CHAPTER XXVIII-2

THE CLAVICLES

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Abstract

Two small fragments of clavicles were found in 1886 alongside the famous Spy Neandertal fossil remains. Taxonomically, they are compatible with a Neandertal association, even if this cannot be definitely proven. Furthermore, whether the two fossils belong to the same individual is even more difficult to determine, although evidence supports this hypothesis. The same doubts apply to the attribution of the clavicular fragments to either of the two adult Neandertal skeletons from the site.

INTRODUCTION

Beginning with the first article written by Fraipont & Lohest (1886) on the Spy skeletal remains the very year of their discovery, as well as the following year in the two researchers' detailed study (Fraipont & Lohest, 1887), two fragments of clavicles (Spy 26E and Spy 4) have been associated with each identified skeleton (Spy I and Spy II). For the excavators, the attribution of these fragmentary clavicles to Neandertals was a certainty. Later, the scholars who mentioned these fragments never expressed any doubts on this matter (e.g. Boule, 1912; Hrdlička, 1930; McCown & Keith, 1939; Patte, 1955; Twiesselmann, 1953, 1971).

However, recent analyses, specifically of the long bones of the upper limb, show that greater caution is required before being able to attribute some of the Spy human remains to Neandertals. For example, the ulna Spy 7A, usually regarded as Neandertal (Fraipont & Lohest, 1887; Thoma, 1975), presents a modern morphology (see Hambücken, this volume: chapter XXVI-1) and was recently dated to the Neolithic (OxA-20981; Semal *et al*., volume 1: chapter XVI). Furthermore, new radiocarbon dates resulted in the re-attribution to the Neolithic of numerous bones collected since 1886. Following these anatomical and radiochronological reservations, it seems judicious to be particularly careful with the taxonomic attribution of the fragmentary Spy bones. This should certainly apply to the fragmentary clavicles housed at the Royal Belgian Institute of Natural Sciences (RBINS) and studied in the present chapter.

This contribution will try to assess the taxonomic position of the two fragmentary clavicles Spy 4 and Spy 26E. To do so, it proposes a general description of indisputable Neandertal clavicles, a short overview of how the Spy clavicles have been presented in the literature over the years, an anatomical description of both specimens, as well as qualitative and quantitative analyses of their endostructural morphology, and finally, a discussion of the numerous questions raised by these analyses.

NEANDERTAL CLAVICLES

The first Neandertal clavicle ever found was the right specimen from the Feldhofer type-site in 1856, whose extremities are damaged. Since the 1886 discovery of the Spy human clavicles discussed in this contribution, numerous unquestionably Neandertal clavicles have been found. The most spectacular examples are those of:

- Krapina (1899-1905, Croatia), fifteen portions of different clavicles, ten of them from adults (Radovčić *et al*., 1988: 84-86; see also Smith, 1976: 267);

- La Chapelle-aux-Saints 1 (1908, France), lateral half of a left clavicle (Boule, 1912);
- La Ferrassie 1 (1909, France), two relatively well-preserved clavicles (Heim, 1982);
- Tabun C1 (1929-1934, Israel), parts of the right and left clavicles (McCown & Keith, 1939);
- Regourdou 1 (1957, France), essentially complete right and left clavicles (Vandermeersch & Trinkaus, 1995);
- Shanidar 1 (1957, Irak), incomplete left and right clavicles, and Shanidar 3 (1960), incomplete left clavicle and very damaged right one (Trinkaus, 1983);
- Amud 1 (1961, Israel), small fragment of a right clavicle and small part of a left one (Endo & Kimura, 1970);
- Kebara 2 (1983, Israel), well-preserved left and incomplete right clavicles (Vandermeersch, 1991);
- Sima de Los Huesos (1976-1994, Spain), 11 right and 4 left fragments of clavicles (Carretero *et al*., 1997).

The corpus of available Neandertal clavicles is therefore currently rich enough to allow a relatively reliable description of this specific bone:

- Since Boule's description (1912), which was based on a smaller corpus, Neandertal clavicles are recognised as being long and slender. Their length is consistent with the broad Neandertal thorax; as for their slender aspect, Neandertal clavicles do tend to be rather gracile in comparison with the other infracranial bones (Vandermeersch & Trinkaus, 1995: 448);
- In general, Neandertal clavicles are considered to be strongly curved (McCown & Keith, 1939; Smith, 1976: 268), both horizontally and vertically. However, it was recently demonstrated that their curvatures in cranial view are no different from the modern ones and that the Neandertal clavicle does not possess a more S-shaped morphology than the modern human one (Voisin, 2004a, 2004b);
- Ligament and muscle attachment sites tend to be pronounced as are the main osseous crests;
- The cranio-caudal diameter of the sternal head tends to be large proportionally to the shaft (Smith, 1976: 268);
- The Neandertal midshaft is usually characterised by an elliptical cross-section. It is generally dorso-ventrally flattened, with a low index (below 80).

Most of these features, however, are in the same range of variation as that of modern humans. Therefore, the attribution of a clavicle to a Neandertal specimen may be substantiated mostly by its context – such as the stratigraphy, other more diagnostic bones found in association, archaeological material – in a kind of circular reasoning.

THE SPY CLAVICLES IN THE ANTHROPOLOGICAL LITERATURE

In their first paper about the Spy human fossils, Fraipont & Lohest refer to the clavicle they associated with Spy I as "A left clavicle"[1] (Fraipont & Lohest, 1886: 745) and to the one they associated with Spy II as "A portion of a left clavicle"[2] (Fraipont & Lohest, 1886: 746).

In the section of their 1887 monograph that inventories the bone specimens, Fraipont & Lohest attribute "A left clavicle whose internal end is broken"[3] to Spy I (Fraipont & Lohest, 1887: 601). Further in the same book, they dedicate 7 lines to the clavicles; this time, they clearly discuss two specific clavicles, respectively attributed to each of the two Neandertal skeletons: "*Clavicle*. This bone was more slender on no. 1 than on no. 2. It lacks its external third and internal quarter portions. The internal curve with internal concavity seems more pronounced, particularly on subject no. 2, than on modern races. The rugosities of the superior face towards the internal end are more visible on skeleton no. 2 than on no. 1 for the insertion of the sternocleidomastoid muscle"[4] (Fraipont & Lohest, 1887: 645).

[1] Original text: "*Une clavicule gauche*".

[2] Original text: "*Un morceau de clavicule gauche*".

[3] Original text: "*Une clavicule gauche dont l'extrémité interne est brisée*".

[4] Original text: "Clavicule. *Cet os était plus grêle sur le n° 1 que chez le n° 2. Il lui manque le tiers externe et le quart interne. La courbure interne à concavité interne paraît surtout plus accentuée chez le sujet n° 2 que dans les races modernes. Les rugosités de la face supérieure vers l'extrémité interne sont mieux marquées chez le squelette n° 2 que chez le n° 1 pour l'insertion du muscle sterno-cleido-mastoïdien*".

Later mentions of these fragments are rare and brief, probably because of their fragmentation that made them difficult to study:

- Boule (1912: 120) shortly mentioned the Spy clavicles, insisting on their slenderness, but with few additional details;
- In his studies of the original Spy specimens (respectively in 1912, 1923 and 1927), Hrdlička apparently recognised only one portion of a left clavicle attributed to Spy I (Hrdlička, 1930: 189, 195). This scholar described it as "weak" (Hrdlička, 1930: 189) and wrote that "The clavicle was slender, its shaft near the acromion rather angular. The fragment is too small to permit of other determinations" (Hrdlička, 1930: 197);
- McCown & Keith (1939: 139) wrote also that "A clavicle was found at Spy, attributed to No. I. It, too, is slender";
- In the two versions of his catalogue of human fossils from Belgium and Luxembourg, Twiesselmann (1953: 99, 1971: 12) mentioned "*2 fragm. clavicula*", both of which he attributed to Spy I;
- Patte (1955: 299) did not provide additional information; his mention is clearly based on Boule's contribution (1912: 120);
- There is no mention of the Spy clavicles in the overview paper of Thoma (1975);
- Heim (1982: 6, 8, 11) also attributed both fragments to Spy I and shortly described some of their anatomical details;
- Finally, Leguebe & Orban (1984: 92) copied Twiesselmann's attribution of the two fragments to Spy I.

DESCRIPTION

Fragment of a right adult clavicle (Spy 4)

This fossil only consists of the lateral half of a right shaft and the incomplete lateral end without the acromial surface (Figure 1). Its preserved length is 77.5 mm.

In superior view, the attachment site for the *M. deltoideus* exhibits some muscular markings composing small linear bulges near the anterior border (Figure 1a: no. 1).

In inferior view, the conoid tubercle (Figure 1c: no. 4) is somewhat long and strong. The subclavius, subclavian or subclavicular groove is only weakly marked (Figure 1c: no. 3), distinctly less than on the Neandertal type-site specimen. The attachment site of the *M. trapezius* is only preserved near the posterior border of the inferior face of the lateral end (Figure 1c: no. 5) and therefore absent on the superior face; the preserved muscular marking, which corresponds to the trapezoid ridge, is quite noticeable. The attachment site for the *M. deltoideus* is limited to a small part of the anterior border of the lateral end; it is not particularly marked. The attachment site for the *M. pectoralis major* is well developed on both faces of the anterior border of the diaphysis (Figure 1c: no. 2).

In anterior view (Figure 1e-f), the acromial end dips below the plane formed by the anterior and posterior borders of the subclavicular groove, as on the Neandertal 1 specimen (see McCown & Keith, 1939: 140).

The section of the diaphysis near the middle is elliptical and relatively flat with a cranio-caudal minimum diameter. Its midshaft index (M-4*100/M-5) is 73.4, with a vertical diameter (M-4) of 10.2 mm and a horizontal diameter (M-5) of 13.9 mm (respectively 10 mm and 14 mm, as well as an index of 71.4 according to Heim, 1982: 6). The incompleteness of the clavicle makes it difficult to precisely quantify its curvatures (Olivier, 1951; Voisin, 2004a, 2004b). However, it is clear that the bone is curved in a normal fashion. In fact, the lateral curve of Spy 4 is very similar to that of the Neandertal type-site specimen and its shaft seems twisted in the same way as the clavicles of Regourdou 1.

Fragment of a left clavicle shaft (Spy 26E)

This fragment is a small partial clavicle shaft of 58.5 mm in length (Figure 2a). Its most striking feature is the presence of a roughened and large area for the attachment of muscles or ligaments near one of its borders (Figure 2a: no. 1). What might this feature correspond to? Definitively neither to the conoid tubercle nor to the attachment site of the costoclavicular ligament. It seems on the other hand that it may correspond to a part of the attachment site of the *M. deltoideus* on the superior surface of the

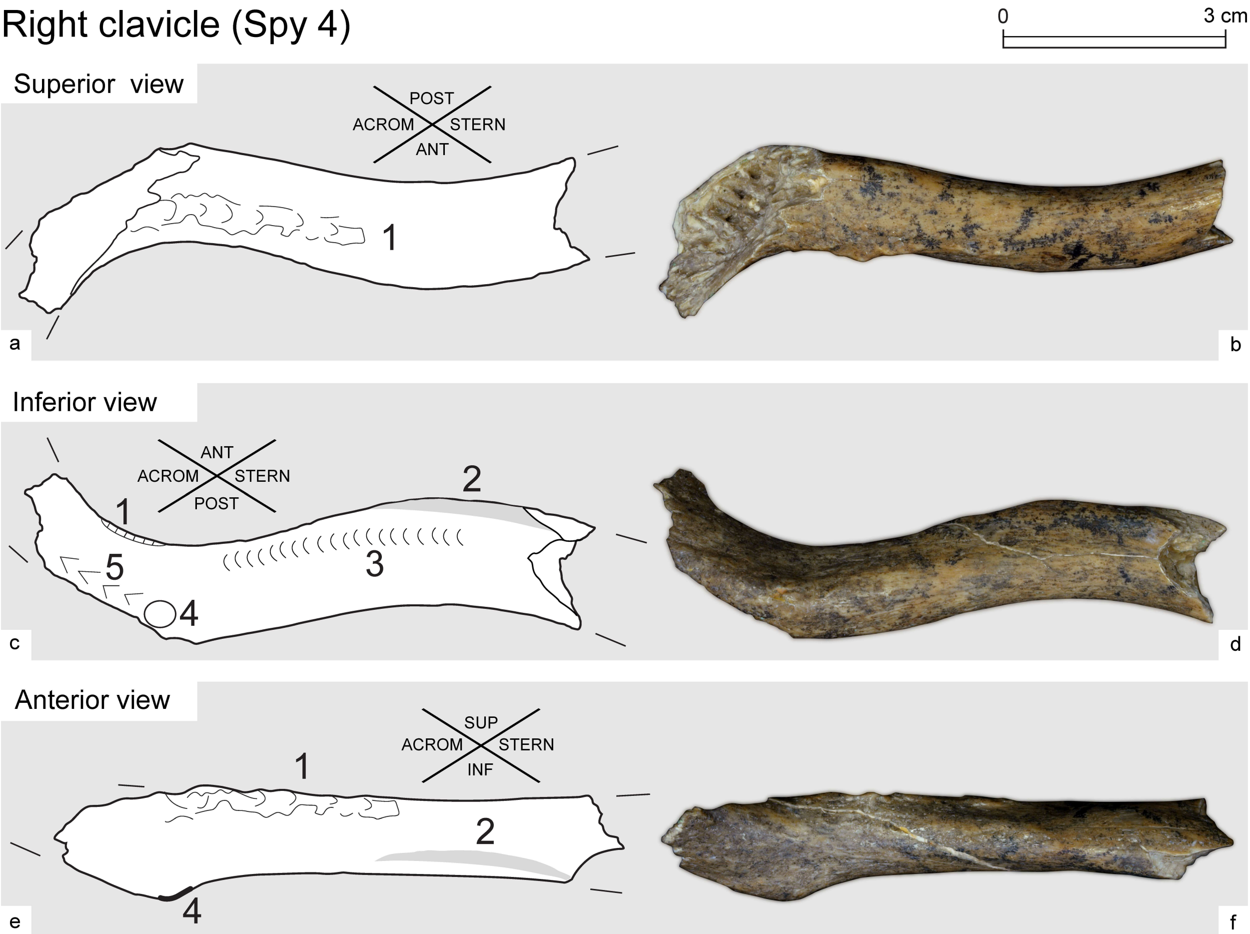

Figure 1. The right clavicle Spy 4. a, b: superior view; c, d: inferior view; e, f: anterior view.
1: attachment area for *M. deltoideus*; 2: attachment area for *M. pectoralis major*;
3: subclavius or subclavicular groove; 4: conoid tubercle; 5: attachment area for *M. trapezius*.

shaft. Moreover, a nutrient foramen is present on the posterior part of the inferior surface (Figure 2c: no. 4). From these two attributes and the general curvature of the fragment, it appears that the Spy 26E fragment represents the centrolateral part of a left clavicle shaft, with the lateral end missing. The presence of an extremely shallow groove on the same surface as the nutrient foramen may correspond to the subclavicular groove (Figure 2c: no. 3), which would reinforce this interpretation. The shaft was laterally cut in the past, apparently to get a sample for an analysis whose result is unknown.

Finally, on the superior face of the bone, there is also a somewhat depressed area which is part of the insertion of the *M. pectoralis major* (Figure 2a: no. 2).

STRUCTURAL ANALYSIS OF THE INNER MORPHOLOGY

Methods

The 3D reconstruction and inner structural analysis of the two adult partial clavicles Spy 4 (right) and Spy 26E (left) are based on a tomographic (CT) recording performed in 2006 with a Siemens Sensation 64 CT scanner (see Balzeau *et al.*, this volume: chapter XXII). The slices were reconstructed and saved in Dicom file format at a voxel size of 195.3x195.3x100 µm and the final volumes were rendered with Amira© 5 (Visage Imaging).

Once reconstructed and anatomically oriented, the two specimens were virtually sectioned

Figure 2. The left clavicle Spy 26E. a, b: superior view; c, d: inferior view. 1: attachment area for *M. deltoideus*; 2: attachment area for *M. pectoralis major*; 3: subclavius or subclavicular groove; 4: nutrient foramen.

at two homologous sites, A and B, as close as possible to 50 % and 35 % of their estimated maximum length.

At both sites, where B is lateral, the following cross-sectional geometric variables of the shaft were measured: total area (TA, in mm^2); cortical area (CA, in mm^2); medullary area (MA, in mm^2); second moments of area about the maximal (I_{max}), minimal (I_{min}), infero-superior (I_x) and antero-posterior (I_y) axes (in mm^4); polar second moment of area (J, mm^4); section moduli about the infero-superior (Z_x) and antero-posterior (Z_y) axes (in mm^3); polar section modulus (Z_p, in mm^3). Additionally, the percent cortical area (PCA), I_{max}/I_{min} and Z_x/Z_y ratios were calculated. PCA indicates the proportion of cortical bone around an entire cross-section; I_{max}/I_{min} represents a kind of biomechanical "shape" index; and Z_x/Z_y provides information about the plane in which the tubular object is more resistant to bending loads (Ruff & Hayes, 1983; Carlson, 2005).

For both specimens, the 3D mapping of the cortical thickness distribution was realised using a semi-automatic segmentation method, and the relative bone topographic variation was rendered by means of a 10-stepped chromatic scale. However, because of their degree of mineralisation and incompleteness, both extremities were not considered.

Present results from the Spy 4 and Spy 26E partial clavicles were compared to the virtual evidence from a right and a left clavicle belonging to the same modern human adult skeleton (MH). Both specimens were recorded at the *Sachsenhausen Krankenhaus* (Frankfurt am Main) by means of a medical CT Philips Brilliance scanner, at the voxel size of 67.71x67.71x330 µm. Additional comparative data about the structural organisation of the two specimens from Spy comes from the µCT-based evidence from the Neandertal (OIS 4) and Magdalenian (OIS 2) skeletons of Regourdou 1 and Chancelade 1, respectively, both from Western France (Volpato *et al.*, 2009, and original unpublished data).

Some uncertainty still exists about the two incomplete Spy specimens and their belonging to the same adult skeleton. For the variables CA, I_x, I_y, J, Z_x, Z_y, and Z_p, we assessed the extent of their quantitative structural differences following the formula ([maximal value - minimal value] / minimal value) * 100 (Trinkaus *et al.*, 1994).

Results

The cross-sectional geometric parameters virtually assessed at two diaphyseal sites in Spy 4 and Spy 26E and in the two modern clavicles (MHr and MHl) are shown in Table 1. In both

	A (~50 %)			*B (~35 %)*		
	PCA	I_{max}/I_{min}	Z_x/Z_y	*PCA*	I_{max}/I_{min}	Z_x/Z_y
Spy 4	83.3	2.0	0.8	69.2	1.7	1.1
Spy 26E	81.5	1.9	0.9	74.8	1.7	1.1
MHr	65.9	1.7	1.1	77.8	1.7	1.3
MHl	74.8	2.2	1.4	74.7	2.3	1.5

Table 1. Cross-sectional geometric parameters virtually assessed at two shaft sites, A and B, in Spy 4 and Spy 26E, and in the right (MHr) and left (MHl) clavicles from a modern adult reference skeleton.

fossil specimens, cortical bone proportions, as represented by PCA, decrease medio-laterally (from 83.3 % to 69.2 % in Spy 4 and from 81.5 % to 74.8 % in Spy 26E). While a similar pattern is also exhibited by the Magdalenian skeleton from Chancelade, both Regourdou Neandertal clavicles display a rather homogeneous distribution of cortical bone (original unpublished data), as does the left modern specimen MHl (Table 1). Conversely, an opposite trend is found in the right reference specimen MHr, where PCA increases laterally.

Towards their midshaft, the Spy clavicles are significantly stronger than those from the modern individual and, to a lesser extent, also from Regourdou. However, they are comparable to those from Chancelade. As the Magdalenian skeleton represents a mature adult male, while Regourdou 1 is described as a relatively young adult (of uncertain sex; Vandermeersch & Trinkaus, 1995), these differences may reflect, at least in part, sex and age-at-death variations.

The index I_{max}/I_{min} indicates a rather ovoid shape in the Spy specimens, even if less accentuated than recorded on the modern human or mostly on Regourdou 1. The ratio Z_x/Z_y increases from the midshaft (A) to the lateral portion (B) in both Spy 4 and Spy 26E, indicating a generalised increase in shaft strength to antero-posterior bending (Table 1). The same is observed for MH, Regourdou 1 and Chancelade 1.

For a number of selected variables describing cross-sectional geometric properties of the shaft, the extent of quantitative differences (here reported as percent values) recorded between the right, Spy 4, and the left, Spy 26E, specimens are shown in Table 2. For guidance, the estimates for the single modern specimen are also included.

For all cross-sectional geometric variables, the maximal values are found on the right element. The most noticeable differences between the two specimens concern the variables I_y and I_x, i.e. the strength to bending stresses along the antero-posterior axis around the midshaft (39.0 %) and in the infero-superior axis on the lateral part (32.8 %).

As a whole, the quantitative differences between the two fossil specimens exceed the degree of asymmetry shown by this single modern individual whose sex, health status, age, body size, and physical aptitude are unknown. Additionally, whenever the evidence for the same parameters assessed for the skeletons of Regourdou 1 and Chancelade 1 are considered

	CA	I_x	I_y	*J*	Z_x	Z_y	Z_p
A (~50 %)	16.0 (2.7)	20.1 (7.0)	39.0 (39.2)	30.5 (9.7)	15.0 (0.3)	24.7 (26.6)	20.1 (11.1)
B (~35 %)	6.1 (0.01)	32.8 (19.4)	21.7 (8.2)	27.7 (9.6)	18.0 (13.6)	12.7 (3.5)	15.5 (6.1)

Table 2. Differences (%) between Spy 4 (right) and Spy 26E (left) for seven cross-sectional geometric variables assessed at two shaft sites, A and B. Estimates for MH are given in brackets.

(Volpato *et al.*, 2009), the whole amount of differences is compatible with an intra-individual degree of functional bilateral asymmetry.

The morphometric maps of cortical bone thickness distribution in Spy 4 and Spy 26E are shown in Figure 3. In both superior and inferior projections, the maps reveal a different distribution pattern between the right and left specimens. In superior view, Spy 4 presents a relatively marked thickening along its anterior margin, a feature missing in the left partial clavicle. Conversely, absolute cortical thickening in the latter specimen is found all along its inferior side, notably close to the anterior margin. The differences between the right and left clavicles in MH and also in Regourdou 1, in terms of cortical distribution pattern and absolute bone thickness, are significantly lower than those observed between the two Belgian specimens. Furthermore, while their absolute bone volumes are substantially equal within the shaft portion A-B (1.970 cm^3 in Spy 4 vs. 1.968 cm^3 in Spy 26E), a proportionally greater amount of cortical bone is found in Spy 26E (83.8 % vs. 71.4 %) related to a relative reduction of the medullary cavity. The same cortical proportion is found for both Chancelade 1 clavicles, with, similarly, a greater amount of bone on the left element. Conversely, in homologous locations, both elements in MH display a rather close proportion of cortical bone.

DISCUSSION

The first question raised by the fragmentary Spy clavicles is whether they are Neandertal. Unfortunately, taxonomic arguments are particularly slim in the case of clavicles. No feature, be it morphological or metrical, is decisive. Morphologically, clavicles possess no unique derived Neandertal characters but they rather show trends like, for example, in the elliptically flattened shape, from top to bottom, of most diaphyses. As for dimensions, values of Neandertals and modern humans globally overlap, even if Neandertals are often close to the limit of modern

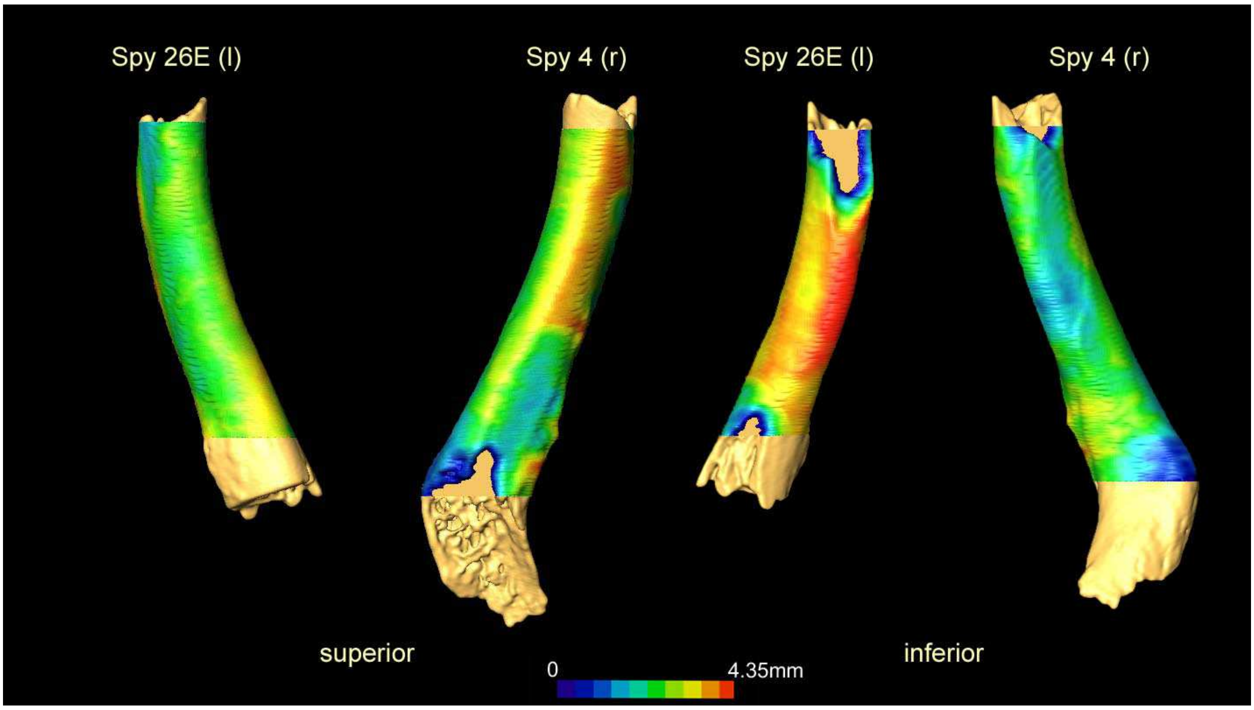

Figure 3. Morphometric maps of cortical bone thickness distribution in Spy 4 (right side) and Spy 26E (left side) shown in superior and inferior views. l: left; r: right.
Thickness rendered by a chromatic scale increasing from dark blue up to red.

humans. Consequently, the attribution of clavicles to Neandertals, especially of broken ones like at Spy, is largely based on the general context of the discoveries, in particular the stratigraphy and the associated archaeological material, and, even more particularly, on their association with other taxonomically diagnostic bones. Therefore, if the clavicles of La Ferrassie, Shanidar or Regourdou had been found outside of any reliable context, as was the case at Spy, they might have been considered as Neandertal only with extreme caution.

Given these limitations, what can be said about the Spy clavicles?

The midshaft index of Spy 4 (73.4) is slightly below the mean of the European Neandertal sample of Trinkaus (1983: 214; 77.6 ± 11.7, n = 13) and slightly above the Neandertal mean of Carretero *et al.* (1997: 374; 68.4 ± 9.1, n = 17); however, the techniques used for measuring the vertical and horizontal midshaft diameters differ between authors (see Carretero *et al.*, 1997: 372). By comparison, the "mean of means" of the midshaft index of modern humans is higher at 86.5 ± 4.6 (Carretero *et al.*, 1997: 374), whereas the "range of sample means" is 79.1-97.0. This low index of Spy 4 corresponds to the elliptical shape of the diaphysis which often characterises Neandertal clavicular shafts. It is also worth reiterating that the distal curvature of Spy 4 is marked, like that of Neandertal 1 and those of the Regourdou 1 clavicles. As for Spy 26E, the main feature that might be compatible with a Neandertal attribution is the probable elliptical section of the shaft.

The 3D reconstruction and the structural analysis of the inner morphology of the Spy clavicles also exhibit substantial quantitative differences compared to the Neandertal Regourdou 1 and modern humans. Among those is the fact that near their midshaft the Spy clavicles present a significantly higher cortical reinforcement. Another difference is that, compared to modern humans and Neandertals, the index I_{max}/I_{min} indicates a less ovoid shape in Spy, suggesting a distribution of bending loads more homogeneous in the shaft, mostly on the lateral portion. To some extent, even more structural similarities are shared between the Spy clavicles and those from the Magdalenian Chancelade 1.

In conclusion, the Spy clavicles, and especially Spy 4, are more compatible with Neandertals than modern humans, even if no definite feature distinguishes them from modern humans. Unfortunately, given that some fossils collected during the 1886 excavation later proved to be modern, like the ulna Spy 7A, the context of the discovery cannot be used as an argument in favour of an attribution of the clavicles to Neandertals, as can be done for other specimens such as those of Regourdou and La Ferrassie.

Another question raised by these clavicles is whether they both belong to the same individual. In other words, either the Spy collection contains two adult Neandertal individuals with one fragment of clavicle each as originally stated by Fraipont – who mistakenly believed that the two fragments are from left clavicles – or the two fragments both belong to one individual, as stated by Twiesselmann. By comparing the diameters of the shaft, the shape of the roughened area for the *M. deltoideus* and the general morphology of the bones, it is difficult to prove that the two fragments of clavicles belong to the same individual, even though they are from opposite sides of the body. In addition, the differences between the right and left Spy clavicles in terms of cortical distribution pattern and absolute bone thickness are high compared to the intra-individual differences observed in modern humans and also in Regourdou 1. On another hand, the quantitative structural differences measured for some cross-sectional geometric properties are comparable to the degree of asymmetry seen on the Chancelade 1 and Regourdou 1 clavicles, and are compatible with both clavicles belonging to the same individual.

In the present state of research, a third question cannot be answered: the association between the two fragments of clavicles and the partial skeletons Spy I and II.

CONCLUSION

The present chapter describes in detail the two fragmentary clavicles housed at the RBINS alongside the Spy Neandertal fossil remains. Taxonomically, these fragments are compatible with a Neandertal association, even if this cannot be definitely proven; only such analyses as DNA or biogeochemistry might be able to provide a final answer. Furthermore, whether the two fragments belong to the same individual is even more difficult to determine, although evidence supports this hypothesis. The same doubts apply to the attribution of the clavicular fragments to either of the two adult Neandertal skeletons from the site.

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