

A Computed Tomography and Dissection Study of a Unique Ychsma Burial Bundle from the site of Pachacamac, Peruvian Central Coast

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Research Article

Keywords:

Posted Date: January 19th, 2023

DOI: <https://doi.org/10.21203/rs.3.rs-2447960/v1>

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Additional Declarations: No competing interests reported.

Abstract

Computed tomography (CT) scans of funerary bundles have become the convention for mummy studies, especially in Andean contexts. Increasingly high-resolution 3D imaging – as well as ethical issues surrounding the treatment of human remains, has led to the increasing conviction that mummy studies should be carried out using solely digital approaches. However, the fact that these approaches are non-invasive inevitably stymies our understanding of how accurate they are, compared to traditional unwrapping. A large, complex Ychsma bundle (dated to AD1020-1150) was recovered from Pachacamac, Peru, in 2018, and was analysed using a dual approach. A series of CT images were scored for bundle structure, body position, element presence, and anatomy/pathology; the bundle was then dissected and the data was compared. CT imaging performed well for body position, element presence and certain aspects of anatomy/pathology. However, the presence of radio-opaque inclusions following the internal deterioration in antiquity served to obscure various elements, while the CT was also unable to distinguish any of the layers of textile and botanical wrappings or any artefacts within them. The CT was also unable to determine that the bundle contained two individuals; the original individual had been partially removed and other elements incorporated, but as there was no element duplication the CT imaging could not differentiate the individuals. In addition to providing new information concerning bundle reprocessing and the use of trophy items among the Ychsma, this is both a support and cautionary tale towards the use of radiographic imaging in the analysis of Andean bundles.

Introduction

Ancient Andean attitudes towards the deceased and the importance of the roles that human remains played in the realm of the living have prioritised mortuary analysis and bioarchaeology (Eeckhout and Owens, 2015; Owens and Eeckhout, 2015a). However, while detailed analyses of burial bundle morphology and structure are key to Andean bioarchaeological research, coverage has somewhat been uneven. The mortuary behaviour of the Ychsma (c. AD 1000–1476) is understudied compared to that of groups such as the Moche, Nasca and Paracas, but is central to an understanding of cultural transitions on the Central Coast, up to and including the Tahuantinsuyu (i.e., Inka) expansion. Large, well-preserved Ychsma funerary bundles are a rarity and require well-conceived research protocols. The discovery of a unique yet damaged funerary bundle at Pachacamac in 2018 prompted a collaborative CT and dissection study; as the mummy could not be preserved, the CT results could be checked against the dissection data, thus testing the former's utility in mummy analysis, and adding important new data to current discussions of Ychsma mortuary behaviour.

Analytical Approaches To Mummies And Funerary Bundles

Mummy studies have benefitted extensively from the development of medical imaging technology. Radiography was first used on Egyptian mummies in 1896 (Koenig, 1896; Lynnerup & Rühli 2015), while the development of CT scans in the 1970s permitted 3D visualization and a better understanding of spatial relationships between skeletal and cultural elements within the bundles (Brier et al., 2015; Cox 2015; Lewin & Harwood-Nash, 1977; Piombino-Mascoli et al., 2015; Villa et al., 2015). Ongoing refinement has permitted the development of facial reconstruction, the mapping of soft tissue deterioration, the planning of dissection protocols, assessment of mummification methods, demographic profiling, palaeopathological assessment and virtual reconstruction of dismembered bodies (Boyd et al. 2015; Chapman et al., 2020; Peter Eeckhout, 1999a; Fantini et al., 2005; Friedrich et al., 2010; Fritsch et al. 2015; Lindsay et al., 2015; Lynnerup, 2015; Oh et al., 2015; Previgliano et al., 2003; Seiler & Rühli 2015; Sutherland et al., 2014; Sydler et al., 2015; Thompson et al., 2014; Wade et al., 2015).

CT is something of a gold standard, owing to the high degree of precision it allows, and because of its non-invasive and non-destructive nature (Jackowski et al., 2008). However, while the technological advantages are unarguable, CT approaches are not without their detractors. Projects are often anecdotal rather than populational and often fail to socially contextualise their findings (Cox, 2015; O'Brien et al., 2009). There are often financial strictures in place, as CT technology is usually only available as a charitable act by medical institutions and may not be available at all in developing nations. Even in cases where the quantity of images permits a populational approach, lack of protocol standardisation and erratic results dissemination have seriously hampered CT's potential in bioarchaeological studies (Cox, 2015). Finally, CT approaches are often carried out by medical staff and reflect their interest in pathological data rather than the cultural information sought by archaeologists. The physical nature of mummified material also differs significantly from living tissue, making diagnoses by CT-Scan less than reliable if not inaccurate (Cox, 2015). CT specialists are likely to understate the importance of bundles' cultural context (i.e., findspot, temporospatial position and funerary/demographic correlates), which is reduced to a few general and superficial points that do not reflect the idiomatically complex cultural ambient to which the remains belong.

Recent work by Sutherland (2019) on a Ychsma bundle highlights these issues, for while the anatomical data is excellent, the bundle cannot be placed into the Ychsma temporospatial framework owing to the lack of cultural background and populational comparisons. The study of grave goods detected inside bundles is also reliant upon archaeological – not medical – specialists (i.e., Watson et al., 2019). For all the foregoing reasons, therefore, bioarchaeologists tend to rely upon the dissection and unwrapping of bundles, an approach which has been utilized by Andeanists to great effect (Diaz Arriola, 2015; Eeckhout, 2012; 1999a; 2002; Flores, 2013; Frame et al., 2004, 2012; Frame & Falcón, 2014; Kauffmann-Doig, 1994; Mendoza, 1983; Paul, 1990; Ravines et al., 1976; Ruiz, 1991; Tello & Xesspe, 1979; Valladolid, 2000). However, unwrapping mummies has always been associated with showmanship rather than with academia and has become increasingly unpopular, given the irreversible damage done to the specimen, the difficulty in accurately recording spatial relationships between elements and inclusions, and the lack of conventions for scoring such information. Further, this approach can never be used on institutional collections or elite (or well-preserved) bundles, as museums and other institutions will always prioritise curatorship and preservation over destructive investigation. Finally, the destruction of what essentially comprises an intact funerary context also raises ethical issues (Kreissl Lonfat et al., 2015).

With a dwindling number of ancient mummies available for study – and even fewer that can be dissected – we need to be certain that CT scanning is a valid *locum tenens* for dissection and performs as well for cultural as for anatomical observations. To assess this, bundle E300 was selected, owing to its large size and apparent complexity – providing a challenge for the CT scanning – while also being so structurally unstable that it could not be conserved in the long

term. It would therefore be possible to dissect the bundle and test the accuracy of the CT imaging of anatomical and cultural phenomena. The unique morphology of the bundle also promised to provide further information about Ychsma burial traditions.

Site Background

Pachacamac is a large multi-period coastal site situated near the mouth of the Lurín River on Peru's Central Coast (Fig. 1). It was founded in around AD 200 (Early Intermediate Period) by the Lima polity (Earle, 1972; Patterson, 1973; Shimada, 2007), with biological continuity into subsequent periods (Vlemincq-Mendieta et al., 2019). The Ychsma resculpted the site towards the end of the Late Intermediate Period (AD 1000–1476), with a series of distinctive dynastic buildings – Pyramids with Ramps – being constructed in the 13th–15th centuries AD (Eeckhout & Lujan, 2022; Eeckhout, 2013a; Michczinsky et al., 2007; Michczyński et al., 2003). The site's invasion by Topa Inka Yupanqui's forces around AD1470 led to further site remodelling (including an Acllahuasi [temple of the chosen women] and a Sun Temple), and widespread promotion of the oracle that became one of the most renowned in the Americas and a destination for long-distance religious pilgrimage (Eeckhout, 2013b; Patterson, 1983; Rostworowski de Diez Canseco, 1992). The Spanish moved the Pachacamac population to the Rimac valley (the site of modern Lima) in 1533, although European settlement appears to have continued at the site (Praet et al., 2017).

Ychsma Burial Practices

Ychsma interments have been recovered from an ever-increasing number of burial sites, notably including Pachacamac, La Rinconada, Armatambo, Puruchuco/Huaquerones, 22nd October Cemetery, Huaca San Pedro, Conde de la Torre and Pampa de Flores. The Ychsma are also known for reworking and reusing older cemeteries, such as Huallamarca, Huaca Pucllana and Huaca Bellavista. Ychsma interments are more known for their variability than their consistency. They tend to be simple pit burials but are sometimes segmented, and/or covered with flat wood or reed roofs. Pit size and burial occupancy vary from 1 to 130, with architectural segmentation into separate chambers; however, the standard size is between 3 to 8 individuals, often arranged in a core/periphery format (Díaz Arriola, 2015). The bodies are usually tied into tightly flexed/crouched sitting positions with the arms wrapped around (or tucked behind) the legs, although extended and erratically posed burials have been reported for children and non-normative interments (Eeckhout & Owens, 2008). Orientations vary considerably, with a tendency towards the E-W axis at Pachacamac, Huaca Santa Cruz and La Rinconada 12, while burials at the 22nd October cemetery are suggested to have been oriented south, arguably towards Pachacamac (Díaz Arriola, 2015; Díaz Arriola & Vallejo 2004; Eeckhout, 1999b; Eeckhout and Owens, 2008).

Ychsma bundle construction and complexity vary between the sexes, and age groups for reasons that are currently unclear (see below). Most have an external textile wrapping; in the simplest burials – especially those of neonates and infants – there are no further layers. In larger and more complex bundles, the external layer is bound in place transversely and longitudinally with reed straps and cordage. This can overlie up to 9 layers of textile, raw cotton, crushed reeds, and reed matting. Textiles are often composed of several conjoined pieces and are also sewn to underlying layers. Textiles are coarser (open weave – beige and white) nearer the external surface, with more refined exemplars (fine weave – beige, brown and blue) nearer the body. Larger burials often have 1 to 4 thick reeds/sticks defining their long axis. Díaz Arriola has suggested that these comprise a status indicator for the Ychsma (Díaz Arriola, 2015; Díaz Arriola & Vallejo 2004), although others have found that – in Pachacamac at least – there is little age, sex or status patterning in the distribution of these pieces, other than being more common in adult burials (Díaz Arriola, 2015; Eeckhout & Owens, 2021a).

The bodies are sometimes supported by pillows and/or cotton pads, or partially contained in textile bags. The bodies are often decorated with red pigment – probably cinnabar – on the hands, faces and heads, and can be dressed in loincloths and uncus[3] (males), tunics (females) and poncho-like garments made from camelid hair. The earlier (Middle Horizon) tradition of wooden, cloth or ceramic false heads inserted into the bundles continues in the Ychsma, often with inlaid, staring eyes and painted with ochre/cinnabar; their function appears to be connected with ancestor worship (Eeckhout, 2020b). Grave goods are both *pars pro toto* among the interments, grouped over/around/under individuals, and – for smaller items – concealed within the wrappings or on the body itself. Grave goods include textile bands and panels, slings, hand-wraps, single/multiple strands *nectandra*[4] seed necklaces, *spondylus*[5] shells, guinea pig bones, bird bones, camelid bones, feathers, *spondylus* jewellery, copper/silver alloy jewellery and fragments, *tupus* (hairpins), bone tools, loose seeds, metal tweezers, wooden scales, strips of metal, woven rush containers, polished stones, human hair (from individuals other than the interred; often dyed with cinnabar [also see Eeckhout, 1999], spindles and thread spools (with female burials), maize cobs, cotton strands, roots, woven hair packets, gourds, plain/fancy ceramics, and possibly umbilical cords.

Certain demographic/funerary correlations have been noted (Owens & Eeckhout, 2015b). Body treatment and grave goods tend to be more flamboyant in older individuals, especially males, who were usually the central figure in core/periphery burial contexts (see above). Peripheral burials tend to be less ornate, mostly comprising younger individuals, females and subadults. The notion of an androcentric gerontocracy is supported by the fact that older individuals (especially males) had more grave goods, whereas children had less. There is little consistency in subadult burials, which were often deposited haphazardly; mounded over the heads of adults, placed on the roofs of burial contexts, and even in Y-supports of tomb structures. This has led to the suggestion that subadults were interred with adults as grave goods in their own right (Eeckhout & Owens, 2021b; 2008; Owens & Eeckhout, 2015b), while Takigami et al. (2014, p. 323) have used the patterning of burials to suggest a dynastic burial system as found at the Paracas site of Wari Kayan.

The accessible nature of many Ychsma tombs poses the possibility that the dead played an active role in the land of the living as seen in various other Andean groups (Eeckhout & Owens, 2015). Investigating this has been hindered by the mixing of burials in multiple contexts – especially in individuals with poor or absent wrappings – although recent work by Owens and Davies-Barrett (2019) and a previous study (Takigami et al., 2014) suggests that skeletal elements were harvested when the bodies were shuffled, removed, rewrapped and redeposited. Regularly absent elements – especially skulls – have also been noted in a further radiographic study by Motley et al., (2021). The purpose of this is uncertain, given that harvested human remains have never been found in a context suggesting ritual or adornment. One notable exception is the inclusion of a human hemi-pelvis in the wall of ritual building B15 (location on Fig. 2), tentatively linked to an adolescent individual (E272) recovered from one of the building's rooms (Peter Eeckhout, 2020a).

[3] A long cotton shirt with sleeves, sometimes decorated with coloured embroidery

[4] Lauracea sp.; the dried seeds possess analgesic, sedative, psychotropic and anticoagulant properties

[5] *Spondylus sp.* – the thorny oyster

Recovery Of Burial Bundle E300

The bundle was located within layer 4 of Feature 239, a cylindrical pit measuring 120cm in width, 85cm deep and 160cm in length, roofed with bundles of reeds – tied with fibre bands – oriented from east to west (Fig. 3). The reeds were lodged in the surrounding sediment to cover the pit; there was no wall construction. The roof was partly supported by a large piece of wood around 85cm in height and 6cm in diameter, running vertically with the bundle's long axis. The burial was associated with ten grave goods, including eight gourds, a fan shell[6] and a bundle of reeds (Fig. 4). The gourds were located around the base of the bundle to the N, E and SE, with some superimposition. No ceramic vessels were associated with the bundle, although the fill contained a bottleneck tentatively dated to the Lima period (c. AD 100-650). This was later found to be intrusive (see below).

[6] *Argopecten purpuratos*

General Description

The bundle was an antero-posteriorly flattened cylinder in overall shape, measuring 75cm tall and 60cm wide (max). There had been internal slippage and slumping, as two ribs and the underside of the skull were visible on the bundle's surface: their orientation indicates that the body was facing the SE. The chamber in which it was found, and the accompanying posts were 85cm tall, probably the bundles' original height pre-collapse. While the breadth was consistent from base to apex, the bundle tapered antero-posteriorly from the base (29cm) to the top (42cm). Weight was estimated at between 20-25kg, including several large stones located in the base: we know of no precedent for this in Ychsma bundles. The exterior was comprised of numerous very fragile and deteriorated ropes and straps made from vegetal fibres. The context was completely sealed and isolated from any other burials, thus confirming that nothing had been overlooked and that anything missing had been absent when the bundle was interred. The bundle was photographed, drawn, and recorded *in situ*, and was then lifted intact and transported to the laboratory for further analysis.

Dating

AMS dating on a fragment of a gourd (grave good #1: see below) provided a date range of AD 1020-1150[7] and thus pertaining to the Early Ychsma horizon as seen elsewhere in the same site sector (10-13th c. (Eeckhout, 2017; 2020b). This also demonstrates that the Lima ceramic fragment was intrusive and was likely already in the sediments when the bundle was inhumed.

CT Study: Approaches and Methods

Bundle integrity was poor, with contents slippage inferiorly and longitudinal splits superolaterally. The large stones that had been used to weigh the base caused further damage and were removed, the cavity being stabilised with packing materials. It was decided to undertake a radiographic assessment to determine whether it was a reasonable prospect for long-term storage. It was transported to AUNA's Clinica Delgado in Miraflores, where tomographic acquisition was carried out using a GE Revolution EVO64 multislice spiral tomograph® – with an isovolumetric spatial resolution of 0.625mm – by radiologist Dr Miguel Trelles. A full 3D visualisation of the bundle was uploaded into RadiAnt® DiCom Viewer[8] and manipulated to provide a series of informative views of which screenshots were taken. The scans confirmed that the bundle could not be preserved long-term.

Body Part Representation

The CT images revealed densely packed organic materials that blocked the visibility of bony elements, while trabecular-rich or very thin bones were essentially invisible (Fig. 5). The remains were in a crouched position, with major long bones roughly in position, but with the displacement of smaller elements. The left arm was not visible. The skull was visible, but not the mandible. The thorax had collapsed and most vertebrae (except a group of four connected lumbar) and ribs were missing or within the radio-opaque base section. There was no sign of the small bones of the hands and feet. Upon dissection, the skeleton was found to be missing six ribs[9], two cervical vertebrae, the mandible, the right scapula, the right humerus and most of the hand, and both clavicles. As none of these could be located elsewhere in this sealed and undisturbed context, it is apparent that these had been removed intentionally at some point before the final deposition took place. The opacity of the bundle base, therefore, prevented us from distinguishing between bones that had collapsed downwards from those that were lost/removed.

Body Position: CT

Initial observation of the CT scan in the anterior, posterior, left, and right demonstrates a partially disarticulated skeleton with parallel femora/tibiae, indicating a crouched sitting position. The left humerus had been flipped so that the proximal end was pointing downwards. The original positions of the skull and thorax had been lost. These findings were confirmed by dissection. Further details obtained through dissection included the fact that the fingers were extended, and that the right foot was crossed in front of (and above) the left foot. The general disorder of the remains suggests that the bundle was heavily disturbed in antiquity.

Internal Grave Goods

No grave goods or offerings could be identified in CT scans of the bundle. However, dissection revealed a total of 9 grave goods (15 individual items) that were either organic (and thus indistinguishable from the wrappings) or exceedingly small (and thus liable to have fallen into the radio-opaque base). See Table 1 for details. The stones that were used to weigh the bundle were deemed to be structural elements, rather than grave goods.

Table 1: Grave goods found inside E300 bundle.

Number	Description	Located	Layer
1	3 maize cobs	Right shoulder	2
2	3 ½ maize cobs	Left shoulder	2
3	Large maize cob	By right elbow	2
4	Maize cob	By left arm	4
5	Maize cob	Right side of the head	5
6	Maize cob	Uncertain (displaced)	Base
7	White shell bead	Inside mouth (palate)	-
8	2 <i>Spondylus</i> beads	Uncertain (displaced)	-
9	Maize cob	Below feet/pelvis	5

The following items were also recovered. They are unlikely to be intentionally deposited grave goods.

- A section of *Prisogaster niger* (abdominal area)
- Tiny marine shell fragments (Layer 2 and 5); species uncertain
- A single plain ceramic sherd (pelvic area)
- Several amphibian bone fragments (possibly *Bufo sp.*)

Two peanut shells; possibly displaced from vegetation layers 2/5.

[7] RICH-27622 (Ych18-E300): 997±25BP

Cal. 68.2% probability: 1030AD -1050AD (14.1%); 1080AD-1150AD (54.1%)

Cal. 95.4% probability: 1020AD-1150AD

[8] www.radiantviewer.com/

[9] Ribs 2, 3, 6 and 7 on the right side; ribs 2 and 10 on the left side.

Bundle Construction

Both textile and raw cotton were visible on the CT scans. Only standalone details were clear, such as textile pieces that were wrapped around the body, connecting the right forearm bones and the skull, around the skull itself, and another attached to the left distal femur (these were pieces of Layer 8 – see below). An organic mass was also detected inside the skull, probably the remnants of the brain/meninges. However, when the organic materials were massed together it was impossible to differentiate individual layers. Upon dissection, nine layers were detected and numbered from 1 (exterior) to 9 (adjacent to the remains). Not all layers were visible in all locales, although the head showed the most superimposition. The layers are summarised in Table 2. Upon dissection it was also noted that the fingers of the right hand had been looped with a cotton thread and that the pelvis had been filled with four large blocks of raw cotton. These did not stand out on the CT images; patches of preserved skin on the cranium, humeri, and scapula were also radiographically invisible.

Table 2: Bundle layers of E300

Layer	Description	Notes
1	Thick vegetal cordage wrapped horizontally	Bands 3 cm across
2	Leaves/twigs bundled together into a discrete layer	7cm thick
3	Thin vegetal cordage wrapped transversely & longitudinally	1cm across
4	Extremely fine cotton netting – highly degraded	Holes c. 1.5cm across
5	Leaves (a few twigs) densely packed into a discrete layer	12-13 cm thick
6	Thin ropes (round cross-section) tied around (5)	<1cm thick
7	Raw cotton with seeds – differential distribution	V. thick on the base
8	Plain cotton textile – close weave	Poorly preserved
9	Raw cotton with seeds	Sporadic

Demography 1: Sexing

The sex of E300 was ascertained by scoring the characteristics of the skull (glabella, mastoid processes, supraorbital torus/margins, bossing, suprameatal crest and nuchal eminence) and the pelvis (ischiopubic ramus, greater sciatic notch, preauricular sulcus and subpubic angle/concavity), using conventions laid out in Bass (2005), Buikstra and Ubelaker (Buikstra & Ubelaker, 1994), Krogman & İşcan (1986) and Phenice (1969). LSO and an independent researcher (ADB) separately scored these traits on the CT scans, and then on the dissected remains. The results are presented in Table 3.

Table 3: Sexing scoring for E300

Trait	CT		Dissection	
	LSO	ADB	LSO	ADB
Nuchal Eminence	Male	Male	Male	Male
Bossing	Male?	-	Male	-
Glabella	Male	? Male	? Male	Indeterminate
Superciliary Ridges	Male	? Male	? Male	Indeterminate
Suprameatal Crest	? Male	Male	? Male	? Male
Superior Temporal Line	? Male	-	Indeterminate	-
Mastoid Processes	Male	Male	Male	Male
Supraorbital Margins	? Male	? Male	? Male	Male
Greater Sciatic Notch	Male	Male	Male	Male
Preauricular Sulcus	Male	Male	Male	Male
Subpubic Angle	Male	Male	Male	Male
Ischiopubic Ramus	Male	Male	Male	Male
Subpubic Concavity	Male	Male	Male	Male

Of the 14 methods, 11 were used by both researchers, and of these, there was precise concordance in 7 [63.6%], and one degree of difference (i.e., between ? M–M, ?F–F, or ? to ? F/?M) in 4 [36.7%]. Once the bundle had been dissected, they were assessed again; dissected observation inter-observer concordance was 8/11 [72.7%], the remaining 3/11 [27.3%] being one degree different.

It is therefore apparent that slight inconsistencies of reporting may be expected more with CT images than when handling the materials directly, a fact also true of photographic images. Intra-observer CT/tactile concordance was therefore 7/11 (100%) for ADB and 12/13 (92.3%) for LSO; all non-matches were one degree different (i.e., between ?M–M, ?F–F or ? to ?F/?M. The highest concordance was between large bony trait structures (i.e., the greater sciatic notch) that were visible on CT images from almost any angle (Fig. 6). Traits that rely more on profile changes on a bone surface – such as the superciliary arches, or bossing – were hard to see, and thus more likely to be scored inconsistently. Pelvic traits were 100% consistently recorded in all cases by both researchers (5/5); cranial trait exact concordance was 33% (ADB 3/6) to 50% (LSO 4/8). While there was only one degree of difference between each non-matched observation, this has obvious implications for more ambiguous individuals for which no strong traits can be observed (see Chapman et al., 2020).

Demography 2: Ageing

Standard methods were employed to ascertain age, including bone development, epiphyseal fusion, dental development/eruption, pubic symphysis, auricular surface, cranial suture closure and dental wear Brooks & Suchey (1990); Buikstra & Ubelaker (1994); Lovejoy et al., (1985); Schaefer et al., (2009). These results are presented in Table 4.

Table 4: Age scoring for E300

Trait	CT	Dissection		Age	
	LSO	ADB	LSO	ADB	
Pubic Symphysis	-	-	3-4	3	Young-Middle Adult (20-49)
Auricular Surface	-	-	3	2	Young Adult (20-34)
Dental Development	21+	21+	21+	21+	Adult (21+)
Bone Fusion	17+	17+	17+	17+	Adult (17+)
Dental Wear	40-50[10]	40+	40-50+	40+	Middle - Older Adult (40+)
Cranial Sutures	35-50+	? [11]	35-50+	-	Middle - Older Adult (35+)

There was 100% inter-observer concordance and between CT and dissection data. The individual was adult based on the fully erupted dentition and fused epiphyses, although many of these (i.e., distal femur/proximal tibia) could not be seen on CT images owing to their high trabecular content. Symphyseal and auricular ageing methods could not be used on CT images. While some cranial sutures were visible, it was impossible to differentiate between fully open (<34) and ectocranially fused (>50). High levels of AMTL precluded dental wear scoring, although extensive AMTL is loosely indicative of an older age.

Anatomy: Cranial Non-Metric Traits

General points concerning the skull's tabular form – notably the deformed occipital, flattened frontal and bulging parietals – were noted and confirmed by both researchers. The CT images of the skull were then scored for selected non-metric traits. Dental traits could not be scored owing to the extreme levels of wear. Nineteen cranial traits were scored: nine ossicular traits (asterionic, occipitomastoid, lambdoid, sagittal, bregmatic, lambda and coronal; Inca bone and *os japonicum*), two sutural (metopic, infraorbital), two tori (maxillary and palatine), four foramina (zygomaticofacial, supraorbital [+supraorbital notch], infraorbital and parietal) and one exostosis (external auricular). Scores (presence/absence) for 16 of the 19 variants (84.2%) were confirmed via dissection. There were no false positives. Scoring inaccuracies occurred in two ossicular and one sutural variants, owing to sutural interdigitation complexity, image resolution and obstruction by organic material obstruction.

Pathology

No pathological lesions were noted on the CT, except for notable dental pathology; inter-observer concordance was 100% for gross details of the dentition (i.e., presence/absence) but differentiating between *ante/post-mortem* was less clear. Differentiating between non-infective periapical activity and infective lesions in CT images was also difficult, although gross exposure of the roots was clear. The strong oblique labial wear to the anterior dentition was visible in the scan, as was damage such as chipping to the right canine. Dissection of the remains indicated some periosteal reaction on the limb bones and ribs and mild vertebral osteophytes.

Overall Burial Interpretations

The skeletal remains indicate the presence of a single individual, which was manipulated/disturbed, and then additional elements from a second individual were inserted into the bundle. The absence of the mandible and first two cervical vertebrae suggests that the original cranium, mandible, humerus and upper vertebrae may have been removed in one piece, whilst still articulated. The bones of the left forearm were also removed, before the insertion of the secondary cranium; the latter does not match the wear extent or pattern of two loose teeth found in the pelvis. This did not take place in the vicinity of the final burial context, which was sealed, roofed and undisturbed, and no other burials or skeletal remains were found nearby. This is highly unusual for the Ychsma – who tended towards group burials – implying special treatment for this individual. The condition of the bundle makes it unlikely that it was exposed long-term, indicating that it was either 1) interred, exhumed/manipulated, then reinterred; or 2) the bundle was interred, then manipulated in situ, then roofed and re-covered. The latter is the more parsimonious interpretation, although the lack of fragments and detritus from the bundle's opening and manipulation is striking. While secondary burial or burial reprocessing has been noted elsewhere at Pachacamac (Takigami et al., 2014; Eeckhout, 2012 [E20: 2000]) and Pampa de Flores; the current bundle was not entirely rewrapped (Eeckhout, 2012), nor disarticulated then repackaged for burial (Eeckhout, 1999b). The bundle appears to have been opened superiorly, elements removed, and packing introduced into the abdomen/pelvic area before the replacement of the (wrong) skull, in some respects resembling the element harvesting observed by Takigami et al., (2014), and a poorly wrapped Ychsma subadult at the same site (E292), the skull of which had been stuffed with cotton in order to make it appear more intact, rigid or 'lifelike' (Owens & Davies-Barrett, 2019).

The lapse of time between initial interment and reprocessing is debatable, but some soft tissue is likely to have remained given that the elements seem to have been removed as a block, yet the body would have been skeletal enough to result in the dropping-off of small elements (finger phalanges) that remained in the base of the bundle. This interment predates E20 and Pampa de Flores by around 3-400 years (Pazdur et al., 2007), and it is probable that the differences between them reflect behavioural trends, given the seeming longevity of burial processing traditions (Takigami et al., 2014; Motley et al., 2021). Finally, E20 is notable for also having been isolated, and seems to have been deposited in connection with the ritual reuse and redevelopment of Pachacamac's "Temple of the Monkey" (Eeckhout, 2012). The isolation and apparently 'special' treatment of the current case may reflect a similar attitude.

[10] Extensive AMTL and some PMTL – attribution uncertain

[11] Inconclusive: Lambdoid and coronal suture visible but squamosal suture unobservable

Conclusion

In some respects, this is a cautionary tale. The CT indicated that the bundle contained a crouched adult skeleton with limited soft tissue preservation. The sex and – to an extent – the age could be ascertained fairly well as could most generalities and some details of skeletal morphology. Surface textural variability – such as detail of auricular surfaces or pubic symphyses – was less visible, however, which would serve to hinder the visibility of minor skeletal pathology such as periosteal reaction. The presence of significant inorganic and massed organic materials in the bundle served to obscure small elements in the bundle base and required an increase in power that rendered trabecular-rich and thin bones invisible; this has implications for bundles containing subadult or mature adult skeletal remains.

However, CT performance must be judged in terms of its detection of both anatomical and cultural phenomena if it is to be archaeologically applicable. It transpired that both osteological and artefactual remains were culturally relevant in this case. Firstly, the CT images did not highlight the possibility of a mismatch between the skull and other remains; and could not sense the unmatched teeth in the base of the bundle, as these were obscured by radio-opaque contamination. Secondly, the CT images were not able to differentiate the nine distinct layers that made up the external wrappings, while the inclusions within the wrappings and in the base of the bundle were also invisible. The structural packaging that had been inserted into the pelvis – implying secondary/post-inhumation manipulation – could also not be differentiated with clarity. While it is possible that the use of more powerful and complex scanners may address this issue (Sutherland et al., 2014), their deployment would be hampered by high cost and reduced availability. The fact that CT methods would easily miss relatively subtle cultural signals that reflect major trends in ancient mortuary behaviour suggests that such approaches may be able to provide generalities of key structures, but that refined perspectives are unlikely to be possible without dissection.

Declarations

Acknowledgements

The authors would like to thank Dr Miguel Trelles (AUNA Clinica Delgado, Miraflores), Christophe Moulherat (Musée du Quai Branly, France), Sylvain Ordureau (Vizua 3D, France), Elsa Tomasto-Cacigao (PUCP) and the MCP for permissions to carry out the work. We would also like to express our gratitude to all the members of the Ychsma Project, especially archaeologist Milton Lujan Dávila for assistance in the field, and Andres Shiguekawa & Kusi Colonna-Preti for their assistance with conservation. LSO would like to thank Ms Letisha M. C. Service for her referencing and editorial control, and Anna M. Davies-Barrett for her assistance in CT image scoring. PE would like to thank Nathalie Bloch (CReA-P, ULB) for processing the line drawing and map. The Ychsma Project at Pachacamac was made possible through the generous support of the Fondation ULB, the Université Libre de Bruxelles, and the Fonds National de la Recherche Scientifique (Belgium).

Authors' contributions

This paper was co-written by both authors who also registered related data and illustrations. LSO performed the anthropological analysis and PE led the excavation of the mummy bundle in the field. Both LSO and PE assisted with the CT scanning of the mummy in Lima.

Author declarations

Funding

The Ychsma Project-Archaeological Investigations at Pachacamac, was funded by the Fonds National de la Recherche Scientifique (Belgium) and the Université libre de Bruxelles, Belgium. The CT scanning was generously offered by the Clinica Delgado in Lima.

Competing interests

The authors declare no competing interests.

Ethics approval

Not applicable.

Consent to participate

We give our consent.

Consent for publication

We give our consent.

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Figures



Figure 1

Map of Peru with the location of Pachacamac (Eeckhout, 2021)

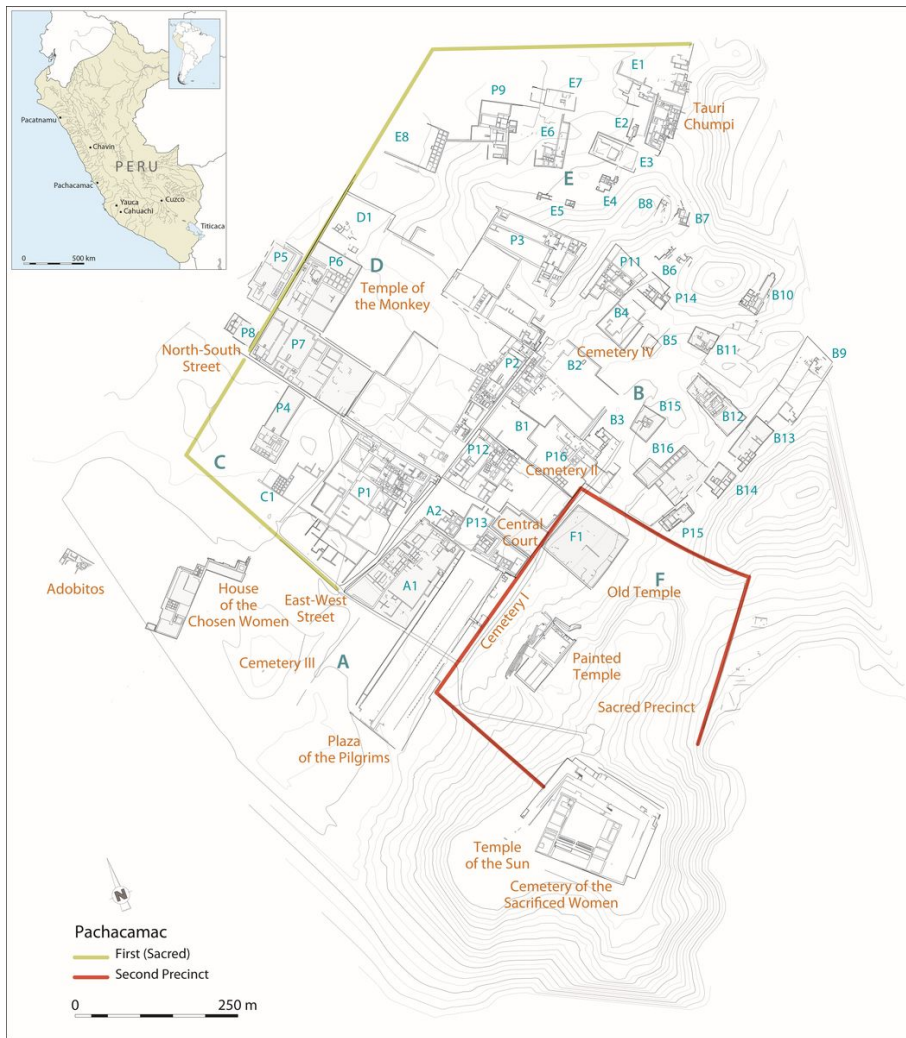


Figure 2

Site map of Pachacamac (Eeckhout, 2021)

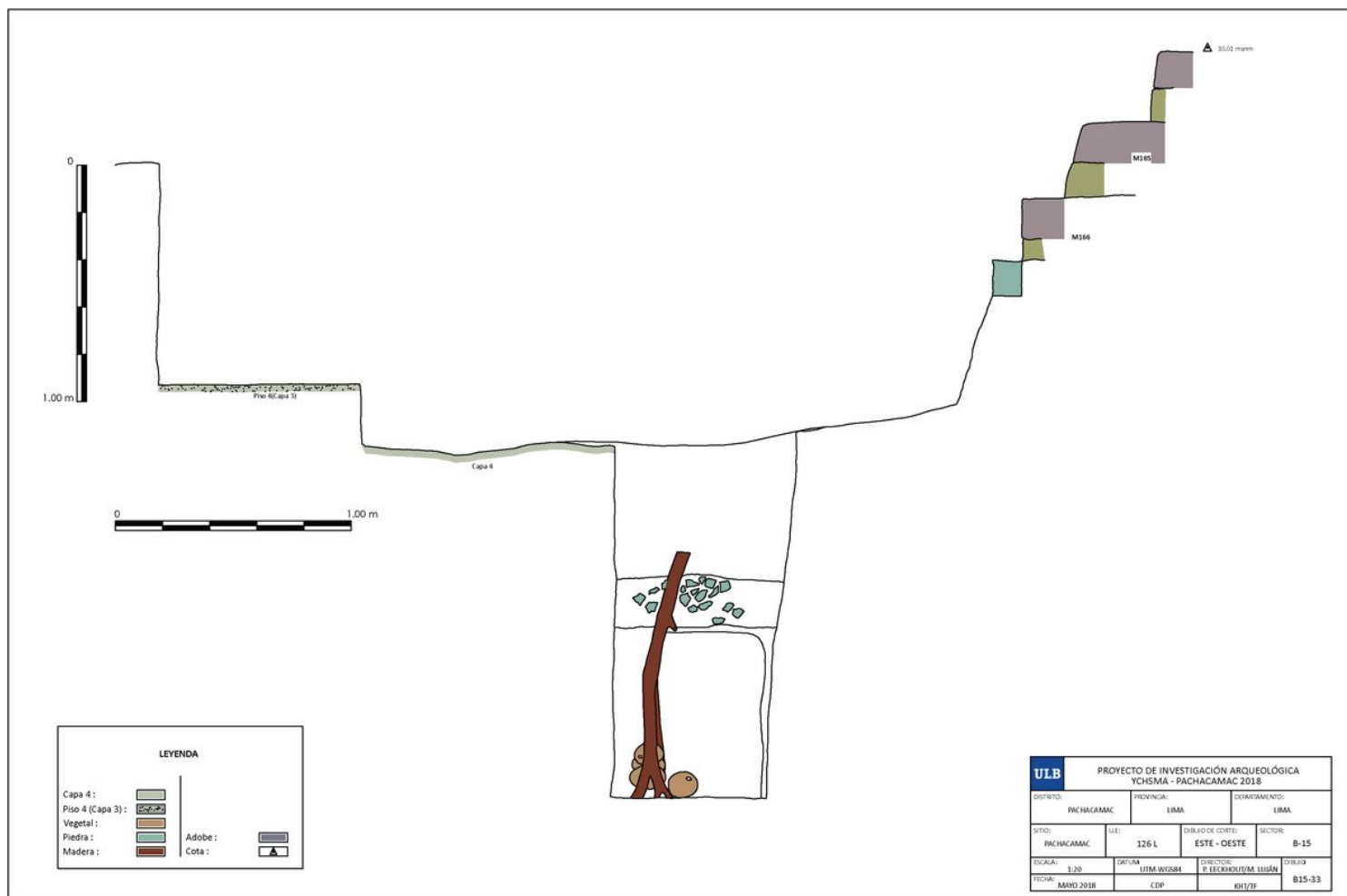


Figure 3

Profile of Feature 239.



Figure 4

South-facing photo of burial bundle E300

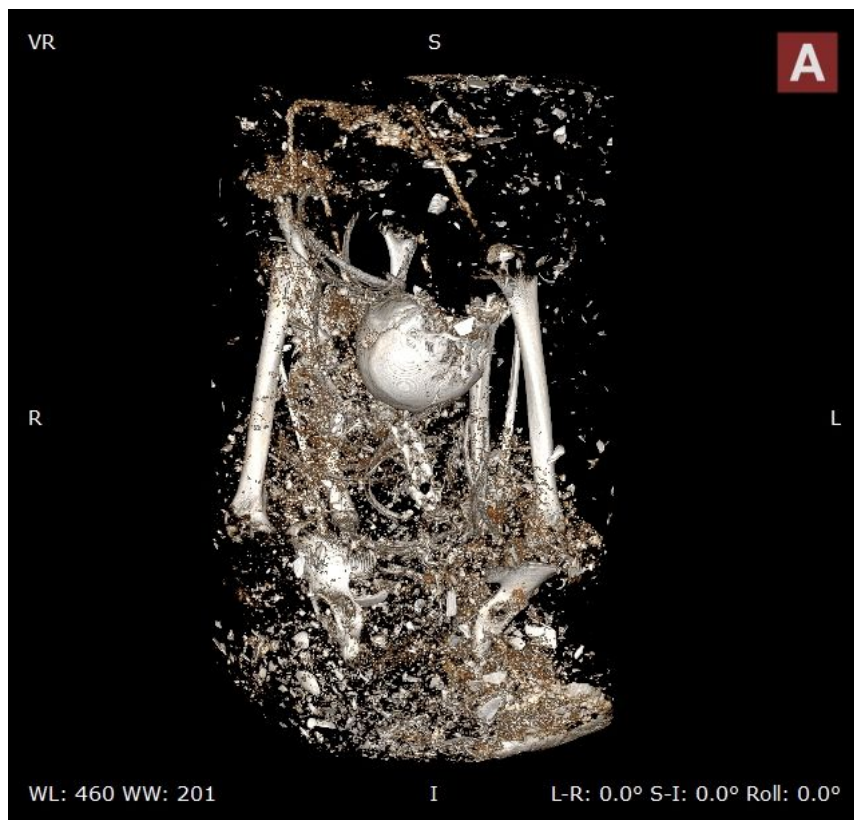


Figure 5

CT image showing the contents of burial bundle E300.

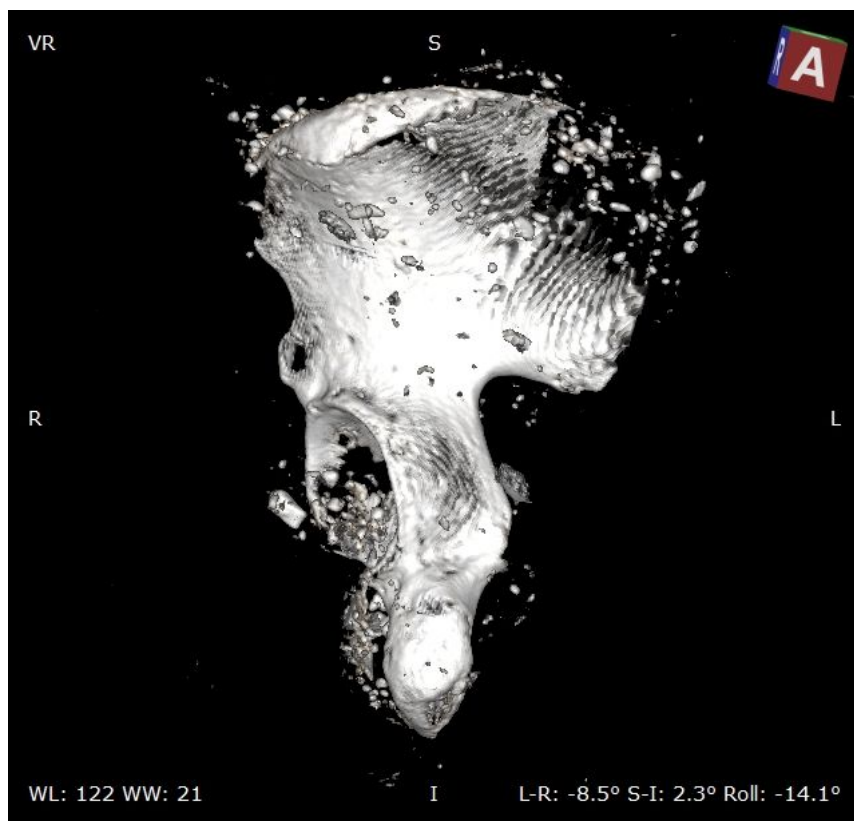


Figure 6

CT scan of E300's pelvis, used to ascertain the sex of the individual