TDM would be required to make a precise evaluation of the thickness of the diploe in addition to the total thickness of the vault, and to study fine structures such as diploic trabeculation, the meningeal/diploic venous system and sutures.

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References

1. Weiss P (1961) Osteología cultural. Prácticas cefálicas. 2da parte. Tipología de las deformaciones cefalicás: estudio cultural de los tipos cefálicos y de algunas enfermedades oseas. Universidad Nacional Mayor de San Marcos, Lima
2. Weiss P (1962) Tipología de las deformaciones cefálicas de los antiguos peruanos, según la osteología cultural. Revista del Museo Nacional Lima 31:15–42
3. Khonsari RH, Friess M, Nysjö J, et al (2013) Shape and volume of craniofacial cavities in intentional skull deformations. Am J Phys Anthropol 151:110–9
4. Boman F, Duchat F, Mérigeaud S, et al (2015) Étude anatomoradiologique d'un crâne déformé d'Ancón (Pérou). In: Charlier P (ed) Actes du 5e Colloque international de pathographie, Berghes, mai 2013. De Boccard, Paris
5. Brothwell DR (1965) Digging up bones: the excavation, treatment and study of human skeletal remains. British Museum, London
6. Stewart TD (1979) Essentials of forensic anthropology: especially as developed in the United States. Charles C Thomas, Springfield, Illinois
7. Krogman WM, Iscan MY (1986) The human skeleton in forensic medicine. 2nd ed. Charles C Thomas, Springfield, Illinois
8. Schmitt A, Georges P (2008) Quelle démarche suivre pour estimer l'âge au décès à partir du squelette ? In: Charlier P (ed) Ostéoarchéologie et techniques médicolégales — Tendances et perspectives — Pour un « manuel pratique de paléopathologie humaine ». De Boccard, Paris, pp 269–80
9. Bruzek J, Schmitt A (2008) Identification du sexe d'un individu à partir du squelette. In: Charlier P (ed) Ostéoarchéologie et techniques médicolégales — Tendances et perspectives — Pour un « manuel pratique de paléopathologie humaine ». De Boccard, Paris, pp 259–67
10. Morton SG (1839) Crania Americana. J Dobson, Philadelphia, Pennsylvania
11. Balzeau A (2007) Variation and characteristics of the cranial vault thickness in the Krapina and Western European Neandertals. Period Biol 109:369–77
12. Balzeau A, Rougier H (2013a) New information on the modifications of the Neandertal suprainiac fossa during growth and development and on its etiology. Am J Phys Anthropol 151:138–48
13. Balzeau A, Grimaud-Hervé DF, Détroit F, et al (2013b) First description of the Cro-Magnon 1 endocast and study of brain variation and evolution in anatomically modern Homo sapiens. Bull Mem Soc Anthropol Paris 25:1–18
14. Balzeau A (2013c) Thickened cranial vault and parasagittal keening: correlated traits and autapomorphies of Homo erectus? J Hum Evol 64:631–44
15. Weber GW, Bookstein FL (2011) Virtual anthropology: a guide to a new interdisciplinary field. Springer, Wien
16. Anzelmo M, Ventrice F, Barbeito-Andrés J, et al (2015) Ontogenetic changes in cranial vault thickness in a modern sample of Homo sapiens. Am J Hum Biol 27:475-85
17. Charlier P (2008a) Diagnostic des malformations humaines en paléopathologie. In: Charlier P (ed) Ostéoarchéologie et techniques médicolégales — Tendances et perspectives — Pour un « manuel pratique de paléopathologie humaine ». De Boccard, Paris, pp 501–26
18. Charlier P (2008b) Les monstres humains dans l'Antiquité : analyse paléopathologique. Fayard, Paris