Appendix 2: Non-metric traits

1 Introduction

Small variations in the presentation or expression of anatomical traits can occur in all tissues, including the skeleton, and unlike physical and skeletal malformations, they are usually not associated with medical or functional restrictions (Mann & Hunt 2019). The exact etiology of many of these traits is still under debate today but generally they are caused by a combination of genetic and/or environmental factors. Therefore, the terminology by which to refer to these variations is also very varied in literature, with some calling them epigenetic traits (meaning of genetic origin but influenced by environmental factors), discrete traits (they do not occur in every individual), anatomical variations (they are different from the normal expression) or non-metric traits (they cannot be measured) (Grupe *et al.* 2015). However, the term, non-metric traits, has gained most traction in recent years as it does not come with any further categorisations than that the traits are not measurable on a metrical scale, and therefore, this terminology will be used in this study for any future reference. In forensic anthropology, evaluations of non-metric and morphognostic cranial traits are frequently used in personal identification and ancestry analysis with varying success and therefore are mostly just used as a support to other methods (Palamenghi *et al.* 2021). In archaeology, these traits are regularly used in kinship analysis or in comparisons of different populations (Hauser & De Stefano 1989; Tyrell 2000; Hanihara & Ishida 2001; Hanihara *et al.* 2003; Ricaut *et al.* 2010; Nikita *et al.* 2012). However, due to the limited knowledge about the genetic origins and heritability of the majority of these traits, their evaluation cannot be used as a substitute to DNA-based kinship analysis (Tyrell 2000). Therefore, in the following chapter, 18 cranial and 12 postcranial non-metric traits were recorded in a standardized way. Frequencies of these traits were calculated for the whole population and differences between males and females as well as between burial locations were tested via Pearson's chi squared tests or Fisher's exact tests in the case of low group counts. Rarer traits that were only noticed during the excavation were only noted but not put in relation to areas present. Since dental non-metric traits have not been recorded systematically in this study, they will not be evaluated based on frequency of occurrence in the total sample.

2 Cranial non-metric traits

Table 1 Frequency of cranial traits in all individuals from the Knuedler cemetery by area present

- Pres. = present; Oss. = ossiculum; For. = foramen; Can. = canalis; Tub. = tuberculum; Cond. = condyles

Frequency of cranial traits					
Trait	Side	variation	Presence of area	Presence of trait	%
Sutura metopica		Pres.	162	16	9.88
Sutura mendosa		Pres.	149	2	1.34
Oss. Lambdoidea	R	Pres.	156	23	14.74
	L	Pres.	156	27	17.31
Oss. apicis lambdae		Pres.	155	12	7.74
Oss. Astericum	R	Pres.	153	9	5.88
	L	Pres.	153	8	153
Oss. Epiptericum	R	Pres.	142	2	1.41
	L	Pres.	142	3	2.11
Oss. Sagittalis		Pres.	159	3	1.89
Oss. at Bregma		Pres.	162	1	0.62
Oss. Coronalia	R	Pres.	160	0	0
	L	Pres.	160	1	0.62
Supraorbital region	R	foramen	140	32	22.86
	R	incisura	140	93	66.43
	R	both	140	15	10.71
	L	foramen	144	28	19.44
	L	incisura	144	104	72.22
	L	both	144	12	8.33
For. Parietale	R	Pres.	154	89	57.79
	L	Pres.	136	78	57.35
For. Zygomaticofaciale	R	multiple	110	26	23.64
	R	missing	110	11	10
	L	multiple	116	32	27.59
	L	missing	116	10	8.62
For. Mentale	R	multiple	145	2	1.38
	L	multiple	151	3	1.99
For. Huschke	R	Pres.	150	1	0.67
	L	Pres.	150	2	1.33
Can. Hypoglossi	R	multiple	137	8	5.84
	L	multiple	136	12	8.82
Can. Postcondylaris	R	Pres.	113	70	61.95
	L	Pres.	114	70	61.40
Tub. Precondylaris	R	Pres.	146	7	4.79
	L	Pres.	146	6	4.11
Cond. Occipitalis	R	double	149	12	8.05
	L	double	148	12	8.11

Frequencies of presence or absence or expression of each trait were calculated in relation to all bone areas where the specific trait occurred preserved in the sample. When the trait appeared on the right and on the left side, it was accounted for in both analyses of left and right bone sides. Although only frequencies for the total population are listed in Table 1, differences in frequency distribution were tested between the sexes and between burial locations.

The most frequently occurring traits in this population were the incisura supraorbitale, the presence, left, right or both of the foramen parietale and the presence of a postcondylar canal. The rarest traits documented were the Wormian bones in the coronal suture which occurred in just one individual on the left side, the foramen Huschke, which occurred only three times, once left and once on both sides , a double or multiple foramen mentale, which occurred once only left and once on both sides, the presence of a sutura mendosa, which were found twice, once forming a large os inca and once a bipartite os inca, and lastly the presence of the os epiptericum, which occurred twice bilaterally and once only left. The frequencies of occurrence of all these traits lies around or under 2%.

The only statistically significant differences between groups were found between church and cemetery burials in the distribution of the sutura metopica ($p=0.0155$), appearing 15 times (13.89%) in individuals buried in the cemetery and only one time (1.85%) among burials from the church complex, and in the distribution of occurrence of Wormian bones in the left lambdoid suture, with a presence of 21.70% in the cemetery versus 8% in the church ($p=0.0348$). Overall, at 9.88%, the occurrence of sutura metopica was rather low. It is also noteworthy that ossicles at asterion occurred mostly in men from the cemetery.

Further traits that were observed but not recorded in a standardized way were 8 palatine tori, which seem to have been rather infrequent in this population. Furthermore, none of the observed mandibles and maxillae presented a mandibular or a maxillary torus respectively.

Examples of cranial non-metric traits

Figure 1 Sutura metopica of 2008-78/182b

Figure 2 Ossicle at Bregma in individual 2008-78/801

2.1 Dental anomalies

Several dental anomalies, including non-metric traits and malocclusions, have been observed over the course of the study but have not been recorded systematically. Several of these non-metric traits and malocclusions have a genetic component, with some showing lower, some higher heritability rates (Hillson 1996). They will be presented briefly in this subsection. Some of the rarely occurring traits and malocclusions with a genetic component will be used in an attempt at reconstructing kinship structures in the cemetery. Table 2 gives an overview on traits considered as non-metric and traits falling within the malocclusions, as they will be presented, in a different order, in the following section.

Table 2 List of dental-non metric traits and malocclusions analysed in this chapter (after Hillson, 1996)

Dental non-metric traits	Dental malocclusions
Peg-teeth	Dental agenesis
Reduced/pegged 3rd molars	Impacted teeth
Enamel pearls	Persisting deciduous teeth
Tuberculum dentale	Overbite/underbite/crossbite
Protostylid	Spacing/mid-line diastema
Parastyle	Dental crowding
Carabelli's cusp	Rotation
	Ectopic eruption

a. Peg teeth

Peg teeth are characterized by a conical form and a lack of morphological features. Scott and Irish (2017) list peg teeth among the variants of the upper second incisors and third molars. They are a rather uncommon trait. The occurrence of reduced/pegged or missing third molars lies around 12% for western European populations whereas that of pegged incisors comes up with around 5% in most populations. The occurrence of reduced, pegged or missing upper third molars has a genetic component and therefore is often used in biodistance analysis (Scott & Irish 2017).

A total of 4 peg teeth were found among all teeth of the sample. 3 were peg teeth of the second maxillary incisors (I2) and 1 was a left maxillary third molar (M3) (Indiv.: 2008_78/154). Of the incisor peg teeth, 2 were right (Indivs.: 2013_015/171, 2008_78/146) and the other left (Indiv.: 2008_78/1106), and while two of them could be clearly classified as peg teeth, one from the right side (Indiv.: 2013_015/171) should rather be considered as diminutive form of an I2, since, although rather rounded and very small, its shape still vaguely resembled that of on I2. Calculated on all permanent teeth, the occurrence of peg teeth lies at 0.29%. The incidence for the three I2 peg teeth would be 2.80% among all adult individuals with scorable I2.

b. Dental agenesis and impacted teeth

Among adult individuals, 89 third molars in total were missing, belonging altogether to 46 individuals. Since no radiographic screening was performed, it cannot be determined with certainty whether the teeth were just impacted, meaning that their eruption path was blocked or altered, for example due to overcrowding, or whether they did not develop. Due to the genetic component of undeveloped teeth, including undeveloped third molars, they often are used, as previously mentioned, in biodistance analysis (Hillson 1996; Scott *et al.* 2016; Scott & Irish 2017). And indeed, several individuals with missing third molars are buried in close proximity to one another. Particularly striking is the case of 2008-78/582a and b, a male and a female senile, which were recovered from the same burial unit and presented the same trait. Individuals 2013-015/353 and 359 and adult male and a young adult female respectively were buried inside the church complex in the same row along the cloister wall, separated only by one further individual. Individuals 2008-78/1293 and 536 were buried right on top of each other within the same layer. 2008-78/106 and 108 were lying right next to each other inside the small annex of the old church and 2008-78/124 was buried directly below 106. Due to the very close

burial locations of these individuals and the fact that they are all missing their third molars, it can be tentatively interpreted, that those individuals were related to each other. The remaining individuals with missing third molar lied more scattered but still in lose groups, so that no immediate tentative interpretations can be made.

Finally, two individuals, 2008-78/1167 and 191 are missing their left and right maxillary canines respectively.

A total of 10 certainly impacted and a further 2 probably impacted teeth were recorded in the sample, all exclusively either lower or upper third molars. They could be detected because they had already partially erupted through the alveola, but their eruption was halted or deviated, mostly because they were growing into the adjoining second molar. Only few impactions did not cause any infections in the jaws but only root deformations in the adjoining teeth, the majority caused either carious lesions on adjacent teeth or alveolar inflammation, including, in two cases pericoronitis. These inflammatory reactions will be addressed in more detail in the pathology chapter of this thesis. While most cases consisted of lower or upper third molars growing towards the second molar, in two cases, the rather large lower third molar was pushed so far back due to dental overcrowding and a lack of space behind the second molar, that it erupted out of the anterior mandibular ramus ridge and its full eruption was halted due to it erupting horizontally onto the crown of the adjoining M2. In one other case, an upper M3 was partially erupted out of the buccal side of the alveolar process. (Figure 3)

Figure 3 3rd molar impaction of 2008-78/200

c. Persisting Deciduous Teeth

As the permanent teeth develop inside the jaw, they start pushing upwards and push their deciduous predecessors out as they continue to erupt. In rare cases however, either because the permanent tooth is missing or because it takes on another eruption path, a deciduous tooth can persist among the permanent dentition into adulthood (Hillson 1996).

A total of 2 confirmed cases of persisting deciduous teeth have been recorded. 2008-78/839, a juvenile aged 17-20y, and 627, an Infans II aged 9-11y, involving a deciduous lower second premolar (DP2) and an upper deciduous right second incisor (DPI2) respectively. A further potential case of persisting deciduous upper right canine was detected in 2016-082/180, a mature male, where all permanent teeth were present, but a small fusing alveola was observed between the maxillary permanent canine and the first premolar. A very small fusing alveola at the place of the canine, was observed for individuals 2008-78/1086 on the right and left and 1065 on the left side, and a very small upper left I2 alveola, likely belonging to a persisting deciduous I2, was observed in individual 2008-78/1178. The three latter individuals will be further discussed in the next section.

d. Ectopic Eruption

If a tooth erupts in any direction that deviates from its normal vertical one, either through its own alveola or somewhere else in the maxilla or mandible, the case is described as ectopic eruption. Ectopic teeth, a rare occurrence, can be supernumerary teeth but are commonly just teeth of the normal maxillary or mandibular tooth contingent. The canines are the teeth most frequently affected by ectopic eruption, with the most common case being that canines erupt above the first premolars (P1) and second incisors (I2) (Scott *et al.* 2016).

Five cases of probably ectopic eruption could be identified in this population, four of them are particularly intriguing. In individual 2008_78/1449, the right mandibular third molar (M3) probably developed in an upside-down position within the mandibular body. Instead of the crown erupting, the tips of the tooth roots were visible in the space behind M2.

The other three cases represent the exact same dental anomaly. In individuals 2008-78/1086, 2008-78/1065, 2008-78/1178 and 2008-78/767, the permanent maxillary canine has partially erupted through the palatine process of the maxilla, right behind the second and first incisors (see Figure 4). The anomalies found in individuals 2008-78/1086, 1065, look like a space with a very reduced alveolar opening between P1 and I2, suggesting the former presence of a deciduous canine that finally fell out, before the adjacent teeth started to close the gap causing the move of the canine into the palate. For individual 2008-78/1178, the situation was slightly different. The I2 was missing and its alveola was very small, evoking a persisting deciduous I2. In all cases the complete maxilla could be evaluated, except for 2008-78/1065 where only the left side is preserved. For 2008-78/1178 and 767, the trait presents only unilaterally, specifically on the left side, whereas in 2008-78/1086 it occurs bilaterally and perfectly symmetrical. Since this quite unique trait occurs identically in at least two individuals, the

probability that these individuals were related is very high. Indeed, individuals 2008-78/1065, a female senile, and 1086, a female young adult, both presented the trait identically, and over that were buried right next to each other in the same burial layer, which increases once again the possibility of a familial relationship. The tomb of individual 2008-78/767, a young adult male, was situated a bit further away from the previous pair. The grave of individual 2008-78/1178, a senile male, was not marked on the excavation map, however the approximate reconstructed burial location, based on comparisons of inventory number, grave number and excavation area, with marked graves, places it in the area between the pairs of 2008-78/1065-1086 and 2008-78/767, and slightly closer to the latter. Due to the trait only occurring unilaterally in the latter two and the lack of direct burial relation, only 2008-78/1065 and 1086 can be addressed as being quite certainly related to each other in some way, at this stage.

Figure 4 Canines partly erupted in processus palatinum behind upper maxillary I2 right and left in 2008-78/1086

e. Enamel pearls

Enamel pearls are located at the ends of extensions of the enamel line towards the root bifurcation. Therefore they are very small, localized, rounded occurrences of enamel-covered dentine nodules on the tooth apex, and are usually found close to the root bifurcation. (Hillson 1996; Scott *et al.* 2016; Scott & Irish 2017). Enamel extensions, and especially pearls occur most frequently on the mesial or distal surfaces of upper permanent second or third molars (Hillson 1996). Two enamel pearls were recorded on the same tooth, an upper left M3 belonging to a Young Adult female from the cemetery, although they usually are observed on

the upper or lower M1. Only the enamel pearl was noted, but generally enamel extensions were not systematically looked out for. The number of enamel pearls might be obscured by the fact that they are often not visible on teeth that are still in their alveolas.

f. Tuberculum dentale

The tuberculum dentale is located on the lingual surface of the cingular base of the upper incisors or canines. Their degree of expression varies from simple ridges to a pronounced tubercle with apex within and between teeth (Hillson 1996; Scott *et al.* 2016; Scott & Irish 2017).

A tuberculum dentale was identified exclusively on 11 maxillary right and left canines and second incisors, belonging to 6 people, whereas in two, they occurred on the left and right side of either I2 or C, in one they occurred on the left I2 and C and in one on the right and left I2 and left C2. (Figure 5)

Figure 5 Tuberculum dentale at cingulum of the maxillary right canine of 2008-78/839

g. Protostylid

Protostylids belong to the category of cingulum derivatives and are positive or negative manifestations of varying degrees of expression, originating at the mesiobuccal cusp of the lower molars (Hillson 1996; Scott *et al.* 2016; Scott & Irish 2017).

A protostylid was present on 3 lower M3, of which two belonged to the same individual and were very strongly pronounced.

h. Parastyle

The parastyle is a tubercle usually expressed on the paracone of the upper molars and shows varying degrees of expression (Hillson 1996; Scott *et al.* 2016; Scott & Irish 2017).
Among the Knuedler population, parastyles occurred in 3 upper M3 from 3 different individuals, whereas one was of strong, another of medium and the last of light appearance.

i. Carabelli's cusp

Carabelli's cusps manifest on the lingual surface of the protocone of the upper molars. Their degree of expression is highly variable, ranging from small pits to large, free-standing tubercles (Scott *et al.* 2016; Scott & Irish 2017). For a long time, it was assumed that the carabelli's cusp was a trait characteristic of the European dentition, however more recent studies have found that frequencies of carabelli's cusps are actually quite similar in other populations even though their ranges of variation differ (Hillson 1996; Scott *et al.* 2016; Scott & Irish 2017). A total of 13 molars presented with varying ranges of carabelli's cusp. The majority was found on the upper first molar, but one case occurred on the second upper molar and two others on the third. Stage 1 expression, the lowest degree of expression characterized by only a small ridge, was present in 4 cases, stage 2 was recorded 4 times as well, stage 3 occurred 3 times and stage 4 and 5 just once. They were detected in 7 individuals, with one individual presenting with a cusp on the left and right upper M1 and M3. Due to its rather high frequency, carabelli's cusp is generally not used in kinship analysis.

j. Dental malocclusions: Overbite, Overcrowding, Rotation and Diastema

Several further dental malocclusions have been observed in the population buried on the Knuedler cemetery.
An overbite, namely when the occlusal surfaces of teeth from the maxilla project anteriorly and considerable before those of the mandible, has been observed in 4 individuals, one senile male, one senile and one adult female and one infans II.
37 individuals showed some degree of dental misalignment, all due to dental overcrowding. Mainly men were affected, and it was represented pretty much equally among cemetery and church burials.
134 rotated teeth belonging to 62 individuals were identified. Most of these individuals displayed multiple rotated teeth, with only light rotation. The most commonly affected teeth were the canines (33 of 134) followed by the premolars and then the incisors, but all tooth types are represented. Teeth from the mandible were more than twice (68.7%) as likely to be affected than those from the maxilla (31.3%). Tooth rotations were predominantly observed in adults

but also in 3 subadults. 10 teeth belonging to 9 individuals showed marked rotation of which 7 even showed a 90 degrees rotation. In most cases, (5 of 10), either upper or lower P1 or P2 were involved, followed by I1 in three cases and C in 2 cases.

Dental spacing was observed between 78 teeth of 19 individuals, with the majority having space between more than three teeth. In most cases, the frontal teeth between I1-P1 were affected (84.6%), including spacing between the left and right I1. Of these 19 individuals, 7 presented only a midline-diastema, a spacing between the first incisors of either the mandible or maxilla (Hillson 1996).

3 Postcranial non-metric traits

Table 3 Frequency of postcranial traits in all individuals from the Knuedler cemetery by area present

- *For. = Foramen ; Pres. = Present*

Frequency of postcranial traits					
Trait	**Side**	**variation**	**Presence of area**	**Presence of trait**	**%**
Foramen sternale		Pres.	97	4	4.12
Foramen xyphoideum		Foramen	43	1	2.33
		Split	43	2	4.65
		Split + For.	43	1	2.33
Clavicular additional fac. art	R	Pres.	155	0	0.00
	L	Pres.	162	2	1.23
Suprascapular region	R	Foramen	135	1	0.74
	R	Notch	135	134	99.26
	L	Foramen	122	1	0.82
	L	Notch	122	121	99.18
Supracondylar spur	R	Pres.	175	4	2.29
	L	Pres.	169	3	1.78
Septal aperture	R	Pres.	173	9	5.20
	L	Pres.	164	11	6.71
Third trochanter	R	Pres.	159	8	5.03
	L	Pres.	162	14	8.64
Allen's fossa	R	Pres.	173	34	19.65
	L	Pres.	176	36	20.45
Poirier facet	R	Pres.	172	26	15.12
	L	Pres.	175	20	11.43
Femoral plaque	R	Pres.	172	43	25.00
	L	Pres.	175	54	30.86
Sustentaculum tali	R	Split	140	48	34.53
	R	Single	140	91	65.47
	L	Split	127	42	33.07
	L	Single	127	85	66.93

Frequencies of presence or absence or expression of each trait were calculated in relation to all bone areas where the specific trait occurs preserved in the sample. When the trait occurred on the right and on the left side, it was accounted for in both analyses of left and right bone sides. Although only frequencies for the total population are listed in Table 3, differences in frequency distribution were tested between the sexes and between burial locations.

The most frequently occurring traits in this population were single sustentaculum tali, followed by femoral plaque and Allen's fossa.

Most of the traits did not show any significant differences in distribution between the sexes or burial locations. However, a significant difference could be detected between the sexes for the femoral plaque occurrence on the right ($p=0.0093$) and on the left ($p=0.0334$) side between men and women, with plaque occurring more often in men (R: 32.38%; L: 37.61%) than in women (R: 14.29%; L: 21.67%). The same trend, albeit non-significant, could be observed for the occurrence of a Poirier facet (M: R: 18.10%, L: 13.76%; F: R: 11.11%, L: 8.33%). Some studies associate the occurrence of Poirier facets or femoral plaque with physical activity rather than with a genetic component (Bühler & Kirchengast 2022). So maybe, the differences observed here would rather point at differences in physical activity patterns between the sexes. However, as the etiology of both traits remains under debate, they will not be used to infer physical activity.

Further significant differences were found among the occurrence of split or single sustentaculi tali, where in the left, a significant difference between church (47.06%) and cemetery (27.91%) ($p=0.0449$) was observed and a significant difference between the sexes was detected for both sides. The parallels that can be observed in the distribution between the burial location and the sexes, namely the clearly higher incidence in church, and the significant higher occurrence in men, may be explained by the fact that more men than women were buried in the church. (M: R: 43.90%, L: 40.79%; F: R: 22.22%, L: 20.45%) (R: $p= 0.0150$; L: $p=0.0228$)

Examples of postcranial non-metric traits	
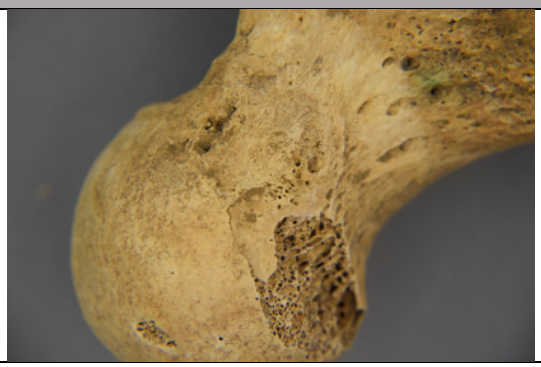	
Figure 6 Femoral plque of 2008-78/208	*Figure 7 Allen's fossa (2016-082/438)*

4 Discussion

Since kinship reconstruction was not part of the original research questions, no elaborate attempt was started in order to reconstruct family relations.

However, an attempt was made to detect potential matches by firstly combine cranial and dental traits with a strong genetic component, then determine which individuals share the most of these traits and finally check their burial locations on the excavation map. Unfortunately, no valid correlation could be found.

Moreover, a few potential matches could be made when using the slightly less frequent traits. For instance, individuals 2008-78/1037 and 746 shared a sutura mendosa as well as ossicles in the lambdoid suture, but did not share any further traits, except for a suprascapular notch, which was the most common expression of that trait. They were buried relatively close together but not next to each other and were recovered from two different layers.

Other examples for potential matches are the correspondences based on dental traits, already mentioned in the chapter of dental anomalies.

Finally, one relatively secure family relation could be established between individuals 2008-78/1065 and 1086 due to the very unique dental anomaly (ectopic eruption) they are sharing and the fact that they are buried in the same layer in two graves directly next to each other.

With the collection of more traits, especially cranial and dental non-metric traits, a more detailed analysis of kinship might have been possible. However, as already mentioned in the beginning, these analyses are not without problems as the etiology of many of the non-metric traits is still unclear, and for proper kinship reconstruction, other methods such as nuclear DNA should ultimately be used.

Bibliography

Bühler B & Kirchengast S 2022 Horse-riding as a habitual activity among the early medieval Avar population of the cemetery of Csokorgasse (Vienna): Sex and chronological differences. *International Journal of Osteoarchaeology* **32** 821–831. (doi:10.1002/oa.3107)

Grupe G, Harbeck M & McGlynn GC 2015 *Prähistorische Anthropologie*. Springer Spektrum.

Hanihara T & Ishida H 2001 Frequency variations of discrete cranial traits in major human populations. I. Supernumerary ossicle variations. *Journal of Anatomy* **198** 689–706. (doi:10.1017/S0021878201007907)

Hanihara T, Ishida H & Dodo Y 2003 Characterization of biological diversity through analysis of discrete cranial traits. *American Journal of Physical Anthropology* **121** 241–251. (doi:10.1002/ajpa.10233)

Hauser G & De Stefano GF 1989 *Epigenetic Variants of the Human Skull*. Stuttgart.

Hillson S 1996 *Dental Anthropology*. University Press Cambridge.

Mann RW & Hunt DR 2019 Non-metric traits and anatomical variants that can mimic trauma in the human skeleton. *Forensic Science International* **301** 202–224. (doi:10.1016/j.forsciint.2019.05.039)

Nikita E, Mattingly D & Lahr MM 2012 Sahara: Barrier or corridor? Nonmetric cranial traits and biological affinities of North African late holocene populations. *American Journal of Physical Anthropology* **147** 280–292. (doi:10.1002/ajpa.21645)

Palamenghi A, Borlando A, De Angelis D, Sforza C, Cattaneo C & Gibelli D 2021 Exploring the potential of cranial non-metric traits as a tool for personal identification: the never-ending dilemma. *International Journal of Legal Medicine* **135** 2509–2518. (doi:10.1007/s00414-021-02654-4)

Ricaut FX, Auriol V, Von Cramon-Taubadel N, Keyser C, Murail P, Ludes B & Crubézy E 2010 Comparison between morphological and genetic data to estimate biological relationship: The case of the Egyin Gol necropolis (Mongolia). *American Journal of Physical Anthropology* **143** 355–364. (doi:10.1002/ajpa.21322)

Scott GR & Irish JD 2017 *Human Tooth Crown and Root Morphology*. Cambridge University Press. (doi:10.1017/9781316156629)

Scott RG, Maier C & Heim K 2016 *Identifying and Recording Key Morphological (Nonmetric) Crown and Root Traits*. John Wiley & Sons, Inc.

Tyrell A 2000 Skeletal non-metric traits and the assessment of inter- and intra- population diversity: past problems and future potential. In *Human Osteology in Archaeology and Forensic Science*. Eds M Cox & S Mays. Cambridge University Press.