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FACIAL RECONSTRUCTION AND MENINGIOMA-RELATED HYPEROSTOSIS IN A 2000 BP MAN FROM THE PERUVIAN ANDES

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Abstract.

We describe here facial reconstruction and skeletal pathological findings in a male aged 40-50 years, from a burial found in the Northern Andes of Peru, belonging to a culture still poorly known. Relying on what was found in the burial pit, the burial has been dated 2000 years BP. Even though little is known about the social structure of this period, the fact that the pit contained valuable items suggests a high social status for the individual during his life. Paleopathological examination was performed on the available skeletal segments, which included part of the skull, the right temporal bone, the mandible, and one femur. The most interesting pathological finding was a local exostosis in the inner surface of the temporal bone, considered consistent with a hyperostotic reaction to a meningioma, a rarely reported lesion in paleopathology. Additional findings include the occurrence of two wormian bones within the right lambdoid suture, rarefaction of the mandibular bone, and, in the femur, a small subchondral cyst and a mild cortical thickening of the compact diaphyseal bone.

Introduction.

During the autumn 2001 field campaign, the Italian archaeological mission "Northern Andes" (CSRL of Venezia, Ministry of Foreign Affairs of Italy) found at Hualcuy (2700 m. a.s.l., near Ayabaca, Department of Piura), the burial of a male individual (classified as "HLSN 01") whose age has been estimated 40-50 years. He was interred at the bottom of an elaborate pit, equipped with a rich and interesting assemblage, including a copper spear point stylistically dated c. 2000 y. BP (Vicuz I). The discovery has been published in the Peruvian newspaper

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El Comercio, December 17 2001, and subsequently in Le Scienze magazine, Italian edition, n. 410, October 2002 and in "La Cordigliera del Condor", Il Punto ed. 2003, by Mario Polia, Chief of Mission; these accounts include further archaeological details.

Archeological Context of Finding.

Even though the cultural complex of the burial is poorly known, it is supposed that 2000 years ago the ancient Peruvians inhabiting the area, at an average altitude of 2500 m.a.s.l., were part of a wider cultural complex trading with Ecuador (Vicuz), the Amazon forest, and coastal Peru. Occasional finds in local burials over the last 15 years, i.e. *Hualcuy Plan Grande* and *Olleros Valley* near Ayabaca and *Cerro Saquir* near Huancabamba, showed contacts with distant and ecologically different areas. In *Hualcuy Plan Grande*, a bead of jade coming from Colombia was found in a hunter's burial, while in *Cerro Saquir* lapis lazuli from Chile reproducing the fruits of *Carica candicans* (wild papaya from the Amazon basin) have been found in association with *Spondylus* shells coming from the Gulf of Guayaquil (Polia, 2003).

The burial described here contained elements from two very distant areas: beads made of *Spondylus* belonging to a necklace consisting of 450 elements found amidst the skull bones of the individual, and a sample of the wood constituting the shaft of the copper spear point, identified as *Guilielmia gasipae*, a tree growing in the rain forest. It is worthwhile noting that in the famous Moche burial in Sipan, *Carica candicans* samples have been found together with *Spondylus* (Polia, 2003).

Materials and Methods.

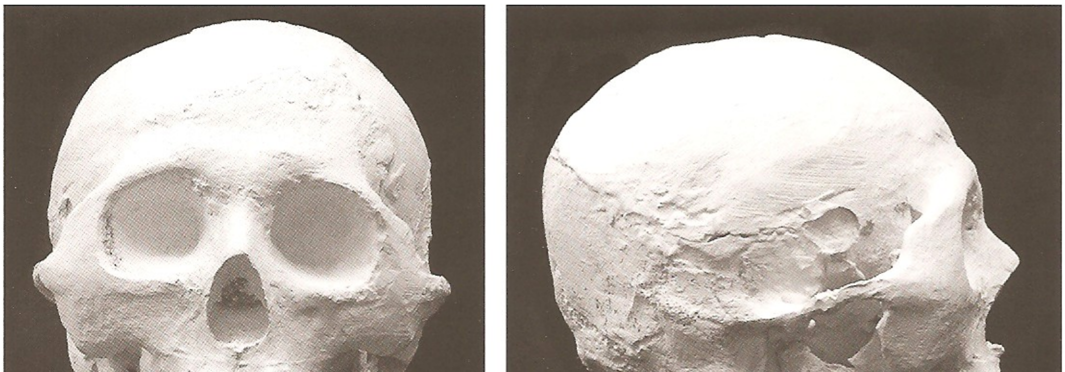
The individual was buried sitting in the fetal position, probably wrapped in fabric or held in position by fastenings, allowing the body to maintain this posture for a long time. The skull, backbone and ribcage slowly descended into the void, left by gradual decay of the soft tissues, between the abdomen and lower limbs; the latter presumably were the last to settle, as is suggested by the stratigraphic order of the bones encountered during excavation. The backbone showed some vertebra still in anatomical connection, giving the idea of a slow descent downward instead of a faster collapse that would result in displacement of the individual elements. The sandy burial pit fill slowly filled the empty spaces without bone compression, and allowed the organic fluids to filter away from the bones, promoting good preservation.

Skeletal segments available for investigation included: skull (part of the parietals, frontal, occipital, right and left temporal bones), mandible, and one femur.

Two different analyses were performed.

The former was undertaken for facial reconstruction and the latter for the gross and radiographic analysis of available skeletal segments.
For facial reconstruction, the first step was to make a plaster cast of each individual cranial segment. These were then assembled and the few remaining voids were filled in, in order to obtain a complete reconstruction of the skull (Fig. 1). Facial reconstruction was then performed by the traditional double-phase manual process. A two-dimensional reconstruction of the profile was

Figure 1. Reconstruction of the skull using reproductions of parts recovered from the archaeological excavation (above). The skull with the missing parts filled in (below).



first sketched; then the three-dimensional reconstruction on the skull cast was completed. The first phase, which is the guide for the second, was performed according to George (George, 1987). Briefly, on a lateral skull X-ray or photograph, the profile was used to identify craniometrical points from which straight lines, perpendicular to the tangents of the skull in these points, are traced following standard methodology (George, 1987). Markers were placed on straight lines to indicate face contour limit. These were then joined, obtaining individual's profile. The result was used as a guide for the three-dimensional phase (Fig. 2). For three-dimensional reconstruction, the "Manchester protocol" was used (Prag & Neave, 1997). Such a protocol is the result of the combination of two methods: the American, based on soft tissue depths which, once placed on the skull surface, are joined together with plastiline or clay stripes; and the Russian, which does not use soft tissue depths but anatomically reconstructs the face placing one single muscle at a time. The soft tissue depths positioned on the skull are mean values obtained from anatomical and radiological research based on sex, ethnic origin, and physical constitution (Rhine & Moore, 1984). For the present individual, values of an adult male of average build were assumed, considering the dimensions of bones found. Toothpicks, matchsticks, or rubber pieces were cut out to the right length and fixed on the skull in correspondence to the 32 landmarks necessary for reconstruction; they served as the guide for the facial contours. Then the cranial-facial muscles were positioned in specific order, starting with the deepest ones and following anatomical indications of muscle insertions and origins (Fig. 3). The eyes were made of resin. Positioning of the eye is usually not difficult. It is sufficient to place the pupil where two

Figure 2. Reconstruction of the profile, based on George's method.

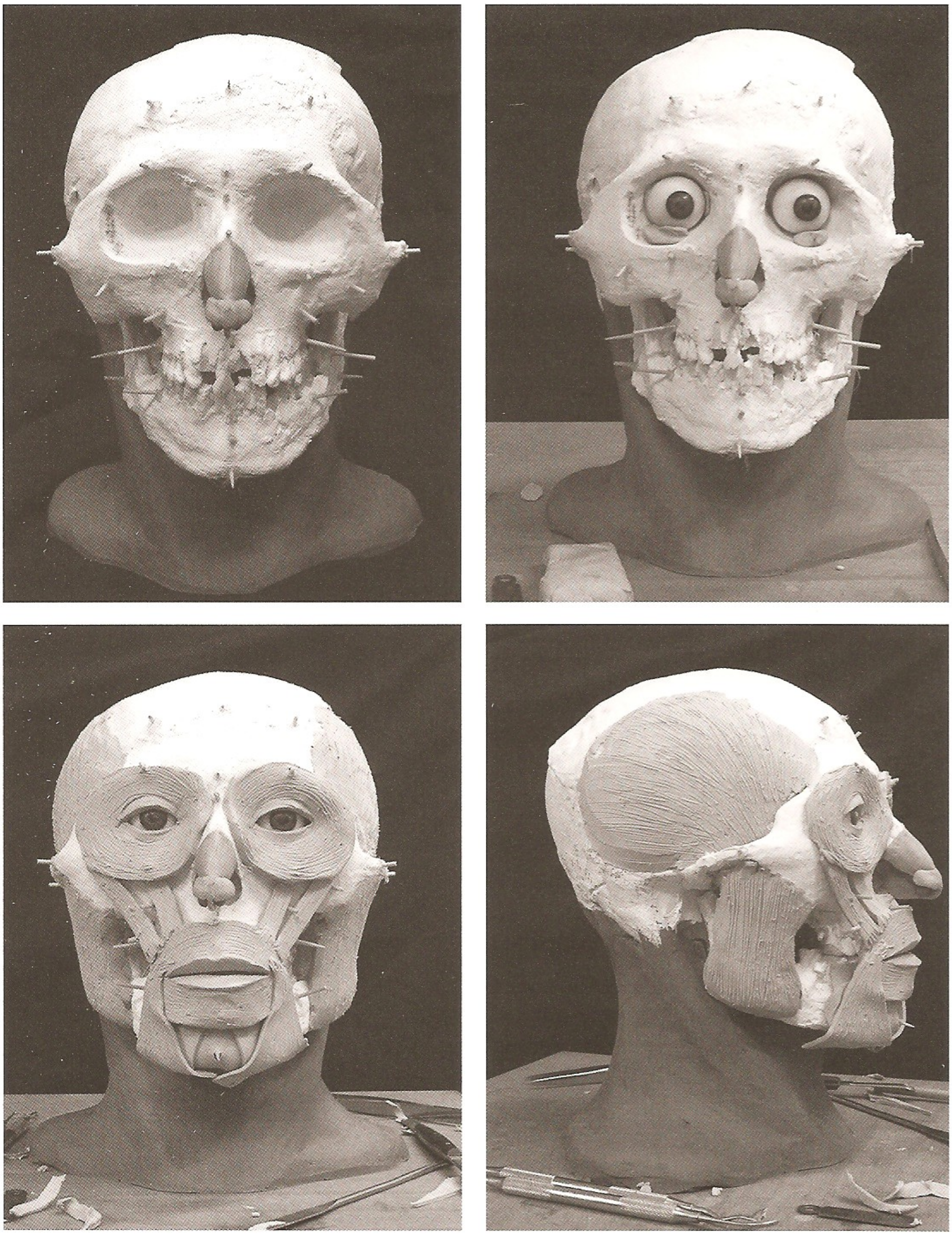


Figure 3. Stages of the facial reconstruction: positioning of the soft tissue depths, insertion of the resin models of the eyeballs, placement of the main cranial-facial muscles (from left, above).

imaginary straight lines meet: a vertical one from the middle points of the upper and lower orbital margins and a horizontal one, joining the internal and the external corners. From a lateral view, the eyeball must not jut outside of the line joining the orbit upper and lower edges. Another important feature is the shape of the eye, affected by the palpebral ligament inside the orbit (Steward, 1983). The nose represents the most critical area of the facial reconstruction process. Scarce research and extreme individual variability make it very difficult to be scientific. Nonetheless, it is possible to have a good idea of the general aspect according to simple anatomical rules. Nasal bone inclination, height and width of the pyriform opening, together with anthropological data, give important guidelines. Inclination of the lower third of the nasal bones gives information about nose curvature: in a broad sense, the more horizontal the bone, the more "curved" is the nose, i.e., it will have a "hump"; the more vertical the bone is, the flatter the nose. In the present case, such general rules were followed.

Concerning the mouth, information given by the skull is scarce in general. In the lateral view, George's two-dimensional reconstruction becomes fundamental. In frontal view, width of the *rima oris* may be deduced from the distance between the canines, which in our case were available (Fig. 3). The ears have no external bony structure to give an indication of their shape and dimension. They were therefore reproduced subjectively in plastiline and positioned adjacent to the acoustic meatus. Once the reconstruction of all deep layers was completed, the final surface layer, which corresponds to the skin of the face, was modeled (Fig. 4).

The morphologic analysis of skeletal segments was performed by gross examination, conventional radiography, and contact microradiography. The skull, the femur, the right temporal bone, and the mandible were photographed in different projections before choosing radiographic orientation. For contact microradiograph, samples from the femur and left temporal bone were used. Transverse sections (100-200 micron thick) were obtained from the femur diaphyseal region by means of a microtome equipped with a rotating diamond knife (Leica, Germany). Sections of the same thickness were also produced by the bone overgrowth detected over the petrous part of the right temporal bone (see below) after plastic embedding. Contact microradiographs were prepared using an X-ray generator (XRG3000; Ital Structures, Riva del Garda, Italy), operating at 12 kV and 20 mA for 15 min, and high-resolution film (Eastman Kodak Co.). Films were developed in Kodak D-19, after fixation and washing were observed with Zeiss Axiophot microscope.

Results.

Facial reconstruction and gross and radiographic analysis of available skeletal segments provided interesting information about the subject's physiognomy and bone pathology.

The most impressive finding detected by examination of reconstructed face was the existence of a mild asymmetry between the left and right sides (Fig. 4). This asymmetry was reflected in a significant flattening of the forehead and naso-labial sulci. In particular, right naso-labial sulcus was almost completely missing.

From the analysis of available skeletal segments, the most interesting finding was observed in the inner surface of the left temporal bone where a prominent esophytic hyperostosis (exostosis), 2.3 cm in maximum size, was detected (Fig. 5 and 6). Considering the limitation of the available sample, the exostosis appeared topographically to involve the area of the temporal bone, where the base of the pars petrosa and the internal surfaces of the squama and mastoid portion are fused. As a result, the petrous-squamous suture was not recognizable. The inner surface of the squama presented multiple digital-like impression of the brain. The bony overgrowth did not involve the inner surface of the mastoid portion. The sigmoid sulcus was easily recognizable. Before the bone overgrowth was excised from the specimen, radiographic analysis was performed and revealed apparent enlargement of mastoid cells. After the excision, which was performed gently by a rotating saw, the inner surface of the temporal bone revealed a complex system of regular tunnel-shaped spaces (Fig. 6), which we suppose included, at least in part, vascular structures. Gross examination of the excised exostosis revealed smooth and well defined edges consistent with a slow-growing lesion. Contact microradiographs performed on sections obtained from the lesion

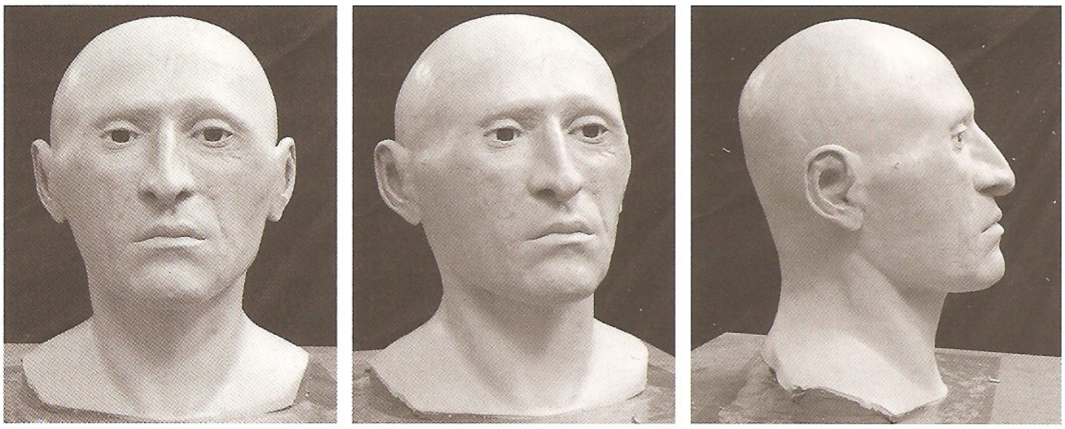


Figure 4. Facial reconstruction, completed by the placement of the cutaneous layer.

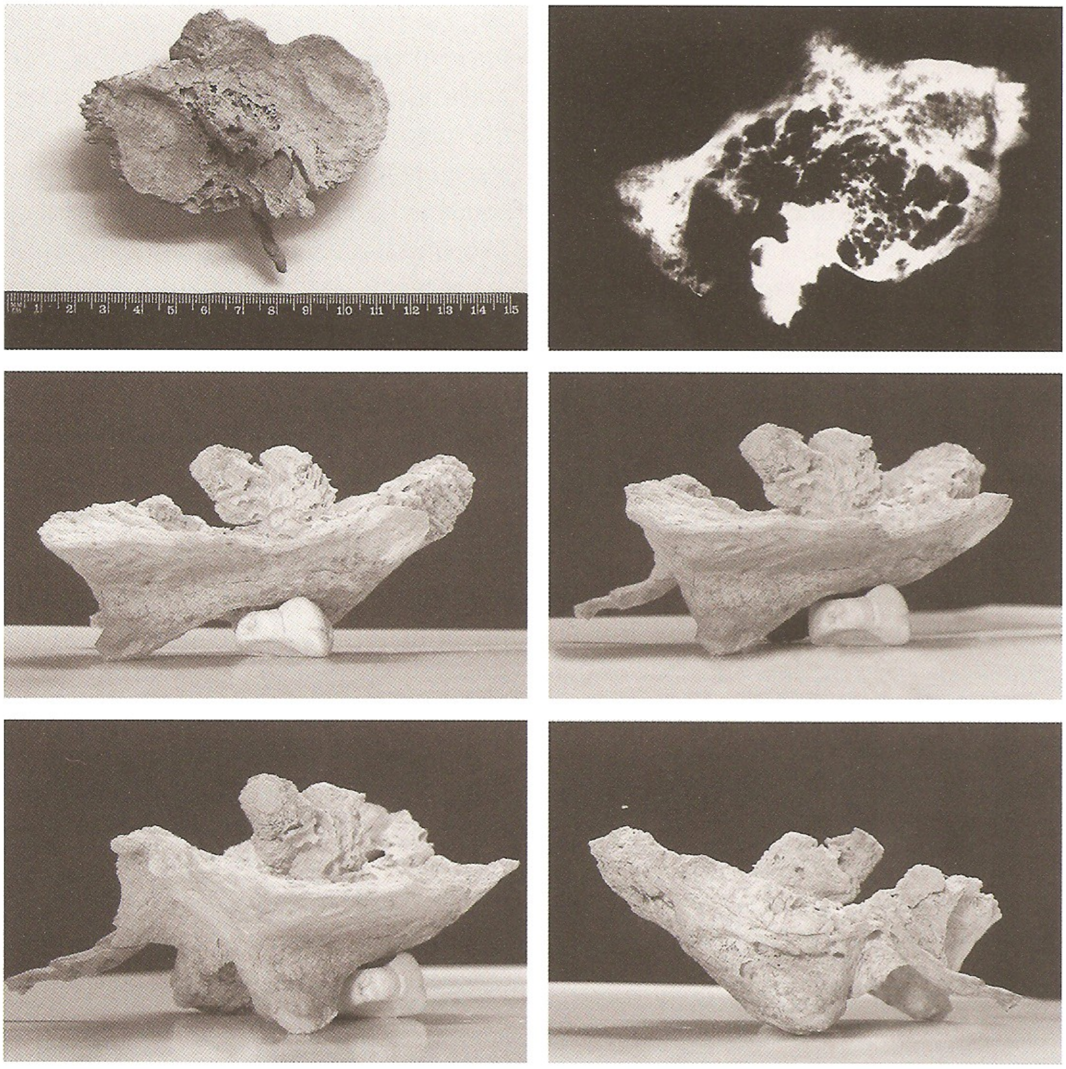


Figure 5. The right and left top panels, respectively, show a complete view of the internal surface of the left temporal bone and its radiograph. The middle and bottom panels show the exophytic hyperotosis from different sides.

after plastic embedding revealed the compact structure of the newly formed bone, which showed a variable degree of mineralization and delimited huge and regular soft tissue spaces. These spaces were thought to be continuous with the tunnel-shaped spaces observed in the inner surface of the temporal bone.

The examination of other available skeletal segments revealed additional interesting findings. The femur (Fig. 7) showed mild symmetric cortical thickening in the absence of significant bowing or detectable focal lesions. Both

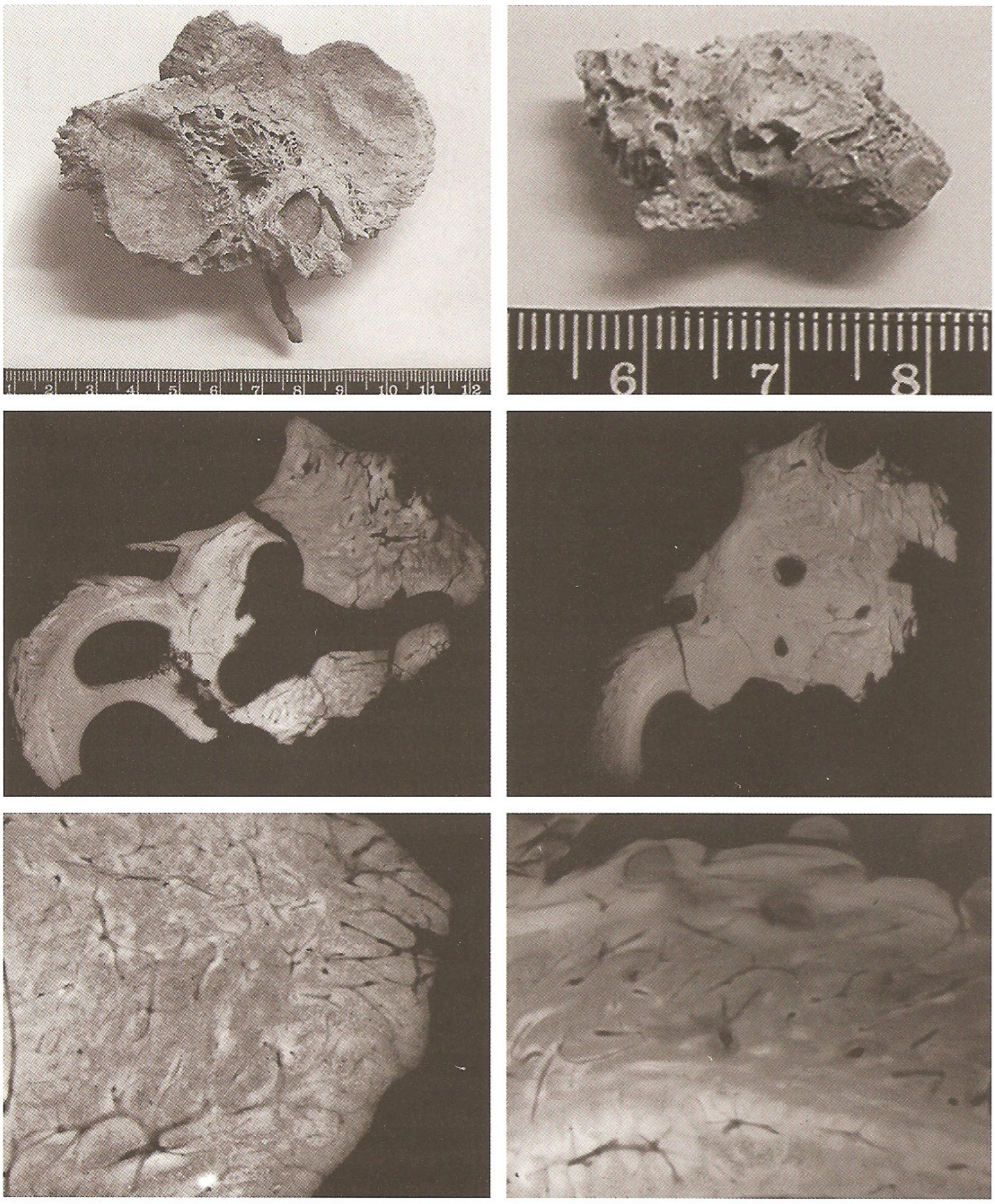


Figure 6. A whole mount view of the internal surface of the left temporal bone after the excision of the exophytic hyperotosis is illustrated in the right top panel. A complex system of regular tunnel-shaped spaces is evident. The left top panel illustrates the exophytic hyperostosis. Middle and bottom panels illustrate contact microradiographic images showing the compact structure and the variable degree of mineralization of the exophytic hyperostosis in which regular soft tissue spaces are evident.

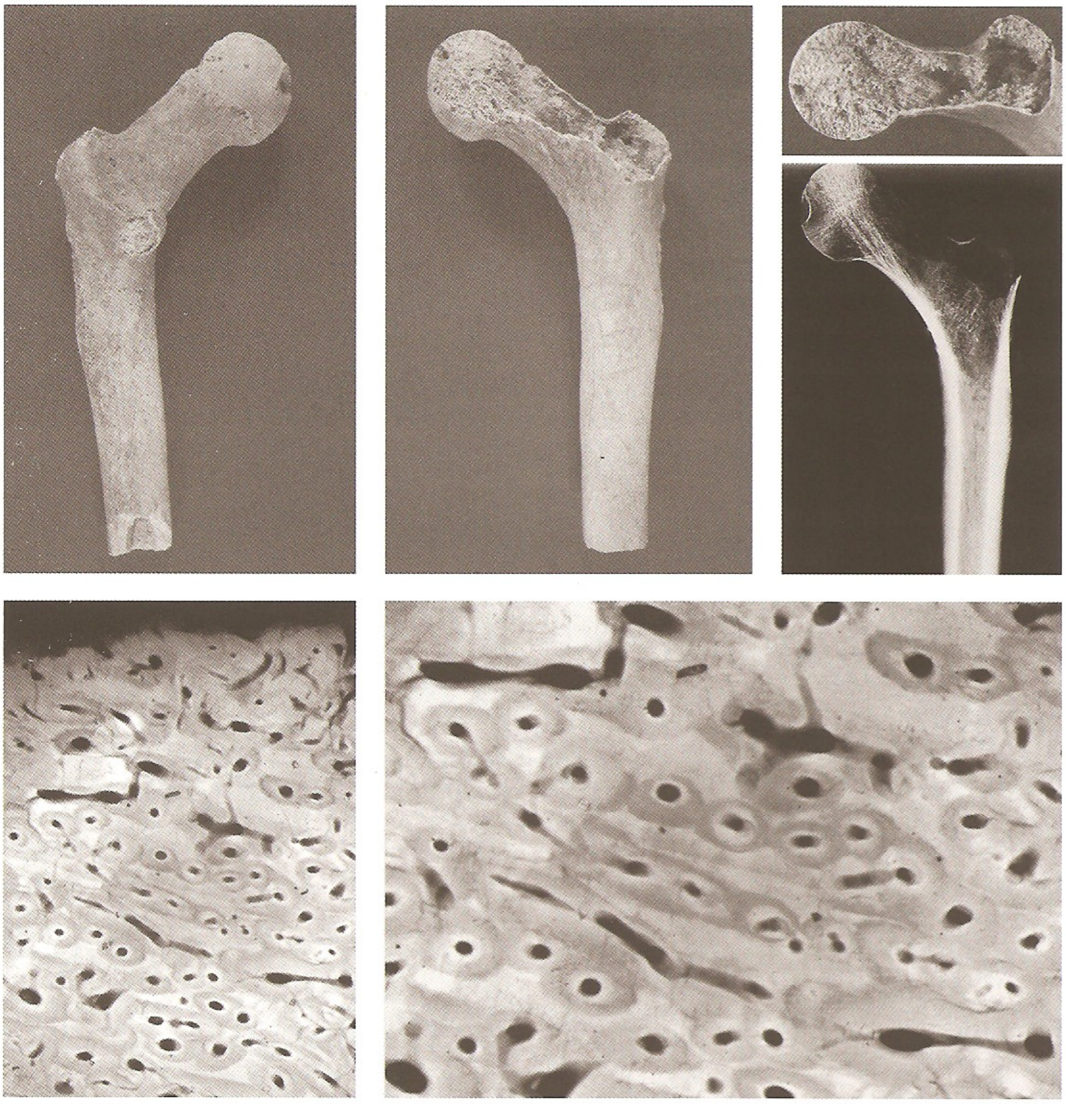


Figure 7. Top panels illustrate the anterior and posterior surfaces, the neck, and the radiograph of the part of the femur available for analysis. The radiograph shows a mild symmetric cortical thickening in the absence of significant bowing or focal lesions. Bottom panels illustrate contact microradiographic images obtained from the diaphyseal cortical bone. Properly formed osteons with variable degree of mineralization are evident.

greater and smaller trochanters were missing. A small cystic defect was evident in the subchondral region. By radiographic analysis, bone trabeculae appeared anisotropic, i.e., they were not randomly arranged in space but arranged around the lines of stress typical of upright posture (Jee, 1988). Microradiographic analysis performed on a transverse section through the diaphyseal compact bone revealed properly formed osteons with variable degrees of mineralization. In the mandible, reduction of bone density was observed in the premolar and molar region of the right side (Fig. 8). Examination of the skull revealed two additional findings. The right temporal bone showed enlargement of mastoid cavities and two wormian bones were identified within the right lambdoid suture (Fig. 9).

Discussion.

Recovering complete and well-preserved skeletal material from archaeological sites is often difficult. However, from available material we were able to produce a facial reconstruction and to identify a local cranial pathology evidenced by an exostosis in the inner left temporal bone.

The scientific value of facial reconstruction is extremely hard to establish. In particular, critical anatomical structures, such as nose, mouth and ear, are not easily reconstructible. As these structures are important for factual appearance and balance among facial structures, the flattening of the forehead and naso-labial sulci cannot definitely be established.

In contrast, analysis of the left temporal bone clearly shows a local inner bone

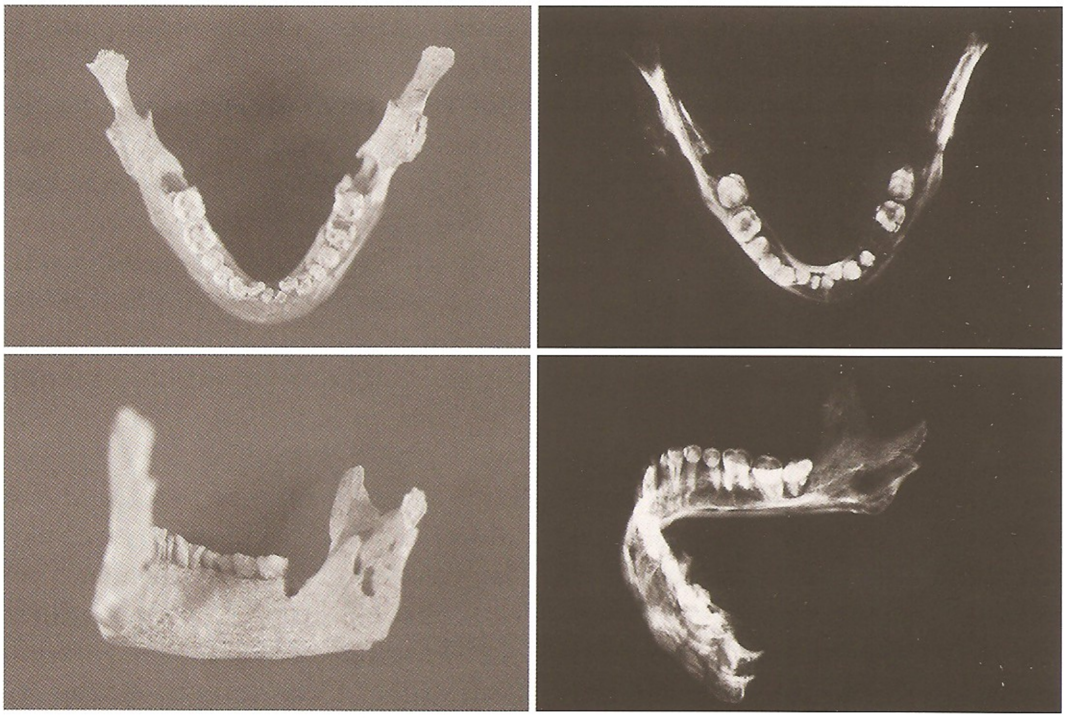


Figure 8. Gross and radiographic images of the mandible are illustrated in the right and left panels, respectively. A reduction of the bone density is evident in the premolar and molar region of the right side.

exostosis. This change, a characteristic trait of bone tissue behavior, may be observed in a long list of conditions including infectious disease, circulatory disorders, healing process after fracture, and primitive bone tumors or tumor-like lesions (Schultz, 2001). Based on the location and the microradiographic findings, which revealed dense and compact newly formed bone (within which huge soft tissue spaces suggestive of a regional high degree of vascularization were observed), we limited the differential diagnosis to osteosarcoma and secondary hyperostotic change to a local meningioma. We think that the diagnosis of osteosarcoma in our sample is very unlikely, for two main reasons: because it is uncommonly so heavily ossified and, more important, it rarely involves cranial bones. Gross examination and contact microradiography also revealed smooth and well defined edges of exostosis, a feature consistent with chronic and slow-growing lesions. For these reasons, we considered exostosis a secondary hyperostotic reaction to a local meningioma. The estimated age of the subject, 40-50 years, supports our hypothesis of meningioma, almost exclusively observed in adulthood (Campillo, 1991). However, gender and location seem to contradict our hypothesis. In fact, meningioma are more common in females than in males and rarely occur in the temporal region, the vault of the skull and the orbital region being the most commonly involved areas (Campillo. 1991; Vrionis & al., 1999; Campillo, 2005). For obvious reasons, we cannot establish the clinical manifestations associated with the lesion presented here. Temporal bone meningioma has been associated to hearing loss (about 70% of the cases), tinnitus (about 50%), headaches (40%), dysphagia, dizziness and otalgia (about 20%), unsteady gait, seizures and fullness of the ear (about 15%) and otorrea (about 10%) (Vrionis & al., 1999). Hence, it is possible only to speculate that one or more of these clinical manifestations were present in our case.

Meningiomas represent about 20% of primary endocranial tumors. In paleopathology, reported cases are few in number. In his personal experience, Campillo (1991) reported five suspected cases of meningioma among 3000 examined skulls. Probably, the most ancient is the one described by Lumley and Piveteau in a parietal bone from an infant *Homo erectus* of about 10 years of age found in the "Le Lazaret" cave in Nice, which has been estimated to be 200,000 years old (Lumley & Piveteau, 1969). About 20% of meningiomas are associated with variable bone changes and these changes, even though not pathognomonic, are considered the most important criteria for the recognition of a meningioma in paleopathological samples (Campillo, 1991). These bone changes are so heterogeneous that eight categories ranging from the absence of skeletal involvement to variable degrees of either osteosclerosis or osteolysis have been distinguished (Campillo, 1991). Based on this classification, our case fits well in the category of the so-called "meningioma that gives rise to thickening of the bone appearing as exostosis" (Campillo, 1991). Most of the paleopathological cases classified as meningioma have been identified on the evidence of bone hyperostosis of variable shape and size such as those from Paucarcancha in Peru reported by MacCurdy (1923), that from Helouan in upper Egypt reported by Rogers (1949), and that from medieval Rochester in Great Britain reported by Anderson (1992). However, all these cases and our case as well have to be considered as exceptional because thickening of the bone appearing as exostosis is not the most frequent lesion associated with a meningioma (Campillo, 1991). The mechanism by which a meningioma may lead to a local hyperostosis is still not clarified (Min & al., 2005). Many mechanisms have been proposed including prior trauma, vascular disturbance, stimulation of normal osteoblasts by humoral factors secreted by neoplastic cells and formation of bone by neoplastic cells themselves (Pieper & al., 1999; Akutsu & al., 2004; Min & al., 2005). However, when bone is directly invaded by meningiomatous tumor cells, hyperostosis occurs more frequently (Min & al., 2005). This view, strongly supported by evidence that bone hyperostosis occurs in more than 60% of intraosseous meningiomas (Crawford & al., 1995), suggests that localization of meningioma cells within the bone/bone marrow microenvironment is the main determinant of meningioma-associated hyperostosis. Obviously, in our sample, if it is speculative to assess that the hyperostosis was the consequence of a meningioma, it is absolutely impossible to demonstrate the existence of local bone invasion as the leading mechanism of hyperostosis because of the processes of autolysis and decomposition naturally involving soft tissues of paleopathological samples.

On the changes observed in the other skeletal segments, it is hard to establish if the mandible bone rarefaction is due to local bone loss or diagenesis (Schultz, 2001). In contrast, it seems reasonable to suspect that unsteady gait occurred, as suggested by the evidence of a small cyst within the subchondral bone (possibly a geode) and by the thickening of the cortical bone of the femur. Whether these putative gait abnormalities were the result of the temporal meningioma or of other conditions cannot be definitely established. However, unsteady gait has been reported in association with temporal meningioma (Vrionis & al., 1995). Regarding the presence of the two wormian bones in the right lambdoid suture, previously published paleopathological studies associated

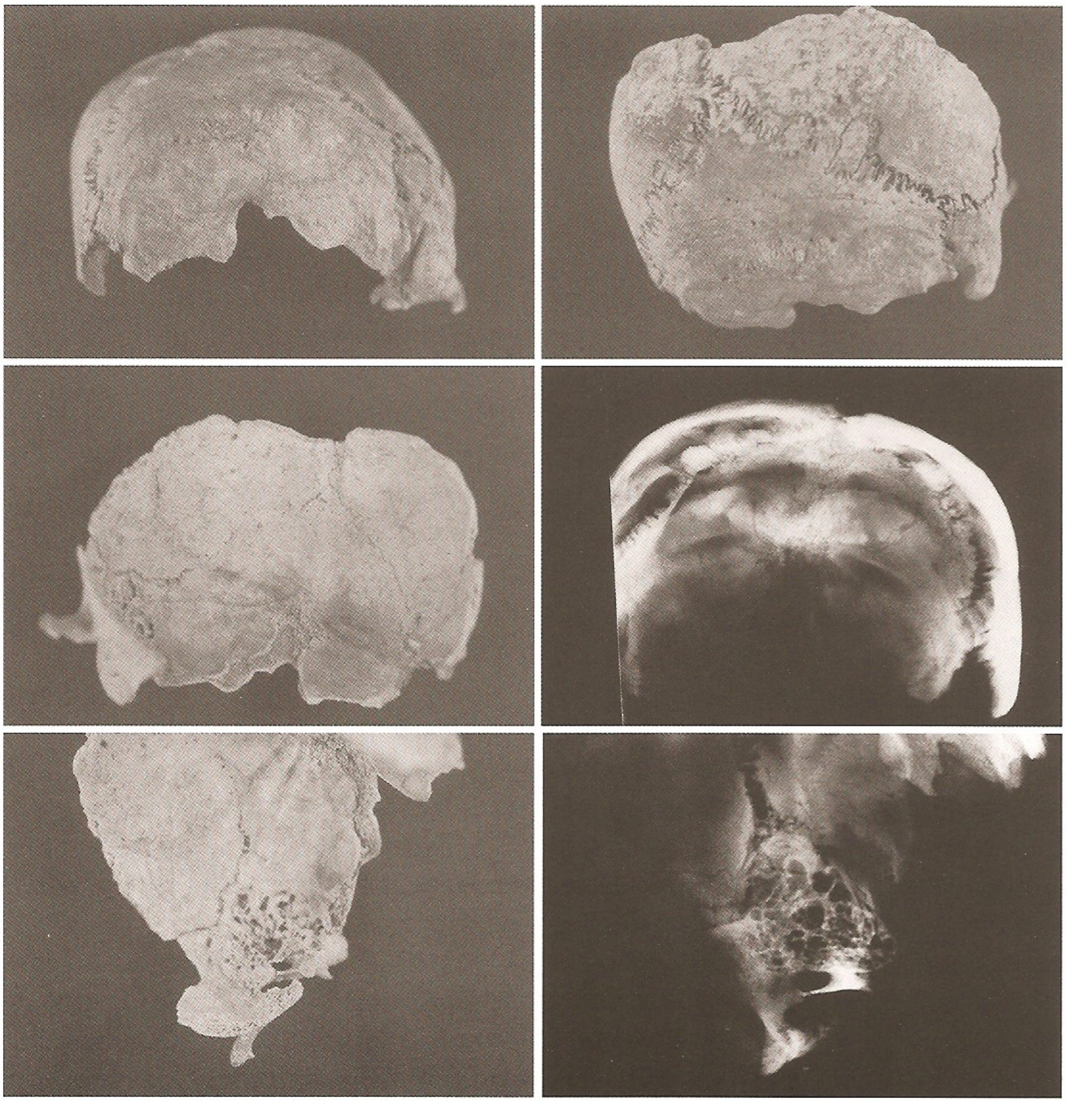


Figure 9. The posterior side of the available portion of the skull is illustrated in the top panels. Two wormian bones are evident within the right lambdoid suture. The inner surface of the skull and the radiograph of the sample are shown in the right and left middle panels, respectively. Right and left bottom panels illustrate the gross and radiographic details of the enlarged right mastoid cavities.

the process of "cultural cranial deformation" with a significantly greater frequency of lambdoid ossicles (Sullivan, 1922; O'Loughlin, 2004), suggesting that environmental forces play a role in their development. The reasons for modifying cranium shape were varied and sometimes culture-specific, as in Pre-Columbian cultures where individuals with deformed skulls were viewed

as more brave, powerful and good looking (O'Loughlin, 2004). However, it must be noted that it is common to see "ranges" of cranial deformation within and among cultures (O'Loughlin, 2004). Some individuals may have had slight cranial deformation, whereas others had more marked deformation. The length of time the deforming apparatus was applied, how tightly the apparatus fit, and the reasons for modifying skull shape contributes to the existence of a "wide range of deformation."
However it must be stressed that in the area where the burial was found in Northern Peru, there is a complete lack of cranial deformation in burials of all periods. Moreover, in Spanish chronicles on native habits and in Inca records of ethnic communities of the area, there is no reference to this cultural habit, whilst others are well documented (Polia, 1995). Thus, the assertion that the wormian bones in our case are the result of this cultural factor must await further archeological and paleopathological studies.

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