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Aaron Fehir

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Artificial cranial modification, more commonly referred to as 'head binding', is the practice of deliberately altering the development of the cranial skeleton with the intent of changing the shape of an individual's cranial vault. This process is accomplished through the prolonged application of a relatively low intensity compressive force to the skull of an infant or neonate. Artificial cranial modification ultimately manifests as an irreversible and highly visible cultural modification which, when interpreted bioarchaeologically, can convey a wealth of social information.

Although a contemporary audience may view the concept of head bindings as inhumane or bizarre, artificial cranial modification is surprisingly widespread; it is not only practiced by a number of geographically dispersed cultures, but it is also found at different points in time throughout history. In order to demonstrate this point, the following is a brief list of evidence and occurrences of artificial cranial deformation with its corresponding culture, time period, and/or geographic region. Artificial cranial deformation has been observed in, but is not limited to: Iraq ca. 45,000 BCE as evidenced by the Shanidar 1 man, the Nile Valley during the 5th century BCE, according to the Hippocratic book entitled *de Aere, aquis et locisi*, the Pre-Columbian Americas as observed across the Olmec, Mayan, Paracas, and Incan culture, as well as prehistorically in the Andean regions (Obladen 672-673). This diversity makes a complete discussion on the topic of artificial cranial deformation impossible for an article of this length. Instead, this article will focus on artificial cranial modification as it has appeared in the geographical regions of Mesoamerica and South America. For convenience of both the author and the reader, this geographic entity will hereafter be referred to as the Americas. The decision to focus on the Americas is motivated by the reason that the Americas have a higher frequency of artificial cranial modification in comparison with other geographic regions. This article will discuss the following: the prevalent categories of artificial cranial deformation present in the Americas and the techniques which produced them, the unintentional consequences of artificial cranial modification, the purposes behind

artificial cranial modification, and the process of diagnosing skeletal remains with artificial cranial modification.

I. Categories and Formative Techniques

There are three common types of deformation found in the Americas: tabular erect, tabular oblique, and annular. Erect tabular deformation is created by flattening the back of the cranial vault, resulting in occipital deformation. This occipital deformation, in combination with frontal deformation, results in a vertical distortion that is commonly referred to as tabular erect (Buikstra and Ubelaker 160). The typical visual effect in a living individual whose skull has undergone tabular erect deformation is a high and broad head with the possibility of acute asymmetry. In instances where the tabular erect deformation is not designated intermediate or severe, it may only be reflected as a flattening of the occipital or occlusal planes.

Tabular erect deformation is widespread across the Americas, though the frequency varies considerably between burial assemblages. Because of this variation, some cultures are particularly well known for their prevalent use of tabular erect deformation. Cultures that are best known for their use of tabular erect deformation are the Olmec and the emulation of Olmec deformation found in Pre-Classical Maya. The tabular erect deformation was so ingrained into the Olmec culture that it also influenced their art; the Olmec figure style "Les Bocas" baby predominantly depicts children with tabular erect cranial deformation (Goodrich and Ponce de Leon 82).

In addition to tabular erect, there is another type of tabular deformation called 'tabular oblique'. Both varieties of tabular deformation involve the use of hard compression instruments to create the desired cranial shape. However, tabular erect and tabular oblique differ in the specific instruments used, as each is produced by distinct stresses placed on the developing bones. The procedure for altering an infant's skull to produce a tabular erect shape involves binding an infant's head to a single compressive surface. The compressive surface used to produce tabular erect deformation is most often a cradleboard, which has the potential to create extreme irregularities in the cranial skeleton of an individual (provided there are irregularities in the compressive instrument) (Tiesler 293). As is true for every category of artificial cranial deformation, the severity of the deformation is dependent on the total amount of time exposed to compression in combination with the amount of compressive pressure (Tiesler 293). Tabular oblique deformation is a subcategory of tabular deformation, but has the implication that the desired morphological alteration of the skull takes place through the use of hard compressive instruments. Unlike tabular erect deformations, tabular oblique modifications are typically produced through the use of free headboards. The employment of pads during tabular oblique deformation has

the potential to generate sinuous skull contour (Tiesler 293).

In contrast to tabular deformation, annular deformation eschews the use of hard compressive instruments. Instead, annular deformations are fabricated through the process of circumferential binding (Buikstra and Ubelaker 162), which is in turn made tangible through the use of compression bands, bandaging, string, rope, pads, textiles, and tight hats (Tiesler 293; Hoshower et al. 14; Blom 9). Annular deformations are strongly associated with the Tiwanku culture, as discussed in José Imbelloni's research. Imbelloni mentions that annular deformation is extremely prevalent in the Tiwanku culture, with several kinds of annular deformation within Tiwanku skeletal remains (Hoshower et al. 152). From a visual standpoint, annular deformation results in a cranium that displays a circular contour (Hosthower et al. 149), albeit annular deformation may produce an elongation of the skull, depending on the extent and severity of the deformation.

II. Unintended Consequences

Artificial cranial deformation has often been regarded as having negative secondary effects on an individual's health. The earliest writings on the matter date to when the church banned the practice in the Americas in 1585 (Obladen 673). This section of the article will investigate the effects of artificial cranial deformation, and the primary results of altering the shape of the cranial vault. There are two types of secondary changes caused by artificial cranial deformation: additional unintentional modification of the crania and an impact on neurological capabilities due to modification of the cranial vault.

The act of artificially deforming the cranial vault should theoretically impact the rest of the cranial skeleton given that both are part of an interconnected skeletal unit. While changes across the entire cranial skeleton are somewhat inconclusive, artificial cranial deformation has recently been proven to both alter facial morphology and leave occlusal traits unchanged (Jiminez et al. 40). To summarize the findings: artificial cranial deformation in the central Andean region was found, using a combination of bioarchaeology and statistical analysis, to cause changes in the growth of upper facial height, minimum frontal breadth, nasal height, orbital breadth, orbital height and bizygomatic breadth in males. In females, artificial cranial modification altered the maxilla-alveolar breadth, upper facial height, orbital height, and bizygomatic breadth (Rhode and Arriaza 463-468).

In addition to the changes that take place to the skull's facial metrics, artificial deformation effects the elements of the cranial skeleton that articulate with the occipital bone. The two most common examples of this are lambdoid ossicles and occipitomastoid intrasuturial bone, which appear ubiquitously in crania that have

undergone any type of artificial cranial deformation (Obladen 675). Despite these examples, the proposed effects of artificial cranial deformation are somewhat inconclusive. Weindel Feindel proposed that artificial cranial modification might have resulted in seizures and epilepsy due to the application of pressure on the hippocampus. Feindel cites the neurological impact of artificial cranial modification as one possible reason for the collapse of the Mayan civilization (Goodrich and Ponce de Leon 93-94). Obladen, however, concluded that artificial cranial deformation of the cranial vault within a year after birth would have no adverse effects on the brain provided the modification took place over an extended period of time (672). Despite the apparent conflict, it is possible that both Feindel and Obladen are correct: artificial cranial modification may be safe as long as it is performed within one year of an individual's birth and over an extended period of time, but the consequence of seizures and epilepsy may manifest should one perform the deformation outside of these parameters. Nevertheless, such a proposition remains speculative given that one would need to perform artificial cranial modification on a living infant to be certain.

III. Proposed Purposes

This section of the article will outline the hypothesized purpose, or purposes, behind the practice of artificial cranial deformation within the Americas. In particular, this section will focus on kinship, ethnicity, status, and sex.

The association between kinship groups and artificial cranial deformation occurs in most articles that discuss artificial cranial deformation. This association is probable for at least two reasons. First, artificial cranial deformation is only possible during a stage of development when an individual cannot give or withhold consent to undergo cranial modification. This suggests that the modification is performed by an individual's family, and thus is part of a continuous symbolic representation of ancestry (Tiesler 290) in the form of descent group traits (Blom 5). This makes studying the relationship between kinship and artificial cranial modification a relatively straightforward task when compared to more complex factors, such as ethnicity. Second, kinship is frequently an integral part of both ethnicity and status, two other proposed purposes, throughout the Americas. Tiesler postulates that cultural change may have stimulated ethnogenisis and kinship bonds during the Mayan Pre-Classical Period (308).

Ethnicity is defined for the purposes of this investigation as the action of assigning importance to a real or perceived affiliation between multiple individuals, as well as acknowledging differences between groups (Suttter 183). Archaeologically, ethnicity is represented through shared material culture and behaviour. As the cranium would have been deformed artificially to convey social information (Tor-

res-Rouff 170), cranial deformations can be classified as material culture (Blom 2). Accordingly, artificial cranial deformations can be used as evidence of intragroup solidarity and intercultural differences (Torres-Rouff 163) in both living populations and the archaeological record.

The culture that provides the best evidence for use of cranial deformation to express ethnic identity is the Andean culture. According to ethnohistorical sources (Blom 3-4), the Andeans wore a variety of headdresses and clothes to signify distinct subdivisions of their geographic region. Each headdress had a corresponding cranial modification, resulting in a highly visible sign of group affiliation which acted as evidence of ethnicity; this was a highly diversified practice that provided rigid symbolic affiliations (Hoshower et al. 147; Blom 3-4). The Andean expression of ethnicity through artificial cranial deformation is not without criticism. In a statistical analysis of several Azapa Valley mortuary sites, cranial deformation was regarded as the least definitive indicator of ethnicity when compared to grave goods, genetic relatedness, and dental pathologies (Sutter 196-198). However, the same analysis demonstrated a weak correlation between tabular oblique deformation and annular deformations, and the Capruza culture and "coastally ethnic" populations, respectively (Sutter 196-198). Sutter's observation of a correlation between annular deformation is also noted by Blom, who uses this information in her alternative explanation for the distribution of annular versus tabular deformation in the Andes; Blom claims that the distribution of cranial deformations was based around ethnicities (15-16). These two theories can be hybridized if one considers that the coastal populations and the populations living in the highlands regarded themselves as two separate and distinct ethnic groups.

Many scholars note that artificial cranial deformations can indicate socioeconomic status (SES), although they concede that this is not necessarily true in all societies within the Americas. Evidence for the correlation between status and artificial cranial modification includes the high frequency of extreme skull elongation in conjunction with Incan burials with highly valuable grave good assemblages. This association may be due to the correlation between lineage and SES in Incan society (Blom 5). Use of cranial deformation to represent status is also present in the Andean culture, but may be misrepresented in the archaeological record. For instance, it was possible for parents with a low SES to emulate the artificial cranial deformations present in elite populations on their own children (Hoshower et al. 146). Nevertheless, between the correlation with high grave goods and the ethnohistorical accounts of punishing those who deviated from their region's artificial deformation (Blom 3), such emulations seem unlikely.

Scholars tend to cite any observed difference in artificial cranial deformation between males and females as statistically inconclusive (Tiesler 304), or as evidence

for the practice of exogamy. In sites within the Atacama region, such as Solcor 3, Toconao Oriente, and Coyo 3, there is evidence for high frequencies of female cranial deformation in a different style than the male populations at the same sites; annular deformation was more common for females, while tabular deformation was more prevalent in males. This discrepancy in cranial deformation can be explained as the result of either colonization or exogamy. These are likely explanations given that females who immigrated into these cultures would be unable to alter the cranial deformations they had previously received as infants or neonates. Perhaps the strongest supporting evidence for this exogamy hypothesis are the differences in facial morphology between males and females on the site of Coyo 3 (Torres-Rouff 169). While the previously mentioned sites are all within the Atacama region, this practice of immigration and exogamy may have taken place throughout the Americas, as evidenced by a stable isotopic analysis from Tlajinga 33 (White et al. 186, 194).

IV. Diagnosis: Indicators, Problems, and Differential Diagnosis

The primary methodology for establishing the taxonomy of artificial cranial deformation was originally developed by Imbelloni, and has since been altered to better reflect data in Mesoamerican cultures by Tiesler and Romano (Tiesler 293). Tiesler and Romano's methodology requires complete descriptions of both metric and nonmetric cranial traits with an emphasis placed on the description of each compression plane and constructional groove. The indicators for diagnosing an observed abnormality in a human cranium as the direct result of artificial cranial deformation varies depending on the type, formative processes, and severity of the cranial deformation present in the skeletal remains. One indicator of artificial cranial deformation, regardless of the type of deformation, is the presence of lambdoid ossicles and occipitomastoid intrasuturial bone because both of these lesions occur in culturally modified skulls in higher frequencies than in unmodified skulls (Obladen 675).

One of the primary obstacles in correctly diagnosing artificial cranial deformation is its subtlety when expressed by a less severe alteration. As previously stated, less pronounced forms of tabular artificial cranial deformation are indicated by flattening of the frontal plane, frontal curve, occlusal curve and occlusal plane. Unfortunately, it is possible for these slight alterations to the cranial shape to go unrecognized (Tiesler 293).

The primary causes for misdiagnosing artificial cranial deformation lies in the prerequisites of artificial cranial deformation. Misdiagnoses can occur in at least two ways: cranial deformations which were unintentional, and those deformation which were intentional but which took place rapidly. The most common misdiagnosis for artificial cranial modification occurs rapidly and unintentionally in the form of spon-

taneous moulding during vaginal birth. While moulding occurs to a limited degree in every vaginal birth, the effect of rickets can restrict the size and shape of the mother's pelvis (Glencross 2013), and cause severe cranial deformation during delivery. This abnormal pelvic morphology results in depressions in the infant's cranium, and in severe cases can cause the slippage of the parietals over the occipital or frontal bone (Obladen 675-676). Moreover, Craniosynostosis, the fetal position, breech head, brow head, Crainiotabes, and premature birth can all result in unintentional cranial deformations that are easily misdiagnosed as artificial cranial deformation (Obladen 677). Another diagnosis that can be misconstrued as artificial cranial deformation is the spontaneous and intentional cranial deformation performed by midwives using head-massages. The rapid nature of cranial deformation caused by head-massage is ultimately damaging to the health of those who receive it.

V. Conclusion

Artificial cranial deformation was a widespread cultural practice across the Americas. While the tabular and annular deformation processes and their formative processes are well documented, a great deal of information about artificial cranial deformation in the Americas is not yet understood. An example of this gap in the literature is the conflicting opinions on the effect of artificial cranial deformation on the brain; artificial cranial deformation was shown to affect morphology of the facial bones. Currently, the purposes responsible for the creation and continued use of artificial cranial deformation have been unsatisfactorily explained, though they likely involve a combination of kinship, status, ethnicity and sex. These interpretive issues, however, will likely decrease as archaeologists find more skeletal remains in the Americas, and have a greater sample size from which they may conduct their studies.

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