Archaeological and Anthropological Sciences (2019) 11:2597–2610
https://doi.org/10.1007/s12520-018-0687-6

ORIGINAL PAPER

Does the shape make a difference? Evaluating the ethnic role of cranial modification in the Pampa-Patagonia region (Argentina) during the late Holocene

Serna Alejandro[1] · Prates Luciano[1] · Flensborg Gustavo[2] · Martínez Gustavo[2] · Favier Dubois Cristian[2] · Perez Sergio Ivan[3]

Received: 22 March 2018 / Accepted: 23 August 2018 / Published online: 3 September 2018

Abstract
The Pampa-Patagonia region in Argentina has been characterized as an ethnically complex territory during the late Holocene. This region presents a high frequency of human burials and, although several papers have focused on the study of cranial vault modification, none of them have discussed systematically the ethnic role of this practice. In this study, we assess the role of cranial modification as a potential expression of ethnic identity among hunter-gatherer groups from northeastern Patagonia and southeastern Pampas during the late Holocene. In order to define morphological groups and to recognize spatio-temporal patterns, we applied 2D landmark-based morphometric methods and multivariate statistical techniques on 216 adult male and female crania, which were grouped into three geographic units. The results of this paper do not support the idea of cranial modification as an ethnic marker within the region, as the different modifications follow a temporal sequence and are present in the entire study area. Also, our results show that the groups of cranial modification are different from each other, and they show variability among the geographic units. The reasons behind the change between cranial modification groups remain unclear, but it coincides approximately with some technological and symbolic changes in the material record. Variability within groups is understood as the result of a non-standardized practice and the existence of *local ways of doing* among the hunter-gatherer of the study region. As we see in shared art motives and decorative patterns, cranial modification would have represented another correlate of a macro-regional visual communication system that worked during the late Holocene in Pampa-Patagonia.

Keywords Cranial vault modification · Pampa-Patagonia region · Geometric morphometric · Hunter-gatherers · Ethnic differentiation

Introduction

Cranial vault modification is the product of compressive forces that guide the growth and shape the neurocranium permanently during the early childhood (Buikstra and Ubelaker 1994; Tiesler 2014). It is well documented that after birth, the head of the newborn is shaped carefully up to 5 years in some cases, by a member of its family or a caretaker (e.g., Blackwood and Danby

✉ Serna Alejandro
aserna@fcnym.unlp.edu.ar

Prates Luciano
lprates@fcnym.unlp.edu.ar

Flensborg Gustavo
gflensbo@soc.unicen.edu.ar

Martínez Gustavo
gmartine@soc.unicen.edu.ar

Favier Dubois Cristian
cfavier3@gmail.com

Perez Sergio Ivan
ivanperezmorea@gmail.com

1 CONICET - División Arqueología, Facultad de Ciencias Naturales y Museo, Universidad Nacional de La Plata, Anexo Museo, Av. 122 y 60 (1900), La Plata, Buenos Aires, Argentina

2 Instituto de Investigaciones Arqueológicas y Paleontológicas del Cuaternario Pampeano (INCUAPA-CONICET), Facultad de Ciencias Sociales, Universidad Nacional del Centro de la Provincia de Buenos Aires (UNICEN), Olavarría, Argentina

3 CONICET - División Antropología, Facultad de Ciencias Naturales y Museo, Universidad Nacional de La Plata, Anexo Museo, Av. 122 y 60 (1900), La Plata, Buenos Aires, Argentina

1955; Hatt 1915). It is also known that the modification of the head is a worldwide practice, that has been implemented by diverse human groups over time and space (Dingwall 1931; Tiesler 2014), especially in South America, where it has been deeply studied (Blom 1999, 2005; Bórmida 1953–1954; Dembo and Imbelloni 1938; Hrdlicka 1912; Knudson and Torres-Rouff 2009; Kuzminsky et al. 2016; Perez 2007; Torres-Rouff 2002, 2003; Weiss 1961; among others).

One of the most frequent archeological questions related with cranial modification has been about their causes. Some scholars have explained it as a sub-product of cultural practices the aim of which was not to alter the shape of the head (e.g., fixing children to a cradle with bandages or straps for transportation, Dembo and Imbelloni 1938). In other cases, cranial modification has been interpreted as a consequence of intentional actions oriented towards shaping the cranium (e.g., labor specialization, Lozada and Buikstra 2005; resemblance with the gods, García and Tiesler 2011). Whether unintentional or intentional, cranial vault modification results from the interaction among the newborns and the caretakers in a social context, and therefore bears social meaning (Tiesler 2014; Torres-Rouff and Knudson 2017). Different social motivations or roles have been proposed in a wide variety of archeological and ethnographical contexts, such as lineage differentiation (Weiss 1961), social status distinction (Dingwall 1931), cosmological purposes (Tiesler 2014), corporal esthetics (Lorentz 2002), health benefits (Hatt 1915), intimidation (Allison et al. 1981), and ethnic demarcation (Blom 2005; Torres-Rouff and Yablonsky 2005; Yépez 2009). In this context, cranial modification is able to comprise relevant information about ethnic affiliation because the human body is both biologically and socially dynamic, and some structural features and social conventions can leave visible marks on it (Knudson and Stojanowski 2008; Tiesler 2014). Ethnicity, as a collective social identity, is usually built in relation with other groups and defined by its *limits* (Barth 1969; Jones 1997). One approach to study these limits is through the study of biological and social interactions among groups that can be assessed by means of the bioarchaeological record (Blom 2005; Serna 2018; Sutter 2005; Torres-Rouff and Knudson 2017).

The transition between Pampa and Patagonia regions, two prominent ecological and cultural areas of Southern South America, has been historically viewed as an area of tension and interaction between adjacent social systems. From the XVIII century on, many travelers and scholars observed and stated that the Negro river valley functioned as an ethnic boundary/buffer between Pampean and Patagonian people ("Pampas" or "Tehuelches Septentrionales Boreales" -to the North-, and "Tehuelches Septentrionales Australes" or "Gününa küna" -to the South-) (Casamiquela 1965; Vignati 1967). Although the northern Patagonian coast was virtually uninhabited by hunter-gatherers from the XVI century, coastal archeological sites were usually thought to have been generated by different people (specialized marine hunter-gatherers), to inland sites (Bórmida 1953–1954; Sanguinetti de Bórmida 1981). Therefore, the whole area has been characterized as an ethnically complex territory, with high biological and cultural variability during the late Holocene (Bórmida 1953–1954; Bórmida and Casamiquela 1958–1959; Borrero 2001; Casamiquela 1985; Cocilovo and Neves 1988–1989; Fortich Baca 1976; Gradin 1982; Orquera 1984–1985; Prates 2008; Pucciarelli et al. 2006; among others). The bioanthropological evidence suggests a context of population convergence and recurrent gene flow (Barrientos and Perez 2002; Bernal 2008; Del Papa 2013; Perez 2006; Pucciarelli et al. 2006), and inferences based on the archeological record have pointed, "cultural convergence" (Outes 1926), "soft borders," and large social networks (Berón 2007, 2016; Martínez 2008–2009; Martínez et al. 2016).

Considering these previous evidences and interpretations, the question that arises in this paper is whether the cranial vault modification expressed ethnic differences in the three main spatial units of the Pampa-Patagonia ecotone during the late Holocene: Inland Southeastern Pampas, Negro River Valley, and the neighboring coast area of the former two (Northpatagonic Litoral) (Fig. 1). For this purpose, we analyze the morphological variation using 2D landmark-based morphometric methods and multivariate statistical techniques, to define morphological and spatio-temporal patterns. Having a clear understanding of morphological variation and its geographic and temporal patterns will allow us to get closer to the social meaning of the cranial modification among hunter-gatherers. Although several papers have focused on the study of cranial modification in this area, its social implications have not been systematically discussed (e.g., Bernal et al. 2008; Berón and Baffi 2003; Berón and Luna 2009; Bórmida 1953–1954; Cocilovo and Guichón 1994; Dembo and Imbelloni 1938; Mendonça et al. 1988–1989; Perez et al. 2009a; Serna et al. 2013; Wiggenhauser 2016).

Materials and methods

Archaeological background and analyzed sample

The bioarchaeological record of the study area is characterized by a high density of sites where the economic activities and the disposal of the dead coexisted. The mortuary practices included primary and secondary burials, often without funerary goods (Flensborg et al. 2018; Madrid and Barrientos 2000; Mariano 2011; Martínez 2010; Prates and Di Prado 2013). Molecular and radiocarbon data indicated that the population growth would have reached its maximum during the late Holocene (Perez et al. 2016). Also, the archeological record shows evidence for the implementation of new technologies

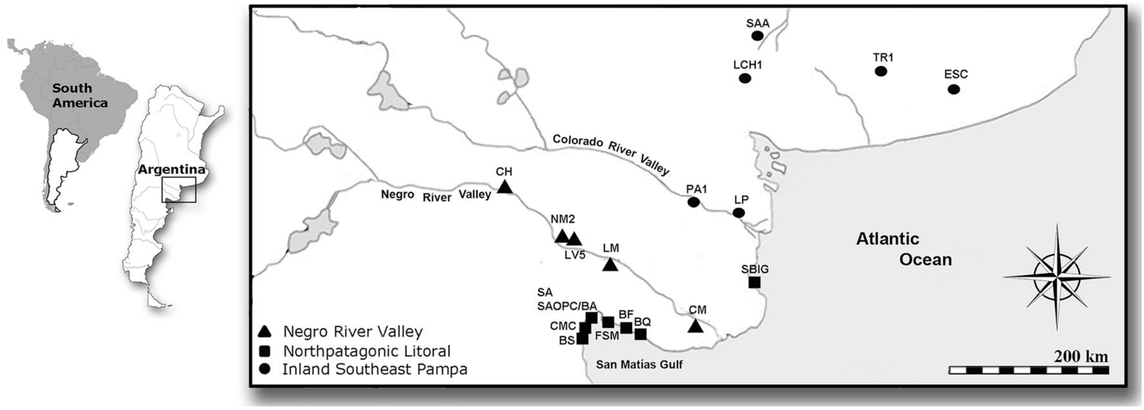

Fig. 1 Study region and location of the sites analyzed in this work

(Borges Vaz et al. 2016; Crivelli Montero 2010), the intensification of long-distance networks of trade (Berón 2007; Gómez Otero 2006), and the existence of shared motives and decorations in different items and surfaces (Acevedo 2015; Carden and Martínez 2014; Curtoni 2006; Di Prado 2015; Gradin 1973, 2001; Menghin 1957; among others).

The analyzed sample consists of 216 adult crania (male and female) from late Holocene archeological sites located in the northeastern Patagonia and southeastern Pampas (Table 1). The sample was analyzed considering three geographical units: Negro River Valley (NRV), Northpatagonic Litoral (NL), and Inland Southeastern Pampas (ISEP) (Fig. 1). The NRV sample ($n = 131$) consists of crania from the Laguna del Juncal archeological locality, in the lower valley of Negro River (Moreno collection, Museo de La Plata), and another site from the middle valley of the same river (Table 1). Laguna del Juncal is one of the most prominent mortuary spaces in northern Patagonia, with more than 25 multiple burial sites in an area of ca. 150 km^2 (Moreno 1874; Fisher and Nacuzzi 1992; Bernal et al. 2008). The NL sample ($n = 61$) includes crania from San Blas, Isla Gama, and San Antonio Este/Oeste archeological localities (Museo de La Plata and Museo Etnográfico Juan B. Ambrosetti), as well as from the north coast of the San Matías' Gulf (Table 1). These archeological localities comprise several sites excavated during the last part of the nineteenth century and the first part of twentieth century (see details in Perez 2006). The ISEP sample ($n = 24$) comprises crania from different sites of the lower valley of the Colorado River and southeastern Pampas (Table 1).

Data acquisition

Previous studies have demonstrated that there is no association between sex and cranial modification among the hunter-gatherer groups in the study area and neighbor regions (Perez 2006, 2007; Perez et al. 2009b). Also, considering that the sample in this study is sex-balanced (Table 1), we chose to pool male/female together in order to keep the highest sample size.

Geometric morphometric analyses were performed on 2D images obtained from crania positioned according to the Frankfurt plane, in the lateral norm and at a distance of 30 cm from the lens of an Olympus SP 350 digital camera. Although the study of cranial modification with three-dimensional data is becoming widely used due to its precision (e.g., Kuzminsky et al. 2016; Mayall and Pilbrow 2018; Menéndez and Lotto 2016; Wiggenhauser 2016), 2D data is still effective to have a first insight and describe broad patterns of variation (e.g., Manríquez et al. 2006; Mayall et al. 2017; Perez 2007; Salazar et al. 2014; Serna and Prates 2012). Cartesian coordinates (4 landmarks and 31 semilandmarks) on each image were digitalized along the contour of the vaults using the tps series software (Rohlf 2015). The landmarks used in this study are nasion (n), bregma (b), lambda (l), and postmastoid (pm) (Fig. 2). In order to assess the reliability of the landmark record, we analyzed the intraobserver error on a random sample ($n = 40$), conducting an intraclass correlation coefficient (Shrout and Fleiss 1979; Zar 1999). This test shows an excellent consistency (ICC > 0.93) between digitization series.

Morphometric and statistical approach

In this paper, we focus on the shape of cranial modification to build morphological categories, rather than using pre-established types. We do not use the classical typological categories proposed by Dembo and Imbelloni (1938)—based on assumed modification devices—not only because the definitions of some types are problematic (Bórmida 1953–1954: 46–47; Cocilovo and Guichón 1994: 25; Dembo and Imbelloni 1938: 271–272; Mendonça et al. 1988–1989: 58), but also because this kind of classification disregards the continuous nature of the morphological variation. Besides, the study of cranial modification based on few categories, instead

Table 1 Analyzed sample

Region	Sample	Site	M/F/Indet	n	Years BP[a]	Reference
Northeastern Patagonia	NRV	Laguna del Juncal (LJ)	65/54/2	121	3300–400	Bernal et al. 2008; Gordón 2011; MLP Catalog (n.d.)
		Loma de los Muertos (LM)	1/2/–	3	3000–500	Prates et al. 2010a, b
		Negro Muerto 2 (NM2)	–/3/–	3	2000–1300	Serna and Prates 2012; Prates and Di Prado 2013
		La Victoria 5 (LV5)	–/2/–	2	1200–900	Prates et al. 2011
		Chimpay (Ch)	1/1/–	2	100	Prates et al. 2016; Serna et al. 2017
	NL	San Blas e Isla Gama (SBIG)	11/15/8	34	1500–400	Perez 2006; Bernal et al. 2008; MLP Catalog
		Bahía Final 6 (BF6)	–/1/–	1	3400–800	Favier Dubois et al. 2009
		Bajo de la Quinta (BQ)	–/1/–	1	3000–450	Favier Dubois et al. 2009
		Buque Sur (BS)	2/2/–	4	2300–2100	Favier Dubois et al. 2009
		Faro San Matías (FSM)	–/1/–	1	2900–1400	Favier Dubois et al. 2009
		CMCriadero (CMC)	1/–/–	1	1500–700	Favier Dubois et al., 2009
		SAOBA	2/–/–	2	2300	Favier Dubois et al. 2009
		SAOPC	1/1/–	2	3100	Favier Dubois et al. 2009
		San Antonio (SA)	10/5/–	15	2500–400	Perez 2006; ME Catalog
Southeastern Pampas	ISEP	La Petrona (LP)	–/2/–	2	770–250	Martínez 2004
		Paso Alsina 1 (PA1)	5/4/–	9	570–440	Martínez et al. 2007
		Tres Reyes I (TR1)	4/2/–	6	2500–1800	Madrid and Barrientos 2000
		Estancia Santa Clara (ESC)	–/1/–	1	2500–1500	Madrid and Barrientos 2000; Perez 2006
		Laguna Los Chilenos 1 (LCH1)	2/1/–	3	470	Barrientos 1997
		Saavedra (SAA)	2/1/–	3	1500–400	Perez 2006
Total			107/99/10	216		

[a] Chronology based on radiocarbon dating and contextual association

of using several typological categories, has been proven to be a suitable research strategy (Boston 2012).

Instead of using typological visual methods (i.e., gross visual assessment), we follow an alternative approach that highlights the continuous nature of the morphological variation (Zelditch et al. 2012), through landmark-based morphometric techniques (Kuzminsky et al. 2016; Manríquez et al. 2006; Mayall et al. 2017; Mayall and Pilbrow 2018; Perez 2006, 2007; Perez et al. 2009a, b). A Generalized Procrustes Analysis was performed to remove any information that may be added by translation, scaling, and rotation factors (Rohlf and Slice 1990). The exclusion of these factors means that the only variable remaining is shape, and it allows us to pool both sexes together for analysis (e.g., Kuzminsky et al. 2016; Mayall et al. 2017). Unlike landmarks, semilandmarks—on their own—do not behave like homolog points between structures, but the homology is established between contours defined by anatomical points (Bookstein 2002). The morphological information is contained in the variation perpendicular to the described contour. To eliminate the tangent variation, and given the large morphometric differences between structures, the semilandmarks were slid along the contours by the bending energy criterion (Bookstein 1997; Perez et al. 2006). The resulting coordinates after these procedures are the Procrustes shape variables or Procrustes coordinates. These procedures were performed with the tps series software (Rohlf 2015).

In order to evaluate and compare the morphological configurations in a multivariate space of reduced dimensions, a Principal Component Analysis or Relative Warps Analysis (RWA) was performed on the Procrustes coordinates (Bookstein 1991; Mitteroecker and Gunz 2009). The RWA is a rigid rotation of the Procrustes shape variables that maximizes the variation among individuals using a spectral decomposition of a covariance matrix (Mitteroecker and Bookstein 2011). In this way, RWA generates orthogonal axes that describe patterns of maximum morphological variation (Bookstein 1989; Rohlf 1993). This analysis redistributes the total variance of the sample into the orthogonal axes that re-describe the patterns of variation among the data. These axes or Relative Warps (RWs) are calculated such that the variance on the first axis (RW1) accounts for the maximum variance in the data (Strauss 2010). An advantage of

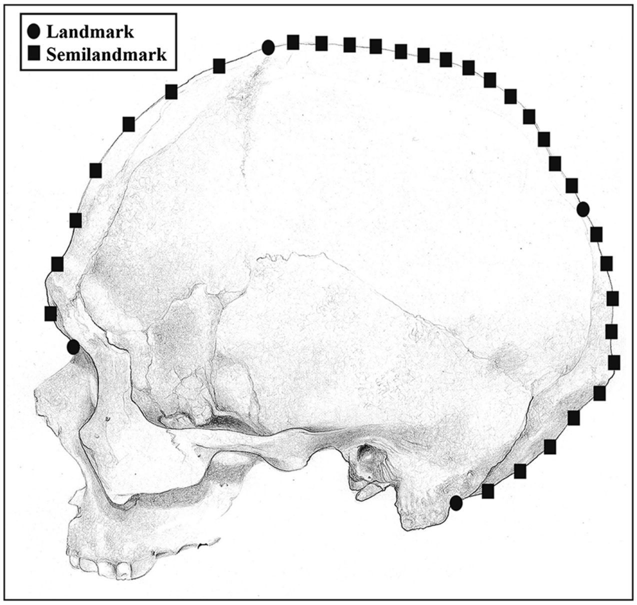

Fig. 2 Coordinates recorded from the vault contours (modified from Perez 2007)

this analysis is that the morphological spectrum can be expressed visually as a deformation diagram of each case with respect to a mean form or consensus. The thin plate spline function was used to visualize the morphological changes along the RWs through a grid of deformation (Bookstein 1991; Rohlf 1993). These procedures were performed with the tps series software (Rohlf 2015).

Although quantitative methods are powerful tools to assess the morphological variation of cranial modification, they still required some criteria to establish cut-off points (Perez 2007; Serna et al. 2013). In this paper, we used the Minimum Spanning Tree (MTS), a procedure that is commonly applied in morphological and genetic studies (Excoffier and Smouse 1994; Curnoe et al. 2015; Rocatti et al. 2017). This algorithm links the objects according to a matrix of distances, and is useful to apply in reduced space ordinations, such as the morphospace built by the RWs (Rohlf 1990). The objects are connected with segments in such a way that all are linked without loops, and these segments represent the shortest possible way to connect all the objects in a coordinate system (Gower and Ross 1969). For each sample (i.e., NRV, NL, and ISEP), a MST was performed with the Euclidean distances of the space built by the first two RWs, to establish cutting-off points to separate among morphologies with precision (unmodified and modified ones). The results were represented with different colors into the two-dimensional space of the RWA. This analysis was performed with R 3.1.0 -package ape- (R Development Core Team 2016).

To explore the morphological variation among the modified crania of each sample, we removed the unmodified crania, and performed a Canonical Variable Analysis (CVA) based on the first two RWs of all the modified crania pooled together. The aim of this analysis is to visualize the differences between and within morphological groups in a space of reduced dimensions. Similar to the RWA, CVA generates a new set of variables (i.e., canonical variables (CVs)) formed by linear combinations of the original variables, but in this case it seeks to maximize the inter-group distance relative to intra-group (Manly 1994; McCune and Grace 2002). From this analysis is possible to obtain the centroids (i.e., the mean values of the CVs) for each sample in each morphological group, and to use them to compare with other variables. The statistical analysis was performed with SPSS 20.

In order to test the association between the morphological ordination produced by the CVA and its temporal-spatial variation, we performed a Procrustes Analysis (Gower 1971; Peres-Neto and Jackson 2001; Perez 2007). The procrustean approach has been demonstrated to be able to detect matrix associations in different contexts, and it has been proposed as a powerful alternative to the Mantel test to compare sets of multivariate data (Peres-Neto and Jackson 2001). Instead of transforming the raw data into a distance matrix, the Procrustes Analysis operates over the raw data, and their ordination is scaled and rotated to find an optimal superimposition that maximizes their fit. So, the metric of association will be the sum of the squared residuals between configurations in their optimal superimposition, standardized to vary between 0 (no association or similarity between ordinations) and 1 (maximum association) (Gower 1971). We used the centroids of each sample in the canonical variable space to build a matrix of morphology, we defined one geographic coordinate per sample as a unique point at the same distance from each site, and we averaged the chronological range for each sample. A permutation procedure is also available to assess the statistical significance of the Procrustean fit (Jackson 1995), but it was not applied due to the low number of cases ($n = 6$). The Procrustes Analysis was performed using the vegan package for R 3.1.0 (R Development Core Team 2016).

Results

The morphometric and multivariate analyses allowed us to summarize and cluster the gradient of morphological variation of the cranial contour for each of the samples. In the NRV sample, the first two RWs account for 63.62% of the morphological variation, and the MST allowed us to establish cut-off points for three morphological groups (Fig. 3). Along the positive segment of RW1 (36.96%) and in the most positive RW2 scores (26.66%), shapes exhibiting compression in the frontal and occipital regions, with different degrees of flattening, obliquity, and projection of the obelonic region, are clustered (cluster F-O). Around the origin of both axes and along the positive part of RW1 and the negative part of RW2, a wide variety of contours are clustered. Although globular shapes

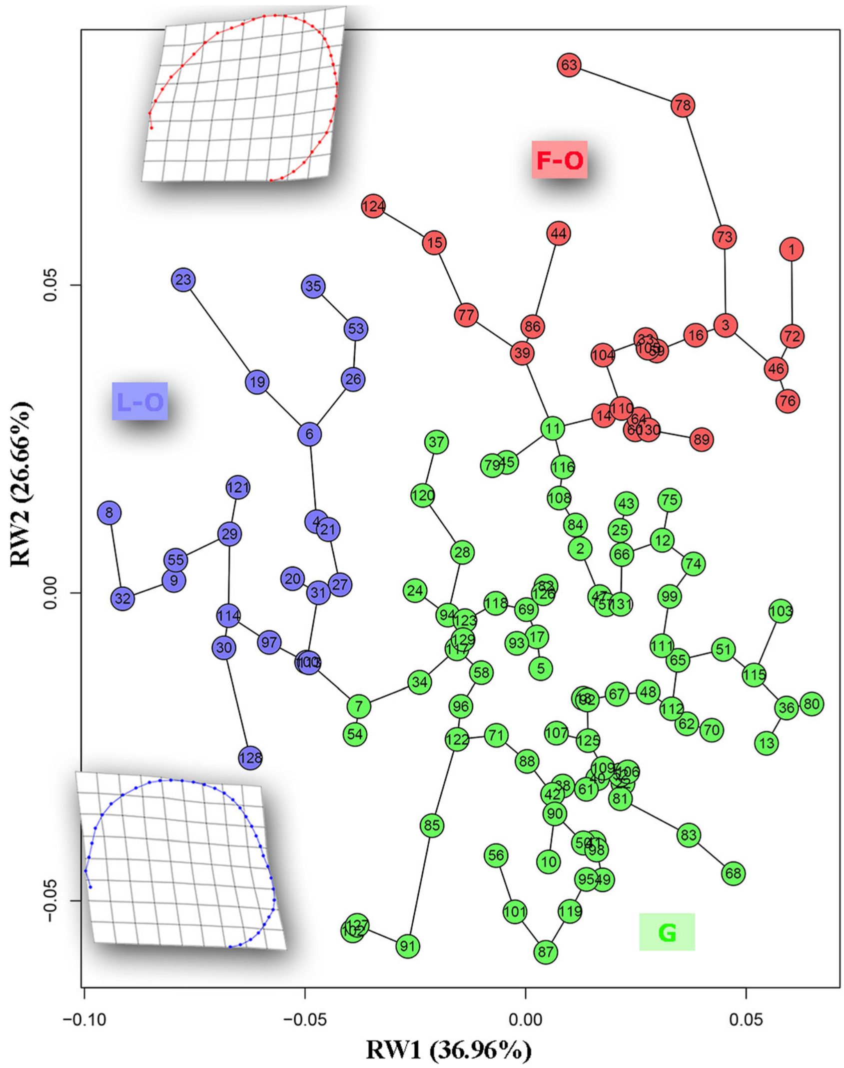

Fig. 3 Relative Warps Analysis with the MST groups—in colors—and deformation grids for NRV sample. *F-O* fronto-occipital morphologies, *L-O* lambdoid-occipital morphologies, *G* globular morphologies (unmodified)

predominate, some variants show different degrees of posterior projection of the occipital protuberance and pressure on lambda (cluster G -unmodified-). Among the most negative values of RW1 and along RW2, morphologies with different degrees of flattening in the lambdoid-occipital area, as well as some frontal projection, can be observed (cluster L-O) (Fig. 3). In total, 56.49% (74/131) of the sample is modified, of which 54.05% (40/74) corresponds to L-O and the remaining 45.95% (34/74) to F-O.

The sum of the first two RWs for the NL sample explains 63.07% of the morphological variation that we clustered in morphological groups (Fig. 4). In the positive segment of RW1 (40.35%) and in the most negative area of RW2 (22.72%), shapes characterized by different degrees of fronto-occipital compression and obliquity are clustered (cluster F-O). In the quadrant formed by the positive values of both axes, globular shapes with different degrees of elongation resulting from a posterior expansion of the occipital protuberance are grouped (cluster G -unmodified-). Along the negative segment of RW1 and around values close to zero of RW2, shapes characterized by different degrees of flattening in the occipital area and expansion of the frontal bone are observed (cluster L-O) (Fig. 4). In total, 60.66% (37/61) of the sample is modified, of which 70.27% (26/37) corresponds to L-O and the remaining 29.73% (11/37) to F-O.

The sum of the first two RWs for the ISEP sample explains 69.23% of the morphological variation of the cranial contour that we clustered according three morphological patterns (Fig. 5). In the negative sector of the RW1 (45.89%), shapes characterized by a fronto-occipital pressure maintaining curved aspects in both bones are grouped (cluster F-O). Near the origin and the negative sector of the RW1 and along the RW2 (23.34%), globular shapes are dispersed (cluster G -unmodified-). Towards the positive values of RW1 and along the RW2, shapes with different degrees of occipital flattening and pressure in the lambda zone, as well as a slight projection of the frontal bone, are clustered (cluster L-O) (Fig. 5). In total, 62.5% (15/24) of the sample is modified, of which 73.33% (11/15) corresponds to L-O and the remaining el 26.67% (4/15) to F-O.

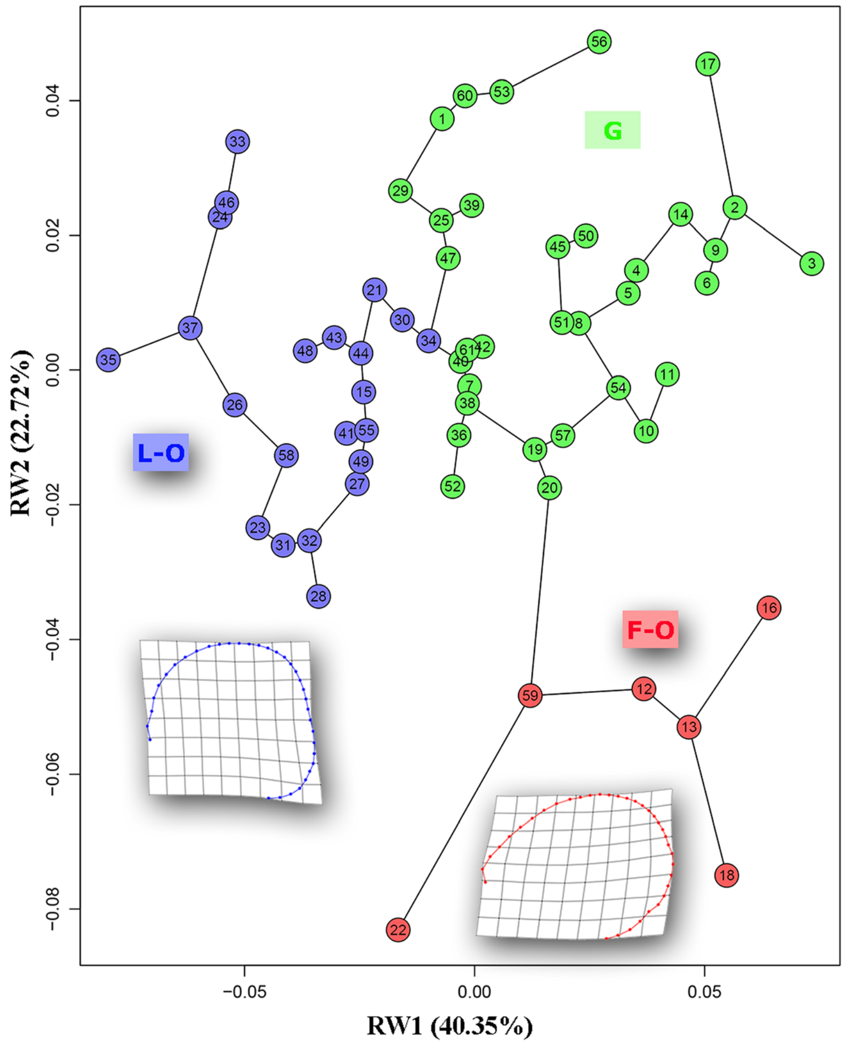

Fig. 4 Relative Warps Analysis with the MST groups—in colors—and deformation grids for NL sample. *F-O* fronto-occipital morphologies, *L-O* lambdoid-occipital morphologies, *G* globular morphologies (unmodified)

Once recognized the unmodified crania in each sample, they were removed from the posterior analysis. All the modified crania with radiocarbon dates were classified in Table 2 according to their morphological group. The F-O spans within the range of ca. 3000–1600 years BP and the L-O within the range of ca. 900–300 years BP. Figure 6 shows the modified crania from each sample in the space built by CV1 (98.8%) and CV2 (1.2%). The distribution of the crania shows a gap between morphological groups. On the left side of the plot, lambdoid-occipital compressed shapes are gathered, and in the opposite side those with fronto-occipital compression. The latter show a wide distribution along the axes, while the former is more constrained. The centroids of each sample reflect this general pattern (Fig. 6). Finally, the Procrustes Analysis shows that the pattern of morphological variation is associated with time (Table 3). The values of the association are around perfect for the variables Chronology ($m_{12} = 0.9903$) and Chronology-geography ($m_{12} = 0.9903$), while Geography exhibited a very low association ($m_{12} = 0.03234$).

Discussion

The core question of this paper is whether cranial vault modification was an ethnic marker in the northeastern Patagonia and southeastern Pampas during the late Holocene. If cranial modification was actually a mechanism for differentiation, we expect the morphological variation to vary—with high frequencies—synchronically throughout the space (e.g., Alfonso-Durruty et al. 2015; Blom 1999, 2005; Boston 2012; Bucci Morales 2013; Gerszten 1993; Hoshower et al. 1995; Kurin 2012; Torres-Rouff 2002, 2003; among others). Our results are different from this expectation, as they show that all geographic units share mostly the same morphological patterns of modification: fronto-occipital (F-O) flattening with projection in the obelonic zone and lambdoid-occipital (L-O) flattening with expansion of the frontal bone (Figs. 3–5). Conversely, from a temporal perspective, these morphologies are chronologically arranged in the whole study area: F-O morphologies are dated to the initial late Holocene (ca. 3000–1000 years BP) and L-O to the final late Holocene

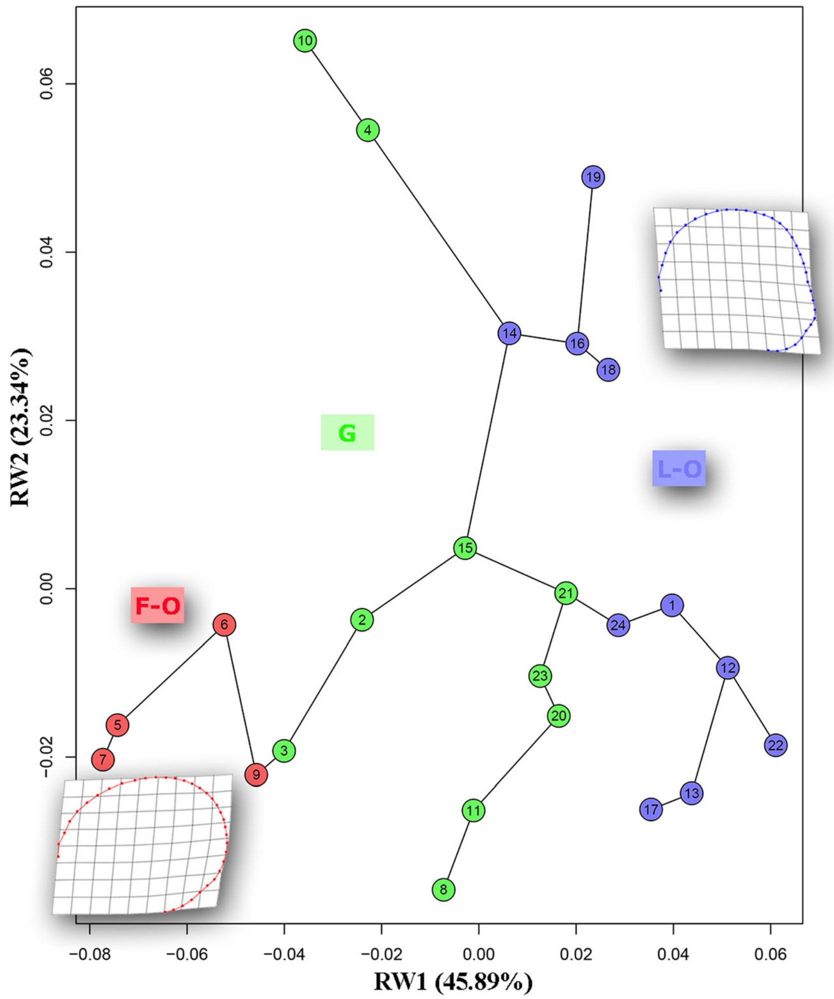

Fig. 5 Relative Warps Analysis with the MST groups—in colors—and deformation grids for ISEP sample. *F-O* fronto-occipital morphologies, *L-O* lambdoid-occipital morphologies, *G* globular morphologies (unmodified)

(ca. 1000–100 years BP) (Table 2; Table 3). The morphological groups follow a chronological sequence and both are represented in the whole region, which is incompatible with the expectation stated. Hence, cranial modification seems not to be connected with ethnic differentiation, which is also congruent with the usual co-existence of modified and unmodified individuals in the same mortuary sites of the area (e.g., Barrientos 1997; Bórmida 1953–1954; Flensborg 2012; Mariano 2011; Prates and Di Prado 2013; Prates et al. 2010a, b; Serna and Romano 2018).

In a macro-regional scale, the available evidence also does not support the ethnic differentiation hypothesis. Even assuming that people from the northeastern Patagonia and southeastern Pampas were part of the same scattered ethnic group, and that the change of morphology over time was related with the penetration of a new ethnic component (e.g., Gerszten 1993; Mayall et al. 2017; Torres-Rouff and Yablonsky 2005), the pattern between morphology and chronology has a similar expression in a large part of Argentina, such as northwestern Patagonia (Perez et al. 2009a), central Patagonia (Gómez Otero and Dahinten 1997–1998; Bernal and Aguerre 2009), Dry Pampas (Berón and Baffi 2003), Central (Drube 2010; Fabra and Demarchi 2013), and Central Western regions (Béguelin et al. 2006). A simultaneous change in the cranial modification pattern among hunter-gatherers in such a large spatial scale (more than 700,000 km^2) is hard to be thought as a part of a process of ethnic penetration and differentiation. Although there is no clear explanation for this trend so far, this change between morphologies coincided approximately with other changes in the Pampean-Patagonian material record. During ca. 1500–1000 years BP, some technologies (bow and arrow, Crivelli Montero 2010; pottery, Borges Vaz et al. 2016) and art motives (*grecas*, Gradin 1973, 2001; Menghin 1957) became widely used and spread. Also, the presence of exotic materials from long distances has been registered (Berón 2004, 2007; Gómez Otero 2003, 2006). The explanation about this change should be addressed with a comprehensive compilation of archeological data.

If cranial vault modification was not an ethnic marker in Pampa-Patagonia during the late Holocene, which role could it have played? An insight to the intra-variation of morphological groups might shed light on this. The results from the

Table 2 Modified crania with radiocarbon dates according to their morphological group

Group	Sample	Individual	Years BP	Lab code	Reference
L-O	ISEP	LP1/1	[a]ca. 352 ± 51 and 314 ± 45	AA-43126/AA-43127	Martínez 2004
		LCH1_E1	470 ± 40	LP-501	Barrientos 1997
		PA1_4 PA1_6 PA1_8 PA1_16 PA1_41 PA1_49 PA1_53	483 ± 20	Weighted mean	Martínez et al. 2007
	NL	CM-Criadero	689 ± 44	AA75712	Favier Dubois et al. 2009
		SB-409	593 ± 40	AA72636	Bernal et al. 2008
	NRV	RN-801	404 ± 40	AA72627	Bernal et al. 2008
		RN-806	512 ± 41	AA72631	Bernal et al. 2008
		RN-804	484 ± 43	AA82516	Gordón 2011
		RN-862	527 ± 44	AA82520	Gordón 2011
		RN-910	591 ± 44	AA82522	Gordón 2011
		RN-890	493 ± 44	AA82521	Gordón 2011
		LV5_2	868 ± 48	AA64293	Prates et al. 2011
F-O	ISEP	TR1_4 TR1_6 TR1_8	[b]ca. 2245 ± 55	AA24048	Madrid and Barrientos 2000
	NL	BQ-S1 Vi	2458 ± 50	AA75708	Favier Dubois et al. 2009
		BS I	2195 ± 49	AA70720	Favier Dubois et al. 2009
		BS IV	2300 ± 49	AA70719	Favier Dubois et al. 2009
		SAOBA-I	2330 ± 49	AA75704	Favier Dubois et al. 2009
	NRV	RN-780	2989 ± 52	AA82514	Gordón 2011
		RN-795	2502 ± 50	AA82515	Gordón 2011
		RN-812	3002 ± 52	AA82517	Gordón 2011
		RN-816	3009 ± 48	AA72628	Bernal et al. 2008
		RN-817	3070 ± 49	AA72630	Bernal et al. 2008
		RN-907	2642 ± 47	AA72634	Bernal et al. 2008
		RN-914	2600 ± 47	AA72632	Bernal et al. 2008
		LM1.E1.1	2088 ± 46	AA81827	Prates et al. 2010b
		NM2_2	1586 ± 47	AA89359	Serna and Prates 2012

[a] The cranium belongs to a multiple secondary burial with two dates: 352 ± 51 years BP (AA43126) and 314 ± 45 years BP (AA43127)

[b] The crania belong to a multiple primary burial dated at 2245 ± 55 BP (AA24048)

CVA shows that the F-O and L-O morphological groups are well separated from each other, and they present variability among samples within them (Fig. 6). The final shape of a modified cranium is the result of a combination of multiple factors (e.g., the intensity and duration of the shaping action, the type of shaping devices), and all of them can be organized and defined with the purpose of obtaining standardized forms, or they can just respond to local arbitrariness (see Geller 2004; Kuzminsky et al. 2016; Mayall et al. 2017; Torres-Rouff 2003). Some scholars have pointed out that the morphological variability of modified crania is mainly due to the personal preferences of the mother or the caretakers (Blackwood and

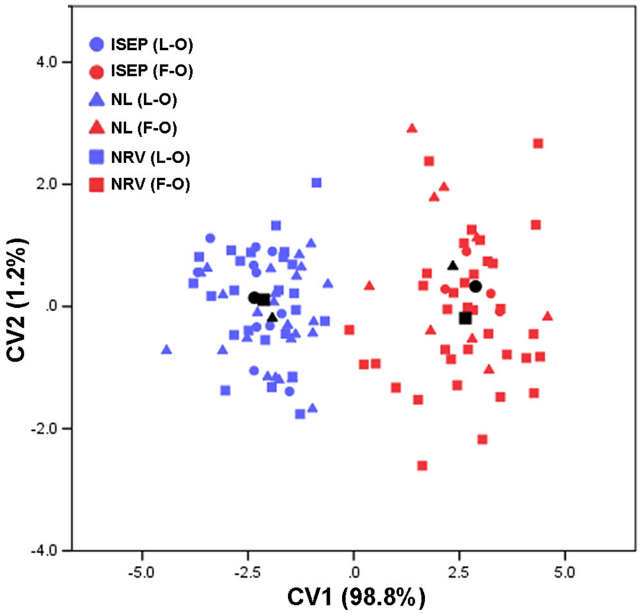

Fig. 6 Canonical Variable Analysis of modified crania from each sample. Color Blue: lambdoid-occipital morphologies (L-O); Color Red: fronto-occipital morphologies (F-O); Color Black: centroid of each sample

Danby 1955; Geller 2004: 381), so the morphologies can be just a consequence of some technical differences (Cassells 1972). In other words, the morphological variability could be related with the fact that the modification is being performed by members of the family (Hatt 1915), without the existence of specialists (Arriaza 1988; Kuzminsky et al. 2016). It is unlikely that there were specialists among the non-stratified and mobile Pampean-Patagonian hunter-gatherer bands, in contrast with stratified societies that may sought to build homogeneous forms of identity through body modifications (e.g., Torres-Rouff 2003). Even the comparison between the frequencies of unmodified and modified (both morphological groups pooled together), shows that the latter reach roughly ca. 60% (NRV 56%, NL 61%, ISEP 63%). This means that cranial modification was not being practiced for the whole population and suggests that there should have been some autonomy in the decision to perform it. Unlike stratified societies, which usually seek to control and organize the modification practice to generate homogeneous forms of identity, small-scale societies do not point to a large-scale unification. In those cases, the cranial vault modification is a less organized practice oriented to more local social processes (Allison et al. 1981; Torres-Rouff 2003: 40–42). In a similar sense, it has been suggested that the variability of the disposal of the dead in the study region may have been due to a low standardization for funerary practices (Madrid and Barrientos 2000; Prates and Di Prado 2013).

Table 3 Procrustes Analysis between the centroids of the samples in the space of Canonical Variable Analysis against geographic location and chronology

Variables	m_{12}
Geography	0.03234
Chronology	0.9903
Chronology-geography	0.9904

The morphological variability of cranial modification observed in this study is understood as the result of a non-standardized practice and the existence of *local ways of doing*. In contrast with the notion of differentiation, cranial vault modification patterns could have played an important role as a visual communication system among the people from Pampa-Patagonia during the late Holocene. As pointed above, several scholars have suggested a context of fluid interaction and communication at that time. The movable and rock art have been relevant for the conformation and reproduction of social networks through shared motives and decorations across large regions (e.g., Acevedo 2015; Bellelli et al. 2008; Carden 2009; Carden and Martínez 2014; Carden and Prates 2015; Curtoni 2006; Fiore 2006; Scheinson 2011; among others). These shared styles have been also observed in egg shells and pottery decoration, which was interpreted as an inter-group cohesion mechanism (Carden and Martínez 2014: 72), and as the consequence of contact situations where the designs were shared and copied (Di Prado 2015: 359). In this context of shared expressions at a macro-regional scale, cranial vault modification might have transmitted broad messages and legitimized ideas through a different surface, the human body.

Conclusions

Different kind of evidences indicated that Pampa-Patagonia is a complex place of biological and social convergence (Barrientos and Perez 2002; Berón 2007, 2016; Bórmida 1953–1954; Bórmida and Casamiquela 1958–1959; Fortich Baca 1976; Prates 2008). In this paper, we address the role of the cranial vault modification as an ethnic marker using geometric morphometric techniques to organize the morphological variation into morphological groups (F-O and L-O), and to recognize spatio-temporal patterns. The overall results of this paper do not support the idea of the cranial modification as an ethnic marker in the northeastern Patagonia and southeastern Pampas during the late Holocene. We found that the modified head shapes follow a temporal sequence and that they are present in the whole study area, as well as at a large geographic scale. This situation is not compatible with ethnic differentiation expectation stated, where the morphologies would vary synchronically throughout the space.

Cranial modification in northeastern Patagonia and southeastern Pampas would have represented another correlate of a macro-regional visual communication system that worked during the late Holocene. As seen in motives and decoration styles in different kinds of material expressions, the stylistic codes would be shared regionally without neglecting *local* *ways of doing* (cranial modification). The prime message would be contained in the modification shape, regardless of the technique or device used. Aside from the specific content of the message, the transmission was probably oriented to shared ideas and the motivation to carry out the modification probably was subject to different local contingencies that the Pampa-Patagonian hunter-gatherers experienced during the late Holocene.

In the future, we plan to implement 3D images with geometric morphometric procedures in order to explore the techniques and devices used to modify the shape of the crania (e.g., Kuzminsky et al. 2016; Mayall and Pilbrow 2018). Through this methodology, we look to focus the attention in the variability within morphological groups and to enhance the discussion started here about the standardization of this modification practice among hunter-gathers.

Acknowledgements We thank the two anonymous reviewers for their comments and suggestions. This work was supported by the Consejo Nacional de Investigación Científica y Tecnológica (CONICET, Argentina), PICT2012-242 and PICT2015-3645 projects.

References

Acevedo A (2015) Hachas grabadas. In: placas grabadas y comunicación visual suprarregional entre grupos cazadores-recolectores de finales del Holoceno tardío Relaciones de la Sociedad Argentina de Antropología XL (2): 589–620

Alfonso-Durruty MP, Giles BT, Misarti N, San Roman M, Morello F (2015) Antiquity and geographic distribution of cranial modification among the prehistoric groups of Fuego-Patagonia, Chile. Am J Phys Anthropol 158(4):607–623. https://doi.org/10.1002/ajpa.22832

Allison MJ, Gerszten E, Munizaga J, Santoro C, Focacci G (1981) La práctica de la deformación craneana entre los pueblos Andinos Precolombinos. Chungara 7:238–260

Arriaza B (1988) Modelo bioarqueológico para la búsqueda y acercamiento al individuo social. Chungara:9–32

Barrientos G (1997) Nutrición y dieta de las poblaciones aborígenes prehispánicas del Sudeste de la Región Pampeana. Ph.D. Dissertation, Universidad Nacional de La Plata

Barrientos G, Perez SI (2002) La dinámica del poblamiento humano del Sudeste de la Región Pampeana durante el Holoceno. Intersecciones en antropología 3:41–54

Barth F (1969) Ethnic groups and boundaries: the social organization of culture difference. Waveland Press, New York

Béguelin M, Bernal V, Del Papa M, Novellino P, Barrientos G (2006) El poblamiento humano tardío del sur de Mendoza y su relación con el norte de Patagonia: una discusión bioarqueológica. Anales de Arqueología y Etnología 61:5–25

Bellelli C, Scheinsohn V, Podestá M (2008) Arqueología de pasos cordilleranos: un caso de estudio en Patagonia norte durante el Holoceno tardío. Boletín del Museo Chileno de Arte Precolombino 13(2):37–55

Bernal V (2008) Procesos de diferenciación biológica entre poblaciones humanas del Holoceno tardío de Patagonia. Ph.D. Dissertation, Universidad Nacional de La Plata.

Bernal V, Aguerre AM (2009) Investigaciones bioarqueológicas en Río Mayo. Aleros Mazquiarán y Manantiales 2 (SO de la provincia de Chubut). In: Pérez de Micou C, Trivi de Mandri M, Burry L (eds) Imágenes desde un alero. Investigaciones multidisciplinarias en Río Mayo, Chubut, Patagonia argentina. Fundación de Historia Natural Félix de Azara. Buenos Aires:43–60

Bernal V, González PN, Perez SI, Pucciarelli HM (2008) Entierros humanos del noreste de Patagonia: nuevos fechados radiocarbónicos. Magallania 36(2):175–183. https://doi.org/10.4067/S0718-22442008000200013

Berón M (2004) Dinámica poblacional y estrategias de subsistencia de poblaciones prehispánicas de la cuenca Atuel-Salado-Chadileuvú-Curacó, Provincia de La Pampa. Ph.D. Dissertation, Universidad de Buenos Aires

Berón M (2007) Circulación de bienes como indicador de interacción entre las poblaciones de la pampa occidental y sus vecinos. In: Bayón C, Pupio A, González MI, Flegenheimer N, Frére M (eds) Arqueología en las Pampas. Sociedad Argentina de Antropología, Buenos Aires, pp 345–364.

Berón M (2016) Dunes, hills, waterholes, and saltpeter beds: attractors for human populations in western Pampa, Argentina. Quat Int 422:163–173. https://doi.org/10.1016/j.quaint.2016.03.001

Berón M, Baffi EI (2003) Procesos de cambio cultural en los cazadores-recolectores de la provincia de La Pampa, Argentina. Intersecciones en Antropología 4:29–43

Berón M, Luna L (2009) Distribución espacial y cronológica de la deformación craneana tabular erecta en Pampa y Norpatagonia. In: Salemme M, Santiago F, Álvarez M, Piana E, Vázquez E, Mansur E (eds) Tendencias teórico metodológicas y casos de estudio en la Arqueología de la Patagonia. Utopías, Ushuaia, pp 561–575

Blackwood B, Danby PM (1955) A study of artificial cranial deformation in New Britain. J R Anthropol Inst G B Irel 85:173–191

Blom D (1999) Tiwanaku regional interaction and social identity: a bioarchaeological approach. Ph.D. Dissertation, University of Chicago.

Blom D (2005) A bioarchaeological approach to Tiwanaku group dynamics. In: Reycraft RM (ed) Us and them: archaeology and ethnicity in the Andes. Cotsen Institute of Archaeology, University of California, Los Angles, pp 153–182

Bookstein FL (1989) "Size and shape": a comment on semantics. Syst Biol 38(2):173–180

Bookstein FL (1991) Morphometric tools for landmark data. Cambridge University Press, New York

Bookstein FL (1997) Landmark methods for forms without landmarks: localizing group differences in outline shape 1: 225–243. DOI: https://doi.org/10.1109/MMBIA.1996.534080

Bookstein FL (2002) Creases as morphometric characters. In: MacLeod N, Forey P (eds) Morphology, shape, and phylogeny. Systematics Association Special Volume series, vol 64. Taylor and Francis, London, pp 139–174

Borges Vaz E, Martínez G, Madrid P (2016) Análisis tecnomorfológicos y tendencias cronológicas del conjunto cerámico del sitio Loma Ruíz 1 (transición pampeano-patagónica oriental): Aportes para Pampa y Norpatagonia. Intersecciones en antropología 17(3):269–280

Bórmida M (1953-1954) Los antiguos patagones. Estudio de craneología. Runa 6(1–2):55–96

Bórmida M, Casamiquela R (1958-1959) Etnografía Gününa Këna. Testimonio del último de los tehuelches septentrionales. Runa (IX), pp 153–193

Borrero LA (2001) El poblamiento de la Patagonia: Toldos, milodones y volcanes (No. 325.3 (828). Emecé Ediciones, Buenos Aires

Boston CE (2012) Investigations of the biological consequences and cultural motivations of artificial cranial modification among northern Chilean populations. Electronic thesis and dissertation repository. Paper 665.

Bucchi Morales AM (2013) Deformación Intencional del Cráneo durante la Prehistoria de Atacama: un Análisis Cuantitativo de su Relación

con el Estatus Social y las Adscripciones Étnicas. Universidad de Chile, Degree Dissertation
Buikstra J, Ubelaker D (1994) Standards for data collection from human skeletal remains. Arkansas Archaeological survey research series No.44. Fayetteville, Arkansas
Carden N (2009) Imágenes a través del tiempo Arte rupestre y construcción social del paisaje en la Meseta Central de Santa Cruz. Buenos Aires, Sociedad Argentina de Antropología
Carden N, Martínez G (2014) Diseños fragmentados. Circulación social de imágenes sobre cáscaras de huevo de Rheidae en Pampa y Norpatagonia. Boletín del Museo Chileno de Arte Precolombino 19(2):55–75
Carden N, Prates L (2015) Pinturas rupestres en un espacio funerario: El caso del sitio Cueva Galpón (Noreste de Patagonia). Magallania 43(1):117–136
Casamiquela RM (1965) Rectificaciones y ratificaciones. Hacia una interpretación definitiva del panorama etnológico de la Patagonia y área septentrional adyacente. Cuadernos del Sur, Instituto de Humanidades, Universidad Nacional del Sur, Bahía Blanca
Casamiquela RM (1985) Bosquejo de una etnología de la provincia de Río Negro. Fundación Ameghino, Viedma
Cassels R (1972) Locational analysis of prehistoric settlement in New Zealand. Aust J Anthropol 8(3):212–222
Cocilovo JA, Neves WA (1988-1989) Afinidades biológicas entre las poblaciones prehistóricas del litoral de Brasil y de Argentina, primera aproximación. Relaciones de la Sociedad Argentina de Antropología 17:31–56
Cocilovo JA, Guichón RA (1994) La deformación craneana "pseudocircular" en el grupo prehistórico de Laguna del Juncal. Revista de Antropología Biológica Argentina 2(2):13–27
Crivelli Montero E (2010) Arqueología de la cuenca del río Limay. Los ríos mesetarios norpatagónicos Aguas generosas del Ande al Atlántico:263–338
Curnoe D, Ji X, Liu W, Bao Z, Taçon PSC, Ren L (2015) A hominin femur with archaic affinities from the Late Pleistocene of Southwest China. PLoS One 10(12):e0143332. https://doi.org/10.1371/journal.
Curtoni R (2006) Expresiones simbólicas, cosmovisión y territorialidad en los cazadores-recolectores pampeanos. Relaciones de la Sociedad Argentina de Antropología 31:133–160
Del Papa M (2013) La estructura y dinámica del poblamiento humano de Pampa y Patagonia continental durante el Holoceno Tardío: un análisis de rasgos epigenéticos craneofaciales. Dissertation, Universidad Nacional de La Plata, Ph.D
Dembo A, Imbelloni J (1938) Deformaciones intencionales del cráneo de carácter étnico. J. Anesi, Buenos Aires
Di Prado V (2015) Estudio comparativo de las prácticas de elaboración y uso de la alfarería prehispánica del centro-este de Argentina desde una perspectiva macrorregional. Ph.D. Dissertation, Universidad Nacional de La Plata
Dingwall E (1931) Artificial cranial deformation. In: A contribution to the study of ethnic mutilations. Bale & Sons & Danielsson, London
Drube H (2010) La deformación de cráneo en las sociedades precolombinas de Santiago del Estero. Relaciones de la Sociedad Argentina de Antropología 35:69–84
Excoffier L, Smouse PE (1994) Using allele frequencies and geographic subdivision to reconstruct gene trees within a species: molecular variance parsimony. Genetics 136(1):343–359
Fabra M, Demarchi D (2013) Análisis morfogeométrico aplicado al estudio de los patrones espaciales y temporales de variación morfológica craneofacial en poblaciones del centro de Argentina. Cuadernos del Instituto Nacional de Antropología y Pensamiento Latinoamericano–Series Especiales 1(1)
Favier Dubois CM, Borella F, Tykot RH (2009) Explorando tendencias en el uso humano del espacio y los recursos en el litoral rionegrino (argentina) durante el Holoceno medio y tardío. In: Salemme M, Santiago F, Álvarez M, Piana E, Vázquez M, Mansur E (eds) Arqueología de la Patagonia. Una Mirada desde el Último Confín. Editorial Utopías, Ushuaia, pp 985–997
Fiore D (2006) Poblamiento de imágenes: arte rupestre y colonización de la Patagonia. Variabilidad y ritmos de cambio en tiempo y espacio. In: Fiore D, Podestá M (eds) Tramas en la Piedra: producción y usos del arte rupestre. SAA, AAINA, WAC. Buenos Aires:43–61
Fisher A, Nacuzzi L (1992) La destrucción sistemática del paisaje y de los sitios arqueológicos. El caso del Valle de Viedma. Arqueología 2: 189–229
Flensborg G (2012) Análisis paleopatológico en el curso inferior del río Colorado (Pcia. de Buenos Aires). Exploración y evaluación del estado de salud de sociedades cazadoras-recolectoras en el Holoceno tardío. Ph.D. Dissertation, Universidad Nacional del Centro de la Provincia de Buenos Aires
Flensborg G, Martínez G, Tessone A (2018) First approach to the paleodiet of hunter-gatherers through stable isotopes (δ 13 C and δ 15 N) in the eastern Pampa-Patagonia transition during the Middle Holocene. J Archaeol Sci Rep 17:571–580
Fortich Baca V (1976) Antecedentes antropológicosfísicos de Nordpatagonia. Relaciones de la Sociedad Argentina de Antropología 10:173–183
García A, Tiesler V (2011) El aspecto físico de los dioses mayas. Arqueología Mexicana 112:59–63
Geller PL (2004) Transforming bodies, transforming identities: a consideration of pre-Columbian Maya corporeal beliefs and practices. Ph.D. Dissertation, University of Pennsylvania
Gerszten PC (1993) An investigation into the practice of cranial deformation among the Pre-Columbian peoples of northern Chile. Int J Osteoarchaeol 3(2):87–98. https://doi.org/10.1002/oa.1390030205
Gómez Otero J (2003) Movilidad y contactos en la costa centro-norte de patagonia argentina en tiempos pre y posthispánicos. In: Mandrini R,Paz C (eds) Las fronteras hispanocriollas del mundo indígena latinoamericano en los siglos XVIII-XIX. Un estudio comparativo. Universidad Nacional del Centro de la Provincia de Buenos Aires, Universidad Nacional del Comahue y Universidad Nacional del Sur, Artes Gráficas Limay, Neuquén, pp 287–312
Gómez Otero J (2006) Dieta, uso del espacio y evolución en poblaciones cazadoras-recolectoras de la costa centro-septentrional de Patagonia durante el Holoceno medio y tardío. Ph.D. Dissertation, Universidad de Buenos Aires
Gómez Otero J, Dahinten S (1997-1998) Costumbres funerarias y esqueletos humanos: variabilidad y poblamiento en la costa nordeste de la provincia de Chubut (Patagonia Argentina). Relaciones de la Sociedad Argentina de Antropología 22-23:101–124
Gordón F (2011) Dinámica poblacional, conflicto y violencia en el norte de Patagonia durante el Holoceno Tardío: un estudio arqueológico. Ph.D. Dissertation, Universidad Nacional de La Plata
Gower JC (1971) Statistical methods of comparing different multivariate analyses of the same data. In: Hodson FR, Kendall DG, Tautu P (eds) Mathematics in the archaeological and historical sciences. Edinburgh University Press, Edinburgh, pp 138–149
Gower JC, Ross GJS (1969) Minimum spanning trees and single linkage cluster analysis. Appl Stat 18:54–64
Gradin C (1973) La piedra pintada de Mamuel Choique (provincia de Río Negro). Relaciones de la Sociedad Argentina de Antropología 7: 145–157
Gradin C (1982) Secuencias radiocarbónicas del sur de la Patagonia argentina. Relaciones (NS) 14:177–194
Gradin C (2001) El arte rupestre de los cazadores de guanaco de la Patagonia. In: Berberián E, Nielsen A (eds) Historia Argentina Prehispánica. Brujas. Córdoba:839–874
Hatt G (1915) Artificial moulding of the infant's head among the Scandinavian Lapps. Am Anthropol 17(2):245–256. https://doi.org/10.1525/aa.1915.17.2.02a00030

Hoshower L, Buikstra J, Goldstein P, Webster A (1995) Artificial cranial deformation at the Omo M10 site: a Tiwanaku complex from the Moquegua Valley, Peru. Lat Am Antiq 6(2):145–164

Hrdlicka A (1912) Artificial deformations of the human skull with special reference to America. Actas del Congreso Internacional de Americanistas: 147–149

Jackson DA (1995) PROTEST: a procrustean randomization test of community environment concordance. Écoscience 2:297–303

Jones S (1997) Archaeology of ethnicity. Routledge, London

Knudson KJ, Stojanowski CM (2008) New directions in bioarchaeology: recent contributions to the study of human social identities. J Archaeol Res 16(4):397–432

Knudson KJ, Torres-Rouff C (2009) Investigating cultural heterogeneity in San Pedro de Atacama, northern Chile through biogeochemistry and bioarchaeology. Am J Phys Anthropol 138(4):473–485. https://doi.org/10.1002/ajpa.20965

Kurin DS (2012) The bioarchaeology of Wari collapse. Ph.D. Dissertation, Vanderbilt University

Kuzminsky SC, Tung TA, Hubbe M, Villaseñor-Marchal A (2016) The application of 3D geometric morphometrics and laser surface scanning to investigate the standardization of cranial vault modification in the Andes. J Archaeol Sci Rep 10:507–513

Lorentz K (2002) Cultures of physical modifications: child bodies in ancient Cyprus. Bar International Series 1040:203–210

Lozada MC, Buikstra JE (2005) Pescadores and labradores among the señorío of Chiribaya in southern Peru. In: Reycraft RM (ed) Us and them: archaeology and ethnicity in the Andes, Cotsen Institute of Archaeology, University of California, Los Angeles, pp 206–226

Madrid P, Barrientos G (2000) La estructura del registro arqueológico del sitio Laguna Tres Reyes 1 (Provincia de Buenos Aires): nuevos datos para la interpretación del poblamiento humano del Sudeste de la Región Pampeana a inicios del Holoceno tardío. Relaciones de la Sociedad Argentina de Antropología 25:179–206

Manly B (1994) Multivariate statistical methods. In: A primer second edition. Chapman & Hall, London

Manríquez G, González-Bergás FE, Salinas JC, Espoueys O (2006) Deformación intencional del cráneo en poblaciones arqueológicas de Arica, Chile: análisis preliminar de morfometréa geométrica con uso de radiografías craneofaciales. Chungará 38(1):13–34

Mariano C (2011) Prácticas mortuorias y registro bioarqueológico en la costa rionegrina del golfo San Matías, Argentina. Intersecciones en antropología 12(1):17–25

Martínez G (2004) Resultados preliminares de las investigaciones arqueológicas realizadas en el curso inferior del río Colorado (Pdos. de Villarino y Patagones; Pcia. de Buenos Aires). In: Martínez G, Gutiérrez M, Curtoni R, Berón M, Madrid P (eds) Aproximaciones Arqueológicas Pampeanas: Teorías, Métodos y Casos de Aplicación Contemporáneos. FACSO, UNCPBA, Olavarría, pp 275–292

Martínez G (2008–09) Arqueología del curso inferior del río Colorado: estado actual del conocimiento e implicaciones para la dinámica poblacional de cazadores-recolectores pampeanos-patagónicos. In: Mazzanti DL, Berón M, Oliva F (eds) Cazadores-Recolectores del Cono Sur. Revista de Arqueología 3. Editorial Universitaria de Mar del Plata, Mar del Plata, pp 73–94

Martínez G (2010) Entierros humanos en lugares sagrados y domésticos durante el Holoceno tardío: El registro bioarqueológico del curso inferior del río Colorado (Provincia de Buenos Aires, Argentina). Werkén 13:145–161

Martínez G, Bayala P, Flensborg G, López R (2007) Análisis de la composición anatómica, sexo y edad de dos entierros secundarios del sitio Paso Alsina 1 (Pdo. de Patagones, Pcia. de Buenos Aires). In: Bayón C, Puppio A, González M, Flegenheimer N, Freire M (eds) Arqueología en las Pampa. Sociedad Argentina de Antropología. Buenos Aires:41–58

Martínez G, Santos Valero F, Flensborg G, Carden N, Stoessel L, Alcaraz AP, Borges Vaz E (2016) Was there a process of regionalization in northeastern Patagonia during the Late Holocene? The Journal of Island and Coastal Archaeology 12(1):95–114. https://doi.org/10.1080/15564894.2016.1163756

Mayall P, Pilbrow V (2018) Generalized Procrustes analysis of an ontogenetic series of modified crania: evaluating the technique of modification in the Migration Period of Europe (4th–7th century AD). Am J Phys Anthropol 166:1–14. https://doi.org/10.1002/ajpa.23412

Mayall P, Pilbrow V, Bitadze L (2017) Migrating Huns and modified heads: Eigenshape analysis comparing intentionally modified crania from Hungary and Georgia in the Migration Period of Europe. PLoS One 12(2):e0171064. https://doi.org/10.1371/journal.pone.0171064

McCune B, Grace B (2002) Analysis of ecological communities. MJM publisher, Oregon

ME Catalog (1988) Catálogo del Museo Etnográfico "Juan B. Ambrosetti" de la Facultad de Filosofía y Letras. Universidad Nacional Buenos Aires

Mendonça O, Bordach M, Cinetti AR (1988-1989) Deformación craneana en Las Lagunas (Neuquén). Viejas y nuevas cuestiones sobre la variante pseudocircular. Relaciones de la Sociedad Argentina de Antropología, Nueva Serie XVII/2: 57–73

Menéndez L, Lotto F (2016) Estudio morfométrico de las modificaciones culturales del cráneo en el centro-oeste de Argentina. Comechingonia 20(1):143–173

Menghin O (1957) Los estilos del arte rupestre de Patagonia. Acta Prehistórica 1:57–87

Mitteroecker P, Bookstein F (2011) Linear discrimination, ordination, and the visualization of selection gradients in modern morphometrics. Evol Biol 38:100–114. https://doi.org/10.1007/s11692-011-9109-8

Mitteroecker P, Gunz P (2009) Advances in geometric morphometrics. Evol Biol 36:235–247. https://doi.org/10.1007/s11692-009-9055-x

MLP Catalog (n.d.) Catálogo del Museo de La Plata (División Antropología) de la Facultad de Ciencias Naturales y Museo. Universidad Nacional de La Plata

Moreno F (1874) Cementerios y paraderos prehistóricos de la Patagonia. Anales Científicos Argentinos 1:2–13

Orquera L (1984–85) Tradiciones culturales y evolución en Patagonia. Relaciones de la Sociedad Argentina de Antropología, XVI: 249–273.

Outes F (1926) Noticias sobre los resultados de mis investigaciones antropológicas en la extremidad sudeste de la provincia de Buenos Aires. Physis 8:387–390

Peres-Neto PR, Jackson DA (2001) How well do multivariate data sets match? The advantages of a Procrustean superimposition approach over the Mantel test. Oecologia 129(2):169–178

Perez SI (2006) El poblamiento holocénico del Sudeste de la Región Pampeana: un estudio de Morfometría geométrica craneofacial. Ph.D. Dissertation, Universidad Nacional de La Plata

Perez SI (2007) Artificial cranial deformation in South America: a geometric morphometrics approximation. J Archaeol Sci 34:1649–1658. https://doi.org/10.1016/j.jas.2006.12.003

Perez SI, Bernal V, Gonzalez PN (2006) Differences between methods to sliding semi-landmarks: its importance in human population analyses. Journal of Anatomy 208:769–784. https://doi.org/10.1111/j.1469-7580.2006.00576.x

Perez SI, Cardillo M, González PN (2009b) Artificial Cranial Deformations in South America: A quantitative approach to cultural variation. In: López G, Cardillo M (eds) Teoría, Métodos y Casos de Estudio en Arqueología Evolutiva. Colección de Complejidad Humana, Editorial SB. Buenos Aires:87–107

Perez SI, Della Negra C, Novellino P, González PN, Bernal V, Cuneo E, Hajduk A (2009a) Deformaciones artificiales del cráneo en cazadores-recolectores del Holoceno medio-tardío del Noroeste de Patagonia. Magallania 37. https://doi.org/10.4067/S0718-22442009000200005

Perez SI, Postillone MB, Rindel D, Gobbo D, González PN, Bernal V (2016) Peopling time, spatial occupation and demography of Late Pleistocene–Holocene human population from Patagonia. Quat Int 425:214–223. https://doi.org/10.1016/j.quaint.2016.05.004

Prates L (2008) Los indígenas del Río Negro. Un enfoque arqueológico. Sociedad Argentina de Antropología, Buenos Aires.

Prates L, Di Prado V (2013) Sitios con entierros humanos y ocupaciones residenciales en la cuenca del Río Negro (Norpatagonia, Argentina): Diacronía y Multicausalidad. Lat Am Antiq 24(4):451–466

Prates L, Di Prado V, Mange E, Serna A (2010a) Sitio arqueológico Loma de los Muertos. Múltiples ocupaciones sobre un médano del este de Norpatagonia (Río Negro, Argentina). Magallania. DOI:https://doi.org/10.4067/S0718-22442010000100010

Prates L, Flensborg G, Bayala P (2010b) Caracterización de los entierros humanos del sitio Loma de Los Muertos (valle medio del río Negro, Argentina). Magallania 38. https://doi.org/10.4067/S0718-22442010000100009

Prates L, Luchsinger H, Scabuzzo C, Mansegosa D (2011) Investigaciones arqueológicas en el sitio La Victoria 5 (Departamento de General Conesa, Río Negro). Intersecciones en antropología 12(1):109–120

Prates L, Serna A, Mange E, de Jong I (2016) Expresión material de la interacción entre indígenas y criollos en un sitio funerario del siglo XIX de Norpatagonia (Chimpay, Río Negro). Intersecciones en antropología 17(1):35–48

Pucciarelli H, Neves W, González-José R, Sardi ML, Ramírez Rozzi F, Struck A, Bonilla M (2006) East-west cranial differentiation in Pre-Columbian human populations of South America. Homo 57(2): 133–150

R Development Core Team (2016) R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna https://www.r-project.org/

Rocatti G, Aristide L, Rosenberger AL, Perez SI (2017) Early evolutionary diversification of mandible morphology in the New World monkeys (Primate, Platyrrhini). J Hum Evol 113:24–37

Rohlf FJ (1990) Numerical taxonomy system of multivariate statistical programs. Version 1.8. New York State University at Stony Brook, New York.

Rohlf FJ (1993) Relative warps analysis and an example of its application to mosquito wings. In: Marcus LF, Bello E, García Valdecasas A (eds) Contributions to Morphometrics. Monografías del Museo Nacional de Ciencias Naturales, Madrid, pp 132–159

Rohlf FJ (2015) The tps series of software. Hystrix, the Italian Journal of Mammalogy. https://doi.org/10.4404/hystrix-26.1-11264

Rohlf FJ, Slice DE (1990) Extensions of the Procrustes method for the optimal superimposition of landmarks. Syst Zool 39:40. https://doi.org/10.2307/2992207

Salazar D, Niemeyer HM, Horta H, Figueroa V, Manríquez G (2014) Interaction, social identity, agency and change during Middle Horizon San Pedro de Atacama (northern Chile): a multidimensional and interdisciplinary perspective. J Anthropol Archaeol 35:135–152

Sanguinetti de Bórmida AC (1981) Síntesis del desarrollo de la cuenca inferior del río Limay en el área del Chocón y su ubicación en el cuadro de la prehistoria de Patagonia. Trab Prehist 1:171–179

Scheinson V (2011) Information and its role in hunter-gatherer bands. In: Whallon R, Lovis W, Hitchcock R (eds) Rock art information in Northwest Patagonia. Cotsen Institute of Archaeology Press, Santa Fe, pp 235–247

Serna A (2018) Interacciones sociales en el noreste de Patagonia durante el Holoceno tardío: un enfoque bioarqueológico. Ph.D. Dissertation, Universidad Nacional de La Plata

Serna A, Prates L (2012) Bioarqueología y cronología del sitio Negro Muerto 2 (Noreste de Patagonia). Magallania 40(2):233–245

Serna A, Romano V (2018) Rescates bioarqueológicos en el valle medio del río Negro (provincia de Río negro): el potencial informativo del registro altamente perturbado. Revista Argentina de Antropología Biológica (In press).

Serna A, D'Addona L, Perez SI (2013) Precisión y replicabilidad de una aproximación no discreta al estudio de las modificaciones artificiales del cráneo. Intersecciones en antropología 14(2):477–481

Serna A, Prates L, Luna L (2017) Osteobiografía de dos individuos inhumados durante la Campaña del Desierto: el caso del sitio Chimpay (Argentina). Revista Española de Antropología Americana 45. https://doi.org/10.5209/REAA.54934

Shrout P, Fleiss J (1979) Intraclass correlations: uses in assessing rater reliability. Psychol Bull 86(2):420–428

Strauss R (2010) Discriminating groups of organism. In: Elewa AM (ed) Morphometrics for nonmorphometricians. Springer, Berlin, pp 73–91

Tiesler V (2014) The bioarchaeology of artificial cranial modifications: new approaches to head shaping and its meanings in Pre-Columbian Mesoamerica and beyond (Vol. 7). Springer Science & Business Media, Berlin

Torres-Rouff C (2002) Cranial vault modification and ethnicity in Middle Horizon San Pedro de Atacama, Chile. Curr Anthropol 43(1):163–171

Torres-Rouff C (2003) Shaping Identity: Cranial Vault Modification in the Pre-Columbian Andes. Ph.D. Dissertation, University of California

Torres-Rouff C, Knudson K (2017) Integrating identities. An innovative bioarchaeological and biogeochemical approach to analyzing the multiplicity of identities in the mortuary record. Curr Anthropol 58:381–409. https://doi.org/10.1086/692026

Torres-Rouff C, Yablonsky LT (2005) Cranial vault modification as a cultural artifact: a comparison of the Eurasian steppes and the Andes. HOMO J Comp Human Biol 56:1–16. https://doi.org/10.1016/j.jchb.2004.09.001

Vignati MA (1967) Los habitantes protohistóricos de la Pampasia Bonaerense y Norpatagonia. Investigaciones y Ensayos 3:37–100

Weiss P (1961) Tipología de las deformaciones cefálicas. Revista del Museo Nacional 31:15–42

Wiggenhauser N (2016) Modificaciones Artificiales del Cráneo: Un estudio de la Dinámica de Cambio Cultural en Patagonia Septentrional durante el Holoceno medio y tardío (4.500–200 años AP). Degree Dissertation, Universidad Nacional del Centro de la Provincia de Buenos Aires.

Yépez Vásquez R (2009) El simbolismo de la modificación cultural de la cabeza en la cultura andina de Paracas del antiguo Perú. Estudios de Antropología Biológica 14(2):523–545

Zar J (1999) Biostatistical analysis. Prentice Hall, Upper Saddle River, NJ

Zelditch ML, Swiderski DL, Sheets DH (2012) Geometric morphometrics for biologists: a primer, second edn. Academic Press, San Diego