Age at Death of the Neanderthal Child From Devil’s Tower, Gibraltar and the Implications for Studies of General Growth and Development in Neanderthals

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KEY WORDS Aging, Dentition, Hominids, Perikymater

ABSTRACT This study combines traditional methods of assessing dental developmental status based upon modern human standards with new techniques based upon histological observations in order to reassess the age at death of the Gibraltar child from Devil’s Tower. The results indicate that the most likely age of this individual at death was 3 years of age. This result is in agreement with an independent assessment of the age of the temporal bone of this specimen (Tillier, AM [1982] Z. Morphol. Anthropol. 73:125–148) and is concordant with dental developmental ages given for modern humans. Moreover, the fact that this specimen appears at the low end of the age scale for calcification stages in modern humans is also supportive of the findings of Legoux (Legoux, P [1970] Arch. Inst. Paleontol. Hum. Mem. 33:53–87) and Wolpoff (Wolpoff, MH [1979] Am. J. Phys. Anthropol. 50:67–114) that dental eruption schedules in Neanderthals were also accelerated. If the cranial bones from Devil’s Tower are associated with the dental material, as we believe, they indicate a remarkably precocious brain growth in this individual, which is consistent with what is known about general growth and development in Neanderthals.

The Devil’s Tower Neanderthal remains were excavated in 1926 from calcareous sands in the mouth of a small cave at the northern end of the Rock of Gibraltar (Garrod et al., 1928). The only absolute age available from this site is a radiocarbon date of more than 30,000 years (Vogel and Waterbolk, 1964), but the Mousterian occupation of Devil’s Tower may be correlated with that of the nearby Gorham’s Cave, where the uppermost Mousterian level is dated by associated charcoal and humus to at least 47,000 radiocarbon years (Vogel and Waterbolk, 1964). Such an age is consistent with faunal and sea level data, which date the Mousterian levels of both Devil’s Tower and Gorham’s Cave to the early part of the last glaciation. Thus the Devil’s Tower Neanderthal child is probably of comparable antiquity to many other Eurasian Neanderthal fossils, and probably derives from a typical European Neanderthal population.

The Devil’s Tower hominid remains consist of a mandible and associated right maxilla, a frontal bone and associated left parietal, and a right temporal bone. In the original report on Devil’s Tower, Buxton (in Garrod et al., 1928) commented upon the apparent discrepancy in development between the temporal bone and the rest of the cranial material. Buxton noted that characters such as the degree of exposure of the petrous and the presence of the foramen of Huschke, indicated an individual younger than 5 years of age. However the large cranial dimensions and supposedly advanced first molar development pointed to an age of more than 5

Received August 19, 1985; revision accepted January 7, 1986.
years at death. Buxton nevertheless concluded that the various bones did represent a single Neanderthal child of about 5 years, a view supported by his reconstruction of the cranial vault employing mirror image models of the missing bones. Additional support was provided by the apparent good fit between the glenoid fossa and the condyle of the mandible. Buxton’s explanation for the discrepancy between the immature development and size of the temporal bone and the development of the dentition and large size of the other cranial bones was that the temporal development was rather retarded in this individual. Cranial expansion must also have been remarkably advanced, and he speculated that precocious brain growth in Neanderthals might explain such large cranial dimensions in a young individual. He accounted for the fact that the Devil’s Tower cranium was even considerably larger than the more mature La Quina 15 cranium by suggesting that the former specimen was a male individual and the latter a female. Buxton’s assessment of the Devil’s Tower material has been generally accepted (Oakley et al., 1971), and his aging of the specimen has been supported by Skinner and Sperber (1982) on the basis of dental developmental data employing modern human standards (see below). Skinner and Sperber assessed the probable age at death as about 5.4 years (male standard) or 4.7 years (female standard). Tillier (1982), using a larger comparative sample than was available to Buxton, re-examined the Devil’s Tower material and confirmed his attribution of most of the material to a Neanderthal child of about 5 years of age, based upon the large cranial dimensions and the conditions of the deciduous and permanent dentition.

Nevertheless, she was not convinced that the retarded development of the temporal bone, shown by the arrangement of the petrous and the lateral orientation of the glenoid fossa, could be attributed to normal ontogenetic variation in Neanderthals. Instead, Tillier identified the temporal bone as representing a separate individual of no more than 3 years of age at death, and she supported this claim by contradicting Buxton’s claim for a good fit between the glenoid fossa and the mandibular condyle. Following doubts about this conclusion (Stringer et al., 1984), we now believe that new aging techniques are able to shed light upon this problem and also contribute to present debate about Neanderthal growth and development.

Data for modern human dental developmental criteria are ordinarily employed to make assessments of the age at death of subadult fossil hominids (Mann, 1975; Skinner and Sperber 1982). Earlier accounts of modern human calcification and eruption times (Symington and Rankin, 1908; Hess et al., 1932; Logan and Kronfeld, 1935; Schour and Massler, 1940), were based largely upon observations made from dissections and radiographs of small numbers of human jaws at postmortem examination. More recently there have been many more studies (some of them longitudinal and on very much larger samples of children), which give a clearer idea of the wide range of variation that exists in both calcification and eruption times within modern human populations (Morreese et al., 1963; Gleiser and Hunt, 1955; Fanning, 1961; Fass, 1969; Nolla, 1960; Haavikko, 1970). Some studies of human dental development have even been specifically directed at precisely estimating the age of human remains from the weight of formed teeth, (Stack, 1960), or by using scoring systems (Demirjian et al., 1973), or have been designed particularly for use in forensic medicine (Anderson et al., 1976; Sundick, 1977). Whereas these kinds of studies have formed the basic data base for most methods employed to estimate the age at death of fossil hominids, other methods more often applied to forensic investigations have been ignored or considered inappropriate. Boyd (1964) has cogently noted that the most reliable methods for estimating age at death are histological methods “where there is no need to refer to the chronology of development in other individuals.”

Boyd (1963, 1964) calculated the age at death of an individual by counting daily incremental cross-striations in tooth enamel, from the neonatal line in a first permanent molar to the end of enamel formation. By using prominent striae of Retzius, counts could be continued cervically or from one tooth to another until the end of enamel formation at death. However, this technique requires that teeth be sectioned for microscopic examination and requires that a neonatal line be identified in the first permanent molar. It is also reliant upon each daily increment being visible. Striae of Retzius are coarser incremental markings within enamel
that result from a regular rhythmic disturbance during enamel formation, the cause of which is as yet unidentified (Newman and Poole, 1974). They are well known to pass obliquely from the enamel-dentine junction to the surface of the tooth, where they become visible as perikymata. Both perikymata and striae of Retzius can be counted, and Asper (1916) has reported that in a series of human permanent maxillary canines there was a mean number of 197.5 striae of Retzius and a range of 174–222 with the longest anatomical crown of the series having the most striae of Retzius and the shortest having the least. Asper also calculated that the interval between any two striae of Retzius was formed in either 5, 7, 8 or 10 days. Newman and Poole (1974) have since observed that this periodicity is commonly 7 or 8 days and is similar to other comparable rhythmic disturbances in bone (Sissons, 1949) and dentine (Bradford, 1967). Therefore, it follows that where perikymata can be counted on the surface of teeth, approximately 1 week’s growth is represented between any two adjacent striae. The obvious advantage of counting perikymata as a method of determining age at death of an individual is that it is nondestructive. Incisor teeth are particularly suitable, as they begin to form soon after birth, and perikymata can be seen all over the surface of the crown, unlike most teeth where they are not visible in cuspal regions. However, in all teeth there are some increments of growth that do not reach the surface and remain hidden beneath the most cuspal enamel. Bromage and Dean (1985) have counted between 25 and 30 striae of Retzius in unworn human incisors (i.e., about 6 months’ growth) before the remainder become visible as perikymata on the surface of the enamel.

The Devil’s Tower Neanderthal remains are particularly suitable for estimating an age at death by counting perikymata on the labial surface of the upper right first permanent incisor. This tooth is exposed and undamaged with a minimum of root formed in the premaxilla. Perikymata can easily be seen with the naked eye on the tooth surface, so well preserved is the incisor in this specimen (see Figure 1C in Brothwell, 1963). As in all primates (Swindler, 1985), permanent upper central incisors begin to calcify shortly after birth and so no more than three or four months are likely to have elapsed before the onset of calcification.

METHODS AND RESULTS

The crown of the permanent upper right central incisor of the Gibraltar child was cleaned with dilute acetic acid and replicated employing high-resolution silicone-based dental impression material and then cast in epoxy resin (Bromage, 1985). The positive epoxy resin replica was then prepared for SE mode scanning electron microscopy, and montage photographs were prepared at \( \times 50 \) magnification of the whole of the labial surface of the tooth. The total number of perikymata were counted from the unworn mammelons incisally to the enamel dentine junction cervically. A constant total count of 119 perikymata was made from the photographs. This count of 119 perikymata was used to calculate the time of crown formation as follows (see also Bromage and Dean, 1985); 119 weeks is equal to 2.3 years. Assuming that 6 months of enamel formation is hidden in the cuspal region, then the total time of crown formation is 2.3 + 0.5 = 2.8 years. Some time must also be added to this crown formation time to account for the short interval between birth and the onset of incisor calcification and also for the very minimal amount of root formation (less than 1 mm). These have together been estimated at 0.3 years. It follows then that the likely age at death of this specimen was 2.8 + 0.3 = 3.1 years. Some margin of error is likely as only the mean number of daily cross-striations between adjacent perikymata have been used in this calculation, and the exact time of onset of incisor calcification remains unknown. It is probable (until further comparative work is carried out) that these two unknowns could only be determined by sectioning the first permanent molar and the upper incisor, identifying the neonatal line in the molar, counting the number of daily cross-striations between the neonatal line and a prominent stria of Retzius common to both the incisor and the molar and continuing the count to the end of enamel formation in the incisor. (In spite of the fact that one first molar has already been removed from the specimen, this still cannot be considered a justifiable proposition as nondestructive techniques designed for fossil hominids are clearly preferable to destructive ones.) Nevertheless, as Boyd (1963, 1964) points out, some degree of confirmation for results like these can be obtained by comparing the gross dental developmental status of the specimen with what
is known from good longitudinal studies of odontogenesis in modern man.

Accordingly, in order to test the hypothesis that 3.1 years is a reasonable age at death for this specimen, data from published radiographs, (see also Fig. 1) and observations made directly from the specimen are presented here and discussed in the light of several studies of hominoid dental development. Skinner and Sperber (1982) present good radiographs of the developing permanent mandibular incisors, which illustrate crown completion and some root formation at LI2 and LI1 (possibly even a quarter of the root formed at LI1, depending of course on the eventual length of the fully formed root). At RI1 and RI2 they comment that subluxation of the deciduous incisor RI1, antemortem, has resulted in the retardation of odontogenesis and rotation of the RI1 and RI2 in their crypts. The permanent mandibular canine and premolar teeth are less well illustrated, but it is clear that none of these crowns is complete, although the canines may be close to completion, and the premolars may be between a quarter and a half formed in the case of the Pm3 and only a quarter (if that) in the case of Pm4. Most important, however, is the good illustration of the mandibular LM1 in which it is possible to see that crown formation is complete and that root formation has begun. As there is 2–3 mm of root formed (on the RM1 that has been removed from the specimen), this fact can be verified. The developing root cone angle is 29 degrees (see Dean 1985; and “Conclusions”). A large bony crypt is present on the right and is partly preserved on the left for the developing second permanent molar. The calcifying RM2 is preserved (recovered separately), and the crown is about a quarter complete, (see Fig. 2). No teeth in the maxilla are easily seen from the radiographs presented in Skinner and Sperber (1982) or in Fig. 1, but they appear to be at identical stages of development to the mandibular dentition.

DISCUSSION

When the developing teeth are considered individually, the developmental ages suggested by Skinner and Sperber (1982) for the Gibraltar child are incorrect and are inconsistent with two other specimens illustrated by these authors (Bruniquel 2, Grotte des Forges, Fig. 66 A–D) and Laugerie-Basse (Fig. 82A–D). In the former, M1 calcification is slightly behind that of the Gibraltar child (i.e., crown formation just complete) and in the latter M1 is, if anything, slightly ahead with more root formed (with a developing root cone angle of 46 degrees). These are attributed very reasonable ages of 2.8–2.9 years and 3.7–3.9 years, respectively. Both of these specimens are attributed to *Homo sapiens sapiens*, and outside ranges for the two are given as 1.6–3.1 years and 3.4–5.9 years, respectively. Judged from gross morphological observations on M1 formation status alone, the Gibraltar child might be expected to fall between the estimates for these other two specimens, i.e., between 2.8 and 3.9 years of age.

Reports in the literature about the age of M1 crown completion in modern humans vary somewhat, Moorrees et al. (1963) show the mean time of M1 crown completion as 2.2 years for both boys and girls with the two standard deviation range as 1.7–2.8 years. Gleiser and Hunt (1955) determined the mean crown completion time as 3.5 years in boys and 3.3 years in girls, with one standard deviation range equal to 5.6 and 4.2 months, respectively. However, Nolla (1960) quotes mean M1 crown completion time as 4 years in boys and 3 years 10 months in girls. Fass (1969) quotes a mean value for both sexes of 2 years 11 months and notes the earliest appearence of M1 crown completion at 2 years 6 months. Finally, Haavikko (1970) quotes a mean crown formation time of 3.5 years for both boys and girls. None of these estimates of M1 crown completion time (perhaps with the exception of Nolla, 1960) is incompatible with an age of 3.1 years for the Gibraltar child, but none would be compatible with an age of 4.7–5.4 years.

Crown formation of LRM2, which as far as can be judged is at a similar stage of development to LPM4, is about a quarter complete, (see also Fig. 2). Demirjian and Levesque (1980) cite 0.5 years for M2 and 0.3 years for Pm4 as the time taken between initiation of calcification of the crown and the point when a quarter of the crown is complete. This implies that calcification of these teeth would have begun at about 2 1/2–2–3/4 years of age in the Gibraltar child. These dates are in agreement with the dates given for modern humans by Logan and Kronfeld (1935), but more recent data (Moorrees et al., 1963) suggest that this is early for M2 crown initiation (2.75 years being 2 S.D.’s below the mean value of 3.5 years for M2
crown initiation in their study). Nevertheless, the developmental status of M2 cannot be considered to be outside the known modern human range, and although the sequence of development of M2 and Pm4 is advanced with respect to M1 in this individual, sequence polymorphisms are well documented (Garn and Lewis, 1963). Additional population data would be required to establish a departure from the normal modern human range.

A comparison of incisor calcification status in the Gibraltar child with that of modern humans and in a specimen of *Homo sapiens sapiens*, Istarits 3, illustrated in Skinner and Sperber (1982, Fig. 75 A–F), demonstrates
that with respect to M1 calcification status the untraumatised LI1 and LI2 of the Gibraltar child are advanced. Their calcification status is close to that of the incisors of Isturits 3 if not slightly ahead of them. However the M1 in this latter specimen is well past the bivirusus stage, the age of the specimen being given as 4.9–5.2 years (the same as that quoted for the Gibraltar child by Skinner and Sperber, 1982). Nolla (1960) quotes the mean time of lower central incisor crown completion time as 3 years 8 months for boys and 3 years 6 months for girls. However Haavikko (1970) quotes 11 (with a quarter of the root formed) and 12 crown completion as occurring at mean values of 4.3 and 3.6 years in boys and girls, respectively. Nevertheless, Fass (1969) noted the earliest occurrence of I1 crown completion at 2 years 10 months and the mean age of crown completion at 3.4 years. Clearly there is considerable variation among the accounts given in the literature for modern man, but taken together they are not incompatible with a dental developmental age for the Gibraltar child of 3.1 years, which would then be at the advanced end of the range of ages recorded for equivalent stages of dental development in modern *Homo sapiens*.

Furthermore, Nolla (1960), Fass (1969), and Haavikko (1970) provide convincing support for the findings of this study with dates for crown completion of the upper first permanent central incisor. Fass notes the earliest completion at 2.9 years with a mean value of 4 years 1 month, while Nolla and Haavikko provide mean ages for crown completion at 4 years 1 month and 3 years 3 months, respectively. This evidence strongly suggests that the time of crown completion derived from the perikymata counts in this study for the Gibraltar child are likely to be accurate, as the figure obtained falls within the known ranges of crown completion in *Homo sapiens*, and so does not represent an unreasonably short duration for crown formation time.

An age of 3 years for the Gibraltar child is also directly compatible with the developmental status of the temporal bone as described by Tillier (1982). Re-examination of the mandibular condyle and glenoid fossa suggests to us that these articulate well (despite the fact that we can know nothing of the intervening articular disc or of the morphology of the head of the condyle as it would have been during life). It then seems unwise to separate the mandible from the temporal bone, particularly as they were found so closely associated at the site and also because the estimates of age at death for each of these are now in agreement. The problem that remains is the status of the large but thin frontal and parietal bones from Devil's Tower, which were found closely associated in the same deposit about 5.5 metres away, and which undoubtedly represent a single individual.

The dimensions of these bones are large enough for Elliot-Smith (in Garrod et al., 1928) to have initially considered a pathological cause such as hydrocephaly, but after discussing the evident contrasts that exist between other Neanderthal specimens, including the La Quina 18 child, he concluded, like Buxton, that the specimen was probably part of the normal range of variation in Neanderthal children. Tillier (1982) was also prepared to accept the association of the separately found mandible and maxilla with the frontal and parietal, and two of her reasons for dissociating the temporal bone from the other two specimens (discordant maturity compared with the dentition and poor articulation of the mandibular condyle and fossa) can now be questioned. We believe that the advanced development of the vault as indicated by the large frontal and parietal when compared with the demonstrably more mature but smaller cranium, La Quina 18, is an indication of population variation in Neanderthal endocranial development.

Given that the Gibraltar 2 frontal and parietal dimensions approximate those of the comparable Engis 2 Neanderthal child (endocranial capacity c. 1,392 ml; Fenart and Empereur-Buisson, 1970) and the more mature child from Teshik-Tash (endocranial capacity c. 1,425–1,531 ml; Tillier, 1984), it is evident that the Gibraltar endocranial capacity was probably also comparable to these volumes. However, the La Quina 18 child was clearly smaller in endocranial capacity c. 1,166–1,250 ml; Tillier, 1984) and from modern ontogenetic patterns should already have been close to its adult value, (Martin, in press). Thus the apparent discrepancy of a larger cranial and endocranial size being present in a less mature individual than La Quina 18 can be explained by the probable presence of sexual dimorphism in brain growth of Neanderthal children as in modern children (Martin, in press), with the La Quina
child representing a particularly small-brained individual even for a putative Neanderthal female.

Considering these factors and that there is no duplication of parts represented, we can find no morphological reason for dissociating them. The temporal bone no longer seems discrepant in development from the immediately associated maxilla and mandible, and we are inclined to follow Buxton in associating all the human material as one individual. Growth and development of Neanderthals as compared to that of modern humans has been a subject of discussion for many years, (Vallois, 1961; Legoux, 1970; Brothwell 1974). Recently, Wolpoff (1979) suggested, on the basis of occlusal eruption schedules and rates of wear, that third molars in Neanderthals achieved occlusal eruption at about 15 years, compared with a mean modern human interpopulation figure of about 19 years. Trinkaus (1984) has also proposed that differences in gestation length between modern humans and Neanderthals may underly differences in their cephalopelvic dimensions.

Our study of the Devil’s Tower specimen demonstrates a similar, albeit slightly advanced, postnatal dental development compared to the average for modern humans. Given the general relationship between dental development and general growth and development (Swindler, 1985), this might suggest a slight increase in the rate of general growth and development in this specimen, but the large neurocranium certainly suggests rapid expansion of the brain.

Trinkaus (1984) has proposed (a), that Neanderthal maternal size and cephalopelvic relationships were consistent with an 11- or 12-month gestation period, and (b) that modern human gestation length is shorter than the predicted length. However, the empirical scaling relationship that exists between maternal body weight and gestation period (Martin and MacLarnon, 1985) suggests that the gestation periods within species or, for two closely related species are most unlikely to be different. Indeed, the body weights of the great apes overlap with modern humans as do their gestation lengths (Martin, 1983).

Wolpoff (1980) and Rosenberg (1985) have proposed another explanation for large Neanderthal cephalopelvic dimensions that suggests the large Neanderthal proportions result from short stature and heavy build, factors that underly a similar intraspecific trend in cephalopelvic dimensions between modern human populations.

However, we prefer to believe, because of the observed advanced neural growth pattern apparent from the new age at death of the Gibraltar specimen and because of the relatively large endocranial capacities of such young individuals (see above), that Neanderthals emphasised a greater proportion of total brain growth in utero but had gestation periods similar to modern humans. It then follows that they would have required a greater pelvic outlet to cope with a neonate of greater endocranial capacity and would have achieved adult cranial capacities earlier in their growth periods than do modern humans.

CONCLUSIONS

It can be concluded that the older accounts of incisor crown formation (often quoted in the dental literature as taking 4–5 years) may be misleading. It has also been established that the dental developmental status of the Gibraltar child is consistent with an age at death of about 3 years. This is compatible with the earlier values within the modern human range for M1, M2, and permanent incisor calcification dates.

The details about dental development presented in this study will not resolve the hypotheses about general growth and development in Neanderthals. However, the young age at death now estimated for this specimen does accentuate the remarkably large dimensions of the frontal and parietal bones suggesting (1) an early and rapid expansion of the neurocranium in this specimen and (2) clear ontogenetic variation among Neanderthal children.

Several other points are also worth noting. One is that the developing root cone angles for the first permanent molars of the Gibraltar specimen fall below the values given for modern Homo sapiens by Dean (1985) by more than 10 degrees (see also Fig. 2). This may simply reflect the taurodont morphology of the growing root, and there is as yet no comparative data about the way taurodont roots grow. It may alternatively reflect a greater speed of root elongation than is typical for modern Homo sapiens. Other dental developmental data for this specimen are within the recorded modern human range but among the more developmentally advanced values (and so not incongruent with the earlier observations of Wolpoff, 1979 regarding Neanderthal dental eruption dates).
Unlike earlier Plio-Pleistocene hominids for which there is good evidence of a "great ape-like" developmental growth period (Bromage and Dean, 1985), the developing dentition of the Gibraltar child falls much closer to, or at the lower end of, the expected range of values known for modern Homo sapiens and as such must be considered to show an accelerated but essentially human pattern of development. However, as we have suggested above, we believe Neanderthals may have been specialised in the manner in which they achieved rapid brain growth before birth and that this resulted in the need for a large pelvic outlet. Full brain growth may also have been completed earlier and, if so, Neanderthal maternal metabolic investment to achieve this must have been high (Martin, 1983).

ACKNOWLEDGMENTS

Support for this work was provided by the Wellcome Trust and the Nuffield Foundation (M.C.D.) and the L.S.B. Leakey Foundation and University of Toronto doctoral grants (T.G.B.). We are especially grateful to Alan Boyde for helpful advice and for making laboratory facilities available to us and also to Bob Martin, Erik Trinkaus, and Bernard Wood for commenting on the manuscript. We would also like to thank the BM(NH) photographic unit for the plates.

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