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Volume IV

Contributions to the Archaeology of Egypt, Nubia and the Levant

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The Enigma of the Hyksos
Volume IV

Changing Clusters and Migration in the Near Eastern Bronze Age

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Edited by
Manfred Bietak and Silvia Prell

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In Memory of Jochen Holger Schutkowski
(1956–2020)

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Contribution of Bioanthropology to Defining the Tell el-Dab‘a Population in the Eastern Delta: Preliminary Findings

by Arwa Kharobi[1], Nina Maaranen[2], Chris Stantis[3], Sonia Zakrzewski[4] and Holger Schutkowski †

Abstract

The data provided in this paper was presented at the workshop ‘Changing clusters and migration in the Near Eastern Bronze Age’, held at the Austrian Academy of Sciences in 4th–6th December, 2019. The work has been conducted under the Hyksos Enigma project’s Research Track 7 (RT7) in Bournemouth University (United Kingdom), focusing on bioarchaeology and the study of skeletal human remains from Tell el-Dab‘a. This paper highlights the potential of using an integrated suite of osteological analyses in the archaeological framework, offers an overview of the field of bioarchaeology, presents some preliminary findings using this framework, and offers further possibilities and directions. The paper focuses on the different aspects of research conducted by RT7, including non-destructive macroscopic (dental nonmetric trait and palaeopathological) analysis and biochemical (aDNA, stable isotope) analysis.

Introduction

Processual archaeology, sometimes referred to as ‘New Archaeology’, was a major paradigm shift which also impacted the wider sub-fields of the discipline. In the study of human remains, this shift began with Washburn in the 1950s, who rejected the previous ‘religion of taxonomy’ and demanded hypothesis testing and a holistic consideration of human remains.[5] Focus was directed towards understanding evolutionary pathways and formulating interpretations combining biological, sociocultural and environmental factors.[6] Today, bioarchaeology, focusing on human remains, is a vast field of research that pursues to contextualise and integrate human remains to the larger understanding of the past.

Egyptology has faced criticism for its lack of progress in some aspects of theoretically-framed and scientific research.[7] The Hyksos Enigma project, with its eight interrelating research tracks, has pursued to reconstruct holistic interpretations of the Hyksos by engaging in such current theoretical and methodological advancements. Research Track 7 (RT7 henceforth) of the project took on the task of analysing skeletal remains from Tell el-Dab‘a and beyond to offer another avenue of evidence in the discussion of the nature and impact of the Hyksos.[8] A multidisciplinary approach was employed, combining non-destructive macroscopic (dental nonmetric traits and palaeopathological) and biochemical (stable isotopes and ancient DNA) analyses. The information these data provide is not only diverse but complementary as the human body is a dynamic entity governed by both intrinsic and extrinsic factors. By combining the different avenues of research and considering them together with the full scope of the archaeological record, it is possible to construct both population and individual life histories.

Skeletal remains were accessed from numerous institutions from several continents, for which we are deeply grateful to our collaborators. Though some of these analyses are currently still in embargo, we are able to present some preliminary findings of our work in Tell el-Dab‘a as well as our list of sites that will be directly engaged in further future work. This work could not have been possible without the guiding hand of Professor Holger Schutkowski, the Principle Investigator of RT7 and our mentor, who sadly passed away on March 30, 2020. The research presented here, and all other further work, is dedicated in loving memory to Holger.

Materials

RT7 focused on collecting data from Middle Bronze Age Egypt and the Eastern Mediterranean. These areas have proven relevant for the study by decades of previous research.[9] Because of the special interest in the Levant and Mesopotamia, efforts were focused on accumulating new data from this area. Material was included in the analysis only if dating could be ascertained to the time period of interest, the Bronze Age. Though the focus was the Middle Bronze Age II period, data were included from individuals dating from the Early Bronze Age to the Late Bronze Age. The chronological window was extended as the absolute timing of ‘the Hyksos invasion’ was uncertain.

Tab. 1 presents a list of sites the authors have engaged with directly, by either receiving data from colleagues, for which we are truly grateful, or collecting the data ourselves. Though the results of such data are not presented here (currently in embargo), it was considered useful for readers to be aware of future directions.

1 Bournemouth University, Université de Bordeaux, akharobi@bournemouth.ac.uk.
2 Bournemouth University.
3 Department of Anthropology, National Museum of Natural History, Smithsonian Institution, Washington.
4 University of Southampton, S.R.Zakrzewski@soton.ac.uk.
5 Mikels-Carrasco 2012; Washburn 1951.
6 Armelagos, Carlson and van Gerven 1982.
7 Matić 2018; Priglinger 2018.
8 Maaranen et al. 2019a.
9 Bietak 1996; 2007; 2010.

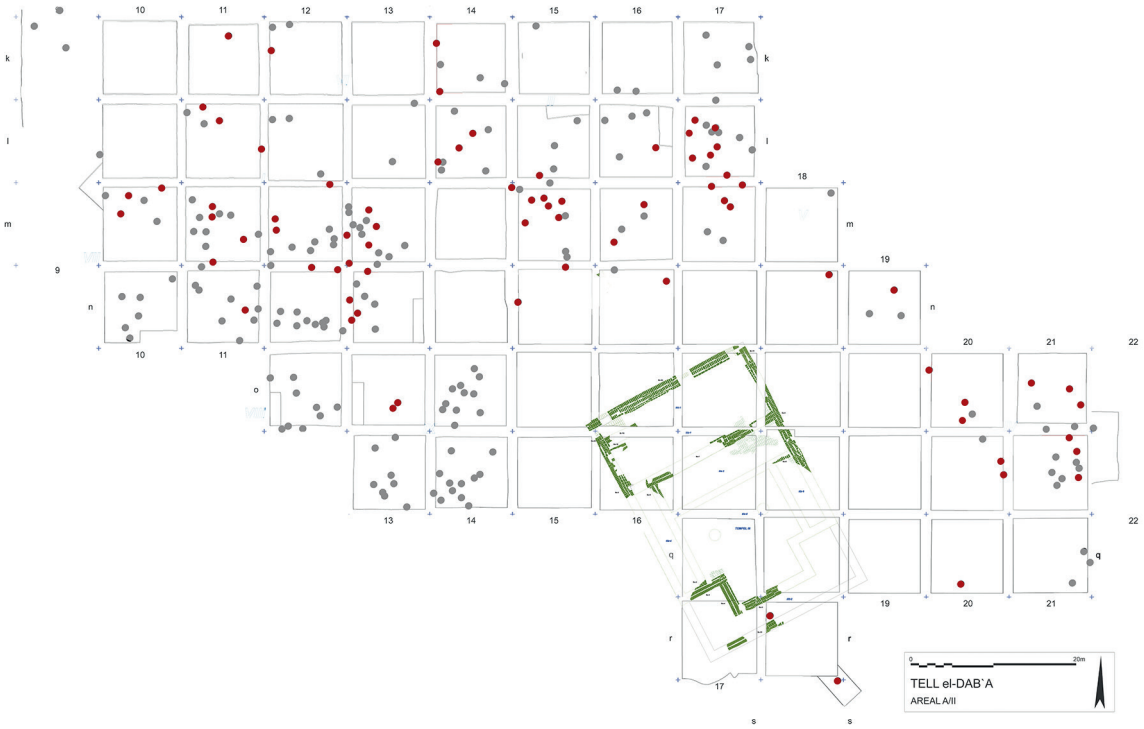

Fig. 1 Map of Area A/II (map by P. Aprent), modified to show all burials (dark grey) and samples (red). The points represent burials, not individuals. The map may not be exhaustive as burials have been located based on published information. Temple III (green) has been provided for reference

It is also pertinent to acknowledge the absence of some major Middle Bronze Age sites, resulting from a lack of appropriate material and/or access. The current paper, as mentioned earlier, focuses on presenting preliminary findings from Tell el-Dab'a and offers some bioarchaeological perspectives to the study of the so-called Hyksos people. Because of the greater volume of published information, some research questions could be focused on the material from Area A/II, representing not only the largest cemetery at the site but also the source of most of the research material for the authors (Fig. 1). Substantially fewer samples were available from Areas A/I and F/I.

Individuals, excavated from Tell el-Dab'a and exported in the late sixties and early seventies, were accessed as outlined in Stantis et al. 2020b.[10]

The state of preservation of the bones ranges from small fragments of smashed bones to larger long bone fragments and skulls. Most of the skulls were deformed by post-mortem soil pressure. Preserved skulls or larger bone fragments were difficult to examine due to their reinforcement with layers of glue, and hence observations were sometimes limited. As an example of the problem of skeletal representation, an individual is sometimes represented only by a fragment of a hand phalanx. Unfortunately, even when some individuals appear to be complete, from Winkler and Wilfing's *in situ* observations, what remained was fragmentary and incomplete.

Demographic patterns, based on Winkler and Wilfing's observations as field osteologists at the site, show a relatively young population. 60% are subadults (≥12 years) with a high mortality of newborns. Of the adults who could have sex estimated, 56% are male.

Methods

Bioarchaeological research has a plethora of possible avenues of analysis. Because of the interests of the Hyksos Enigma project, and the (extremely poor) preservation condition of the Tell el-Dab'a material, methods employed by RT7 were focused on developing mechanisms that might yield the best possible research outcome. In many cases, teeth were the best-preserved elements of the individuals, and thus were used in several different and distinct methodological approaches.

aDNA

Recent developments in ancient DNA analysis techniques have already begun to transform the field of biodistance analysis, providing much more

10 Stantis et al. 2020b.

Site	Data acquired via	Sample size			
		aDNA	Stable isotopes	Dental non-metric data	Paleo-pathology
Ajjul, Tell el-	Duckworth Laboratory, Cambridge	-	-	17	-
Arbid, Tell el-	Data courtesy of Prof Arkadiusz Sołtysiak and Dr Jessica Walker	-	18	31	13
Arqa	Data courtesy of Dr Joyce Nassar	13	44	93	-
Ashara	Data courtesy of Prof Arkadiusz Sołtysiak and Dr Jessica Walker	-	5	87	-
Barri	Data courtesy of Prof Arkadiusz Sołtysiak and Dr Jessica Walker	-	21	28	119
Brak, Tell	Data courtesy of Prof Arkadiusz Sołtysiak and Dr Jessica Walker	-	5	34	-
Burak, Tell el-	Pompeu Fabra University, Barcelona	-	-	4	-
Dab‘a, Tell el-	University of Vienna, Medical University of Vienna, Natural History Museum (Vienna)	10	178	96	178
Dra‘ Abu el-Naga‘	Musée de l‘homme (Paris)	-	4	43	-
Fadous, Tell el-	Tell Fadous-Kfarabida project (American University of Beirut)	-	6	6	-
Far‘ah, Tell el-	Duckworth Laboratory, Cambridge	-	-	20	-
Jericho	Nicholson Museum (Sydney), Australian Institute of Archaeology (Melbourne), Duckworth Laboratory (Cambridge), British Museum (London)	2	3	69	-
Mozan, Tell	Bournemouth University	5	17	26	120
Pella	Pella in Jordan project (University of Sydney)	2	22	33	-
Sidon	Sidon project (Sidon), Bournemouth University	9	56	104	104
Sukas, Tell	Panum Institute (University of Copenhagen)	-	9	11	-
Ugarit (Ras Shamra & Minet el-Beida)	Musée de l‘homme	-	3	42	42
Umm el-Marra	Johns Hopkins University, courtesy Prof Glenn Schwartz	8	21	-	-

Tab. 1 A list of sites and sample size included in RT7 database for each bioarchaeological approach of this study

information of the individual and the population.[11] The introduction of next-generation sequencing (NGS) has removed issues inherent in PCR methods, such as the detection of contamination and ability to analyse lower-quality DNA.[12] With NGS, the whole genome can be sequenced, eliminating bias of prior selection, and one sequence can be used to map out sex, ancestry, kinship and pathology. NGS increases the range of samples that can be analysed or re-analysed, as many samples were overlooked in the past because of a failure to PCR amplify aDNA. Researchers before were restricted to regions where exceptional aDNA preservation was likely. NGS can effectively analyse much lower quality aDNA. The smallest DNA fragment size range for PCR is 60–70 base pairs (bp), but most of the informative aDNA extracted from an archaeological specimen is smaller than this due to post-mortem decay.[13]

The success of aDNA analysis depends strongly both on good source material and a careful extraction technique that targets small fragmented sequences and minimises contamination.[14] Previous studies have shown that various bone types stochastically preserve endogenous DNA, as demonstrated by varying levels of preservation within individuals.[15] The sample material should be cohesive and impermeable to the environment. Tooth and petrous bone have been demonstrated as reliable sources of endogenous and good quality DNA.[16] In particular, the petrous part of the temporal bone of the skull appears to yield the highest amount of authentic human DNA compared to other bone material. Pinhasi et al. 2015 have demonstrated that it is possible to obtain endogenous ancient DNA from petrous bones from arid environments, such as Asia and North Africa. The DNA concentrations from the dense petrous bones turned out to be up to 126-fold higher compared to trabecular bone. The quality of the endogenous DNA based on read lengths and damage pattern was substantially better. No suitable aDNA-material from Tell el-Dab‘a could, however, be accessed.

Stable Isotopes

Isotopic analysis is a potentially powerful toolset traditionally used to investigate mobility and diet,[17] along with exciting new perspectives providing novel insight into research questions surrounding infant weaning[18] and disease.[19] In Egypt, Sudan, and the Near East, isotopic data has been integrated with existing archaeological knowledge in order to elaborate on complex topics such as economic exchange networks and culturally mediated access to food.[20]

With Tell el-Dab‘a, research integrating stable isotopes analysis has the opportunity to approach questions not only related to large-scale processes, but the individual-level effects of the overlying cultural environment.[21] So far, analysis of animal bones from the site have displayed a restricted $^{87}Sr/^{86}Sr$ range in values,[22] providing promise of a means of confidently identifying those who immigrated to the northeastern Nile Delta during their lifetime. Analytical methods of isotopes will not be described in detail in this chapter.[23]

Dental Nonmetric Traits

Dental morphological studies rest on tooth ontogeny, governed by c. 300 genes in interaction with epigenetic and environmental factors.[24] According to Thesleff (2014), four main families of signalling molecules, along with mediators and transcription factors, initiate and direct various stages of odontogenesis. These processes are considered sufficiently stable to for the teeth to be viewed as ideal structures for biological distance (biodistance henceforth) analyses. Biodistance studies can use tooth size and morphology both separately and together, using odontometrics, nonmetrics or geometric morphometrics. Due to the preservation of the Tell el-Dab‘a material, investigation focused on nonmetric dental traits.

Dental nonmetric traits, also referred to as discrete, discontinuous or epigenetic traits, are accessory ridges, tubercles, styles, accessory cusps in crowns and deviations in root numbers in teeth.[25] Like the rest of the bioanthropological field, dental morphology studies shifted away from racialized typology after World War II.[26] At Arizona State University in the United States, Dahlberg (1950) made a great leap by casting the first series of plaques depicting morphological variation, beginning the standardization process of dental (nonmetric) trait recording. Spurred on by his work and the increasing number of discovered dental traits, dental morphology has been synthesized into biological distance analyses at various scales.[27] Further information on the utilized dental traits and methodology has been discussed previously.[28]

11 Killgrove 2013.
12 Keller et al. 2012; Knapp, Lalueza-Fox and Hofreiter 2015.
13 Jobling, Hurles and Tyler-Smith 2013.
14 Dabney and Meyer 2012.
15 Gamba et al. 2014.
16 Allentoft et al. 2012.
17 Stantis and Schutkowski 2019.
18 Stantis et al. 2020a; Tsutaya 2017.
19 Mekota et al. 2006; Salesse et al. 2019.
20 Buzon and Simonetti 2013; Buzon, Simonetti and Creaser 2007; Buzon, Smith and Simonetti 2016; Perry, Coleman and Delhopital 2008; Perry et al. 2009; 2011.
21 Stantis et al. 2020b.
22 Stantis et al. 2019.
23 See Stantis and Schutkowski 2019 for suggested reading.
24 Ramirez Rozzi 2016; Thesleff 2006; Townsend et al. 2009; 2012.
25 Scott, Turner and Christy 1988.
26 Dahlberg 1945; 1951; Kraus 1951; 1959; Lasker 1950.
27 Scott 1973; Scott and Dahlberg 1982; Turner 1986.
28 Maaranen et al. 2019b.

Biodistance methods are commonly used to assess intra- or inter-site variation or regional continuity, but, with enough samples in size and number, analysis can be extended to continental and even global variation. Inter-regional analyses have remained popular as they consider a broader spectrum of human evolution, but they have theoretical challenges due to the extended temporal contexts. Consequently, regional and intra-cemetery analyses with more restricted time frames have a better theoretical foundation, and can offer insight into kinship, cemetery structure analysis, post-marital residence analysis, phenotypic variation and temporal microchronology.[29] The theoretical and methodological development of intra-site analyses is varied, strongest for post-marital and temporal microchronology studies but still developing for studies regarding phenotypic variation.[30]

The intra-site analysis of Tell al-Dab'a presented here focused on temporal change at the site. Two major statistical techniques were used for this, the modified Mean Measure of Divergence (MMD) available as an R package AnthropMMD by Santos (2018), and the Gower distance analysis conducted using the R package by Maechler et al. (2019). Both methods can accommodate missing values, an issue with most archaeological material. The former uses grouped frequencies, first dichotomized into present (1) and absent (0), while the latter method can use either to compare individuals. Both were employed in the current analysis for a more robust interpretation of the population structure and its changes.

Palaeopathology

Paleopathology is the reconstruction of past health and disease and is one of the primary foci of bioarchaeology. The plasticity of the skeleton allows for functional adaption to environmental changes, whether natural or cultural. The skeleton is thus a reflection of a lifetime of interaction with the world, displaying physical responses to damage, mechanical stress and disease. This plasticity signifies that the skeleton is a record of the history of social relationship.[31]

The aim of the palaeopathological analysis in this study is to document indicators of health and stress, then to examine differences between skeletons regarding age, sex and chronological phases. This will help answering questions regarding the causes and ways of immigration, the apparent Hyksos failure, and their longer-term impact on Egypt. An adapted protocol for these objectives has been established based on the guidance on the recording paleopathology of Roberts and Connell 2004. Each available bone and tooth were analysed to record:

Indicators of oral health including ante mortem tooth losses (AMTL),[32] abscess,[33] dental caries,[34] dental wear/attrition[35] and calculus.[36]

Indicators of stress including dental enamel hypoplasia (DEH),[37] *cribra orbitalia*[38] and *cribra femora*.[39]

The different kinds of *cribra* are markers of either nutritional deficiencies or physiological stress. Some authors attributed it to genetic or infectious anaemia.[40] *Cribra orbitalia* is a form of porotic hyperostosis present on the orbital roof, whose aetiology is still somewhat obscure.[41] *Cribra femora* is a porous lesion on the anterior aspect of the femoral neck, often explained by physiology, but it could also be related to a diet rich in cereals during the weaning period.[42] It appears to be observed more frequently in subadults.[43]

The results of each indicator are presented in frequency according to presence or absence using either crude prevalence rates (CPR)[44] or true prevalence rate (TPR).[45] The frequency is considered moderate when it is $\leq 50\%$, and high when it is $\geq 50\%$ based on the trends from the Bronze Age period in the Near East. Two-tailed Fisher's exact tests were used to compare frequencies of all pathological conditions between the chronological periods. Fisher's exact test was selected due to small sample sizes.

Result

aDNA

Suitable samples were acquired from Tell el-Dab'a for analysis, however, due to poor preservation, no DNA was successfully extracted from the individuals from this site.[46] Work on samples from comparative sites is still in progress.

Stable Isotopes

Stable isotopes analysis of 75 individuals from Tell el-Dab'a found that more than half of all individuals (40/75 or 53%) from Tell el-Dab'a spent their childhood

29 Stojanowski and Schillaci 2006.
30 Stojanowski and Schillaci 2006.
31 Dutour 2016; Ortner 2003; Robert and Manchester 2007.
32 Buikstra and Ubelaker 1994.
33 Dias and Tayles 1997.
34 Lukacs 1989; Hillson 2000; 2001.
35 Smith and Knight 1984.
36 Brothwell 1981.
37 Buikstra and Ubelaker 1994; Reid and Dean 2000.
38 Ortner and Ericksen 1997; Ortner, Kimmerle and Diez 1999; Stuart-Macadam 1987; 1989; 1992.
39 Lewis 2017; Ortner 2003.
40 Ortner, Kimmerle and Diez 1999; Walker et al. 2009.
41 Brickley 2018; Rinaldo et al. 2019.
42 Lewis 2017; Ortner 2003.
43 Djuric et al. 2008; Paredes, Ferreira and Wastelain 2015.
44 CPR is equal to the number of individuals exhibiting the condition (n) divided by the number of individuals examined (N) X 100.
45 TPR is equal to the number of teeth affected (n) divided by the number of teeth examined (N) x 100.
46 Saupe et al. forthcoming.

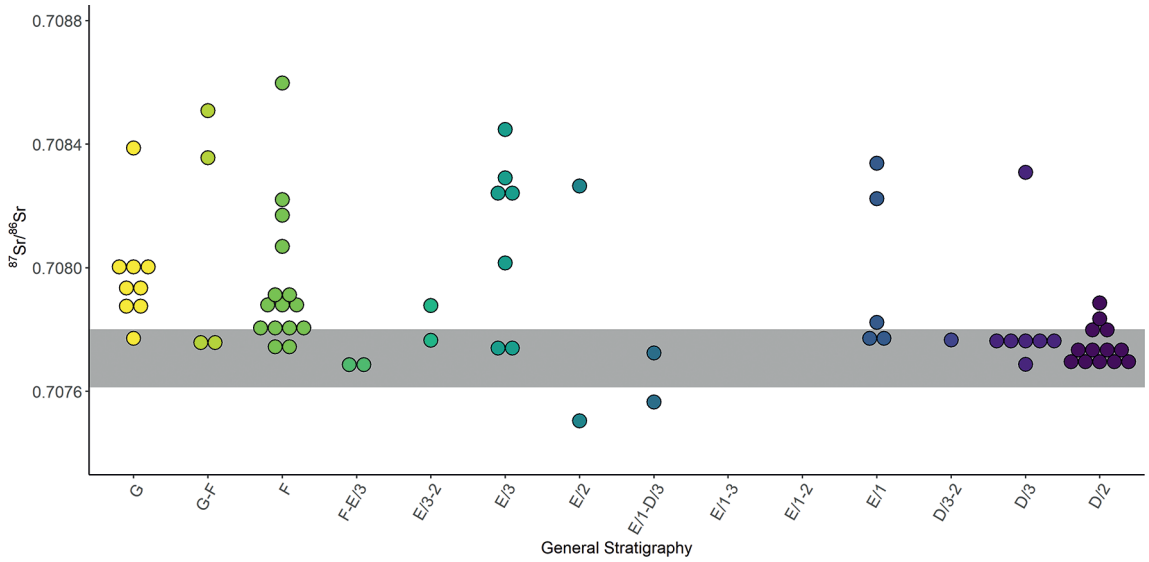

Fig. 2 $^{87}Sr/^{86}Sr$ results by general stratigraphic phases. Shaded rectangle denotes 'local' values

outside the Nile Delta.[47] Of those individuals for whom sex estimation was possible, 78% of females (21/27) and 50% of males (9/18) displayed $^{87}Sr/^{86}Sr$ values outside of the local values. Pairing $\delta^{18}O$ with previous $^{87}Sr/^{86}Sr$ data identified 60% of the cohort analysed (45/75) was identified as non-local.[48] Examining individuals by the site stratigraphy, there seems to be no clear pattern, although examining the more general phases (e.g. looking at movement between dynastic periods) might yield clearer patterns (Fig. 2).

Dental Nonmetric Traits

The dental nonmetric traits from Tell el-Dab'a were utilised to consider questions of both intra-site temporal change and inter-site biological distance. The first step of the analysis comprised simply an observation of the dental traits present in Tell el-Dab'a. Accessory cusps were common (such as Carabelli cusps, upper molar cusp 5 and premolar accessory cusps), as were two-rooted premolars. Most dental traits were consistent in their mean score across strata, though some traits showed fluctuation particularly during strata E/3–1.[49] The changes were temporary and the scores between the earlier and later strata were not significantly different ($p > 0.05$).

MMD, as a grouping method, was able to engage with the entire Tell el-Dab'a data set (n=96). The results showed little change in the biological affinities of the Tell el-Dab'a population when transitioning from the end of Middle Kingdom to the Second Intermediate Period ($p<0.05$). For the Gower distance analysis, the individuals under analysis were restricted to Area A/II, the portion of the site containing the greatest amount of available contextual information. At this stage, because of missing data, the sample size dropped from 84 (the number of individuals from Area A/II available for analysis) to 31 individuals and 18 dental traits. The number of individuals, however, from stratum G all the way to D/2, was spread evenly in the sample and across Area A/II, making it at least representative of the area. No significant changes were noted between the Middle Kingdom and the Hyksos strata. An additional analysis was conducted by dividing the Tell el-Dab'a individuals into morphological groups and comparing those to time periods. Partitioning around medoids (PAM), a statistical tool designed to detect groups from nonparametric data, was used to explore the 31 individuals by morphology alone. The individuals divided into two groups but the difference between these groups was weak and showed no significant division according to time periods ($p<0.05$).

Lastly, though not the focus of this paper, some preliminary findings can be presented from inter-site analyses. A comparison between Tell el-Dab'a and other temporally close Egyptian sites (el-Lisht, Thebes and Qurna), available from Irish,[50] indicated a significant difference particularly between the 'Hyksos' and the other sites.[51] Recent analysis of the Tell el-Dab'a corpus, together with the sites mentioned earlier (Tab. 1), suggest a strong biological affinity with contemporary Levantine populations.[52] The results offer strong support for the foreign origin

47 Stantis et al. 2020b.
48 Stantis et al. 2021.
49 Maaranen et al. forthcoming.
50 Irish 2006
51 Maaranen et al. 2019c.
52 Maaranen et al. forthcoming.

of the Tell el-Dab'a population, established already during the Middle Kingdom.

Palaeopathology

Indicators of Oral Health

Examination of food archaeological remains in middens and evidence of food preparation areas and tools are a means of reconstructing past nutrition. However, more direct evidence of diet can be derived from human teeth.[53] Many studies demonstrate the direct relationship between oral health and lifestyle[54] since dental diseases can considerably impact on quality of life.[55]

The 82 skeletons examined from Tell el-Dab'a show a high rate of dental wear at 80%CPR, a moderate rate of calculus at 24%CPR, and a low rate of caries at 6%CPR. No significant differences were noted between mandibular and maxillary permanent teeth or between the anterior and posterior dentition for those oral health indicators. Additionally, no statistically significant difference between the sexes was observed. The deciduous teeth did not show any carious lesions nor dental attrition, supporting the normative notion that the prevalence of dental caries and wear increases with age.

Finally, AMTL was observed in 4.8%CPR of the studied alveoli of the permanent dentition. Mandibular alveoli were more affected than maxillary alveoli (78.5 vs 21.5%TPR), and posterior alveoli were more affected than anterior alveoli (100 vs 0%TPR). This may be related to dental wear, caries or dietary practices. Abscesses are present in 0.7%CPR of the mandibles with permanent dentition, while those with deciduous dentition do not show this pathology.

Indicators of Stress

Stress indicators are divided into 1) general cumulative indicators; 2) general episodic indicators and 3) indicators of specific insults.[56] Regardless of the type, they are all linked to the general health status of individuals. Such indicator lesions can be seen on human teeth or bones, and may be useful in inferring environmental, cultural and economic factors that affected the population.[57]

Among the dental samples examined here, dental enamel hypoplasia (DEH) is observed in 31 of 75 individuals showing multiple episodes. Most lesions were of moderate severity, and the estimated mean age at development of this defect in permanent teeth is 4.1 ± 1.1 years. Anterior teeth are, unsurprisingly, more affected; this is the expected physiological pattern observed globally.[58] Females are slightly more affected than males, and subadults more than adults. The presence of DEH in deciduous teeth suggests high metabolic stress during early childhood or malnutrition of both infant and mother. The health of the mother directly influences the health of her infant, and so enamel defects occurring during the intrauterine period suggest maternal stress.[59]

Of the 18 skeletons suitably qualified for scoring *cribra femora*, 10 are affected, deriving from 4 subadults (($\geq$ 12 years) and 6 young-middle adults (36–50 years).

Ten cases of *cribra orbitalia* were recorded in the Tell el-Dab'a assemblage. Adults and subadults were affected equally, with no differences noted between the sexes.

By examining the chronological context of the assemblage, it seems that the trends of all indicators of oral health and/or stress are mostly similar; no changes were identified between the earlier Hyksos and the pre-Hyksos ones, nor even the final decades of their living (Fig. 3).

Discussion

In its narrowest definition, the term Hyksos would only cover the kings of the 15th dynasty and some contemporary smaller dynasties.[60] In the context of the current research question, it was extended to all the people residing at Tell el-Dab'a over the time period, performing the same material culture, and who were possibly the founders of the Hyksos dynasty. The archaeological evidence does not point to a single origin, which has led some researchers to criticise the use of denominator like the Hyksos in the first place as *"the propagation of such monocultural assumptions, combined with the simplistic conceptions of ethnicity that have typified much research on the ancient Near East, have resulted in the framing of inappropriate research questions, in particular those which have sought to use archaeology to identify the 'homeland' of the Hyksos"*.[61] By combining bioanthropological and statistical tools, it was possible to explore these phenomena in a manner that does not assume that either (single versus diverse, sudden versus continuous) mode is correct.

It is unfortunate that no ancient DNA appears to have survived from the sampled Tell el-Dab'a individuals, at least using modern NGS techniques. This highlights the necessity of multi-disciplinary approaches to investigating questions about ancestry, identity, and population movement.

Regarding isotopic analysis, those individuals deemed 'non-local' using isotopic analysis cannot be assigned origins. Isotope analysis is a powerful

53 Cohen and Armelagos 2013.
54 Hillson 1979; Schutkowski 2006.
55 Soames and Southam 1998.
56 Goodman et al. 1988.
57 Cook 1981; Goodman and Armelagos 1989.
58 Hillson 1996.
59 Pezo-Lanfranco et al. 2020; Sandberg et al. 2014.
60 Bietak 2001; Bietak 2010.
61 Philip 2006, 236.

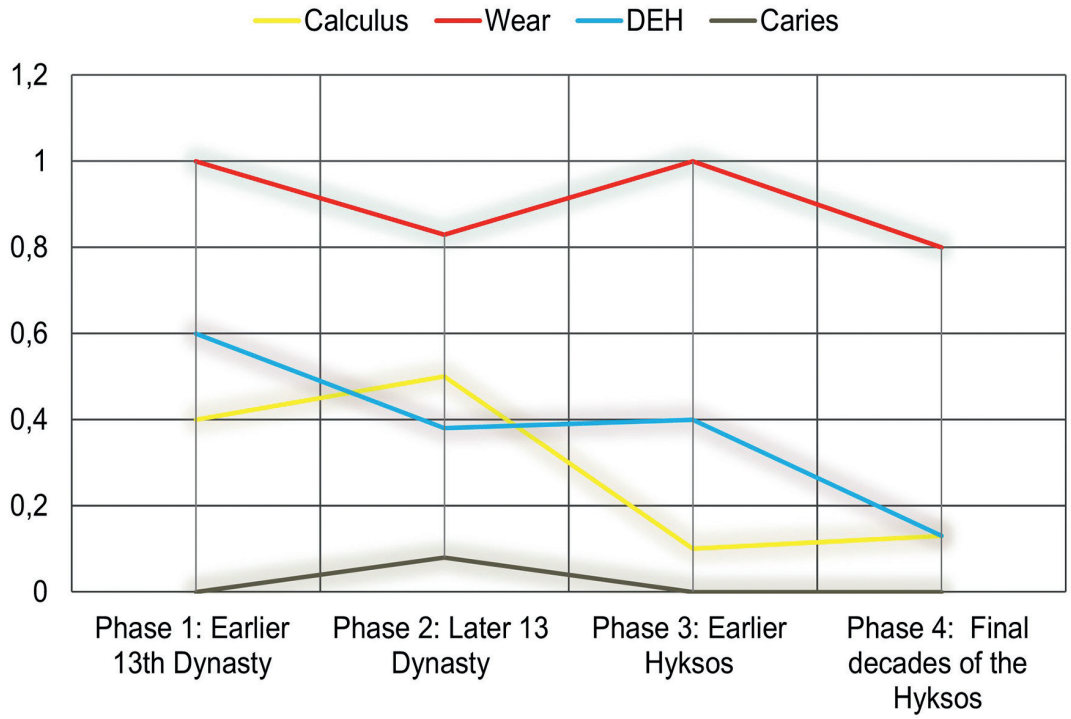

Fig. 3 Frequency of oral health indicators by general chronological phases

tool for exploring past mobility and identifying non-locals. However, identifying the origin of non-locals using this method is much more difficult. The wide range of values suggests that non-locals, before or during Hyksos rule, did not come from one unified homeland, but an extensive variety of geographic origins. This is interesting, as the population interred at Tell el-Dabʿa seems to represent a multicultural hub throughout the site's occupation. Further analysis of the collaborating sites may not help in identifying the origins of those deemed non-local at Tell el-Dabʿa but will enrich our understanding of movement between Egypt and the Levant during the Middle Bronze Age.

Based on the dental nonmetric trait analysis, Tell el-Dabʿa was not only distinctly different from other contemporary Egyptian sites[62] but also distinctly similar to Levantine sites.[63] The finding supports the stable isotopes results demonstrating a foreign origin for the Tell el-Dabʿa population. Further intra-site analysis of the Hyksos capital indicated population continuity from the earliest strata with available samples (stratum G) onwards, though a slight fluctuation was noted during stratum E, the transition to the Hyksos dynasty. This could potentially suggest an introduction of newcomers from slightly different region(s). This coincides with some unexpected isotope values, seen in Fig 2. The temporary fluctuation did not cause changes in the population structure and may have been an isolated event.[64]

Oral indicators, such as dental caries and dental wear, as well as stable isotopes in bone and teeth are widely used in combination to reconstruct diet in past populations.[65] The dental picture that was obtained via the palaeopathological approach from Tell el-Dabʿa attests to having a facility enabling access to good food resources. The low frequency of dental caries implies consumption of starchy staple foods and fresh fruit. The susceptibility to dental caries decreases with a high protein diet intake from meat and milk.[66] The finding coincides with the relatively high rate of calculus, also suggesting a dietary intake rather high in protein, but with modest carbohydrate input.[67] This type of diet is probably related to the supposed high social status of inhabitants of Tell el-Dabʿa as dental health reflects biological factors as well as economic and sociocultural structures.

The high frequency of hypoplasia at Tell el-Dabʿa sub-adults and the females is likely related to the stress placed on those individuals in particular as they experienced the cultural changes associated with the

62 Maaranen et al. 2019c.
63 Maaranen et al. forthcoming.
64 Maaranen et al. forthcoming.
65 Keenleyside 2008; Petersone-Gordina et al. 2018; Stantis et al. 2016; Tomczyka et al. 2020.
66 Moynihan and Petersen 2004.
67 Smith and Knight 1984.

socio-political changes in the Middle Bronze age and to the difficulties in adaptation when passing from a climate to another. These trends support the stable isotope and dental nonmetric trait analysis results of a foreign origin for the Tell el-Dab‘a population.

Winkler and Wilfing (1991) have also paid special attention to stress indicators (i.e. enamel hypoplasia, porotic hyperostosis, thickening of the frontal and parietal bone tubera and Harris lines) when they first analysed skeletons from Tell el-Dab‘a. They concluded that "*the inhabitants of Avaris must have suffered to an extremely high degree from deficiency diseases and anaemic states caused by periodical scarcity of food, attacks by parasites and infectious diseases"*.[68] This finding, among others, can be led back to difficulties in adaptation of the Tell el-Dab‘a inhabitants when passing from the temperate dry climate of their original region to the humid-warm, marshy climate of the East Delta.

The majority of Tell el-Dab‘a samples in these studies derived from the Area A/II. Despite having some wealthy burials (including equid and weapon burials), it has been regarded as a non-elite burial ground.[69] Though Area A/II represents the largest cemetery excavated at the site, it is by no means the only one. Researchers have argued that the different tells should be considered separately.[70] There is no way of knowing whether the different areas represent different ethnic enclaves with potentially different migration backgrounds without acquiring a large enough sample size from all the separate tells. Only few individuals from Area F/I, the suspected higher status burial ground, were appropriate for analysis, but the volume of missing data prevented any meaningful statistical analysis comparing it to Area A/II or other sites.

Conclusions

Despite a poor state of preservation, interesting bioanthropological conditions have been gathered from this multi-approach study providing new data of past peoples lived in Tell el-Dab‘a. The dental anthropology using stable isotopes, nonmetric trait analysis, and indicators of health and stress have shown a foreign origin for the Tell el-Dab‘a population.

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68 Winkler and Wilfing 1991, 140.
69 Mourad 2018.
70 Priglinger 2019.

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