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# The size of ancient Egyptian pigs

## A biometrical analysis using molar width

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**Abstract**: *A large assortment of pig mandibles from eleven ancient Egyptian sites dating from the Old Kingdom through the Ptolemaic-Roman period (c. 2686 BC and up through AD 400) were analyzed and their measurements compared to: 1) a modern domestic pig standard sample from Egypt, and 2) a wild boar standard sample from Turkey. Age at death, sizes of first, second, and third molars ($M_1$, $M_2$, and $M_3$), and coefficients of variation (CV) were consistent with the presence of domestic pig-only populations for most sites. However, tooth sizes, CV, and tendency towards bimodality in the distribution of sizes for Mendes and Kom Firin suggests the presence of either two populations of similar animals or sexual dimorphism. For these two sites, comparisons with the two standards were consistent with the presence of domestic pigs and either larger feral pigs or wild boar, sometimes at similar densities. Furthermore, results for the Abydos Settlement Site suggested that wild boar/feral pigs might have been hunted occasionally. Consistent with previous studies, mandibular wear scores (MWS) showed that pigs were slaughtered within the first 18-21 months of age. Neither MWS, data distribution tendency, molar width, nor CV alone were sufficient to distinguish between pure and mixed pig populations; but, taken together they provided strong evidence for the presence of larger size pigs (possibly wild boar or feral pigs) in ancient Egypt.*

**Key words**: teeth; domestic pig; wild boar; Egypt

## Introduction

The relation between wild boar (*Sus scrofa* Linnaeus 1758) and the origin of domestic pigs (*S. scrofa domesticus* Erxleben 1777) and whether or not wild boar in fact belongs to the indigenous fauna of Egypt is a debated topic in Egyptological and zoological literature. Some have argued for an independent local domestication of the pig from a possible native population of wild boar (Hecker 1982; Newberry 1964; Houlihan 1996), whereas others (Epstein 1971; Lobban 1994, 1998) have suggested an introduction of domestic pigs possibly along with wild boar into Egypt sometime around

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6000 BC. Previous literature (Manlius & Gautier 1999; Uerpmann 1987) has concluded that the wild boar is not a typical member of the ancient Egyptian fauna due to the lack of positively identified boar remains from excavated sites and its complete absence in late Paleolithic assemblages, even suggesting that all wild boar in Egypt may actually be feral pigs (Manlius & Gautier 1999). However, all of the known Paleolithic assemblages come from the Western Desert (Gautier 1976; Gautier & Van Neer 1989; Van Neer 2000; Van Neer et al. 2000; Linseele & Van Neer 2009), which is not the ideal habitat for wild boar as it is complete desert. Thus, this lack of wild boar evidence could be attributed to the absence of Paleolithic sites from the Nile Delta, which is a more ideal habitat for the species.

At present, the only identified wild boar remains (presumably done based on size) come from the sites of Merimde Beni-Salame (Boessneck 1988; von den Driesch & Boessneck 1985), Buto (von den Driesch 1997), and Neolithic Fayum (Canton-Thompson & Gardiner 1934; Butzer & Hansen 1968). Yet, the identification of wild boar from the Fayum is questionable (Uerpmann 1987). These areas have each yielded a small number of identified wild boar elements (no more than one or two per site). One possibility for the contrasting results is that larger feral pigs could have been counted as wild boar in some sites. However, the small number of observations in many cases precludes a more rigorous assessment of the origin of exploited suids in ancient Egypt. In order to address this issue, a biometrical analysis of molar width from ten sites was undertaken to determine if more than one suid population is present. If the results point to more than one population, it could include wild boar/feral pigs not previously identified or alternatively be the result of sexual dimorphism.

Wild boar has been among the most common and widely distributed animals since the beginnings of Eurasian agricultural civilization (c. 7000 BC). Recent DNA studies have shown that the origins of the wild boar lie in the islands of South East Asia (ISEA), more specifically on the Malaysian peninsula and the islands of Sumatra, Borneo, and Java. They then spread into the Indian subcontinent, China/Japan and eventually west to North Africa/Western Europe (Larson et al. 2005; Larson et al. 2007; Giuffra et al. 2000; Kijas & Andersson 2001).

Due to their distribution across large geographic areas, and the environmental diversity of Eurasia and North-West Africa, wild boar are extremely variable. At least sixteen different wild boar subspecies have been identified (Ruvinsky & Rothschild 1998) from which domestic pigs are descended. Furthermore, there is now enough evidence to confirm that wild boar has been domesticated several times independently (Larson et al. 2005). More research on DNA sequencing is needed on the phylogeny of the domestic pig, and in the complete absence of such studies for Egypt, the ability to accurately identify wild boar from domestic pig forms in faunal remains is solely derived from morphological characteristics (Bökönyi 1969; Zeuner 1963).

Although the origin of the wild boar in Egypt is unclear, various travelers' accounts from the 19th century document its presence in the Nile Delta, Fayum, Wadi Natrun, and other wet and marshy regions of the country (Rifaud 1830; Wilkinson 1847; Anderson & deWinton 1902; Murray 1935). However, these accounts cannot be considered as firm evidence for the presence of wild boar, as it is important to take into account the possibility of feral pigs (Manlius & Gautier 1999). Wild boar has since become extinct, largely due to a massive program of extermination by the government in 1846 in an effort to control crop damage. During this program, 860 boar were shot (Murray 1935; Diener & Robkin 1978), although some may have been able to survive until 1902 (Anderson & deWinton 1902; Flower 1932; Russell 1951).

As in several mammal species, the transition from wild boar to domestic pigs entails a shortening of the cranium, trunk, and particularly the mandible. This results in the reduction of tooth size and sometimes even changes in the number of teeth (Bökönyi 1969, 1974; Clutton-Brock 1981; Zeder 2006a). Since dentition is generally affected by changes in the size of the skull, the measurement of tooth size (Rütimeyer 1860; Winge 1900; Degerbol 1942; Boessneck et al. 1963; von den Driesch 1976; Payne & Bull 1988) can be an extremely valuable tool for the distinction of wild boar from domestic pigs (Mayer et al. 1998; Albarella 2002; Boessneck & von den Driesch 2004; Albarella & Payne 2005). This, however, should be used with caution, as wild and domestic forms are known to overlap in their molar size (Evin et al. 2013). This is further complicated when taking feral pigs into consideration, as they are known to cross-breed with, and are morphologically indistinguishable from wild boar (Albarella et al. 2009).

Biometry is most effective in zooarchaeology when a large sample exists because this ensures statistical reliability. However, this is not always possible in the case of ancient Egyptian faunal material. In part, this is due to the uneven preservation of faunal remains (teeth in this case), but more importantly, it is due to the paucity of excavated material from settlement sites where pig bones would be found. The sites from which material has been recovered often represent only a few excavated trenches, resulting in a *total* faunal assemblage number of individual specimens (NISP) of no more than 10,000. Delta sites, in particular, are a challenge due to the high water table, which poses a problem for both the preservation of faunal material and for the actual area of the site that can be excavated before reaching the aquifer. The few exceptions that are used in this study are: 1) sites which have been continuously excavated for well over twenty years (e.g., Amarna and Abydos) and which have retained the faunal remains, 2) large state-supported centers (Giza Workmen's Village), and 3) sites that were continuously occupied for long periods of time throughout ancient Egyptian history (e.g., Elephantine and Aswan). All these provided large samples from the amount of settlement debris built up over time.

Using biometrical analysis of the molar size of the three permanent lower (mandibular) molars, this paper aims to establish if more than one population of pigs were present in ancient Egyptian settlement contexts, possibly including wild boar/feral pigs by comparing ten analyzed pig samples to two established standards.

## Materials and methods

The evidence discussed in this paper comes from ten different archaeological sites all over Egypt (**Figure 1**) representing time periods from the Old Kingdom through the Ptolemaic-Roman period (c. 2686 BC and up through AD 400). Data was collected between 2006-2009 from the sites of Aswan (ancient Syene), Elephantine, Abydos Settlement Site, South Abydos (town of Wah-Sut), Amarna, Giza Workmen's Village, Kom Firin, Kom el-Hisn, Saïs, and Mendes (**Table 1**). A modern comparative sample of nineteen domestic pig mandibles from Cairo was also collected to act as a control group against which to compare the archaeological material. Although this is not a very large sample of modern material, unfortunately, attempts to acquire additional pigs have failed due to the 2009 cull.

**Table 1**. Settlement sites analyzed along with their date.

| Site | Time period |
|---|---|
| Giza Workmen's Village | c. 2686-2125 BC (Old Kingdom) |
| Kom el-Hisn | c. 2686-2125 BC (Old Kingdom) |
| Mendes | c. 2686-2125 BC (Old Kingdom) |
| Abydos Settlement Site | c. 2160-2055 BC (First Intermediate Period) |
| South Abydos | c. 1870-1831 BC (Middle Kingdom) |
| Elephantine | c. 1550-1069 BC (New Kingdom) |
| Amarna | c. 1352-1336 BC (New Kingdom) |
| Kom Firin (incl. possible fortress settlement) | c. 1550-1069 BC (New Kingdom) |
| Saïs | c. 1064-664 BC (Third Intermediate Period) |
| Aswan | c. 664 BC – AD 395 (Ptolemaic-Roman) |

The selection of sites was based on the availability of materials, the generosity of excavation directors, and permission from the Supreme Council of Antiquities. As is often the case with earlier excavations in Egypt, animal bones were either not collected or not properly curated and recorded. Therefore, the selection of teeth in this study comes from sites that have been excavated within the last thirty years, which restricts the sample.

The following protocol was used to record all teeth: tooth type (as first molar [$M_1$], second molar [$M_2$], or third molar [$M_3$]), side (right or left), and age. Eruption and wear stages in teeth were recorded following Grant (1982), which calculates the

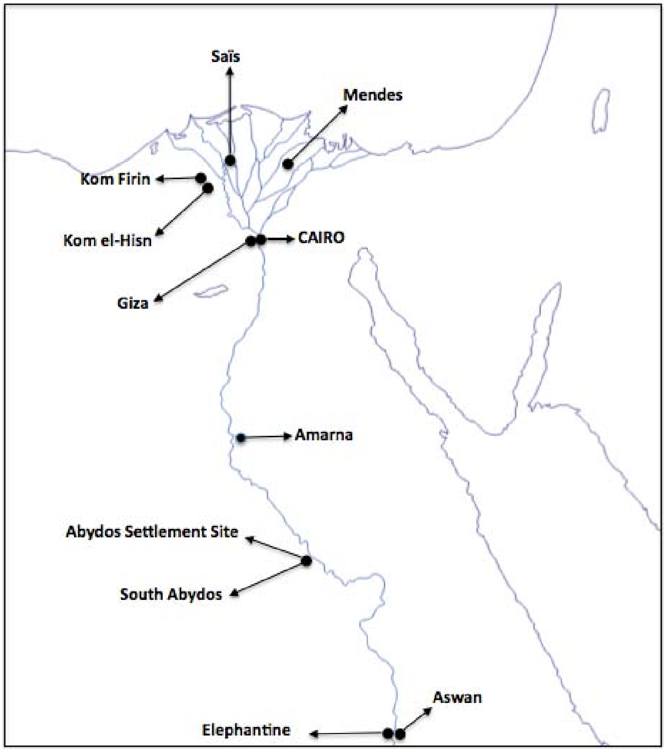


**Figure 1**. The location of each of the eleven archaeological sites where samples were collected.

age based on the tooth wear pattern of the occlusal surface of every individual molar, and when added up together equal the mandibular wear score (MWS). Hambleton (2001) was also used to convert the MWS into an estimated age, as summarized in **Table 2**. Only mandibular teeth are included in this study. Maxillary teeth are excluded in an attempt to reduce redundancy in data collection and also because all established ageing methods are only for mandibular teeth. Only permanent molars preserved in the mandibles were recorded, since isolated teeth are difficult to classify as either $M_1$ or $M_2$.

The choice of measurements taken was based on the recommendations in Payne and Bull (1988) and Albarella and Payne (2005). Accordingly, the measurements taken were the posterior cusp row width of the $M_1$ and $M_2$, and the anterior cusp row width of the $M_3$. These measurements were then used in biometrical analyses to compare differences in tooth width size. All measurements were taken to the nearest 0.1mm with digital calipers. The pig tooth width measurements from all eleven sites in this paper were compared using the size index scaling technique (Meadow

1999). This relates the measurements to an established tooth standard based on the collected modern Egyptian sample. The widths were compared also to a second set of standard measurements of Turkish wild boar (Payne & Bull 1988) from the central Anatolian plateau region. The relative tooth size of each of the ten sites' measurements in comparison to the modern Egyptian standard was calculated as the decimal logarithm of the ratio between the measurement and its standard (Simpson et al. 2003). This method allows different measurements to be compared directly, in which the distribution of the archaeological measurements is shown in relation to the "0" line provided by the modern Egyptian standard. One disadvantage of this type of analysis is that by combining different types of measurements, there is some loss in resolution. Nonetheless, this method allows for larger samples to be dealt with, and also enables a direct comparison of teeth data from many different sites (Albarella 2002; Albarella et al. 2006; Simpson et al. 2003). The other standard served as a comparison point for tooth size of the samples against wild boar, but measurements were not standardized against it.

## Modern Egyptian domestic pigs

The modern Turkish wild boar standard (Payne & Bull 1988) along with the Neolithic domestic pigs from Durrington Walls, UK (Albarella & Payne 2005) are standards commonly used by zooarchaeologists. However, there was a need to establish a standard that was more relevant to ancient Egyptian material. Thus, a sample of domestic pigs was collected in order to establish a modern Egyptian standard along with providing a control group with a known life history to which the archaeological material could be compared. This sample consisted of nineteen domestic pig mandibles collected from a local butcher in Shobra, Cairo on March 25, 2008. These domestic pigs were raised on a private farm outside Mohandessein, Cairo, and fed a diet primarily of potatoes, tomatoes, and other various grains and vegetables (Mr. Magdy, Shobra store

**Table 2.** Conversion of Grant's (1982) MWS into estimated ages based on Hambleton (2001).

| **MWS Grant (1982)** | **Suggested age Hambleton (2001)** |
|---|---|
| 0-1 | 0-2 months |
| 2-8 | 2-7 months |
| 9-17 | 7-14 months |
| 18-32 | 14-21 months |
| 33-42 | 21-27 months |
| 43-46 | 27-36 months |
| 46+ | 36+ months (adult) |

owner, personal communication). Although having a modern standard is important for comparison, the pigs discussed in this paper all come from the same farm and were slaughtered in the same year, underestimating variability. As previously stated, attempts to acquire additional pigs have not been successful to date as a result of the 2009 cull.

The modern domestic pig currently in Egypt—including the population present before the 2009 pig cull as a result of the swine flu (H1N1) scare (Mercola 2009)—is a mixed breed of the Egyptian domesticate with European and American breeds (Mr. Magdy, personal communication). To confirm this, four hair samples from two domestic pigs were taken and their haplotypes were determined using a fragment of the d-loop in the mitochondrial genome (Larson et al. 2005, 2007). Based on mitochondrial DNA, it was determined that three of the hair samples possessed standard European haplotypes, whereas the fourth had a standard East Asian haplotype. The East Asian haplotype is often present in pigs from Europe and the United States since many breeds are hybrids between European and Asian domestic pigs (White 2011). Because only mitochondrial DNA was analyzed, the rest of the nuclear genome could have been Egyptian derived. However, efforts to type those markers have failed so far (Greger Larson and Keith Dobney, personal communication). More modern samples are needed for further analysis.

## Statistical analyses

Potential differences in the mean widths of $M_1$, $M_2$, and $M_3$ among populations were assessed by one-way analysis of variance (ANOVA) followed by Tukey-Kramer post hoc tests for multiple comparisons. Tukey-Kramer tests are more conservative than other post hoc analyses, which result in more rigorous pairwise comparisons (Day & Quinn 1989). Prior to the analyses, normality was checked and homogeneity of variances was assessed using Levene's F-test. All tooth-width data were then log transformed. Although this could not correct for all of the variance heteroscedasticity (and in a few cases, deviations from normality), one-way ANOVA is considered to be robust and less sensitive to type I or type II errors (Schmider et al. 2010). Nonetheless, to avoid losses in statistical power, we only compared simultaneously sites that yielded a minimum of five teeth ($N \geq 5$). Thus, the Giza sample is the only one excluded from the analyses of $M_2$ (see **Tables 3-5** for tooth sample sizes).

The coefficient of variation (CV) was used to determine whether samples were comprised of more than one population of different sizes. However, a note of caution with this method is needed, as variances are sample estimates of trends and their variation in populations. Thus, there can be aspects, which are easily overlooked by focusing on these estimates only. Although there are other methods that can be used to detect multimodality and/or clusters in the data such as multivariate and geometric statistics, for the purposes of this article for easy comparison to previous publications that make use of this method (Albarella & Payne 2005; Albarella et al. 2009), the CV will be used. Although experimental assessments show that pure samples for animal metrics often have a mean CV of 5-6 (Simpson et al. 2003), we used a more conservative approach and considered samples to be "pure" only if their coefficient of variation was below 8.3. This baseline was chosen according to experimentally obtained CV from the modern Egyptian domestic pig sample (see below). Our approach also allowed us to compare different sites because CV is not sensitive to differences in scales or units (Simpson et al. 2003). Although the modern domestic sample has similar CV's to the established domestic standard from Durrington Walls (Albarella & Payne 2005), the threshold is somewhat less (**Tables 3-5**). As the modern Egyptian domestic standard obviously has larger CV's, this might indicate pigs of different sizes present in the sample, providing a more conservative comparison for the possibility of feral pigs or wild boar among remains.

## Results

A total of 523 recordable teeth were analyzed from all of the archaeological sites, along with the modern domestic sample of 55 teeth, totaling 578 teeth (**Tables 3-5**).

**Table 3**. $M_1$ posterior width (to the nearest 0.1mm) summary statistics for all pig populations and established standards used. Letters to the left of the mean represent significant groupings based on Tukey-Kramer post hoc pairwise comparisons; sites with similar letters were statistically equivalent in mean tooth width. Overall differences among means were assessed by one-way ANOVA ($p<0.001$).

| Site | N | Min. | Max. | Mean | SD | CV |
|---|---|---|---|---|---|---|
| Giza | 5 | 9.9 | 11.5 | abc 10.9 | 0.60 | 5.49 |
| Kom el-Hisn | 11 | 10.2 | 13.2 | abc 11.6 | 0.88 | 7.62 |
| Mendes | 11 | 8.2 | 14.9 | ab 12.0 | 2.31 | 19.22 |
| Abydos Settlement Site | 9 | 8.3 | 14.6 | abc 11.7 | 2.16 | 18.54 |
| South Abydos | 12 | 9.5 | 13.4 | abc 10.8 | 1.08 | 9.97 |
| Elephantine | 16 | 9.8 | 11.7 | bc 10.7 | 0.47 | 4.40 |
| Amarna | 44 | 8.5 | 12.1 | bc 10.7 | 0.69 | 6.45 |
| Kom Firin | 46 | 8.3 | 15.5 | a 12.0 | 1.44 | 11.99 |
| Saïs | 9 | 10.9 | 14.7 | ab 12.0 | 1.35 | 11.18 |
| Aswan | 16 | 8.1 | 12.8 | bc 10.8 | 1.04 | 9.59 |
| Shobra | 19 | 8.9 | 11.7 | c 10.2 | 0.66 | 6.49 |
| **Total (all sites)** | 198 | | | | | |
| Albarella and Payne (2005) | 125 | 9.8 | 12.4 | 10.9 | | 5.0 |
| Payne and Bull (1988) | 18 | | | 12.5 | 0.46 | 4.0 |

In general, mandibles were sufficiently abundant in the study collection at most sites. The only exception was Giza, which yielded five mandibles.

## Age and sex of the modern and archaeological pigs

Age distributions based on both modern and archaeological pig mandibles were compared following Grant (1982), using the frequencies of mandibles for which we could calculate an MWS (**Figure 2**). All pig samples appeared to come from individuals of subadult age, with most falling close to 1.5 years of age given their MWS values (Hambleton 2001). Sex could not be calculated for any of the archaeological samples.

Most of the modern pigs (Shobra) seem to have been killed at about a year and a half based on their MWS, which peaks between 20-24. All 19 mandibles from the modern sample had their $M_2$ completely formed, and all $M_3$ were either developing or in the early stages of wear. Based on the eruption sequence of pig teeth (McCance et al. 1961; Mohr 1960; Briedermann 1972), this would place two individuals from this sample, which had their $M_3$ developing, anywhere between 15 and 18 months old. The other seventeen mandibles that have the $M_3$ just erupted or in early wear stages can be aged to at least 18 to 20 months, corresponding with the ages calculated based on the MWS; these pigs were likely born around April 2006. Sex was estab-

**Table 4**. $M_2$ posterior width (to the nearest 0.1mm) summary statistics for all pig populations and established standards used. Letters to the left of the mean represent significant groupings based on Tukey-Kramer post hoc pairwise comparisons; sites with similar letters were statistically equivalent in mean tooth width. Overall differences among means were assessed by one-way ANOVA (p<0.001). Due to the small sample size, Giza was excluded from the analyses.

| Site | N | Min. | Max. | Mean | SD | CV |
|---|---|---|---|---|---|---|
| Giza | 4 | 12.6 | 14.3 | - 13.3 | 0.78 | 5.88 |
| Kom el-Hisn | 9 | 11.4 | 14.6 | ab 13.4 | 0.92 | 6.86 |
| Mendes | 23 | 10.0 | 17.8 | a 15.0 | 2.02 | 13.43 |
| Abydos Settlement Site | 13 | 10.4 | 16.9 | ab 13.9 | 1.87 | 13.42 |
| South Abydos | 17 | 11.6 | 15.1 | b 12.9 | 1.01 | 7.79 |
| Elephantine | 13 | 10.5 | 13.7 | b 12.6 | 0.85 | 6.77 |
| Amarna | 37 | 11.1 | 16.7 | b 13.2 | 1.06 | 8.04 |
| Kom Firin | 36 | 11.2 | 17.9 | ab 13.9 | 1.19 | 8.59 |
| Saïs | 14 | 10.5 | 14.7 | ab 13.5 | 1.06 | 7.84 |
| Aswan | 17 | 10.2 | 14.9 | b 13.2 | 1.29 | 9.77 |
| Shobra | 19 | 11.1 | 14.7 | b 12.8 | 0.79 | 6.17 |
| **Total (all sites)** | 202 | | | | | |
| Albarella and Payne (2005) | 68 | 12.5 | 15.9 | 14.2 | | 4.5 |
| Payne and Bull (1988) | 15 | | | 16.3 | 0.61 | 4.0 |

lished for this sample based on information from the butcher (Mr. Magdy, personal communication) and was confirmed on the basis of the canine teeth and their alveolar sockets (Harcourt 1971). Nine females and ten males were present, giving an equivalent percentage of both sexes in the sample. When simultaneously compared, there are no significant differences between the width measurements of the modern male and female pig samples (p=0.405, T-test).

## Size of the modern and archaeological pigs

When samples from sites that had enough teeth for statistical analysis were simultaneously compared to the modern domestic pig sample (Shobra), there were significant differences between the width measurements for all $M_1$, $M_2$, and $M_3$ ($p \leq 0.0001$, one-way ANOVA for all analyses; **Tables 3-5**). The $M_1$'s from the modern domestic sample were significantly smaller than those from Kom Firin, Saïs, and Mendes (**Table 3**), the $M_2$'s were significantly smaller than those from Mendes (**Table 4**), and the $M_3$ width was significantly smaller than those of Kom El-Hisn, Mendes, Kom Firin, Saïs, and Amarna (**Table 5**). Other sites yielded teeth of intermediate sizes that were statistically equivalent to those on the higher and lower ranges.

**Figure 3** shows the width measurements combining all three permanent molars for each of the thirteen samples using the size index scaling technique and plotted as

**Table 5**. $M_3$ anterior width (to the nearest 0.1mm) summary statistics for all pig populations and established standards used. Letters to the left of the mean represent significant groupings based on Tukey-Kramer post hoc pairwise comparisons; sites with similar letters were statistically equivalent in mean tooth width. Overall differences among means were assessed by one-way ANOVA (p<0.001).

| Site | N | Min. | Max. | Mean | SD | CV |
|---|---|---|---|---|---|---|
| Giza | 5 | 15.3 | 16.3 | abc 15.8 | 0.36 | 2.28 |
| Kom el-Hisn | 12 | 14.7 | 18.8 | a 16.4 | 1.44 | 8.76 |
| Mendes | 28 | 13.1 | 19.9 | a 16.4 | 1.90 | 11.59 |
| Abydos Settlement Site | 13 | 13.2 | 17.8 | abc 15.3 | 1.18 | 7.69 |
| South Abydos | 19 | 12.7 | 17.3 | a 14.7 | 1.18 | 8.03 |
| Elephantine | 10 | 13.4 | 15.6 | abc 14.7 | 0.75 | 5.11 |
| Amarna | 30 | 12.1 | 17.3 | ab 15.3 | 1.25 | 8.16 |
| Kom Firin | 27 | 13.7 | 18.2 | a 16.2 | 1.17 | 7.24 |
| Saïs | 5 | 14.7 | 19.8 | ab 16.9 | 2.19 | 12.91 |
| Aswan | 12 | 12.4 | 16.7 | bc 14.6 | 1.20 | 8.22 |
| Shobra | 17 | 11.3 | 15.3 | c 13.9 | 1.15 | 8.26 |
| Total (all sites) | 178 | | | | | |
| Albarella and Payne (2005) | 42 | 13.9 | 17.5 | 15.7 | | 6.0 |
| Payne and Bull (1988) | 5 | | | 18.3 | | |

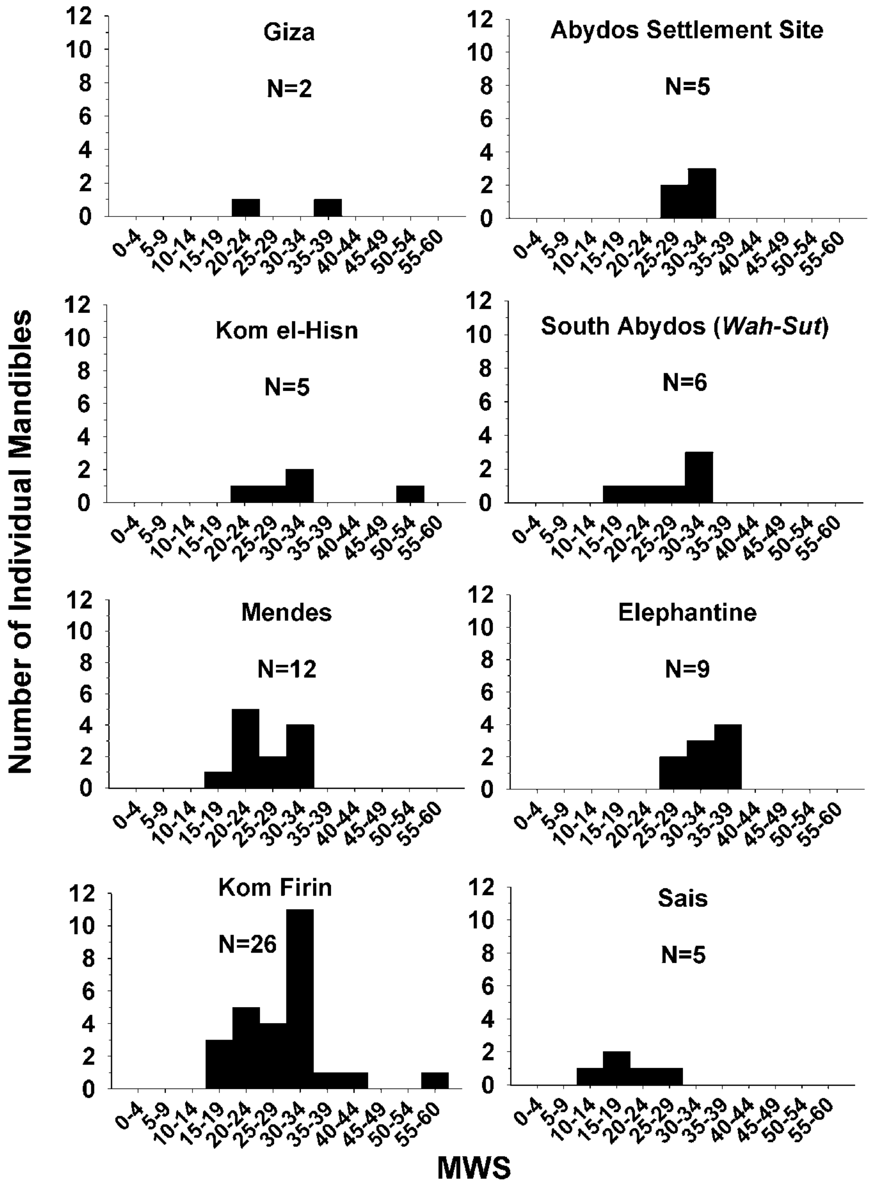


**Figure 2.** Comparison of age distributions for all archaeological and modern pig samples based on conversions into mandibular wear scores (MWS) as per Hambleton (2001; see also **Table 2**).

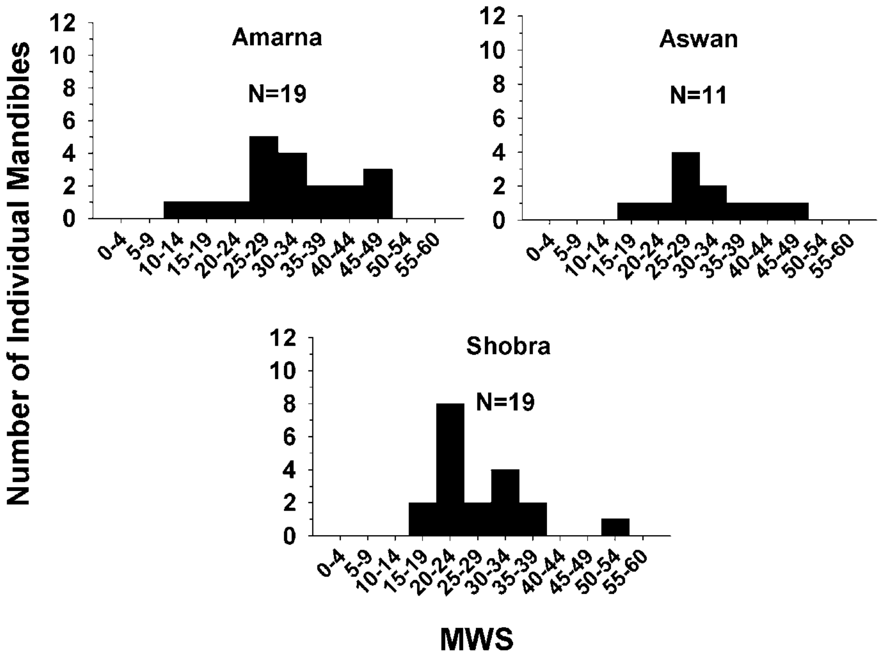


**Figure 2.** (continued)

a running mean (Meadow 1999). This allowed for a larger sample size to be pooled in order to directly compare a population to a standard value (modern Turkish wild boar and modern Egyptian domestic pig standards). The coefficient of variation (CV) showed differences suggesting that a number of pig samples might have comprised of more than one population. This was the case for Mendes (CV for $M_1$=19.22, CV for $M_2$=13.43, CV for $M_3$=11.59), Kom Firin (CV for $M_1$=11.99, CV for $M_2$=8.59, CV for $M_3$=7.24), and the Abydos Settlement Site (CV for $M_1$=18.54, CV for $M_2$=13.42, CV for $M_3$=7.69) (**Tables 3-5**).

## Discussion

### Age and sex of the modern and archaeological pigs

Like the modern domestic sample, that had an MWS peak between 20-24, most of the archaeological samples also seemed to have a killing peak at an immature age, with an MWS around 25. These animals were likely between 18 to 21 months at time of

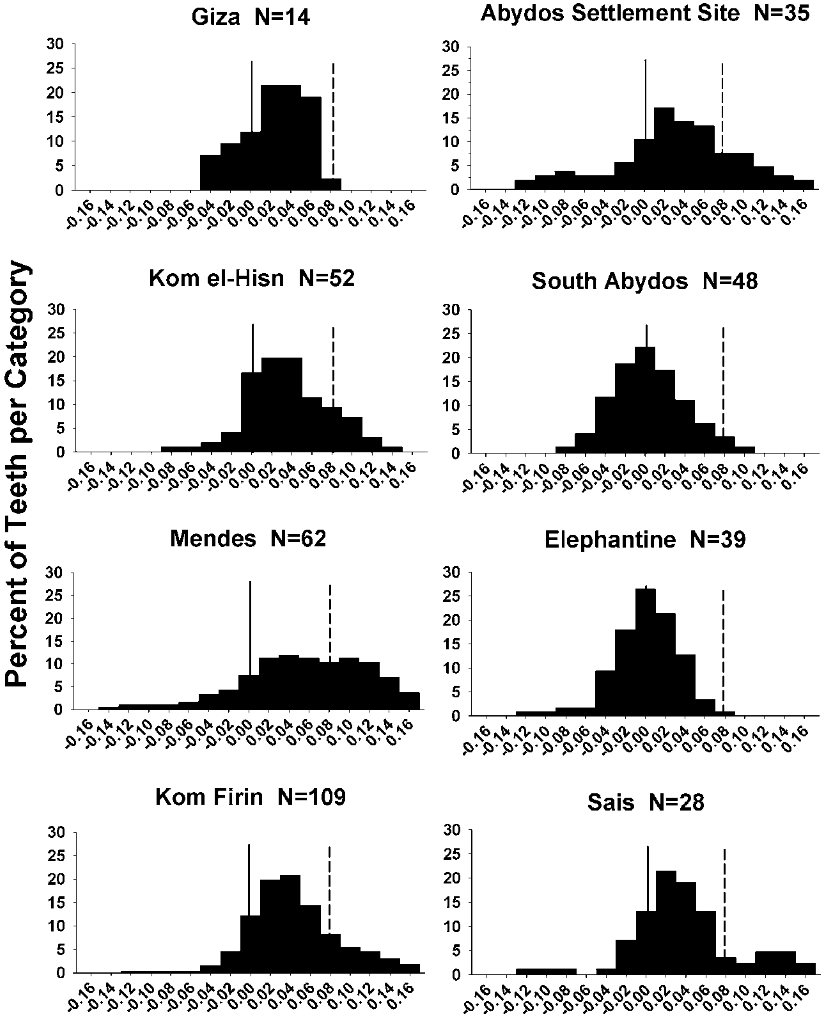


**Figure 3.** Comparison of pig lower molar measurements from all Egyptian populations studied. The posterior width of the first and second molar along with the anterior width of the third molar are combined using the log ratio technique and plotted as a running mean. The vertical lines inside panels represent the means from the modern Egyptian at 0, and Turkish wild boar (Payne & Bull 1988) at 0.08, standards (see text). Frequencies are presented as percentages of each sample.

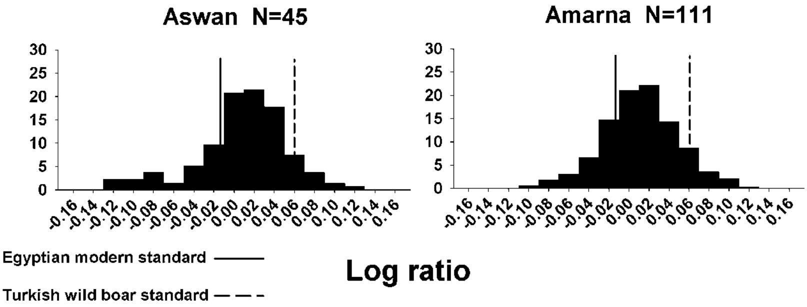


**Figure 3**. (continued)

death, which is similar to the results of previous work on age distributions at other sites such as Kom el-Hisn and Amarna. For example, Redding's (1991) survivorship curve suggests that the slaughter of pigs at Kom el-Hisn reached its peak between 12 to 24 months of age, based on epiphyseal fusion. Previous work at Amarna revealed a similar pattern, with the preferential age of slaughter falling into one of two categories: two to eight months (mostly males) and 14 to 24 months (mostly females), with a very small percentage surviving into their third year (Hecker 1982).

Although Hecker's reported age of slaughter may be similar to the age distribution in this analysis, there are some important differences to note. First, Hecker stated that from a total of 89 mandibles, analysis of 39 of them suggested those pigs were killed before nine months, about the same number killed before 24 months, and about 12 mandibles showed that the pigs survived beyond their second year (Hecker 1982). However, only 19 mandibles at Amarna had age data recorded during the present analysis. This large discrepancy between the 89 mandibles that Hecker reported in 1982 and our data suggests that large portions of the faunal sample for Amarna have since disappeared. Nevertheless, the Amarna sample recorded here has both a largely normal distribution and the widest age range in all the recorded samples. This possibly reflects a more intensive pig-rearing regime of domestic pigs at Amarna (Kemp 1991; Shaw 1984; Bertini 2011), where they were kept in pens due to a heavier demand for meat needed to support the citizens of the workmen's village. Although this age distribution encompasses all three age groups that Hecker discusses, our sample peaks at 18 to 21 months of age, reflecting the difference between the two analyses.

Kom el-Hisn and Kom Firin also displayed interesting age at death distributions (**Figure 2**). Although the Kom el-Hisn age distribution is based on five mandibles and the Kom Firin on twenty-six, both distributions appear to have a number of older individuals present in both samples. These could possibly represent either females being kept for breeding purposes or hunted adult wild boar. While Kom el-Hisn dates to the Old Kingdom and Kom Firin to the New Kingdom, both sites are located fairly close to each other in the western delta, indicating either similar husbandry regimes or the possibility of continuously hunting older wild boar during this approximately 1,200 year period. Only sites like Amarna (also possibly Saïs and Ptolemaic/Roman Aswan) that were more involved in rearing (Bertini 2011) seem to have pigs being slaughtered at an earlier age (approximate MWS around 5-10).

## Size of the modern and archaeological pigs

A number of the pig samples in **Tables 3-5** displayed CV ranges as high as 19.22 (e.g., Mendes $M_1$). However, when the total sample number of teeth is low, the CV may not necessarily be representative of the population due to the small sample size. Nonetheless, the sites of Mendes, South Abydos, Amarna, Kom Firin, Saïs, and Aswan had sample sizes greater than 10 teeth and had a CV greater than 8.3 for at least one of the molars, suggesting the presence of more than one population (**Figures 4-6**). Since the Shobra (modern) sample was the only one confirmed to represent a single, fully domestic population, it served as the baseline against which to compare the other samples. As expected, the values of CV for this sample were relatively small: 6.49 ($M_1$), 6.17 ($M_2$), and 8.26 ($M_3$) (**Tables 3-5**, **Figures 4-6**).

Evidence for the presence of more than one population was found in the Mendes sample. This was evidenced by the high values of CV (19.22 for $M_1$, 13.43 for $M_2$, and 11.59 for $M_3$ in **Tables 3-5**), and by the fact that mean molar sizes were significantly larger than those of the modern domestic sample (**Tables 3-5**). Although not clearly bimodal, the large distribution of tooth sizes in **Figure 3** shows a number of teeth larger than the Turkish wild boar standard. In order to better look at the Mendes distribution, the raw measurements of the $M_1$, $M_2$, and $M_3$ were plotted (**Figures 4-6**). All three molars show the presence of both larger and smaller sizes, although the $M_2$ measurements are slightly larger. Given the tight age distribution (**Figure 2**) of younger individuals combined with an almost equal percentage of both larger and smaller pigs, this may indicate a husbandry regime where wild boar/feral pigs were equally slaughtered alongside domesticated ones, or there is a presence of different populations of domestic pigs of different breeds/sizes. Sexual dimorphism is also another possibility. However, given the young age distribution, the possibility of larger size teeth representing older females kept for breeding purposes remains remote.

Kom Firin, however, revealed a different pattern. The CV of the three teeth were 11.99 ($M_1$), 8.59 ($M_2$), and 7.24 ($M_3$) (**Tables 3-5**). Based on this high CV for the $M_1$ and $M_2$, more than one population was likely present. Although, the presence of more than one population does not conform to the low CV for the $M_3$, the larger

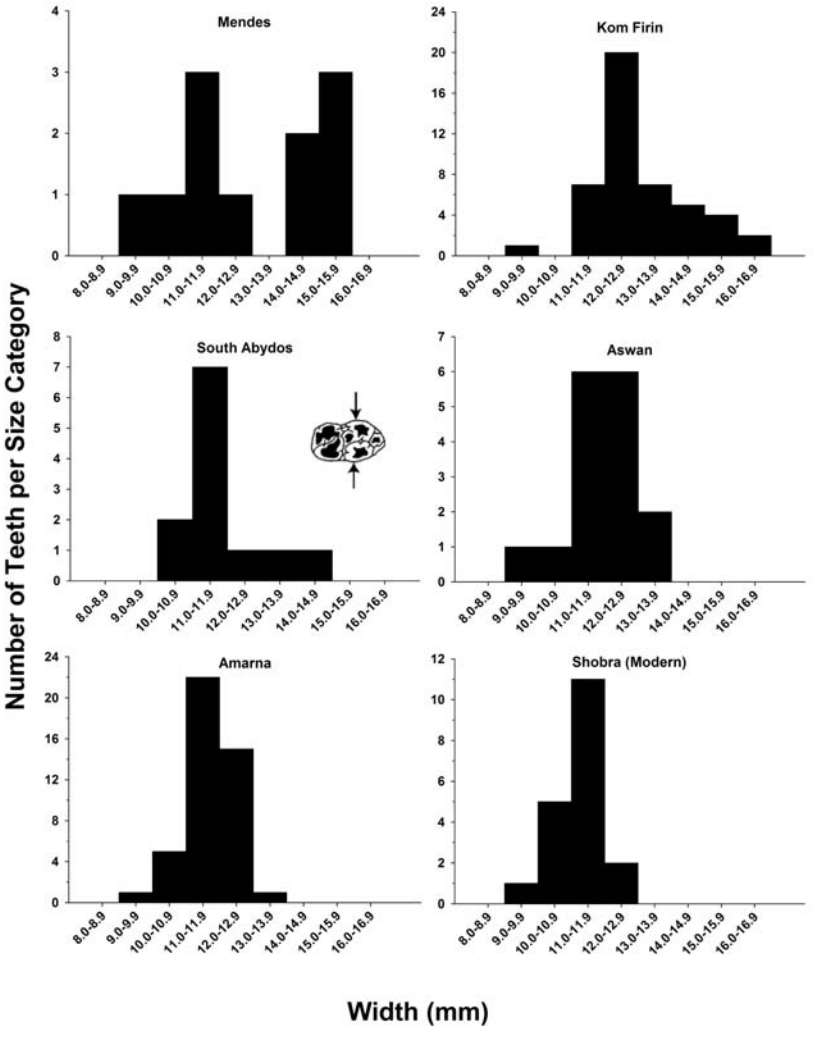


**Figure 4**. Comparison of raw first molar posterior widths from selected Egyptian pig samples. Arrows indicate the distance measured to determine tooth width.

tooth width for $M_3$ and the sequence of tooth eruption in pigs support the presence of a mixed sample. A similar situation was seen at the European Neolithic site of Gomolava (Rowley-Conwy et al. 2012), where it was concluded that wild boar and domestic pigs were killed at different ages. The percentage of domestic animals was

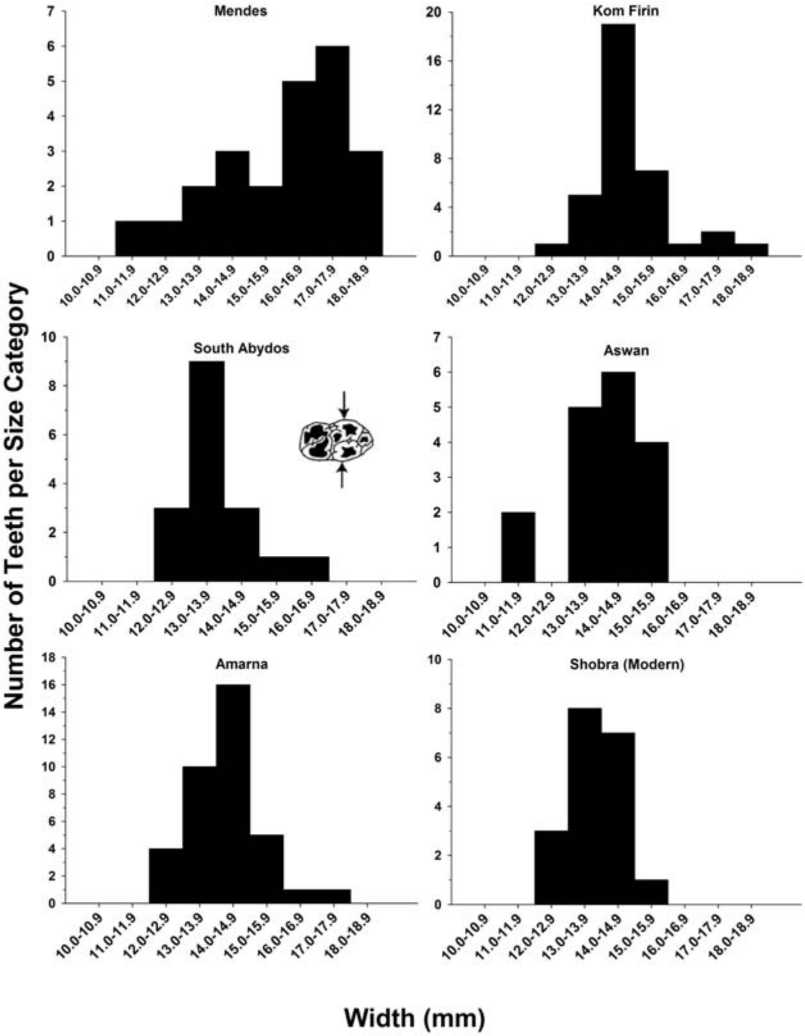


**Figure 5**. Comparison of raw second molar posterior widths from selected Egyptian pig samples. Arrows indicate the distance measured to determine tooth width.

highest in the $M_1$, the earliest erupting tooth, and lowest in the $M_3$, which erupts last. If most domestic pigs were killed at a young age, few would have erupted $M_3$. If more wild boar were killed as adults, their $M_3$ would be more common (Rowley-Conwy et al. 2012). This is visually seen in **Figures 4-6** where the $M_3$ shows a significantly lower

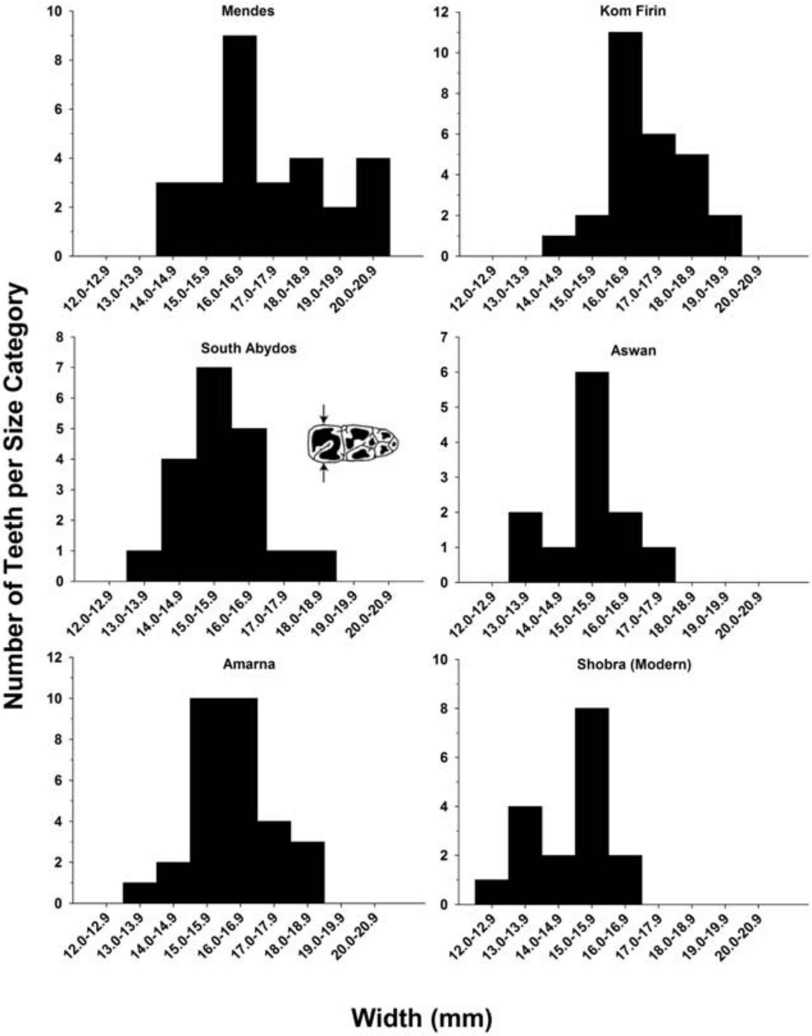


**Figure 6**. Comparison of raw third molar anterior widths from selected Egyptian pig samples. Arrows indicate the distance measured to determine tooth width.

percentage of smaller pigs present as compared to the $M_1$ and $M_2$. Thus, similar to the case of Gomolava, the pig economy at Kom Firin could be based on the slaughter of juvenile domestic pigs and the hunting of more adult wild boar/feral pigs.

The Middle Kingdom site of South Abydos, along with the sites of Amarna and Aswan all seemed to have single populations based both on their low CV (**Tables 3-5**) and as seen in **Figures 4-6**. While widths of all three molars at these sites were statistically equivalent to those of the modern domestic sample (with the exception of Amarna $M_3$, which were statistically larger; **Tables 3-5**), all sites had some larger teeth. Although it is possible that there may be one or two wild boar/feral pigs in the samples, it is also possible that sexual dimorphism or different breeds/sizes of pigs could account for these findings, especially at Amarna. Given both the intense pig-rearing regime at Amarna (Kemp 1991; Shaw 1984; Bertini 2011) coupled with its desert environment, it is highly unlikely that wild boar/feral pigs were present. The more likely scenario is either the presence of small number of females kept for breeding purposes along with juvenile domestic pigs slaughtered for consumption or the presence of different breeds/sizes of pigs.

## Conclusion

This article represents the first wide-ranging analysis of pig teeth from ancient Egypt. Through biometrical analysis we establish the presence of more than one pig population. While this study represents only the first step towards answering more fundamental questions, such as the possibility of an independent local domestication of the pig and the role of wild boar/feral pig in the diet and economy of ancient Egypt, this article shows that larger pigs were present in various settlements, most notably in the Nile Delta. Work on goats (Zeder 2006b), however, has demonstrated that what seem to be changes in body sizes are actually a change in the sex ratio. Although this could also be another possibility to explain the presence of more than one population, as none of the archaeological samples were able to have sex estimated, coupled with the fact that there were no significant differences in the modern male and female population, this is also another avenue of future study.

In terms of methodology, this study also highlights the use of biometrical methods as an easy and inexpensive way to assess the presence of more than one population in a sample. Future work could include a geometric morphometric study following the work by Cucchi et al. (2011) and Ottoni et al. (2013) to further investigate whether the hypothesis of wild boar presence in Egypt holds up or not. It would also be informative to compare these teeth metrics to post-cranial measurements and evaluate if the same patterns emerge. This, however, may be problematic because of the poor preservation of post-cranial remains at most sites, especially around the Nile Delta.

Pigs are the most difficult of the domesticated animals to classify as either wild or domestic. The use of the coefficient of variation (CV), along with the shape of data distributions and comparisons of molar widths, can be useful in distinguishing populations when proper sample sizes are available. However, caution should be exercised to account for the possibility of sexual dimorphism, differences between breeding versus animals slaughtered for food, and the problems with assessing the variability of wild boar/feral pig populations (Albarella et al. 2009). In this study, all single populations appeared to be domestic, and no evidence of settlements relying exclusively on hunting wild boar/feral pigs was observed. Our data also suggest there was a presence of larger pigs—either wild boar, feral pigs, or different populations of domestic ones. Future work, however, is needed from earlier (Neolithic) settlement contexts with the hopes of adding insight on the origin of the domestic pig in Egypt.

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