C. R. Palevol xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Comptes Rendus Palevol

www.sciencedirect.com

Human Palaeontology and Prehistory (Palaeoanthropology)

Assessing cranial plasticity in humans: The impact of artificial deformation on masticatory and basicranial structures

Évaluer la plasticité crânienne chez l'Homme : impact des déformations artificielles sur les structures masticatrices et basicrâniennes

Marion Cottin [a], Roman Hossein Khonsari [b], Martin Friess [a,*]

[a] *UMR 7206, département "Homme et Environnement", Muséum national d'histoire naturelle, Musée de l'Homme, 75016 Paris, France*
[b] *Service de chirurgie maxillofaciale et stomatologie, Assistance publique–Hôpitaux de Paris, hôpital universitaire Pitié-Salpêtrière, université Pierre-et-Marie-Curie, 75013 Paris, France*

ARTICLE INFO

Article history:
Received 29 July 2016
Accepted after revision 8 March 2017
Available online xxx

Handled by Roberto Macchiarelli

Keywords:
Artificial cranial deformation
Basicranial flexion
Temporomandibular joint
Covariation
Geometric morphometrics

Mots clés :
Déformation crânienne artificielle
Flexion basicrânienne
Articulation temporomandibulaire
Covariation
Morphométrie géométrique

ABSTRACT

Artificial cranial deformations (ACD) are a widespread cultural practice found in numerous historical and prehistoric contexts. Their study can yield valuable insight into craniofacial growth, specifically into the interactions between neurocranial and basicranial modules. This study seeks to reinvestigate the presumed effect of ACD on basicranial and masticatory elements by applying a 3D geometric morphometric approach to CT scans. A total of 51 French and Bolivian skulls, representing anteroposterior and circumferential deformations and including undeformed individuals, were scanned, and 3D landmarks were submitted to between-group principal components analysis and two-block partial least-squares analysis. Our results illustrate changes in basicranial shape and in cranial base angles induced by ACD, as well as in masticatory geometry, namely in the relative position of the mandibular fossae. Furthermore, our findings highlight differential effects of the various deformation types, which suggest that patterns of covariation between modified vaults and their associated basicrania are more complex than previously assumed, thereby stressing the degree of plasticity in human craniofacial growth.

RÉSUMÉ

Les déformations artificielles du crâne (DAC) désignent une pratique culturelle observée dans de nombreux contextes historiques et préhistoriques. Leur étude nous renseigne sur la croissance craniofaciale, notamment l'interaction entre les modules neuro- et basicrâniens. L'objectif de cette étude est de réexaminer l'effet présumé des DAC sur les éléments basicrâniens et masticateurs, en appliquant des méthodes de morphométrie géométrique 3D à des analyses tomodensitométriques. Au total, 51 crânes d'origine française et bolivienne, représentant les déformations antéropostérieures et circonférentielles, ainsi que des individus non déformés, ont été scannés, et les coordonnées de points de repère 3D ont été

* Corresponding author.
E-mail address: martin.friess@mnhn.fr (M. Friess).

http://dx.doi.org/10.1016/j.crpv.2017.03.001
1631-0683/

étudiées par analyse en composantes principales intergroupes ainsi que par régression des moindres carrés partiels (PLS) avec deux blocs de covariation. Nos résultats illustrent des changements de conformation et d'angulation de la base du crâne, induits par les DAC, ainsi que de la géométrie masticatrice, notamment concernant les positions relatives de la fosse mandibulaire et du reste de la base du crâne. Nos observations soulignent des effets différentiels selon les types de déformation, ce qui suggère que les patrons de covariation entre une voûte modifiée et la base crânienne sont plus complexes que précédemment proposé.

1. Introduction

The custom of transforming the human body, be it for aesthetic motives or for the purpose of demonstrating membership to social or ethnic groups, has been omnipresent throughout human history and, in the case of artificial cranial deformations (ACD), can be traced back as far as the Palaeolithic period (Antón and Weinstein, 1999; Brown, 1981; Dingwall, 1931). Anthropologists continue to study deformations as a phenomenon at the interface between culture and biology that can inform on a variety of aspects regarding population history, craniofacial growth dynamics, but also respond to the very practical necessity to identify deformed skulls in collections or archaeological samples (Clark et al., 2007; Hoshower et al., 1995; O'Brien and Stanley, 2011; Tiesler, 2014; Torres-Rouff, 2002; Verano, 2003).

1.1. *Deformational effects on the cranial base and face*

From a morphological perspective, ACD can be seen as the outcome of a real-life experiment, albeit unplanned, on altering growth trajectories (Cheverud et al., 1992; Jimenez et al., 2012; Liebermann et al., 2000). As such, it has been used to investigate patterns of craniofacial variation in humans by looking at secondary effects of vault modifications induced on other structures, namely the face and the base. Previous studies have shown that, due to the morphological integration of the skull, deforming the braincase during extended periods of growth leads to changes in the cranial base and face. However, as it has been pointed out (Antón, 1989; Friess and Baylac, 2003), findings differ between studies, leaving some doubt as to the exact nature and patterns of some of these changes, and possibly reflecting uncertainties in the identification of deformation types. While the number and nomenclature of ACD vary according to different authors, a major distinction found in many publications is made between annular (or circumferential, C) and tabular (or anteroposterior, AP) types. This binary system is thought to reflect the two main types of deformation devices: soft wrapping vs. hard materials (tablets made from wood or stone). The use of these devices also tends to result in fundamentally different cranial shapes: C-type deformations lead to postero-superiorly protruding and mediolaterally narrow vaults, whereas the AP-type is characterized by anteroposteriorly shortened and mediolaterally widened braincases (Antón, 1989; Dembo and Imbelloni, 1938; Falkenburger, 1938). Within AP deformations, a subdivision into erect and oblique forms, though not supported by all scholars, has been proposed on the basis of the vertical/inclined orientation of the occipital squama (e.g., Dembo and Imbelloni, 1938).

In addition to the general change in neurocranial shape, various associated modifications in the face and base have been reported, though not all studies agree on all of these. Thus, several authors found facial broadening in AP-type deformations vs. narrowing in C-type deformations (Antón, 1989; Cheverud et al., 1992; Jimenez et al., 2012; Kohn et al., 1993). Increased facial height dimensions have also been reported in AP deformations (Antón, 1989), while some studies observed different degrees of facial shortening and flattening in AP (Cheverud et al., 1992; Jimenez et al., 2012).

With respect to the cranial base, the effects of the various deformation types have been estimated inconsistently: several studies (Antón, 1989; McNeill and Newton, 1965) found flattened basicrania (platybasia) in both AP- and C-type deformations, while others observed platybasia in C-, and basicranial kyphosis in AP-types (Martínez-Abadías et al., 2009; Moss, 1958). Furthermore, support for platybasia in AP also comes from Oetteking (1924), while Schendel et al. (1980) found no effect on the cranial base angle (CBA) at all. Conversely, the overall proportions of the cranial base, when investigated, have been consistently found altered depending on the deformation type: AP deformations result in anteroposteriorly shortened and mediolaterally widened basicrania, while C deformations yield the opposite shape, i.e., an anteroposteriorly lengthened and mediolaterally narrowed base (Antón, 1989; Cheverud et al., 1992; Cocilovo et al., 2011; Kohn et al., 1993; Martínez-Abadías et al., 2009).

Regarding the inconsistent findings with respect to CBA, previous studies have identified as potential causes differences in: (1) sample size, varying between $N = 65$ (Moss, 1958) and $N = 1586$ (Cocilovo et al., 2011); (2) classification of deformation types; (3) methodology (e.g., external vs. radiographic-based measurements, different definitions of CBA; see Antón, 1989; Cocilovo et al., 2011). However, differential effects on the base by deformation type have also been observed in studies with comparatively large sample sizes (e.g., Baylac and Friess, 2005; Martínez-Abadías et al., 2009) and, according to Antón (1989), differences in CBA definition do not account for these inconsistencies either. External vs. internal measurements (radiography, computed tomography) may also represent a potential cause for differences in the assessment of CBA.