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Índice

Antropología y Patrimonio Cultural

Trayectorias Laborales y Transformaciones Contemporáneas del Trabajo
en Personas Mapuche del Gran Concepción

Constanza Torres y Andrea Aravena 7

Arqueología y Bioantropología

Artificial Cranial Modification in San Pedro de Atacama and the Loa Basin:
A Quantitative Approach to its Role as a Marker of Social Identity

Ana María Bucchi, Thomas Püschel y Germán Manríquez 19

Variabilidad Fenotípica en Maíz (*Zea Mays*) del Sitio de Caserones - I,
Región De Tarapacá (Cal. 20-I.020 D.C.)

*Alejandra Vidal-Elgueta, Erika Salazar, Luis Felipe Hinojosa,
Mauricio Uribe y Sergio Flores*..... 31

La Arquitectura Formativa de Guatacondo y Caserones:
Diseño, Organización y Configuración del Espacio Arquitectónico

Constanza Pellegrino, Leonor Adán y Simón Urbina 41

Nuevas Excavaciones en Tulán-54: Revelando la Arquitectura Ceremonial
Durante el Formativo Temprano de la Puna de Atacama

*Lautaro Núñez, Isabel Cartajena, Carlos Carrasco, Patricio López,
Francisco Rivera, Patricio de Souza, Boris Santander y Rodrigo Loyola* 65

Nuevos Datos para las Inhumaciones en Urnas de Sitios Arqueológicos
Guaraníes del Extremo Meridional de la Cuenca del Plata.

Bárbara Mazza, Alejandro Acosta y Daniel Loponte 81

Arqueobotánica y Etnografía del Extremo Sur Americano:
Estudio de Piezas de Museo (Arcos y Astiles)

Laura Caruso 97

Reseñas Bibliográficas

Botitas Negras en Calama: Género, Magia y Violencia
en una Ciudad Minera del Norte de Chile (Lilith Kraushaar)

Reseñado por Diana Espirito-Santo 109

Laboratorios Etnográficos: Los Archivos de la Antropología
en Chile (1880-1980) (Jorge Pavez)

Reseñado por Rolf Foerster 111

Artificial Cranial Modification in San Pedro de Atacama and the Loa Basin: A Quantitative Approach to Its Role as a Marker of Social Identity

Modificación Intencional del Cráneo en San Pedro de Atacama y la Cuenca del Loa: Un Análisis Cuantitativo de su Rol como Marcador de Identidad Social

Ana Bucchiⁱ, Thomas Püschelⁱⁱ y Germán Manríquezⁱⁱⁱ

ABSTRACT

Diverse hypotheses have been proposed to explain artificial cranial modification (ACM) in South America. In the Atacama area (Northern Chile), some studies have concluded that it was used to create a communal identity that could serve to resist, or to form alliances with, different external groups (Inter Site Distinction hypothesis, this work). On the other hand, other studies have suggested that there was a relationship between ACM and the social status and gender of the individuals within the community (Intra Site Distinction hypothesis, this work). These studies, however, have relied mainly on typological methods and the archaeological contexts to which these modification categories are associated have been simplified as well.

In this work we use a quantitative multivariate approach to assess the relationship between cranial morphology and funerary context. The modification patterns of populations inhabiting Northern Chile during the Formative (3500-1600 B.P) and Late Intermediate (950-500 B.P) periods were studied. We analyzed the X-rays of 203 individuals belonging to 7 archaeological sites and, when possible, they were correlated with the corresponding funerary context. The results indicate that cranial morphology correlates with the interaction networks among sites, therefore these results support the Inter Site hypothesis.

Keywords: *Artificial Cranial Modification, Pre-Hispanic Atacama, Geometric Morphometrics, Multiple Correspondence Analysis.*

RESUMEN

Diversas explicaciones han sido propuestas para explicar la modificación intencional del cráneo (ACM) en Sudamérica. En Atacama, algunos estudios han concluido que fue utilizada para crear una identidad común que sirvió para resistir o formar alianzas con distintos grupos foráneos (aquí, Hipótesis de Distinción Inter-Sitio). Otros han sugerido que estaba relacionada con el estatus social y/o el sexo de los individuos dentro de la comunidad (aquí, Hipótesis de Distinción

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Intra-Sitio). Sin embargo, los métodos usados para llegar a estas conclusiones tienen limitaciones significativas porque han usado principalmente métodos tipológicos y los contextos arqueológicos a los que han sido asociados estas categorías de ACM han sido simplificados.

Aquí usamos un enfoque multivariado y cuantitativo para evaluar la relación entre la morfología craneal y el contexto funerario. Se analizó la ACM de las poblaciones que habitaron el Norte de Chile durante el Periodo Formativo (3500-1600 B.P) y el Periodo Intermedio Tardío (950-500 B.P.). Se analizaron los rayos X de 203 individuos pertenecientes de 7 sitios arqueológicos y, cuando fue posible, estos fueron correlacionados con su contexto funerario. Los resultados indican que la morfología craneal se correlaciona con las redes de intercambio entre los sitios. Estos resultados apoyan la Hipótesis de Distinción Intra-Sitio.

Palabras clave: *Modificación Intencional Del Cráneo, Atacama, Morfometría Geométrica, Análisis De Correspondencias Múltiples.*

INTRODUCTION

Artificial cranial modification (ACM from now on) was a cultural practice of corporal modification distributed worldwide (e.g. Dembo and Imbelloni 1938; Weiss 1962; Duncan and Hofling 2011; Tritsaroli 2010) showing high demographic frequencies among pre-Hispanic South American populations (Dingwall 1931; Pérez 2007). Its main effect is the permanent modification of the normal pattern of growth and development of the skull, by using different deforming devices during the first years of postnatal life (Manríquez *et al.* 2006). Although several causal explanations for ACM have been proposed, the question about why humans modified the skull vault form is still open (Gerszten and Gerszten 1995; Schijman 2005). The possible answers certainly will depend on the specific cultural history of each group under study.

In the South Central Andes, ACM appears early in the archaeological record (Munizaga 1980) and spans in Northern Chile for around 4000 years (Munizaga 1980 and 1987). In order to explain this phenomenon, two main explanations have been proposed to understand the origins of this practice in this area: i) ACM was an Inter Site identity symbol, therefore it was used as a social ascription sign to distinguish between different sites of the region (Torres-Rouff, 2002, 2007 and 2008) and ii) ACM was a symbol of intra site identity, used to denote the social position of an individual within society (Munizaga 1987; Torres-Rouff 2007). Both hypotheses refer to social identity at two different levels; the first hypothesis implies ethnicity or the ascription to a group and the identification of others as strangers (members of another ethnic group) (Barth 1969). The second hypothesis is related to a status

differentiation among individuals from the same group (Munizaga 1987; Torres-Rouff 2007).

Traditionally ACM has been studied from a descriptive, typological approach, classifying skulls into *a priori* categories based on simple visual inspections (e.g. Dembo and Imbelloni 1938; Weiss 1962). Although inter-landmark and angular measurements have been also applied for classificatory purposes (e.g. Falkenburger 1938; Imbelloni 1924), they did not have any significant impact on the later research of ACM.

Despite the straightforwardness and wide application of this typological approach, it has some limitations: i) the reduction of the total morphological variance of the skulls into a discrete and limited number of categories that supposedly are able to describe without any drawbacks the morphological continuum of craniofacial variation, and ii) the difficulty to compare the results obtained by different researchers, due to the high subjectivity of the method and the lack of well-defined classification criteria. In order to overcome some of these limitations, some researchers have applied linear morphometrics to classify ACM by applying multivariate statistics. Despite the fact that these methodologies increase objectivity and better describe the morphological variation subtleties, the absence of an appropriate mathematical background to separate shape and size components of variation led the application of geometric morphometrics to analyse ACM (Frieß and Baylac 2003; Manríquez *et al.* 2006 2011; Pérez 2007 and Pérez *et al.* 2009). As compared with traditional morphometrics, it is based in a coherent and well developed statistical theory of shape and allows a direct visualization of the patterns of shape variation (Slice 2007).

The Atacama Desert, the area of this study, extends over 3500 km. between the 15°S and 26° S. Despite the presence of scarce fertile and verdant oases in this region (e.g. San Pedro de Atacama, Calama, Pica), it is considered the driest desert in the world. This severe environment has been the scenario of a long and successful history of settlement. Numerous archaeological evidences demonstrate that oases has been occupied since the Formative period (ca. 3.000-1.850 B.P.) by agro-pastoralist settlers that posteriorly experienced strong processes of cultural influence and exchange with the Tiwanaku culture during the Middle period (ca. 1.550-950 B.P.) (Berenguer and Dauelsberg 1989). After these periods, the area was characterized by the development of regional identity traits within the different oases (*ayllus*), in a moment known as Late Intermediate period. The last prehistoric stage of the Atacama Desert populations corresponds to the Late period (550-600 B.P.), which has been characterized by the arrival of the Inca culture and its decline and posterior collapse due to the Spaniards invasion (Berenguer and Dauelsberg 1989).

Archaeological sites from the region show ACM frequencies from 50% on average (SPA oases) to even 90% (Chorrillos cemetery, Middle Loa Basin) (González and Westfall 2006; Torres-Rouff 2007). These high ACM frequencies in the prehistoric populations

from Northern Chile, emphasize the problem regarding the possible motivations underlying this body modification practice. In order to address the two traditionally proposed explanations for this question (Inter Site vs. Intra Site identity hypotheses), ACM patterns from different regions were compared synchronically and diachronically by means of standard geometric morphometric techniques. Associations between ACM patterns and funerary context were established applying a multiple correspondence analysis, which allowed the analysis of the available grave goods information.

MATERIAL

The total sample was composed by 203 skull radiographs from northern Chile archaeological sites of the Formative and Late Intermediate periods (Table 1). The radiographs are housed in the imagenological database of modern and prehistoric South-American native populations "Craneoteca de Chile", Center for Quantitative Analysis in Dental Anthropology (CA2), Faculty of Dentistry, Universidad de Chile. We selected sites with numerous, well-preserved skulls and with good archaeological context, although this was not possible in all cases (Table 1). The sex distribution was 110 females and 87 males.

Site	Geographic Area	Period	N.R.*	N.F.**	Sex distribution (F/M)	Modification distribution (D/ND***)
Regimiento Chorrillos	Middle Loa Basin	Formative	31	30	14/17	31/0
Chunchuri	Middle Loa Basin	Late Intermediate	28	0	18/10	14/14
Caspana	Superior Loa Basin	Late Intermediate	39	0	24/15	32/7
Solor 3	San Pedro de Atacama	Formative	17	6	10/7	6/11
Tchecar	San Pedro de Atacama	Late Intermediate	39	39	19/20	14/25
Catarpe 2	San Pedro de Atacama	Late Intermediate	43	36	24/19	13/30
Playa Miller 7	Arica	Formative	6	0	ND****	6/0

Table 1: Sample of archaeological sites used in this study. The radiographic records used in this study are housed in the Program of Human Genetics, ICBM, Faculty of Medicine, Universidad of Chile. *N.R.: Number of radiographies (Total: 203). **N.F.: Number of individuals with funerary context information available. ***Modified and Not modified skulls. ****No data available.

Tabla 1: Sitios arqueológicos usados en este estudio. Las radiografías utilizadas se encuentran disponibles en el Programa de Genética Humana, ICBM, Facultad de Medicina, Universidad de Chile. *N.R. Número de radiografías (total: 203). **N.F.: Número de individuos con contexto funerario disponible. ***Cráneos modificados y no modificados. ****Datos no disponibles.

The skulls belong to cemeteries from San Pedro de Atacama, Superior Loa River, and Middle Loa River geographical areas (Figure 1). In order to test the Inter Site hypothesis an Arica cemetery (Playa Miller 7) was included as an outgroup. Besides this radiographic record, archaeological information from the graves was included to test the Intra Site hypothesis. This information was obtained from the fieldwork report of the Chorrillos archaeological excavation and from the field notes of Tchecar and Catarpe 2 sites written by Le Paige, during his surveys and excavations in San Pedro de Atacama Oases.

As Tchecar was used as a cemetery for a long period of time (711-1206 DC according to Hubbe *et al.* (2011)), we analyse the entire sample but use the funerary context for classify individuals to the late Middle and Late Intermediate Periods. Sadly, this was not possible for Catarpe 2 because of the absence of diagnostic grave goods. Besides, 3 of the 7 sites were only used for the ACM morphological analysis (Hypothesis 1) and not to test the Hypothesis 2 because of missing information of grave goods (Solor 3 and Chunchuri) or absence of individual grave goods (Caspana) (Table 1).

METHOD

The X-Ray material was obtained following standard radiographic procedures (Frankfurt plane anatomical position, 60 Kv, 2 mA during 2 seconds, at a 2 m distance from the target film) using a Portable Geo Ray II X Ray system as X-Ray source. The radiographic plates were digitized using an Epson Expression 10000 XL scanner (300 pp resolution). Sex was estimated according to discriminant dimorphic cranial morphological attributes as described in Walrath *et al.* (2004) and as adulthood criterion, both the closure of the spheno occipital synchondrosis and/or third molar final eruption were applied (Hillson 1996).

Twelve landmark coordinates (Table 2) were digitized on each skull using TPSdig 2.16 v. software (Rohlf 2010). A priori morphoscopic ACM classifications distinguishing erected and oblique artificial skull modifications were corroborated using a cross validated discriminant analysis assessing the matching level with the a priori defined classification, while the significance of the differences between site multivariate means, was calculated using a Hotelling's T2

test. The skulls that were misclassified according to the discriminant function were reanalysed and excluded if after this second round still occupied an ambiguous location in the sample morphospace. Geometric morphometric (GM) analyses were carried out in MorphoJ (Klingenberg 2011). Following standard GM protocols to remove the effect of scale, translation and rotation, landmark coordinates were aligned by a Procrustes fit and projected as points to a tangent linear space. In this space, analogous to the morphospace obtained by a Principal Component Analysis, each PC axis represents a shape component resuming in a decreasing order the overall variance of the observed skull shape variation. Due to the multidimensional nature of its raw data, in GM size can be considered as a shape independent variable (i.e. "size" as the centroid size or the square root of the sum of squared distances of a set of landmarks from their centroid). This property allows to avoid the problems associated with the effect of artificial skull modification onto the linear (interlandmark) morphometrics as is thoroughly discussed and almost definitely solved by Rhodes and Arriaza (2006). Linear statistical analyses were carried out in the Past (Hammer *et al.* 2001) software.



Figure 1: Map showing the approximate location of sites.

Figura 1: Mapa que muestra la localización aproximada de los sitios.

Number	Landmark	Reference
1	Glabella	Martin and Saller (1957)
2	Bregma	Martin and Saller (1957)
3	Frontal	Martin and Saller (1957)
4	Lambda	Martin and Saller (1957)
5	Boveda	Manríquez <i>et al.</i> (2006)
6	Ophistion	Martin and Saller (1957)
7	Occipital	Salinas (2010)
8	Basion	Martin and Saller (1957)
9	Posterior Clinoid Process	Martin and Saller (1957)
10	Frontomaxillare	Martin and Saller (1957)
11	Nasospinale	Martin and Saller (1957)
12	Posterior Nasal Spine	Martin and Saller (1957)

Table 2. Landmarks used in this study.

Tabla 2: Landmarks usados en este estudio.

The Intra Site hypothesis was tested using a multiple correspondence analysis (MCA) of the frequency data obtained from the funerary contexts (Tchecar and Catarpe 2), or based on the spatial distribution of the graves within the cemetery (Chorrillos) (Xlstat 2010 package), of all the individuals (with and without ACM). Additionally, a Mantel test was applied to test whether there was a relationship between the morphological differences and the funerary context distances. The correlation level was assessed after comparing Procrustes (i.e. the morphometric distances between all the skulls within each site), and Euclidean (i.e. the MCA distances corresponding to the differences found in grave goods) distance matrices by computing the product moment correlation and the Mantel test statistic (observed Z values compared to their permutation distribution). Finally, we carried out another Mantel test using Procrustes distance matrices and the number of funerary goods (Tchecar and Catarpe 2) or in the case of Chorrillos, the spatial distance matrix. In the case of the Inter Site hypothesis, the ACM shape variation was analysed via a Principal Component Analysis (PCA). Mahalanobis distances were calculated in order to establish the morphological affinities between the shape components of skulls with and without ACM from different geographic areas. These distances were estimated separately for the sites of individuals with and without ACM considering the shape components explaining up to 95% of the overall cumulative variance. Pairwise Hotelling's T² tests with Bonferroni corrections were

applied to test for significance, whilst a cross-validated discriminant analysis was performed to establish the matching level between ACM and the different classification criteria (i.e. geographic origin, chronological period). Finally, an UPGMA cluster analysis was performed using the Procrustes distances, in order to visualize the morphological affinities between sites.

RESULTS

The results are presented in two sections corresponding to the two hypotheses being tested. In the first section we have described and compared (both diachronically and synchronically) the patterns of skull shape variation of all the analysed sites. In the second section, the results obtained from the statistical tests relating cranial morphology with funerary contexts were shown.

Inter Site distinctions

Regardless the site of origin, there were no significant differences among individuals with and without ACM (Table 3). In contrast, the individuals with ACM exhibited several significantly different comparisons, being Chorrillos the archaeological site that shows the most different modification pattern (i.e. oblique) compared to San Pedro de Atacama skulls (i.e. mostly erect). The diachronic comparisons showed that there were no significant differences between the individuals

with ACM in any of the San Pedro de Atacama sites (Hotelling's T^2 test, $p < 0.001$). Unlike San Pedro de Atacama, in the Loa River basin there were statistically significant differences in the morphology of modified skulls between the Formative and the Late Intermediate Period. In this latter period there was greater similarity between the ACM observed in the Chunchuri site (Middle Loa Basin) and the sites of San Pedro de Atacama. The UPGMA of the average shape for each site (Figure 2) showed that Chorrillos clustered with Playa Miller 7 site. This result is consistent with the

low percentage of skulls correctly assigned in the cross validation table (Table 4), the closest Mahalanobis distance compared to the other sites (Table 3), and the shared distribution area in the PCA graphic (Figure 3). Interestingly, the comparison between Tchecar and Chorrillos presented the highest Mahalanobis distance (Table 3). These sites can be described in classical terms as exhibiting the erect and oblique modification types respectively, which is again noticeable in the morphospace defined by the first shape component (Figure 3) (PC1 = 30.29% of the overall variance).

	Solor 3	Tchecar	Catarpe 2	Caspana	Chorrillos	Chunchuri	Playa Miller 7
Solor 3	0	2.22 (0.64)	3.67 (0.22)	7.66 (0.98)	ID	5.30 (0.81)	ID
Tchecar	6.5 (0.56)	0	1.61 (0.23)	9.29 (0.12)	ID	3.33 (0.4)	ID
Catarpe 2	2.61 (0.99)	4.85 (0.28)	0	8.40 (0.13)	ID	2.85 (0.48)	ID
Caspana	6.61 (0.08)	8.85 p<0.001	3.07 (0.13)	0	ID	ID	ID
Chorrillos	10.96 (0.01)	14.52 (p<0.001)	11.06 (p<0.001)	11.90 (p<0.001)	0	ID	ID
Chunchuri	5.18 (0.72)	3.74 (0.33)	11.06 p<0.001	8.54 (p<0.001)	11.9 (p<0.001)	0	ID
Playa Miller 7	ID	13.68 (0.21)	11.83 (0.44)	11.6 (0.004)	8.27 (0.039)	10.23 (0.34)	0

Table 3: Mahalanobis Distance, p value (in parentheses), of the Hotelling T^2 test between skulls with ACM (lower left triangle) of each site and individuals without ACM (upper right triangle). Significant values are in bold. ID: insufficient data.

Tabla 3: Distancia de Mahalanobis, (p-valor entre paréntesis), del test de T^2 de Hotelling entre los cráneos modificados (triángulo inferior izquierdo) de cada sitio y los cráneos sin modificación (triángulo superior derecho). Valores significativos están en negrita. ID: Datos insuficientes.

	Solor 3	Tchecar	Catarpe 2	Caspana	R.Ch.	N.C.	PM 7
Solor 3	100	73.3	61.5	87.5	46.6	33.3	66.6
Tchecar	50	100	69.2	91.6	86.6	46.7	33.3
Catarpe 2	33.3	66.7	100	78	93.3	60	100
Caspana	66.7	80	76.9	100	83.3	66.7	83.3
R.Ch.	66.7	93.3	100	90.6	100	53.3	50
N.C.	33.3	80	61.5	90.6	86.7	100	33.3
PM 7	83.3	53.3	100	90.6	86.6	80	100

Table 4: Cross validation test of modified skulls. The table list the percentage of modified skulls correctly assigned to each site according to the discriminant analysis. It should be read horizontally for correct interpretation.

Tabla 4: Validación cruzada de los cráneos modificados. La tabla indica los porcentajes de cráneos modificados correctamente asignados a cada sitio de acuerdo al análisis discriminante. Para una correcta interpretación se debe leer horizontalmente.

In none of the sites sex was an important variable to distinguish between individuals with ACM,

neither to explain the main variability found in the grave goods.

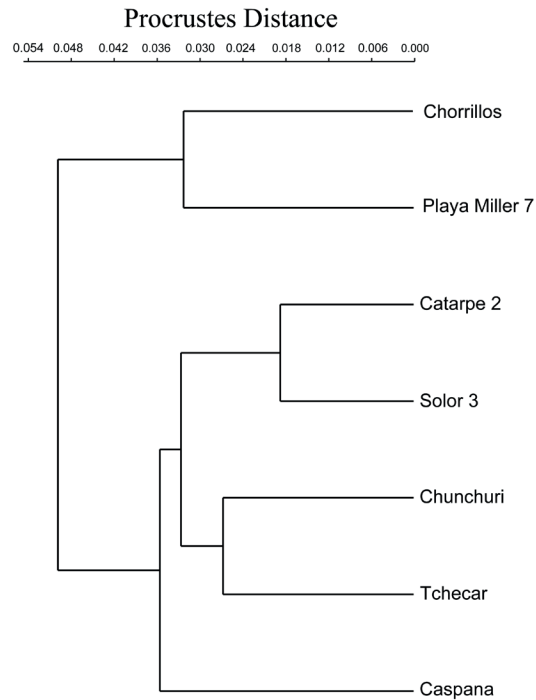


Figure 2: UPGMA tree based on the geometric morphometrics distance between the consensus configurations of the sites.

Figura 2: Dendrograma UPGMA de las distancias geométrico-morfométricas entre las configuraciones de consenso de los sitios.

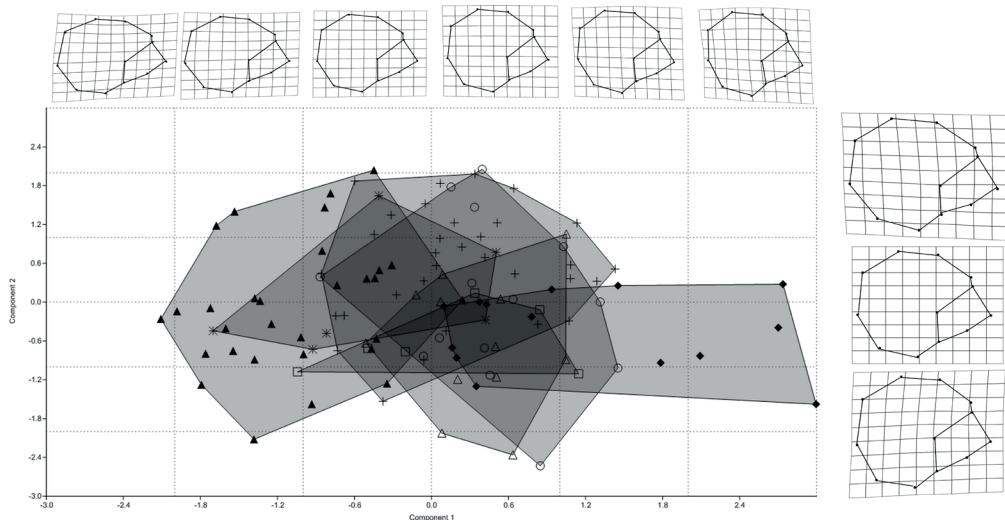


Figure 3: Relative warp analysis of all skulls with ACM. The grids represent the magnitude and direction of the variation in the skull form along the X and Y axes of the bivariate graph (RW1 = 30.29% and RW2 = 17.6% of the total variance). The skulls of Regimiento Chorrillos are represented with ▲, Churchuri with ○, Caspana with +, Solor 3 with □, Tchecar with ◆, Catarpe with △ and Playa Miller 7 with ✱.

Figura 3: Análisis de torsión relativa de todos los cráneos modificados. Las grillas representan la magnitud y dirección de la variación de la forma del cráneo en el eje X e Y (RW1: 30,29% y RW: 17,6% de la varianza total). Individuos de Chorrillos están representados con ▲, Churchuri con ○, Caspana con +, Solor 3 con □, Tchecar con ◆, Catarpe con △ y Playa Miller 7 con ✱.

Intra Site distinctions

The first two dimensions explain, respectively, the 36.99% and 19.93% of the total variance of Catarpe 2 (Figure 4). Although grave goods as a whole do make some contribution to the variance (the contribution to the first two dimensions ranged between 0.010 and 0.25 out of a possible maximum of 1), highlight the importance of some of them. The graph showed that the largest differences between individuals did not correspond to the presence or absence of grave goods, but to the presence or absence of specific types of objects in the graves. These major variances are explained by objects showing low frequencies in the graves, and especially by the

association of these grave goods with others that are also infrequent, for example bows and arrows, textiles, drug consumption paraphernalia and cucurbits. These last three categories and the presence of foreign objects make a large contribution to the first two dimensions for Tchecar, explaining 35.94% and 19% of the total variance in grave goods (Figure 5). Individuals assigned to late Middle Period and to Late Intermediate Period tend to group separately according to these variables in this site. These graphics also showed that the supplementary variables “sex” and “type of burial” are located near the center of both the X and Y axes, hence they do not affect the distribution of grave goods in the tombs.

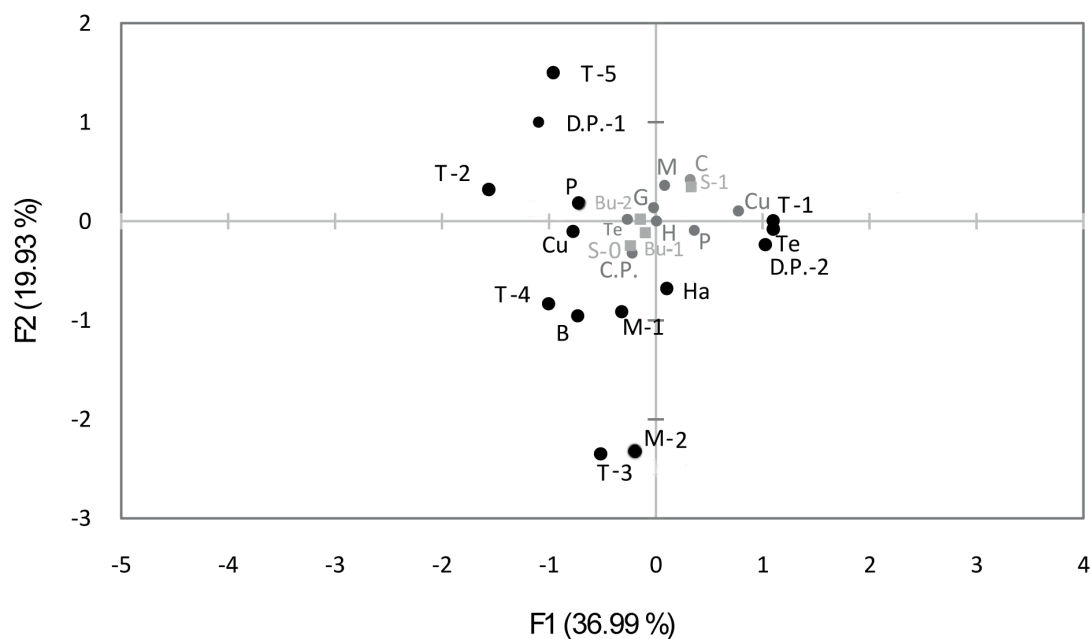


Figure 4: Multiple correspondence analysis for the grave goods at Catarpe 2. The two axes represent the 56.92% of the total variance. B: Presence of baskets. Bu-1 and Bu-2: Single and multiple burials. Cu: Cucurbits. D.P.-1 and D.P.-2: iconographic and undecorated drug consumption paraphernalia. Ha: Hats. M-1, M-2: beads and metal ornaments. P: pottery. S-0 and S-1: Male and female. Te: Textile. T-1, T-2, T-3, T-4 and T-5: bows and arrows, awls, tie hooks (used to tie bundles to llamas), spindles, and several tools in the same grave, respectively. Light gray labels are supplementary variables.

Figura 4: Análisis de correspondencias múltiples de los bienes funerarios de Catarpe 2. Ambos ejes representan el 56,92% de la varianza total. B: presencia de cestería. Bu-1 y Bu-2: enterramientos individuales y múltiples, respectivamente. Cu: calabazas. D.P.-1 y D.P.-2: complejo psicotrópico con y sin iconografía. Ha: gorros. M-1, M-2: cuentas de collar y ornamentos de metal. P: cerámica. S-0 y S-1: individuos masculinos y femeninos. Te: textiles. T-1, T-2 T-3 T-4 y T-5: arcos y flechas, punzones, ganchos, husos y varias herramientas en la misma tumba, respectivamente. Variables suplementarias en gris claro.

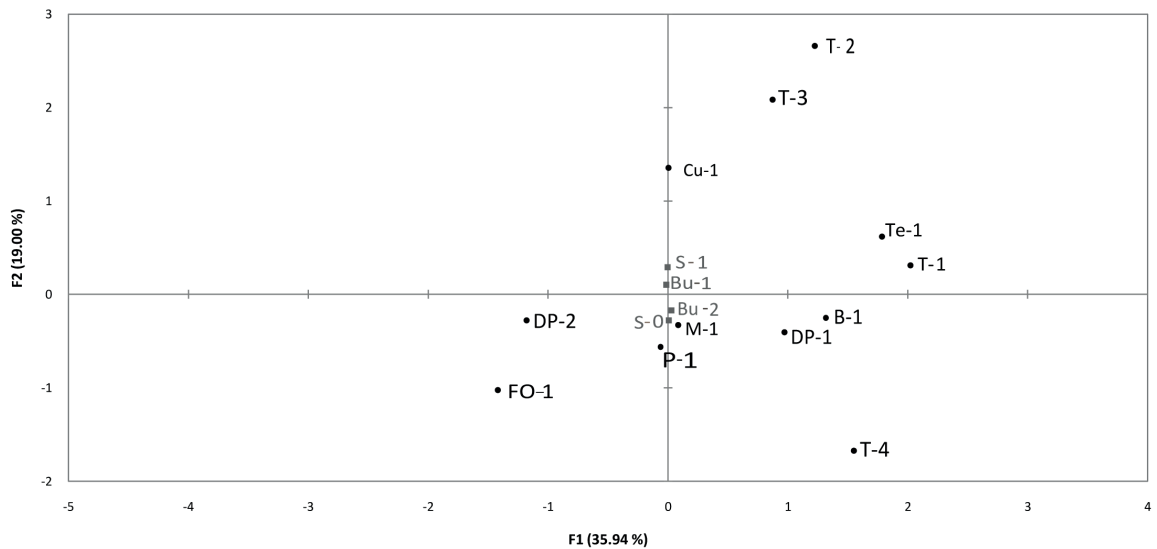


Figure 5: Multiple correspondence analysis for the grave goods at Tchecar. The two axes represent the 54.94% of the total variance. B: Baskets. Bu-1 and Bu-2: single and multiple burials. Cu: Cucurbits. DP-1 and DP-2: iconographic and undecorated drug consumption paraphernalia. FO: foreign objects. M: beads. P: Pottery. T1, T2, T3 and T4: bows and arrows, spindles, tie hook and axes, respectively. S-0 and S-1: Male and female. Te: textile. UO: unique object (not found in another graves). Light gray labels are supplementary variables.

Figura 5: Análisis de correspondencias múltiples de los bienes funerarios de Tchecar. Ambos ejes representan el 54,94% de la varianza total. B: cestería. Bu-1 y Bu-2: enterramientos individuales y múltiples. Cu: calabazas. DP-1 y DP-2: complejo psicotrópico con y sin iconografía. FO: objetos foráneos. M: cuentas de collar. P: cerámica. T1, T2, T3 y T4: arcos y flechas, husos, ganchos y hachas, respectivamente. S-0 y S-1: Individuos masculinos y femeninos. Te: textiles. UO: objeto único (no encontrado en otras tumbas). Variables suplementarias en gris claro.

Finally, the Mantel test computed between morphological (Procrustes) distances and the Euclidean distances (calculated on the basis of the symmetric graph of the multiple correspondence analysis), showed a non significant correlation ($p > 0.05$). Similar results were obtained by the Mantel test correlating the Procrustes distances and the quantity of objects in the tombs (the reduced sample size of Solor 3 did not allow to run this particular test for this site). The results of the Mantel test for the Chorrillos site were also not significant.

DISCUSSION

The present work contrasted both the Intra and Inter Site hypotheses in order to elucidate the possible role of ACM in San Pedro de Atacama and the Loa Basin. The first hypothesis was tested by comparing the modification patterns of the sites, in order

to evaluate if they could be related with ethnic ascriptions and interaction networks between geographically distant sites. We compared the variability of cranial morphology with the variability of the funerary context within the sites to evaluate the second hypothesis.

Relationship between ACM and grave goods (Intra Site distinction hypothesis)

The analysis of the evidence does not support the Intra-Site hypothesis. Although the multiple correspondence analysis allowed to clearly distinguish the identity of the individuals in their funerary context, these differences do not correlate with the shape of the skull as noticeable in Mantel test results. Moreover, there was no relation between Procrustes distances and the number of objects in the graves, or between Procrustes distances and the location in which the individuals were buried (Chorrillos).

This hypothesis was tested by performing multivariate tests considering two factors simultaneously: the variability of the grave goods as a whole, and the continuous variations of cranial shapes in the sites (measured as Procrustes distances). It is possible to conclude that social identity can be studied based on the grave goods as a whole, without discarding any of the objects *a priori*, unless it has been shown that certain objects contribute very little to the variance of the grave goods.

Although the relative contribution of the objects to the variance of the grave goods varies from site to site, some of the objects have a similar and marked influence on the variance, as is shown in both Catarpe 2 and Tchecar. At both sites, we found certain tools (spindles, shovels, axes), metal objects and iconographic drug consumption paraphernalia, which made a great contribution to the variance of the grave goods and to the identity of the individual. If future studies attempt to show that this is a common pattern for different geographically distant sites, the identity comparisons could be done not only within the sites, but also between them.

ACM patterns and their mutual relations (Inter Site distinction hypothesis)

The results of this study indicate that during the two analysed periods, there were two different modification patterns (erect and oblique, for Tchecar and Chorrillos, respectively). This is in agreement with previous observations on northern Chile artificially modified skulls (Manríquez *et al.* 2006). However, the cranial shape of the great majority individuals with ACM ranges within a continuous distribution of variation between these two extremes (Figure 3), complicating the any *a priori* classification of these skulls into either category. This could imply that studies using typological methods as the one proposed by Dembo and Imbelloni (1938), should either apply morphometrics methods or openly clarify their applied classification criteria. Geometric morphometric approaches allow to preserve all the cranial shape variation without having to classify them into a *priori* typological categories as was showed in the present study.

Based on the above results, it is possible to state that the modification patterns vary over time in

certain areas, while other areas show no significant changes: in San Pedro de Atacama there is a continuity in the modification patterns between the Formative Period and later periods (end of the Middle and Late Intermediate Periods), as shown by the Hotelling T2 test (Table 3) and the Principal Component Analysis (Figure 3). However, this does not mean that certain individuals could have exhibited really dissimilar cranial vault modifications.

The modification patterns of Middle Loa sites have not been previously compared between themselves or with other areas. The results of this study indicate that, unlike San Pedro de Atacama, the modification patterns of the human populations living in the Middle Loa vary significantly between the two analysed periods.

It is interesting to note that while Chorrillos shows the largest Mahalanobis distances of all the sites, Chunchuri (same area, different period) is more similar to the sites of San Pedro de Atacama, no presenting statistically significant differences with them (Figure 3 and Table 3). The smallest Mahalanobis distance of Chorrillos is with the Arica coastal site Playa Miller 7 (Table 3, Table 4 and Figure 3), which is from an equivalent time period, but located in the coast of the Pacific Ocean at a distance of over 400 kms. (Figure 1). Regarding this point, it is suggestive to mention that the archaeological context of Chorrillos indicate the existence of specialized exchange networks with the coast, San Pedro de Atacama, the southern Altiplano, and north-western Argentina (González and Westfall 2006).

Some authors proposed that the transformation of Northern Chile groups into Formative societies was influenced by interaction networks with foreign sites, especially with populations coming from the highlands of Altiplano, and in lesser extent with the Atacama Plateau and the Northwest Argentina (Muñoz 1989) and, on the other hand, recently it has been highlight a greater importance of local traditions and cultural particularities of the Formative groups (Uribe 2008; Uribe and Vidal 2012), as, for instance, in the local textile and ceramic production instead of an Altiplano resemblance of these materials (Ayala 2001; Agüero 2012). Regarding ACM patterns, Arica and the Bolivian Altiplano have shown no significant differences (Püschel 2012). Therefore, the interaction networks of these populations may also

explain the resemblance between Arica and Chorri-
llos ACM patterns.

Regarding the lower variance of skull shapes during the Late Intermediate Period compared to the Formative Period (Figure 3) and the observed similarity between Chunchuri and the sites of San Pedro de Atacama during the Late Intermediate Period, the available information suggests that there was an "Atacameño" cultural unit during this period, which was expressed, for instance, in common regional textile styles (Agüero 2000) and funerary ceramics (Uribe 2002) that could explain these results. This cultural unit could also explain the modification pattern similarities during this period and could indicate the importance of San Pedro de Atacama in this common identity. In brief terms our results show that ACM patterns vary not just through time in some regions, but is consistent with the interaction networks and superregional identities described in the archaeological literature.

CONCLUSIONS

Due to sample limitations we could not use all sites to test both hypotheses. For this reason some of our conclusions are constrained temporally and geographically, although we found important insights for the understanding why the head was targeted for manipulation in San Pedro de Atacama and the Loa Basin.

The results of this study do not support the Intra Site Distinction Hypothesis in the Formative and Late Intermediate periods. The grave goods of individuals were studied in great detail. However, these variations do not correlate with the morphology of the skulls with and without ACM in the three sites studied for this purpose.

On the contrary, the modification patterns could be related with ethnic ascriptions and interaction networks between geographically distant sites as has been described in part of the literature. The modification patterns may vary over time, and when they do so, they are influenced by modification patterns of other sites in the interaction network. These conclusions support the Inter Site Distinction Hypothesis and are in agreement with previous works (Torres-Rouff 2002). However, it is important to notice that there may not be one single reason for cranial modifi-

cation and individual and group identity can be studied with others markers besides interaction networks and grave goods. Physical anthropology can make a major contribution in the complex study of identity, analysing for instance dietary habits, musculo-skeletal stress markers and pathologies, and this way enhance the understanding of the social role of this practice.

This study has corroborated the need to represent grave goods and cranial morphologies as objectively and precisely as possible. We think that further studies should consider large numbers of synchronous archaeological sites over extensive geographical areas, in order to achieve conclusions of the role of ACM in all Atacama Desert and the Andes where ACD was extensively practiced.

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