Non-Metric Traits of Deciduous and Permanent Dentitions of Ten Non-Adult Individuals from Area C

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Introduction

The striking feature of three double and one multiple burial of non-adults in Ba`ja raises the question of biological relationships between the individuals buried closely together (Benz *et al.* 2020, this volume, Part 1; Gresky this volume; Haddow this volume). Due to poor preservation, genetic testing did not reveal sufficient results (Skourtanioti and Feldman this volume). Although being severely limited by the small number of individuals, their poor skeletal preservation, and furthermore, by the very young age of the individuals, we systematically checked for non-metric traits on the deciduous and, if available, permanent dentitions to detect possible biological relationships between these individuals.

Non-metric traits are also known as epigenetic variants, discontinuous morphological features, or discrete features and can occur in bones and teeth (Hauser and DeStefano 1989; Turner *et al.* 1991; Mann *et al.* 2016). In the human dentition, crown and root traits include structural variations that are macroscopically observed and recorded in two ways: (1) "presence-absence" features such as accessory ridges, furrow patterns, supernumerary cusps, and roots, or (2) as variations in morphology such as angles and curves (Hillson 1996; Scott and Turner 1997). The assumption of hereditary non-metric trait studies is that phenotypic (*i.e.*, morphological) similarities between individuals or populations reflect underlying genetic similarity (Buikstra *et al.* 1990; Larsen 1997; Stojanowski and Schillaci 2006; Konigsberg 2009). While non-metric traits are not directly related to sequence changes in the DNA, they might be inherited by modification of gene expressions (*e.g.*, Dupont *et al.* 2009). Recent studies combining non-metric dental traits and genetic data from the same individuals indicate that hereditary dental morphological traits can adequately serve as proxy for underlying genetic relationships (Hubbard *et al.* 2015; Rathmann and Reyes-Centeno 2020; Rathmann *et al.* 2023). Odontological features are used for testing for biological relationship in family groups or on a population level in prehistoric studies as they occur more frequently in individuals with close genetic relations than in other people (Alt 1997; Corruccini and Shimada 2002; Stojanowski and Schillaci 2006; Alt *et al*. 2013). Some of these discontinuous features seem to be particularly suitable for family analysis (*e.g*., number and shape of teeth) or analyses of population history (*e.g*., Scott *et al.* 2017). However, Stojanowski and Hubbard (2017) suggest that standard dental non-metric traits do not have sufficient resolution to identify direct family relationships. This contribution focuses on the detection of possible biological relationships between the individuals in Ba`ja and adds original data of non-metric traits of deciduous teeth for future analyses to create a larger picture of the populations of the Near East (Lovell and Haddow 2007; Pilloud and Larsen 2011).

Material and Methods

122 deciduous teeth of 10 individuals and 111 permanent teeth of 7 individuals were available for investigations (Table 1). All non-metric traits scored for each individual are listed in Appendix 2. Due to the impossible determination of sex in most of the individuals and the fact that the evaluated non-metric traits of this study have no significant sexual dimorphism (Scott and Turner 1997) we treated it as one sample. All individuals having at least two teeth preserved were included in the study. All data were collected by a single observer (J.S. Krauß).

For the scoring of non-metric traits on the deciduous and permanent dentitions, the criteria of the Arizona State University Dental

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Table 1 Numbers of deciduous and permanent teeth of ten non-adults present for investigation of non-metric traits. Individuals of Loci CR5:53/54, C10:405I-II, and CR28.2:122a/b/123a were buried in two double burials, and in a multiple burial, respectively. Note that Ind. Loc. CR6:23a was also associated with isolated remains of an infant; however, no teeth were preserved for the second individual.

Teeth (n=233)		**Deciduous Teeth**			**Permanent Teeth**		
Individuals (Loc.)	**Incisors**	**Canines**	**Molars**	**Incisors**	**Canines**	**Premolars**	**Molars**
C1:46	0	2	4	8	3	6	7
CR5:54	2	0	0	0	0	0	0
CR5:53	4	2	8	4	3	5	2
C10:405-II	8	4	8	2	0	0	2
C10:405-I	7	4	8	0	0	0	0
CR6:48	5	2	8	6	4	8	7
CR28.2:122a	5	4	4	6	3	3	7
CR28.2:122b	6	4	4	2	2	0	7
CR28.2:123a	4	0	3	0	0	0	0
CR6:23a	4	4	6	7	4	0	3

Anthropology System (ASUDAS) by Turner *et al*. (1991), Scott *et al.* (2017), Scott and Irish (2017) and Edgar (2017) were used (Table 5). Although for recording non-metric traits on the deciduous dentition the method by Sciulli (1998) is generally used, we applied the ASUDAS system because of the presence of several mixed dentitions. Trait numbers were used after Alt (1997) to detect possible biological relationships between the individuals (Table 2, Table A2).

To calculate frequencies, the different dental trait expression scores of the ASUDAS traits were dichotomised into present and absent. The ASUDAS criteria which had numbers only and no 0 = absent were evaluated as follows: winging: straight = trait not present; incisor root number: one root = trait not present; canine root number: one root = trait not present; premolar root number: one root = trait not present.

Calculations and visualisations were conducted with Python 3 and the Python libraries pandas, networkx and matplotlib. Statistical analyses were performed in order to find a measure for potential degrees of relatedness (Alt 1997). A Jaccard index for each pair of individuals was calculated: the number of characteristics shared by both individuals was divided by the total number of shared assessable characteristics (Table A1). In principle, a higher index could suggest a higher biological relationship. However, for the present sample, this is greatly limited due to the low number of characteristics assessable between individual pairs. This small data set could lead to distortions (under- or overestimation of kinship); however, it could still serve as a basis for further research.

Table 2 Non-metric traits in deciduous and permanent dentition, trait numbers after Alt (1997).

Trait No. (Alt 1997)	Description of the Traits
7	lingual surface flat - 31 41
9	lingual surface flat - 32 42
14	lingual area concave - 11 21 12 22
15	lingual surface flat - 31 41 32 42
17	lingual marginal ridge mesial - 11 21
18	lingual marginal ridge mesial - 12 22
22	lingual marginal ridge mesial - 33 43
24	lingual marginal ridge distal - 11 21
28	lingual marginal ridge distal - 32 42
29	lingual marginal ridge distal - 33 43
73	root number - 33 43 (2)
143	root number - 14 24 = 2
146	root number - 15 25 (2)
150	root number - 34 44 (2)
159	number of main cusps: 3 cusps - 17 27
171	root number - 16 26 (2)
174	root number - 17 27 = 1
175	root number - 17 27 (2)
212	number of main cusps: 5 cusps - 36 46
215	number of main cusps: 4 cusps - 37 47
219	number of main cusps: 4 cusps - 38 48

Table 2 (continued)

Trait No. (Alt 1997)	Description of the Traits
220	number of main cusps: 5 cusps - 38 48
249	fissure pattern: y - 36 46
251	fissure pattern: x - 36 46
253	fissure pattern: y - 37 47
254	fissure pattern: + - 37 47
255	fissure pattern: x - 37 47
257	fissure pattern: y - 38 48
259	fissure pattern: x - 38 48
262	root number - 36 46 = 3
265	root number - 37 47 = 1
267	root number - 37 47 (3)
270	root number - 38 48 (1)
399	Tuberculum Carabelli - 16 26
523	entoconulid - 36 46
524	entoconulid - 37 47 = 1
526	entoconulid - 38 48
527	foramina molaria - 36 46
528	foramina molaria - 37 47
529	foramina molaria - 38 48
554	paramolar tubercle: microform - 38 48 = 1
555	paramolar tubercle: microform - 38 48
576	tuberculum intermedium - 38 48
631	enamel extensions - 38 48
632	enamel extensions - 37 47
642	congenital absence - 31 41
646	congenital absence - 35 45
649	congenital absence - 38 48
651	congenital absence - 31 41 35 45 15 25 12 22
679	maxillary molar peg or reduction - 18 28 = 1
1021	torus mandibularis r l = 1
1022	torus palatinus a = 1

Table 3 Number of observable and present non-metric traits of the permanent dentition per individual (scoring after Alt 1997).

Individual	Observable Traits	Present Traits	Non-observable Traits
C1:46	27	13	25
CR5:53	7	5	45
C10:405-II	8	1	44
CR6:48	26	14	26
CR28.2:122a	21	11	31
CR28.2:122b	12	10	40
CR6:23a	16	12	36

Table 4 Number of observable and present non-metric traits of the deciduous dentition per individual.

Individual	Observable Traits	Present Traits	Non-Observable Traits
C1:46	21	7	21
CR5:53	23	10	19
C10:405-II	39	16	3
CR6:48	18	9	24
CR28.2:122a	17	7	25
CR28.2:122b	18	5	24
CR6:23a	22	11	20
CR5:54	9	4	33
CR28.2:123a	14	4	28
C10:405-I	32	11	10

Results

Frequencies of Non-Metric Traits of the Deciduous and Permanent Dentitions (Scoring After ASUDAS)

The most common non-metric traits of the deciduous teeth in the ten non-adult individuals (Table 5) from Ba`ja are metacone and hypocone, cusp 5, molar root numbers, Carabelli's trait, and anterior fovea, each with a relative frequency of 100%. Shoveling, double shoveling, and labial curvature occur with a frequency of 87.5%. Other traits were observed less often. The permanent dentition of seven of these ten individuals showed similar frequencies. Metacone, hypocone, cusp 5, molar root numbers, and labial curvature are present in 100% of assessable traits, Carabelli's trait and shoveling in 87.5%, anterior fovea in 60% and double shoveling in 57.1% of the observable teeth. The mean percentage of the relative frequency of present traits in permanent and deciduous teeth shows that most of these traits are present in the deciduous as well as in the permanent dentition (Table 5).

Detecting Possible Biological Relationships (Scoring After Alt 1997)

To detect possible biological relationships, the shared traits between the individuals were compared. Two individuals stand out from the group (Fig. 1): Loc. C10:405-II seems hardly related to anybody while Loc. CR5:53 has high indices in relation to most of the other individuals. In both cases, however, there are only very few comparable traits present so that the results are not reliable. Regardless the small number of comparable traits in both cases, of these Loc. CR5:53

Table 5 Relative and observable frequencies of non-metric traits (ASUDAS) of the deciduous and permanent dentition per trait. Mean = mean of permanent and deciduous trait frequency.

	Permanent (n=7)				Deciduous (n=10)				Mean
Non-metric trait	Observable	%	Trait present	%	Observable	%	Trait present	%	%
Metacone	7	100	7	100	6	60	6	100	100
Hypocone	7	100	7	100	5	50	5	100	100
Cusp 5	5	71.4	5	100	4	40	4	100	100
Lower molar root number	2	28.6	2	100	4	40	4	100	100
Upper molar root number	2	28.6	2	100	4	40	4	100	100
Labial curvature	6	85.7	6	100	8	80	7	87.5	93.75
Carabelli’s trait	7	100	6	85.7	3	30	3	100	92.85
Shoveling	7	100	6	85.7	8	80	7	87.5	86,6
Anterior fovea	5	71.4	3	60	4	40	4	100	80
Double shoveling	7	100	4	57.1	7	70	6	85.7	71.4
Tuberculum dentale	7	100	4	57.1	9	90	3	33.3	45.2
Distal accessory ridge	6	85.7	3	50	5	50	2	40	45
Enamel extension	4	57.1	2	50	7	70	2	28.6	39.3
Trigonid crest	5	71.4	2	40	3	30	1	33.3	36.65
Metaconule	7	100	2	28.6	3	30	1	33.3	30.95
Groove pattern	5	71.4	2	40	2	20	0	0	20
Interruption groove	6	85.7	2	33.3	8	80	0	0	16.65
Protostylid	5	71.4	0	0	7	70	2	28.6	14.3
Foramina malaria	6	85.7	1	16.7	9	90	0	0	8.35
Dens invaginatus	7	100	0	0	10	100	0	0	0
Parastyle	7	100	0	0	3	30	0	0	0
Congenital absence	6	85.7	0	0	10	100	0	0	0
Talon tooth	6	85.7	0	0	9	90	0	0	0
Enamel pearl	6	85.7	0	0	9	90	0	0	0
Peg/reduced tooth	6	85.7	0	0	9	90	0	0	0
Mesial bending	6	85.7	0	0	9	90	0	0	0
Foramen caecum dentis	6	85.7	0	0	7	70	0	0	0
Mesial ridge	6	85.7	0	0	7	70	0	0	0
Tuberculum paracone	5	71.4	0	0	6	60	0	0	0
Cusp 7	5	71.4	0	0	4	40	0	0	0
Cusp 6 (entoconulid)	5	71.4	0	0	4	40	0	0	0
Deflecting wrinkle	5	71.4	0	0	2	20	0	0	0
Incisor root number	2	28.6	0	0	7	70	0	0	0
Canine root number	2	28.6	0	0	6	60	0	0	0
Supernumerary	2	28.6	0	0	2	20	0	0	0
Hypodontia	2	28.6	0	0	2	20	0	0	0
Torus mandibularis	1	14.3	0	0	2	20	0	0	0
Torus palatinus	1	14.3	0	0	1	10	0	0	0
Accessory cusps	3	42.9	3	100	0	0	0	N/A	N/A
Premolar complexity	3	42.9	2	66.7	0	0	0	N/A	N/A
Premolar number	2	28.6	1	50	0	0	0	N/A	N/A
Mesial accessory ridge	3	42.9	1	33.3	0	0	0	N/A	N/A

Table 5 (continued)

Non-metric trait	Permanent (n=7) Observable	%	Trait present	%	Deciduous (n=10) Observable	%	Trait present	%	Mean %
Elongated form	3	42.9	1	33.3	0	0	0	N/A	N/A
Distosagittal ridge	4	57.1	1	25	0	0	0	N/A	N/A
Odontome	4	57.1	0	0	0	0	0	N/A	N/A
Tricuspid premolar	4	57.1	0	0	0	0	0	N/A	N/A
Tome's root (only LP1)	2	28.6	0	0	0	0	0	N/A	N/A
Winging	0	0	0		2	20	2	100	N/A
Triangular shape	0	0	0	33.3	7	70	1	14.3	N/A
Diastema	0	0	0		1	10	0	0	N/A

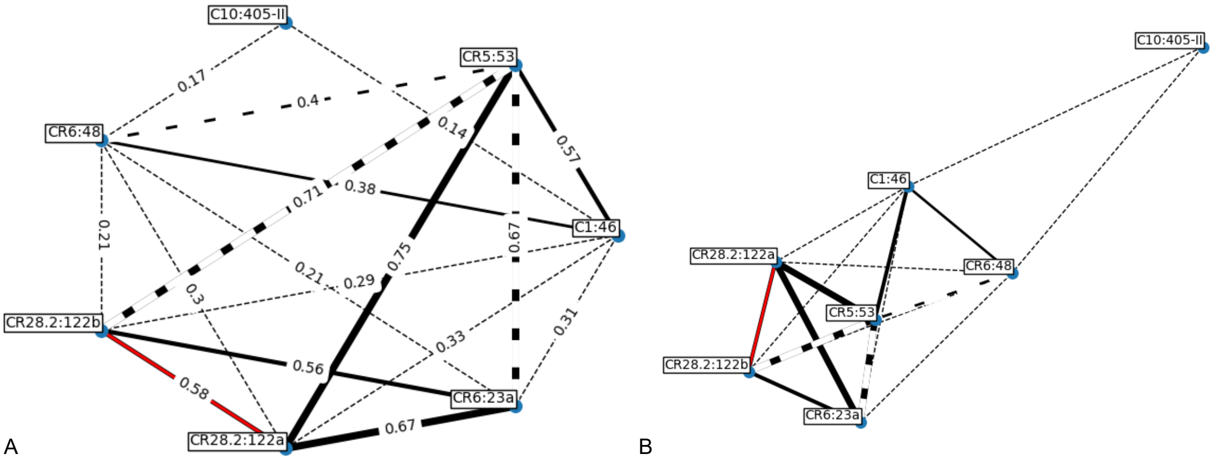

Fig. 1 *A* Relationship graph demonstrating the Jaccard indices between the individuals with permanent dentition. The thicker the line, the higher the supposed biological relationship: thick = higher than 0.6, middle = higher than 0.45, thin = higher than 0.375, dotted = smaller than 0.375. Dotted thick lines emphasise missing mutual comparable traits, here the indices are not reliable due to missing data. The red line indicates that these two individuals were buried together, *B* relationship graph with a different layout to show the distances. (Graph: J.E.W. Gresky)

still has many in common with the others, while Loc. C10:405-II has not. Considering the straight lines with high Jaccard indices, meaning that sufficient comparable and identical traits are present, individuals CR28.2:122a, CR28.2:122b and CR6:23a could belong to one group of relatives. Loci CR28.2:122a and CR28.2:122b are the only two individuals who were interred in the same burial. Their local proximity is indicated by the red line in Fig. 1. Loc. CR5:53 could belong to this group as well, but due to the small number of assessable teeth, we cannot be sure about it. Loci CR6:48 and C1:46 seem to differ slightly from this group, but could be related to each other (they share 11 present of 24 assessable traits, see Table A1. The individuals Loci C1:46 and CR6:48 both were buried in single graves.

Apart from their frequencies it was checked which types of traits are shared by most or by least of the individuals (Table A3, Fig. 4). The traits with the numbers 17, 18, 24, and 212 (categories of Alt 1997) occurred in 10 pairs of individuals, traits with the numbers 14, 159, and 399 in six pairs, suggesting a very common distribution in this group of non-adults. These traits are mainly affecting the maxillary incisors having a lingual marginal ridge mesial (traits 17, 18, 24) or their lingual area being concave (trait 14). Molar cusp number is a frequent trait with five cusps of teeth 36 and 46 (trait 212) and three of teeth 17 and 27 (trait 159) as well as the presence of Carabelli's trait on teeth 16 and 26 (trait 399).

Interestingly, some traits only occur in three pairs, traits 9, 15, 28, 171, and 215 (Table A3, Fig. 2). These traits are mainly scored as absent in the teeth of the other individuals. They are visible in the mandibular incisors as flat lingual surface (traits 9, 15) and lingual marginal

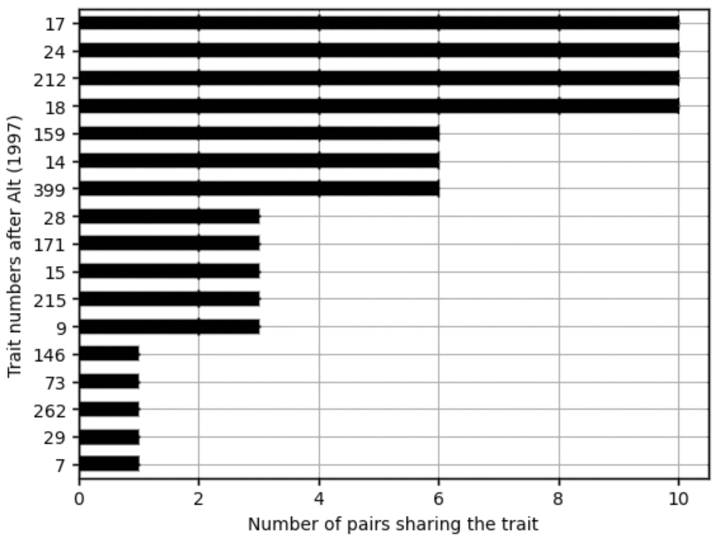

Fig. 2 Numbers of traits (y-axis) shared by pairs of individuals (x-axis). (Graph: J.E.W. Gresky)

ridge distal (trait 28). Four main cusps of teeth 37 and 47 (trait 215) and two roots of teeth 16 and 26 (trait 171) are rare traits as well. Traits 9, 15, 28 exclusively occur in the individuals of CR28.2:122a and CR28.2:122b (who are buried together) and CR6:23a.

Discussion

Dental non-metric traits have a long history of worldwide research (*e.g.*, Carabelli 1842; Tomes 1889; Hrdlička 1911, 1920, 1921) and are still under investigation as there is a lot of facts unknown regarding their heritability. Recent research has shown that some non-metric dental traits or their combinations are more suitable to evidence neutral genomic signatures while others are more prone to changes by environmental factors and rather display adaptational processes (Rathmann and Reyes-Centeno 2020).

While many studies have addressed the question of inter-population affinities using dental traits (*e.g.*, for the Near East, Ullinger *et al.* 2005; Lovell and Haddow 2007; Sołtysiak and Bialon 2013; Maaranen *et al.* 2022), fewer studies have attempted to detect biological relationships on an intra-population level (Corruccini and Shimada 2002; Stojanowski and Schillaci 2006; Pilloud and Larsen 2011; Alt *et al.* 2013, 2015). Most of the studies use the permanent dentitions of individuals due to better preservation of the teeth and longer duration of them in life, but an increasing corpus of studies of deciduous teeth has been produced in the last decades (*e.g.,* Kitagawa, 2000; Lease and Sciulli 2005; Lovell and Haddow 2007). These studies are conducted on teeth of ancient skeletons as well as of recent populations which gives this field of research an interesting advantage to other palaeopathological studies which are mainly restricted to archaeological skeletal material.

For the study of the dental traits from the deciduous and permanent dentitions of ten non-adults from Ba`ja, the main limiting factor is the very small sample size which prohibits any interpopulation comparisons, but also the intrapopulation approach is very limited. Furthermore, for the evaluation of biological relationships, less frequently occurring metric dental traits are of more significance than rather common traits which have a high frequency of occurrence within the population. In Ba`ja, most of the traits are rather common, therefore, in contrast to the populations of Basta (Alt *et al.* 2013) or Kfar HaHoresh (Alt *et al.* 2015) no specific relationships can be validated. In Basta, the trait of congenital absence of the lateral maxillary incisors was very common, whereas in Ba`ja this trait does not appear in any of the dentitions. The same accounts for the presence of protostylid or foramina molaria of the lower second molars in Kfar HaHoresh, which are missing in the dentitions from Ba`ja.

Whereas in Basta and Kfar HaHoresh mainly teeth of the permanent dentitions were evaluated, in Ba`ja more teeth of the deciduous than of the permanent dentition were available. Although non-metric dental traits of deciduous teeth can be used to detect biological relationships as well (Kitagawa 2000; Lease and Sciulli 2005), due to the unknown genetic processes (Hughes *et al*. 2000) they cannot be equated with traits of the permanent dentition. However, more recently, Paul and Stojanowski (2017) suggest that deciduous dental traits better reflect biological relatedness than traits of the permanent dentition. Furthermore, non-genetic factors are discussed for the differences between traits of deciduous and permanent dentition, like adaptation to higher masticatory demands (Townsend *et al.* 1990; Kitagawa 2000). Because of this, deciduous and permanent dentitions are treated as two different samples, although in the individuals with mixed dentition from Ba`ja, many traits in deciduous dentition are present in the permanent dentition as well (Table 5).

Comparison of traits between the individuals showed that three of them, CR28.2 122a and 122b from the same burial and CR6:23a from a different burial, had not only most of the traits in common (Fig. 2) but also shared three traits which were assessable but absent in all other individuals. This might suggest a closer relationship of this group in comparison to the others. However, the other traits are shared by most of the individuals, except C10:405, which shows a quite homogeneous group.

Considering a relationship based on sharing similar non-metric traits could add to the hypothesis of Skourtanioti and Feldman (this volume) that either the population size of Ba`ja was small or that endogamy was a common practice in Ba`ja. However, in a population of small size, accumulation of "familial" or rare traits is to be expected which is the case in Basta, a contemporary and closely located site, where a very high frequency (35.7%) of individuals showed the specific non-metric trait of congenital absence of the lateral incisors of the maxilla (Alt *et al.* 2013). This high frequency points to an overly close familial relationship but this is not the case with the individuals from Ba`ja; furthermore, as well as the fact that no other more specific traits are accumulated.

Isotopic results indicate that there is no difference in mobility between the individuals from Ba`ja (Knipper *et al.* this volume) and that this group based their subsistence on food and water sources from the same region. Due to the lack of sufficient numbers of adult individuals, especially females, no statement can be made about the difference in the mobility pattern between the sexes. The current state of data suggests a similar local appearance for all individuals. The almost similar $^{87}Sr/^{86}Sr$ ratios of all subadults point to a common locality. There is just one individual, Loc. CR6:23a, with slightly higher radiogenic values, but this is still in the range of local human and fauna (Knipper *et al.* this volume). Based on its non-metric traits, Loc. CR6:23a seems to be close to the two individuals from Loci CR28.2:122a and CR28.2:122b, which might point to commonalities despite the higher strontium values, whereas the only outlier (C10:405-II), by non-metric traits, fits perfectly into the nonadult group based on its $^{87}Sr/^{86}Sr$ ratio.

However, for comparisons of residence patterns in Ba`ja to the sites of Kfar HaHoresh where a preliminary interpretation might point to a matrilocal community structure (Alt *et al.* 2015) and to Çatalhöyük where latest genetic and strontium isotopic research suggest a local community (pers. comm. I. Hodder), so far, our data is not sufficient.

Outlook

Future excavations will hopefully produce more skeletons of all age classes to have more teeth for comparison. Then, also metric analyses could be added. With developing genetic analyses, these methods together will detect biological relationships which can then be combined with the archaeological and taphonomic results and help us understand the special ways of burial customs in Neolithic Ba´ja.

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References

Alt K.W.
1997 *Odontologische Verwandtschaftsanalyse: individuelle Charakteristika der Zähne in ihrer Bedeutung für Anthropologie, Archäologie und Rechtsmedizin*. Stuttgart [a.o.]: Fischer.

Alt K.W., Benz M., Müller W., Berner M.E., Schultz M., Schmidt-Schultz T.H., Knipper C., Gebel H.G.K., Nissen H.J. and Vach W.
2013 Earliest evidence for social endogamy in the 9,000-year-old-population of Basta, Jordan. *PLoS ONE* 8(6): e65649. DOI: 10.1371/journal.pone.0065649

Alt K.W., Benz M., Vach W., Tal L. Simmons and Goring-Morris A.N.
2015 Insights into the social structure of the PPNB site of Kfar HaHoresh, Israel, based on dental remains. *PLoS ONE* 10(9): e0134528. DOI: 10.1371/journal.pone.0134528

Benz M., Gresky J. and Alarashi H.
2020 Similar but different – displaying social roles of children in burials. In: H. Alarashi and R.M. Dessì (eds.), *The art of human appearance. 40° Rencontres internationales d'archéologie et d'histoire de Nice*: 93-107. Nice: Éditions APDCA.

Buikstra J.E., Frankenberg S.R. and Konigsberg L.W.
1990 Skeletal biological distance studies. American physical anthropology: recent trends. *American Journal of Physical Anthropology* 82: 1-7.

Carabelli G. von
1842 *Anatomie des Mundes*. Vienna: Braumüller und Seidel.

Corruccini R.S. and Shimada I.
2002 Dental relatedness corresponding to mortuary patterning at Huaca Loro, Peru. *American Journal of Physical Anthropology* 117: 118-121. DOI: 10.1002/ajpa.10020

Dupont C., Armant D.R. and Brenner C.A.
2009 Epigenetics: definition, mechanisms and clinical perspective. *Seminars in Reproductive Medicine 27(5): 351-357. DOI: 10.1055/s-0029-1237423*

Edgar H.
2017 *Dental morphology for anthropology: an illustrated manual*. New York: Routledge.

Hauser G. and DeStefano G.F.
1989 *Epigenetic variants of the human skull*. Stuttgart: Schweizerbart'sche Verlagsbuchhandlung.

Hillson S.
1996 *Dental anthropology*. New York: Cambridge University Press.

Hrdlička A.
1911 Human dentition and teeth from the evolutionary and racial standpoint. *Dominion Dental Journal* 23: 403-417.
1920 Shovel-shaped teeth. *American Journal of Physical Anthropology* 3: 429-465. DOI: 10.1002/ajpa.1330030403
1921 Further studies of tooth morphology. *American Journal of Physical Anthropology* 4: 141-176. DOI: 10.1002/ajpa.1330040204

Hubbard A.R., Guatelli-Steinberg D. and Irish J.D.
2015 Do nuclear DNA and dental nonmetric data produce similar reconstructions of regional population history? An example from modern coastal Kenya. *American Journal of Physical Anthropology 157: 295-304.*

Hughes T., Dempsey P., Richards L. and Townsend G.C.
2000 Genetic analysis of deciduous tooth size in Australian twins. *Archives of Oral Biology* 45: 997-1004. DOI: 10.1016/s0003-9969(00)00066-2

Kitagawa Y.
2000 Nonmetric morphological characters of deciduous teeth in Japan: diachronic evidence of the past 4000 years. *International Journal of Osteoarchaeology* 10(4): 242-253. DOI: 10.1002/1099-1212(200007/08)10:4<242::AID-OA526>3.0.CO;2-A

Konigsberg L.W.
2009 A post-Neumann history of biological and genetic distance studies in bioarchaeology. In: J.E. Buikstra and L.A. Beck (ed.), *Bioarchaeology. The contextual analysis of human remains*: 263-279. New York: Routledge.

Larsen C.S.
1997 *Bioarchaeology. Interpreting behavior from the human skeleton*. New York: Cambridge University Press.

Lease L.R. and Sciulli P.W.
2005 Brief communication. Discrimination between European-American and African-American children based on deciduous dental metrics and morphology. *American Journal of Physical Anthropology* 126: 56-60. DOI: 10.1002/ajpa.20062

Lovell N.C. and Haddow S.D.
2007 Nonmetric traits of the deciduous dentitions from Bronze Age Tell Leilan, Syria. *International Journal of Dental Anthropology* 11: 1-21. DOI: 10.26575/daj.v16i3.155

Maaranen N., Walker J. and Sołtysiak A.
2022 Societal segmentation and early urbanism in Mesopotamia: biological distance analysis from Tell Brak using dental morphology. *Journal of Anthropological Archaeology* 67: 101421. DOI: 10.1016/j.jaa.2022.101421

Mann R.W., Hunt D.R. and Lozanoff S.
2016 *Photographic regional atlas of non-metric traits and anatomical variants in the human skeleton*. Springfield: Thomas.

Paul K.S. and Stojanowski C.M.
2017 Comparative performance of deciduous and permanent dental morphology in detecting biological relatives. *American Journal of Physical Anthropology* 164(1): 97-116. DOI: 10.1002/ajpa.23260

Pilloud M.A. and Larsen C.S.
2011 ''Official'' and ''practical'' kin: inferring social and community structure from dental phenotype at Neolithic Çatalhöyük, Turkey. *American Journal of Physical Anthropology* 45: 519-530. DOI: 10.1002/ajpa.21520

Rathmann H. and Reyes-Centeno H.
2020 Testing the utility of dental morphological trait combinations for inferring human neutral genetic variation. *Proceedings of the National Academy of Sciences* 117(20): 10769-10777. DOI: 10.1073/pnas.1914330117

Rathmann H., Perretti S., Porcu V., Hanihara T., Scott G.R., Irish J.D., Reyes-Centeno H., Ghirotto S. and Harvati K.
2023 Inferring human neutral genetic variation from craniodental phenotypes. *PNAS Nexus* 2(7). DOI: 10.1093/pnasnexus/pgad217

Sciulli PW.
1998 Evolution of the dentition in prehistoric Ohio valley Native Americans. II. Morphology of the deciduous dentition. *American Journal of Physical Anthropology* 106: 189-205. DOI: 10.1002/(SICI)1096-8644-(199806)106:2<189::AID-AJPA6>3.0.CO;2-L

Scott G.R. and Irish J.D.
2017 *Human tooth crown and root morphology: the Arizona State University Dental Anthropology System*. Cambridge: Cambridge University Press.

Scott G.R. and Turner C.G.
1997 *The anthropology of modern human teeth: dental morphology and its variation in recent human populations*. New York: Cambridge University Press.

Scott G.R., Turner II. C.G., Townend G.C. and Martinón-Torres M.
2017 *The anthropology of modern human teeth: dental morphology and its variation in recent and fossil Homo sapiens* (second edition). Cambridge: Cambridge University Press.

Sołtysiak A. and Bialon M.
2013 Population history of the middle Euphrates valley: dental non-metric traits at Tell Ashara, Tell Masaikh and Jebel Mashtale, Syria. *HOMO* 64(5): 341-356. DOI: 10.1016/j.jchb.2013.04.005

Stojanowski C.M. and Hubbard A.R.
2017 Sensitivity of dental phenotypic data for the identification of biological relatives. *International Journal of Osteoarchaeology* 27: 813-827.

Stojanowski C.M. and Schillaci M.A.
2006 Phenotypic approaches for understanding patterns of intracemetery biological variation. *Yearbook of Physical Anthropology* 49: 49-88. DOI: 10.1002/ajpa.20517

Tomes C.S.
1889 *A manual of dental anatomy: human and comparative.* London: Churchill.

Townsend G., Yamada H. and Smith P.
1990 Expression of the Entoconulid (sixth cusp) on mandibular molar teeth of an Australian Aboriginal population. *American Journal of Physical Anthropology* 82(3): 267-74. DOI: 10.1002/ajpa.1330820305

Turner II. C.G., Nichol C.R. and Scott G.R.
1991 Scoring procedures for key morphological traits of the permanent dentition: the Arizona State University Dental Anthropology System. In: M.A. Kelley and C.S. Larsen (eds.), *Advances in dental anthropology*: 13-31. New York: Wiley-Liss.

Ullinger J.M., Sheridan S.G., Hawkey D.E., Turner II. C.G. and Cooley R.
2005 Bioarchaeological analysis of cultural transition in the southern Levant using dental nonmetric traits. *American Journal of Physical Anthropology* 128(2): 466476. DOI: 10.1002/ajpa.20074

Appendix 1

Table A1 Cross table of observable and present traits for teeth of the permanent dentition. [x,y,z] = [number of observable traits in both individuals, number of present traits in both individuals, Jaccard-Index: present/observable]

	C1:46	CR5:53	C10:405-II	CR6:48	CR28.2:122b	CR28.2:122a	CR6:23a
C1:46	[0, 0, 0]	[7, 4, 0.57]	[7, 1, 0.14]	[24, 9, 0.38]	[21, 6, 0.29]	[12, 4, 0.33]	[16, 5, 0.31]
CR5:53	[7, 4, 0.57]	[0, 0, 0]	[0, 0, 0]	[5, 2, 0.4]	[7, 5, 0.71]	[4, 3, 0.75]	[6, 4, 0.67]
C10:405-II	[7, 1, 0.14]	[0, 0, 0]	[0, 0, 0]	[6, 1, 0.17]	[5, 0, 0.0]	[3, 0, 0.0]	[5, 0, 0.0]
CR6:48	[24, 9, 0.38]	[5, 2, 0.4]	[6, 1, 0.17]	[0, 0, 0]	[19, 4, 0.21]	[10, 3, 0.3]	[14, 3, 0.21]
CR28.2:122b	[21, 6, 0.29]	[7, 5, 0.71]	[5, 0, 0.0]	[19, 4, 0.21]	[0, 0, 0]	[12, 7, 0.58]	[16, 9, 0.56]
CR28.2:122a	[12, 4, 0.33]	[4, 3, 0.75]	[3, 0, 0.0]	[10, 3, 0.3]	[12, 7, 0.58]	[0, 0, 0]	[12, 8, 0.67]
CR6:23a	[16, 5, 0.31]	[6, 4, 0.67]	[5, 0, 0.0]	[14, 3, 0.21]	[16, 9, 0.56]	[12, 8, 0.67]	[0, 0, 0]

Table A2 Relative and observable frequencies of non-metric traits of the deciduous dentition per trait after Alt's (1997) scoring which was used to calculate the Jaccard indices.

N=7 Trait No.	Trait Present	Observable	Observable Frequency %	Relative Frequency %
171	3	3	42.9	100
73	2	2	28.6	100
215	3	3	42.9	100
212	5	5	71.4	100
159	4	4	57.1	100
150	1	1	14.3	100
146	2	2	28.6	100
143	1	1	14.3	100
262	2	2	28.6	100
24	5	5	71.4	100
18	5	5	71.4	100
17	5	5	71.4	100
399	4	5	71.4	80
14	4	6	85.7	66.7
28	3	5	71.4	60

N=7 Trait No.	Trait Present	Observable	Observable Frequency %	Relative Frequency %
9	3	6	85.7	50
15	3	6	85.7	50
7	2	5	71.4	40
29	2	6	85.7	33.3
527	1	5	71.4	20
22	0	5	71.4	0
523	0	5	71.4	0
524	0	3	42.9	0
528	0	3	42.9	0
632	0	3	42.9	0
642	0	5	71.4	0
646	0	2	28.6	0
651	0	6	85.7	0
1021	0	1	14.3	0
1022	0	2	28.6	0

Table A3 Cross table of present traits for teeth of the permanent dentition in 10 non-adults.
[x,y,z] = [trait numbers (after Alt 1997) occurring in both individuals]

	C1:46	CR5:53	C10:405-II	CR6:48	CR28.2:122b	CR28.2:122a	CR6:23a
C1:46	[ ]	[17, 18, 24, 159]	[171]	[18, 73, 146, 159, 171, 212, 215, 262, 399]	[17, 18, 24, 159, 212, 215]	[17, 24, 212, 399]	[17, 18, 24, 212, 399]
CR5:53	[17, 18, 24, 159]	[ ]	[ ]	[18, 159]	[14, 17, 18, 24, 159]	[14, 17, 24]	[14, 17, 18, 24]
C10:405-II	[171]	[ ]	[ ]	[171]	[ ]	[ ]	[ ]
CR6:48	[18, 73, 146, 159, 171, 212, 215, 262, 399]	[18, 159]	[171]	[ ]	[18, 159, 212, 215]	[29, 212, 399]	[18, 212, 399]
CR28.2:122b	[17, 18, 24, 159, 212, 215]	[14, 17, 18, 24, 159]	[ ]	[18, 159, 212, 215]	[ ]	[9, 14, 15, 17, 24, 28, 212]	[7, 9, 14, 15, 17, 18, 24, 28, 212]
CR28.2:122a	[17, 24, 212, 399]	[14, 17, 24]	[ ]	[29, 212, 399]	[9, 14, 15, 17, 24, 28, 212]	[ ]	[9, 14, 15, 17, 24, 28, 212, 399]
CR6:23a	[17, 18, 24, 212, 399]	[14, 17, 18, 24]	[ ]	[18, 212, 399]	[7, 9, 14, 15, 17, 18, 24, 28, 212]	[9, 14, 15, 17, 24, 28, 212, 399]	[ ]

Appendix 2

Scoring sheets of non-metric traits of the deciduous and permanent dentitions of the non-adult individuals from Ba`ja.

Link: https://www.exoriente.org/baja/archive/