Skeletal Remains from Punic Carthage Do Not Support Systematic Sacrifice of Infants

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Abstract

Two types of cemeteries occur at Punic Carthage and other Carthaginian settlements: one centrally situated housing the remains of older children through adults, and another at the periphery of the settlement (the "Tophet") yielding small urns containing the cremated skeletal remains of very young animals and humans, sometimes comingled. Although the absence of the youngest humans at the primary cemeteries is unusual and worthy of discussion, debate has focused on the significance of Tophets, especially at Carthage, as burial grounds for the young. One interpretation, based on two supposed eye-witness reports of large-scale Carthaginian infant sacrifice [Kleitarchos (3rd c. BCE) and Diodorus Siculus (1st c. BCE)], a particular translation of inscriptions on some burial monuments, and the argument that if the animals had been sacrificed so too were the humans, is that Tophets represent burial grounds reserved for sacrificial victims. An alternative hypothesis acknowledges that while the Carthaginians may have occasionally sacrificed humans, as did their contemporaries, the extreme youth of Tophet individuals suggests these cemeteries were not only for the sacrificed, but also for the very young, however they died. Here we present the first rigorous analysis of the largest sample of cremated human skeletal remains (348 burial urns, N = 540 individuals) from the Carthaginian Tophet based on tooth formation, enamel histology, cranial and postcranial metrics, and the potential effects of heat-induced bone shrinkage. Most of the sample fell within the period prenatal to 5-to-6 postnatal months, with a significant presence of prenates. Rather than indicating sacrifice as the agent of death, this age distribution is consistent with modern-day data on perinatal mortality, which at Carthage would also have been exacerbated by numerous diseases common in other major cities, such as Rome and Pompeii. Our diverse approaches to analyzing the cremated human remains from Carthage strongly support the conclusion that Tophets were cemeteries for those who died shortly before or after birth, regardless of the cause.

Introduction

Some biblical scholars maintain that the Carthaginians frequently and systematically practiced infant sacrifice perhaps as early as Queen Dido's founding of the Phoenician colony on the northern coast of Africa in the 9th or 8th century BCE until 146 BCE, when the Romans won the third and last Punic War [1–5]. This interpretation derives from the following: 1) Kleitarchos (3rd c. BCE) described Carthaginians throwing live infants onto a pyre, Diodorus Siculus (1st c. BCE) told of infants' throats being slit prior to cremation, and non-eyewitness reports claim the simultaneous sacrifice and burning of many children; 2) since the Eastern Mediterranean Phoenicians were the Canaanites described in the Old Testament as actually or potentially sacrificing offspring, and specifically first-born males, they continued this ritual as Carthage and its colonies; 3) the centrally situated Carthaginian cemetery contains remains of children and adults while a geographically separate area (the Tophet, Figure 1A) presents small urns (Figure 1B) with burned bones of very young animals (usually lamb or kid); humans (single or multiple individuals) (Figure 1C) and, occasionally, both; 4) inscriptions on some Tophet grave markers (stelae) (Figure 1D) suggest an offering was made to one or both primary deities, Ba’al Hamon and Tanit; and 5) one stela depicts a man, interpreted as a priest, carrying a child. The “all humans were sacrificed” thesis also rests on the argument that, since the animals interred in the Tophet were surely sacrificial victims, so too were the humans also interred in the Tophet [4,5].

Other biblical scholars [6–14], upon reviewing the evidence from the Tophet at Carthage and others at Carthaginian settlements in Cyprus and Sardinia, admit that humans may occasionally have been sacrificed, but also argue that sacrifice alone was not the primary factor underlying human interment in Tophets because: 1) perinatal humans, perhaps stillborn, have tentatively been identified at these sites; 2) the general age-representation of these human samples is consistent with infant
mortality, which would have been high; 3) the presence of the very youngest humans in marginally rather than in cross-generational and centrally located cemeteries attests to attributes specific to the young, such as death before at age at which they would have been accepted into society as real individuals; 4) postmortem human cremations were offerings to the deities; and 5) the classical “descriptions” of repeated, large-scale infant sacrifice were exaggerations if not anti-Carthaginian propaganda.

In the latter 1970s, excavations at Carthage were undertaken as part of a UNESCO sponsored, multinational archaeological effort to salvage as much information as possible from the vast site before expansion of building covered everything. The Tunisian Department of Antiquities granted permission to the American Team to excavate and analyze all material–osteological or otherwise–recovered from the Tophet. Once urns were removed from the field, the processing, sorting, osteological analyses of their contents, and the presentation of the results was under the direction of JHS.

Here we provide the results of the first in-depth study not only of the largest sample of the skeletal remains (348 urn contents) from the Tophet at Carthage (summer field seasons 1976 to 1979), but from any Carthaginian Tophet of [see Supporting Information Tables S1, S2]. Our objective was to address the following questions. Were all humans interred in the Tophet sacrificed? Whether sacrificed or merely cremated, how many individuals per event were involved (one, two, or en masse)? Regardless of number of individuals, was each treated with care from pre- to post-cremation? And, as inferred from passages in the Old Testament, were victims exclusively male?

**Methods**

Because the water table rose subsequent to use of the Carthaginian Tophet, JHS determined that each excavated urn should be placed in a water-filled bucket until he could extract its contents; otherwise dissolved calcium carbonate would solidify urn contents into a cement-like block as they dried [15,16]. A weak stream of water aided in removing urn contents onto plastic mesh supported above ground, and in removing adherent silt as urn contents were separated and laid out in a single layer to dry. Bones and teeth, clay that once sealed the urn’s mouth, charcoal, urn fragments, and/or amulets or other objects removed from the urn were then sorted [15,16]. The individually stylized and decorated, but poorly fired red-clay urns of the earlier Carthaginian phases were more frequently broken–likely from the weight of water-logged soil and subsequent urn burials–than the more uniform yellow-clay urns of later phases [2,5,16].

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**Figure 1. Location of Carthage and excavation of, including objects associated with, the Tophet.** A: Map of Western Mediterranean showing location and landmarks of Carthage. B: In order to excavate the Tophet, water had to be continually pumped out of the site (arrows point to urns). C: Broken urn revealing calcined bones and sediment that had seeped in as the water table rose. D: Stelae with different amounts of detail (e.g. one bears an image of an urn and another an inscription).

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Since damage to urns and dislodging of the clay seal made possible the loss of material from an urn as well as the intrusion of silts and even bones into the urn [15], soil around the urn was collected to determine the presence of osteological material (JHS). With the exception of the rare small fragment, this “extra-urn” soil was free of burned human bone; on one occasion part of a recent sheep scapula was found inside an urn. The primary intrusive material was, therefore, earth, which seeped in with the water. The complete list of the osteological remains recovered is presented in Tables S1, S2 (Supporting Information). All bones were inspected for evidence of cut marks and other signs of trauma but none was discovered.

Age estimation was based on comparative measurements of skeletal elements (basilar portion of the occipital or basilaris, sphenoid, petrosal, ischium, and pubis) [17], states of tooth formation [18], and presence or absence of a neonatal line (NL) in the enamel of tooth crowns. The transition from an intra- to extra-uterine environment leaves its mark in deciduous teeth and first permanent molars (the mesial cusp) as an accentuated enamel incremental ring called the neonatal line (NL) [19,20] (see Figure 2). The NL, which separates the enamel formed during intrauterine life from that formed after leaving the womb, is observable in individuals who survive at least 7 to 10–15 days ex utero [21–24].

Given the periodicity of enamel deposition and the fact that prenatal enamel does not normally present accentuated lines, an NL is the first postnatal hypoplasia (i.e. stress-induced alteration of enamel deposition). It thus marks the brief period of disruption of enamel secretion (decrease in daily rates of enamel formation) that occurs immediately postpartum. The emergence of an NL most
likely reflects a drop in blood serum calcium values during the first 48 to 72 hours ex-utero [25,26], as well as the dynamics of a fetus leaving the womb [27].

An NL can be identified easily in ground sections because both the difference in quality between pre- and postnatal enamel and its characteristic location is specific for each tooth class [24,28]. In incisors, this line extends from the dentino-enamel junction at the cervix (neck) of the crown onto the crown’s surface, leaving only a small portion of postnatally formed enamel. In canines and molars, this line is present closer to the incisal/occlusal part of the enamel, with only a small portion of prenatally formed enamel present [29]. Postpartum, the crown thickens via apposition of additional layers of enamel [30].

Analysis of NL presence/absence is routine in forensic investigations, which is noted not only in its increasingly prevalence in analyses of archaeological populations [31–34], but especially now in its application to fossil human teeth [35,36]. Indeed, NL analysis has rapidly become the only currently available osteodontic analytical technique capable of discriminating between infant death during the first postpartum week and the succeeding three weeks.

For this analysis, JHS and FH sent LB and RM well-preserved crowns of deciduous incisors and deciduous molars of 50 individuals, whose estimated ages bracketed the morphologically determined perinatal period and thus the period of transition from in- to ex-utero. Only specimen numbers were provided to LB and RM.

Specimens were cleaned in an ultrasonic bath and embedded in epoxy resin. Longitudinal labio- (bucco-) lingually oriented ground sections were prepared with a diamond blade microtome (Leica 1600) following the protocol of Caropreso et al. [37]. The sectional plane was situated as close as possible to the tip of the dentine horn (for the two deciduous molars, the dentine horns of the mesial cusps). While the quality of the cutting procedure was not always assured because of the condition of the tooth crowns, most specimens were sufficiently preserved enamel to permit reliable NL site-specific assessment.

At least three thin sections per specimen were produced. ~300 μm-thick slices were subsequently reduced to 80–100 μm with a motorized grinder (Minimet 1000 Buehler), polished, mounted for routine microscopy, and then etched for few seconds with a gel of phosphoric acid in order to enhance enamel microstructure. Of the three slides per tooth, the one with the least diagenetic damage and the most clear-cut microstructure was used in the analysis [33].

Sections were scrutinized under polarized light with an optical transmitted-light microscope (Laborlux S, Leica AG) and images taken with Polaroid Digital Microscope Camera (DMC 1) at 100× and 400×. Contrast enhancement convolution filters (3×3 and

Figure 3. Examples of variably burned bone, female vs male ilia, and duplicate skeletal elements. A: From a single urn, the calcined remains of the remains of a single individual (as reflected in the diversity and non-duplication of preserved skeletal elements). B: Reassociated, partially calcined upper and barely burned middle parts of a right humerus to illustrate the possible degree of fragmentation, dissociation, and consequent disparate crematory fates of parts of the same bone. C: Differently charred cervical vertebrae still in anatomical position representing one of various indications of incomplete cremation. D: Various pelvic ilia with intact greater sciatic notches (indicated by arrows), whose width (from most to least obtuse) suggests classification as hyperfeminine (upper left), feminine (upper right), hypermasculine (lower left), and masculine (lower right). E: Two left (left) and four right unfused petrosal bones; a straightforward analysis of MNI may suggest the presence of four individuals, but detailed analysis of the urn contents that yielded these petrosals does not provide evidence of four complete individuals in the same urn. (Scales in mm.)
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Table 1. Probable Sex of Human Remains [based on Greater Sciatic Notch (GSN) width], Carthaginian Tophet.

| Urn | Individual | Side | GSN width (in Degrees) | GSN Morphology | Suggested Sex |
|-----|------------|------|------------------------|----------------|--------------|
| *17 | 1          | R    | 113                    | Narrow and Deep | Male          |
| *20 | 1          | L    | 100                    | Wide and Shallow | Female        |
| *36 | 1          | L    | 98                     | Wide and Shallow | Female        |
| *37 | 1          | R    | 93                     | Wide and Deep   | Female        |
| *172| 1          | L    | 93                     | Deep (?)        | Male (?)      |
| *187| 1          | R    | 101                    | Wide and Shallow | Female        |
| *213| 1          | L    | 100                    | Wide and Shallow | Female        |
| *222| 1          | R    | 95                     | Narrow and Deep | Male          |
| *232| 1          | R    | 98                     | Wide and Shallow | Male          |
| 5409| 1          | R    | 98                     | Narrow and Shallow | Female        |
| 5414| 1          | R    | 101                    | Wide and Shallow | Female        |
| 5529| 1          | L    | 98                     | Wide and Shallow | Female        |
| 5538| 1          | R    | 100                    | Narrow and Deep | Male          |
| 5545| 2          | L    | 98                     | Wide and Shallow | Female        |
| 5545| 1          | L    | 101                    | Wide and Shallow | Female        |
| 5577| 1          | R    | 101                    | Wide and Shallow | Female        |
| 5579| 1          | L    | 101                    | Wide and Shallow | Female        |
| 5623| 1          | R    | 100                    | Narrow and Deep | Male          |
| 5817| 1          | R    | 101                    | Deep (?)        | Indeterminate |
| 5824| 1          | R    | 116                    | Narrow and Shallow | Female        |
| 5827| 1          | R    | 107                    | Wide and Shallow | Female        |
| 5829| 1          | L    | 109                    | Narrow and Deep | Male          |
| 5830| 1          | R    | 107                    | Deep (?)        | Indeterminate |
| 5835| 1          | L    | 103                    | Wide and Shallow | Female        |
| 5841| 1          | R    | 116                    | Wide and Shallow | Female        |
| 5843| 1          | R    | 116                    | Wide and Shallow | Female        |
| 5849| 1          | R    | 110                    | Wide and Shallow | Female        |
| 5850| 1          | L    | 72                     | Narrow and Deep | Male          |
| 5881| 1          | L    | 103                    | Wide and Deep   | Male          |
| 5887| 2          | R    | 119                    | Shallow         | Male          |
| 5887| 1          | R    | 114                    | Narrow and Deep | Male          |
| 5890| 1          | L    | 93                     | Wide and Deep   | Male          |
| 5893| 1          | R    | 103                    | Narrow and Deep | Male          |
| 5894| 1          | L    | 103                    | Narrow and Deep | Male          |
| 5895| 1          | R    | 103                    | Wide and Shallow | Female        |
| 5903| 1          | R    | 103                    | Wide and Deep   | Female        |
| 5920| 1          | L    | 103                    | Wide and Shallow | Female        |
| 5922| 1          | R    | 103                    | Wide and Shallow | Female        |
| 5945| 1          | L    | 114                    | Wide and Shallow | Female        |
| 5946| 1          | R    | 114                    | Shallow         | Female        |
| 5948| 1          | L    | 102                    | Wide and Shallow | Female        |
| 5959| 1          | R    | 95                     | Wide and Shallow | Female        |
| 5962| 1          | L    | 116                    | Wide and Shallow | Female        |
| 5963| 1          | R    | 103                    | Narrow and Deep | Male          |
| 5967| 1          | R    | 127                    | Wide and Shallow | Female        |
| 5971| 1          | R    | 100                    | Wide and Shallow | Female        |
| 5984| 1          | L    | 104                    | Narrow and Deep | Male          |
| 5986| 1          | R    | 104                    | Wide and Shallow | Female        |
5 × 5 kernels) produced sharper detail while change in the look-up table function increased site-specific contrasts of intensity profiles. Several partial images (from 7 to 15) were used to reconstruct the entire crown as a digital photomosaic. Because tooth enamel contains significantly less organic material than bone (1% vs. 20%, respectively), it reacts differently to heat and is less prone to plastic deformation [38]. In addition to its rheological properties, the enamel of unerupted crowns experiences relatively limited cracking and flaking because the structure is buffered against the direct effects of heat by the surrounding bone [39–41]. While the color of the outermost enamel surface clearly reflects changes in both the burning environment (reduced vs. oxygenic) and temperature [42], the effect of heat on inner enamel microstructure tends to be locally constrained [43,44]. Within each tooth class, but independent of an individual’s sex, the location of the NL is an indirect indicator of gestation length (time of initial mineralization in utero through postpartum), with preterm birth shifting the line more occlusally [24,28].

Results

Urn Contents

Urn contents could contain burned bones and teeth of humans, animals (primarily lamb or kid), or both (Table S1). There could be evidence in a single urn of only one human (Figure 3A) or, when number of duplicated parts was used to infer minimum numbers of individuals (MNI) (Figure 3E), as many as seven individuals (Table S2). In cases where one or two individuals were hypothesized present on the basis of MNI, the suite of preserved skeletal elements typically demonstrated that entire individuals had been interred. When, however, MNI indicated the presence of more than two individuals, sufficient numbers of duplicated bones and/or teeth could not be associated on the basis of size or burn pattern to reconstruct with confidence that number of individuals. Thus while multiple duplicates of a skeletal element may indeed reflect the prior existence of that number of individuals, the traditional approach to determining MNI does not provide evidence of an urn containing the complete or nearly complete skeletal remains of each of these individuals. Rather, there was never enough skeletal material to suggest that more than two (relatively) complete skeletons were placed in a single urn, which is inconsistent with a scenario of Carthaginians sacrificing or at least cremating groups of infants whose remains were then carefully collected and interred together in the same urn.

Bones and teeth from the same individual were rarely uniformly charred or calcined, and many were only minimally affected by heat (Figure 3B,C). This irregular burning pattern is consistent with a body on a funeral pyre in which tinder and hot ash were unequal in size and uneven in distribution [45]–to which the presence of burnt small branches in urns attests [16]–and into which bones fell randomly as they separated or burst from the heat and at the same time that pyre-tenders prodded embers to maintain the intensity of the fire [46]. Consequently, when an urn contained nearly complete skeletons, multiple duplicates but little associated skeletal remains, or a single duplicated element amidst the relatively complete remains of one or two perinates, we could infer with confidence that if individuals had been dealt with separately, such attention did not persist beyond cremation. Instead, we suggest, bones and teeth that fell deep into the pyre were left behind and inadvertently collected with the remains of subsequently cremated individuals. Similarly, if multiple cremations had occurred, either simultaneously or in short succession, there was obviously no attempt to prevent comingling of bones and teeth from different individuals.

Table 1. Cont.

| Urn   | Individual | Side | GSN width (in Degrees) | GSN Morphology       | Suggested Sex |
|-------|------------|------|------------------------|----------------------|---------------|
| 5987  | 1          | R    | 110                    | Wide and Deep        | Male          |
| 5991  | 1          | L    | 123                    | Wide and Shallow     | Female?       |
| 5992  | 1          | R    | 129                    | Wide and Shallow     | Female        |
| 5995  | 1          | R    | 110                    | Wide and Shallow     | Female        |
| 6000  | 1          | R    | 110                    | Wide and Shallow     | Female        |
| 6001  | 1          | L    | 110                    | Wide and Shallow     | Female?       |
| 6028  | 1          | R    | 105                    | Wide and Shallow     | Female        |
| 6029  | 1          | R    | 110                    | Wide and Shallow     | Female        |
| 6032  | 1          | L    | 110                    | Wide and Shallow     | Female        |
| 6037  | 1          | L    | 110                    | Wide and Shallow     | Female        |
| 6043  | 1          | L    | 96                     | Narrow and Deep      | Male          |
| 6047  | 1          | R    | 97                     | Narrow and Deep      | Male          |
| 6064  | 1          | R    | 135                    | Narrow and Deep      | Female        |
| 6068  | 1          | L    | 110                    | Narrow and Deep      | Male          |
| 6379  | 1          | R    | 103                    | Narrow and Deep      | Female        |
| 6380  | 1          | R    | 110                    | Narrow and Deep      | Male          |
| 6392  | 1          | L    | 95                     | Narrow and Deep      | Male          |
| 6396  | 1          | L    | 110                    | Narrow and Shallow   | Female        |
| 6398  | 1          | L    | 101                    | Narrow and Deep      | Male          |

Key: * = Basket Number; R = Right; L: Left.
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Figure 4. Plots of ages-at-death determined by actual (maximum) and incrementally increased size of skeletal elements sufficiently preserved for accurate measurement. A: Hypophyseal fossa length. B: Hypophyseal fossa width. C: Petrosal length. D: Petrosal width. E: Pars basilaris length. F: Pars basilaris width. G: Ischium length. H: Ischium height. I: Pubis length. In the graph, the same bones are compared to data from Fazekas and Kósá [17] and also increased by 5, 10 and 25%. The horizontal line in each represents birth.

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Table 2. Neonatal Line (NL) Analysis of Human Deciduous Teeth (N = 50), Carthaginian Tophet.

| Urn   | Tooth                  | NL      | NL thickness (µm)* | Notes                                                      |
|-------|------------------------|---------|-------------------|------------------------------------------------------------|
| *198  | upper central incisor  | Present | -                 | NL observed lingually                                      |
| *200  | upper central incisor  | Present | 9.6               | NL observed labially, close to outer margin                |
| *208  | upper central incisor  | Present | 6.7               | almost complete NL, observed both labially and lingually   |
| *223  | lower second molar     | Absent  |                   |                                                            |
| 2522  | incisor (indeterminate)| Present | -                 | NL observed lingually, close to outer margin               |
| 5163  | upper lateral incisor  | Absent  |                   |                                                            |
| 5331  | incisor (indeterminate)| Absent  |                   |                                                            |
| 5410  | lower central incisor  | Absent  |                   |                                                            |
| 5531  | upper lateral incisor  | Present |                   | NL observed lingually, close to the outer margin           |
| 5570  | lower central incisor  | Present |                   | NL observed labially, close to cervix                      |
| 5576  | upper central incisor  | Absent  |                   |                                                            |
| 5582  | lower central incisor  | Absent  |                   |                                                            |
| 5583  | incisor (indeterminate)| Present | 12.1             | NL observed lingually, close to cervix                     |
| 5587  | upper central incisor  | uncertain|                   | a possible NL-like accentuated ring close to the labial cervix |
| 5591  | incisor (indeterminate)| Present | 10.8             | NL observed labially, close to the cervix                  |
| 5599  | upper central incisor  | Present | 14.3              | NL observed labially                                       |
| 5625  | upper central incisor  | Present |                   | NL observed lingually, close to outer margin               |
| 5817  | upper central incisor  | Present | 9.7               | NL observed labially, close to external margin             |
| 5818  | incisor (indeterminate)| Absent  |                   |                                                            |
| 5829  | upper central incisor  | Present | 8.2               | NL observed labially, close to cervix                      |
| 5831  | upper lateral incisor  | Absent  |                   |                                                            |
| 5834  | upper lateral incisor  | Absent  |                   |                                                            |
| 5840  | upper central incisor  | Absent  |                   |                                                            |
| 5852  | upper central incisor  (?)| Present | 14.5             | NL observed both labially and lingually                    |
| 5855  | lower central incisor  | Absent  |                   |                                                            |
| 5862  | upper first molar      | Present |                   | NL observed buccally and occlusally                       |
| 5868  | upper lateral incisor  | Present | 8.2               | NL observed both labially and lingually                    |
| 5880  | lower central incisor  | Absent  |                   |                                                            |
| 5883  | upper central incisor  | Present |                   | NL observed labially, close to the outer margin           |
| 5902  | upper central incisor  | Absent  |                   |                                                            |
| 5948  | upper lateral incisor  | Present |                   | NL observed labially, close to the outer margin           |
| 5952  | upper lateral incisor  | Absent  |                   |                                                            |
| 5966  | upper central incisor  (?)| Absent (?)|                   | crown fragment                                              |
| 5971  | incisor (indeterminate)| Absent  |                   |                                                            |
| 5991  | upper central incisor  | Present |                   | NL observed labially                                       |
| 5998  | upper central incisor  | Absent  |                   |                                                            |
| 6003  | upper lateral incisor  (?)| Absent (?)|                   | crown fragment                                              |
| 6023  | upper lateral incisor  | Present |                   | NL observed lingually                                      |
| 6039  | lower lateral incisor  | Absent  |                   |                                                            |
| 6049  | upper lateral incisor  | Absent  |                   |                                                            |
| 6051  | upper lateral incisor  | Absent  |                   |                                                            |
| 6054  | upper central incisor  | Absent  |                   |                                                            |
| 6055  | upper lateral incisor  | Present | 6.3               | NL observed labially, close to outer margin                |
| 6058  | incisor (indeterminate)| Present |                   | NL observed labially, close to external margin             |
| 6066  | upper lateral incisor  | Absent  |                   |                                                            |
| 6069  | incisor (indeterminate)| Absent  |                   |                                                            |
| 6070  | upper central incisor  | Present |                   | NL observed lingually, = at mid-crown                      |
| 6393  | upper lateral incisor  | Absent  |                   |                                                            |
| 6398  | upper lateral incisor  | Absent  |                   |                                                            |
| 6399  | lower lateral incisor  | Present | 11.2              | NL observed labially                                       |

Key: * = Basket Number; *: mean value.
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Comparison of Ages-at-Death Determined by Neonatal Line (Histological [H]) and Morphological (M) Analyses of Human Deciduous Teeth, Carthaginian Tophet.

**Table 3.** Comparison of Ages-at-Death Determined by Neonatal Line (Histological [H]) and Morphological (M) Analyses of Human Deciduous Teeth, Carthaginian Tophet.

| Urn  | Neonatal Line | Morphology   | H versus M |
|------|---------------|--------------|------------|
| 6070 | Present       | ~Birth       | M<H        |
| 6399 | Present       | ≤Birth       | M>H        |

Key: M = H: Morphological and Histological ages similar; M > H: Morphological age advanced compared to Histological age; M < H: Histological age advanced compared to Morphological age.

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**Table 3.** Cont.

| Urn  | Neonatal Line | Morphology   | H versus M |
|------|---------------|--------------|------------|
| 3178 | Absent        | ≤Birth       | M = H      |
| 5163 | Absent        | ≤Birth       | M = H      |
| 5331 | Absent        | ?            | Histological Age Only |
| 5410 | Absent        | Birth        | M = H      |
| 5576 | Absent        | Late Third Trimester | M = H |
| 5582 | Absent        | ≤Birth       | M = H      |
| 5818 | Absent        | Late Third Trimester | M = H |
| 5831 | Absent        | Late Third Trimester | M = H |
| 5834 | Absent        | ≤Birth       | M = H      |
| 5840 | Absent        | Late Third Trimester | M = H |
| 5855 | Absent        | Late Third Trimester | M = H |
| 5880 | Absent        | Late Third Trimester | M = H |
| 5902 | Absent        | ≤Birth       | M = H      |
| 5952 | Absent        | Late Third Trimester | M = H |
| 5966 | Absent        | ~Birth       | M > H      |
| 5971 | Absent        | Late Third Trimester | M = H |
| 5998 | Absent        | ≤Birth       | M = H      |
| 6003 | Absent        | Late Third Trimester | M = H |
| 6039 | Absent        | Late Third Trimester | M = H |
| 6049 | Absent        | Birth to 1 Month | M = H  |
| 6051 | Absent        | ~Birth       | M = H      |
| 6054 | Absent        | ≤Birth       | M = H      |
| 6068 | Absent        | ~Birth       | M = H      |
| 6069 | Absent        | Birth        | M = H      |
| 6393 | Absent        | ~Birth       | M = H      |
| 6398 | Absent        | ≤Birth       | M = H      |
| 3159 | Present       | 1 to 2 months postnatal | M = H  |
| 3167 | Present       | ~Birth       | M = H      |
| 3163 | Present       | Late Third Trimester | M = H |
| 2522 | Present       | ?            | Histological Age Only |
| 5531 | Present       | ~Birth       | M = H      |
| 5570 | Present       | ~Birth       | M = H      |
| 5583 | Present       | ?            | Histological Age Only |
| 5587 | Present       | Late Third Trimester | M = H |
| 5591 | Present       | ?            | Histological Age Only |
| 5599 | Present       | ~Birth       | M = H      |
| 5625 | Present       | 2 Months     | M = H      |
| 5817 | Present       | ?            | Histological Age Only |
| 5829 | Present       | ≤Birth       | M = H      |
| 5852 | Present       | Birth        | M = H      |
| 5862 | Present       | ≤Birth       | M = H      |
| 5868 | Present       | ≤Birth       | M = H      |
| 5883 | Present       | Late Third Trimester | M = H |
| 5948 | Present       | Birth        | M = H      |
| 5991 | Present       | ≤Birth       | M = H      |
| 6023 | Present       | ≤Birth       | M = H      |
| 6055 | Present       | Late Third Trimester | M = H |
| 6058 | Present       | ≤Birth       | M < H      |

**Determination of Sex**

Seventy pelvic ilia were sufficiently preserved for visual assessment of sex, for which we relied on angle and depth of the greater sciatic notch and, when preserved sufficiently to be scrutinized, curvature of the iliac crest (Figure 3D). In Schutkowski’s [47] study of a sample of children sexes and ages-at-death were well-documented, greater sciatic notch angle correctly assigned, respectively, males 95% and females 71.4%, notch depth 81.2% and 76.5%, and crest curvature 81.2% and 62.1% of the time. In our sample of 36, 26 very probably and one unquestionably represented male, and 38 probably and two more questionably female (Table 1); three specimens were indeterminate. Given the likelihood that at least some individuals we identified as female were indeed female, the hypothesis of first-born males being the focus of a Carthaginian ritual of sacrifice is falsified.

**Estimation of Age: Tooth Formation and Osteometrics**

Only bones and teeth and tooth crowns that were preserved sufficiently intact to provide an accurate (not estimated) measurement were used in our estimation of age. Based on skeletal measurements (of the basilar portion of the occipital or basilaris, sphenoid, petrosal, ischium, and pubis; Tables S3, S4) [17], as well as relative states of tooth formation (Table S2) [18], most of the sample fell within the range of 2 to 12 postnatal months, clustering between 2 and 5 months at death (Table S2). At least another 20% of the sample (depending on the representation of the specific skeletal element) could be identified as prenatal. These results are consistent with modern infant mortality data [48,49]. We ruled out misclassifying infants of “low birth weight” (LBW) as prenatal because, while mortality is 40% higher in perinates [50], LBW is not reflected in diminished bone length or retarded tooth development [51].

Although experiments on heat-induced bone shrinkage were not done in the manner of Carthaginian cremation, we nonetheless thought it prudent to consider them. Most of these studies used ovens rather than fire as well as dry and defleshed green rather than fleshed bone [e.g. 52–54]. In all cases, bone shrinkage was minimal. Richard [55] did, however, cremate parts of human infant cadavers, but focused only on temperature and degree of bone carbonation and calcination. Baby [56], who cremated fleshed adult human remains, concluded that bone size was either not, or at most only minimally, altered. Buikstra and Swegle [57] cremated fleshed adult animal remains and found that while bone shrinkage could be as much as 6%, in general, bone size was minimally affected. Dokládal [58] compared bones from cremated halves of five adult cadavers with their uncremated counterparts and reported shrinkage between 5 and 12%. Muller’s [59] cremations of defleshed human fetal and newborn bones suggest shrinkage could reach 10%.
values from a modern sample of 147 children ranged from 10 to 50.9 years) buried at the Imperial Roman cemetery of Isola Sacra and from 209 crowns representing 109 children (aged 6 months to 124 crowns representing 102 modern European children [43,60].

Estimation of Age: Neonatal Line (NL) Analysis

In the Carthaginian sample, NL thickness ranged from 6.3 to 14.5 μm, with a mean of 10.1 μm (±2.76 μm). Comparative estimates obtained by the same investigative methods on deciduous teeth of all morphological classes were available from 124 crowns representing 102 modern European children [43,60] and from 209 crowns representing 109 children (aged 6 months to 9 years) buried at the Imperial Roman cemetery of Isola Sacra [31,60]. In the modern sample, NL thickness ranged from 6.5 to 50.9 μm and the mean value corresponded to 17.3 μm (±7.97 μm). In the archaeological sample, the range of variation range 9–36 μm with a mean of 16.7 μm (±4.40 μm). Additional values from a modern sample of 147 children ranged from 10 to 24 μm [27].

An NL results from perturbation in matrix deposition of enamel prisms reflecting stress in the transition from an intra- to extra-uterine environment (Figure 2), which does not always correspond to parturition following a full-term pregnancy [61]. Given the periodicity of enamel deposition, a newborn must survive at least 7 and even as many as 10 to 15 extra-uterine days in order for an NL to emerge fully. A definitive NL was observed in 24 Carthaginian specimens (Table 2); the amount of subsequent enamel deposition suggests these individuals survived at least 2 weeks postpartum. An NL was absent in 26 Carthaginian specimens (Table 2), which suggests that these individuals were either stillborn, spontaneously aborted, or died during the first extra-uterine week. Unambiguous counts and measurements of daily enamel cross-straitions, which provide information on the timing and rate of enamel deposition and thus indirect evidence of gestation length [31,33], could not be obtained on this sample. However, because other analyses in our study indicate the presence of individuals who had not reached full term, we suggest that individuals lacking an NL probably fall into the prenatal category because comparison of morphological/metric and NL age estimates demonstrates that when they differed, the histological (NL) age more frequently over-aged individuals than did morphological age (M < H 22%, M > H 10%; see Table 3). Consequently, if we include with the prenates those individuals who did not survive beyond one or even two weeks postpartum, we must conclude that a significant number of individuals could not have been sacrificed because they were either not alive or not yet old enough to be considered viable sacrificial entities [7,8,10,13] (Figure 5).

Discussion

The identification of prenatal individuals in the Carthaginian Tophet sample is consistent with current data from modern-day studies on the incidence of stillbirth and spontaneous abortion as being the primary contributors to “reproductive wastage” [62], as well as with recent data on infant mortality [48,49]. For example, in England and Wales from 1969 to 1976, 48.4% of 6517 deaths within two weeks of live birth occurred between 30 minutes and 24 hours and 39.3% between 7 and 13 days [61]. These statistics easily accommodate our results.

Infectious diseases known to lead to stillbirth include smallpox, vaccinia, and listeriosis; those resulting in prematurity and perinatal mortality include severe viral infections and malaria [49]. Noninfectious diseases resulting in stillbirth, abortion, or preterm delivery include cholestasis, hypertension, toxemia, and renal disease [50]. The Carthaginians were probably exposed to and susceptible to all of these afflictions. If conditions of sanitation at Carthage, including management of water supply and human and animal excreta, were similar to those at Pompeii, Ostia, and Rome [63], the Carthaginians would also have been potential victims to and vectors of cholera, dysentery, gastroenteritis, infectious hepatitis, leptospirosis, typhoid, and parasitic intestinal infestations, most of which result in severe dehydration, which is a common cause of infant death [50].

In sum, while the Carthaginians may occasionally have practiced human sacrifice, as did other circum-Mediterranean societies [1,63,64], our analyses do not support the contention that all humans interred in the Tophet had been sacrificed. Rather, it would appear that the Carthaginian Tophet, and by extension Tophets at Carthaginian settlements in general, were cemeteries for the remains of human prenates and infants who died from a variety of causes and then cremated and whose remains, sometimes on a catch-as-catch-can basis, interred in urns. Following widespread practice at this time in history, it is likely that at least some, if not all, of the cremated animal remains represent sacrificial offerings.

Supporting Information

Table S1 Species Identification of Skeletal Remains from Urns, Carthaginian Tophet.
Table S2  Demographic Profile of Human Remains, Carthaginian Tophet.

Table S3  Dimensions of Human Cranial Bones (in mm.), Carthaginian Tophet.

Table S4  Dimensions of Human Pelvic Bones (in mm.), Carthaginian Tophet.

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Found at: doi:10.1371/journal.pone.0009177.s002 (0.93 MB DOC)
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