BONE ARCHITECTURE IN THE TRIQUETRUM OF EXTANT HOMINIDS AND *HOMO NEANDERTHALENSIS*

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Introduction

Soft and hard tissue structures at the ulna-side of the wrist, such as reduced ulna-triquetrum articulation and the Triangular Fibrocartilage Complex (TFCC), are conspicuous synapomorphies of hominoids [Fig.1]. These structures are historically linked to biomechanics characteristic of the hominoids such as high degrees of ulnar deviation and forearm supination [1,2]. Nevertheless, there is notable variation in the bony and soft tissue anatomy of the wrist among hominoids that affects how loads are transferred from the hand to the forearm. However, the functional consequences of these differences are not fully understood, in part because the functional morphology of the triquetrum is understudied. Although both committed tool users, it is unknown whether force is transferred through the triquetrum in a similar way between humans and Neanderthals, particularly as the Neanderthal triquetrum is closer to the morphology of the hypothesized human-Neanderthal last common ancestor [3]. Here we investigate for the first time the internal trabecular bone structure of the triquetrum and test the null hypothesis that great apes will exhibit similar distributions of relative trabecular bone volume to total volume (BV/TV) and degree of anisotropy (DA).

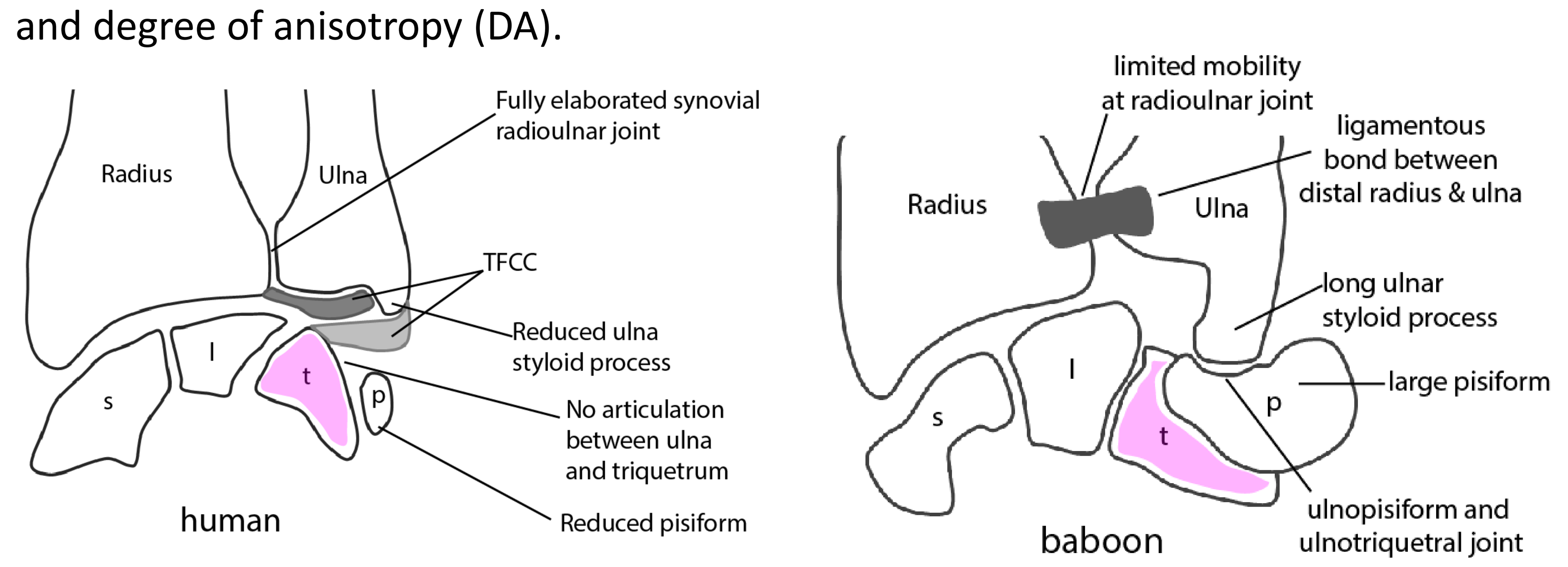

Fig. 1. Schematic of the radiocarpal joint adaptations in humans (left) relative to a baboon (right). The triquetrum is in pink and labelled with a t. p=pisiform; l = lunate; s=scaphoid. Adapted from [4]

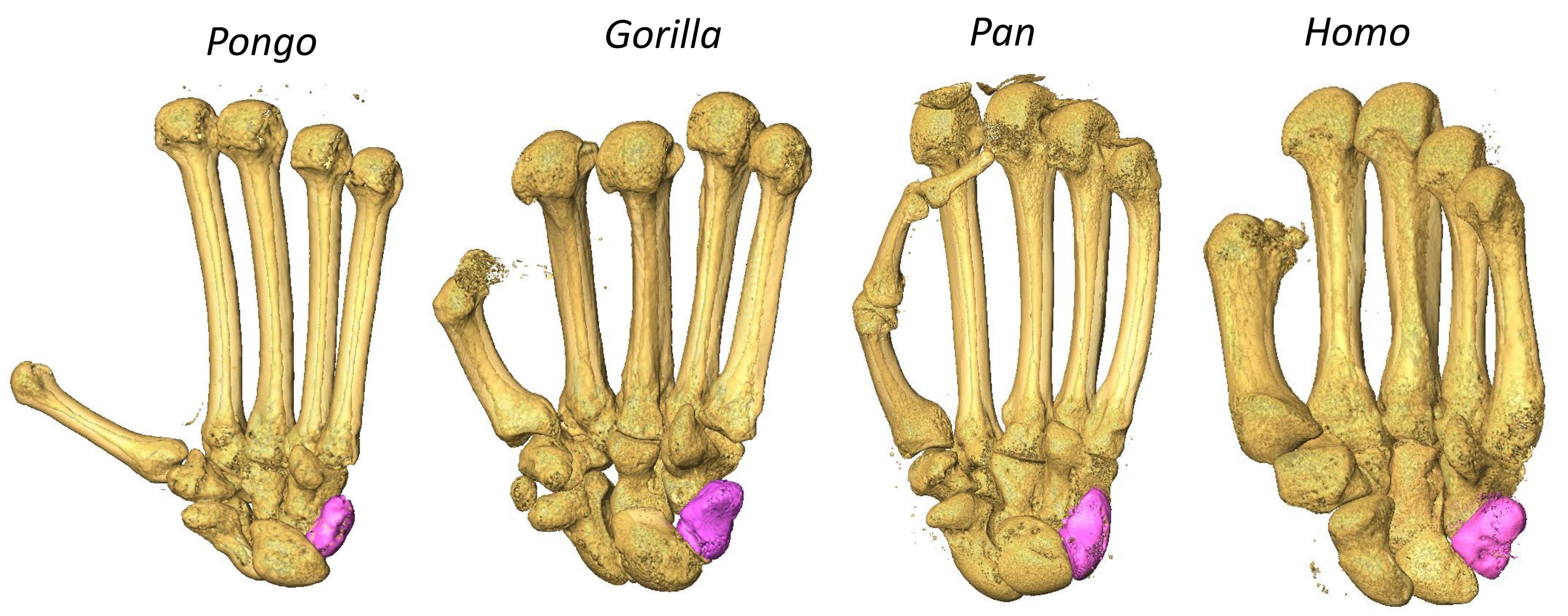

Fig. 2. Morphology of the triquetrum (in pink) across the four study taxa. *Homo* is represented by *Homo sapiens*. Image is of the left hand, view from the palm.

Methods

- **Internal bone structure related to strength** (BV/TV and DA) were analysed in the triquetrum to **test whether bone architecture correlates with soft and hard tissue structures in the ulna wrist**
- The sample consisted of *Pongo* (n=12), *Gorilla* (n=10), *Pan* (n= 10), **Neanderthals** (n=3; El Sidron SD-1227, Tabun C1, and Amud 1), and modern humans (n=21).
- Triquetra were µCT scanned (30-50 microns) (Fig.3A) then segmented (Fig.3B,C). The triquetra were then analysed holistically in 3D using medtool (Fig 3D) [5].
- **BV/TV and DA** values were visualised across the entire bone using Paraview (3.89.0).
- **Low DA** was identified as values equal to or less than 20%. **High BV/TV** was identified as the top 20% of values for that individual's range.

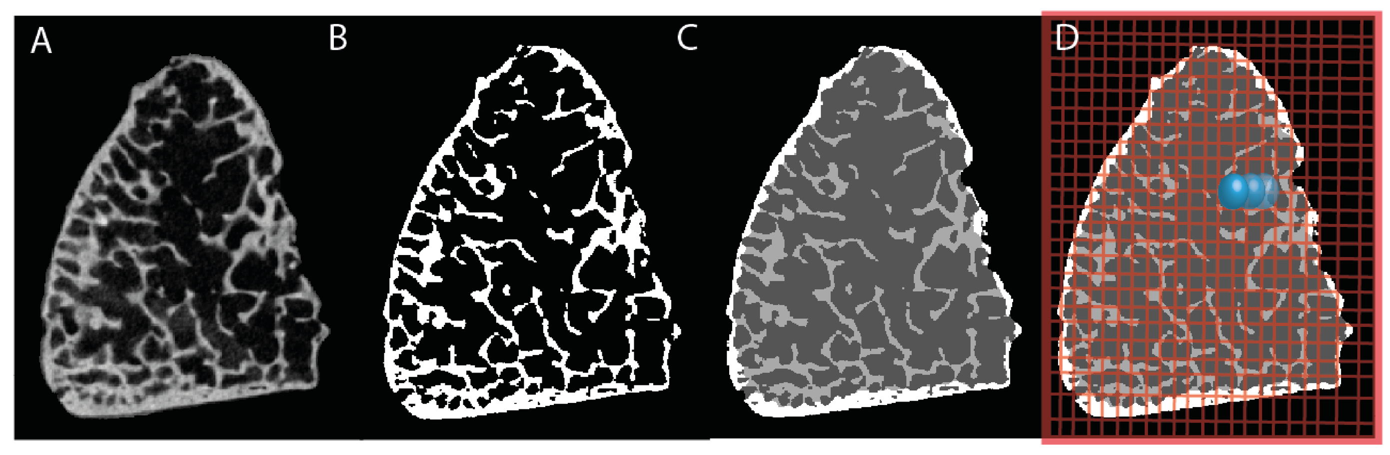

Fig. 3. Steps of trabecular and cortical bone analysis using medtool. Dorsal is up, Proximal is left.

Predictions and Results

Joint	Predictions	Results	*Pongo*	*Gorilla*	*Pan*	Neanderthals	humans
Triquetrum-TFCC	Low DA		41% (5/12)	100% (10/10)	90% (9/10)	100% (3/3)	76% (16/21)
Triquetrum-Hamate	High BV/TV		75% (9/12)	90% (9/10)	70% (7/10)	100% (3/3)	61% (13/21)
Triquetrum-Lunate	High BV/TV		91% (11/12)	20% (2/10)	0% (0/10)	33% (1/3)	0.04% (1/21)

Table 1. Predictions are on the left of the table, results are on the right. The results follow the prediction in the same row. Eg: 41% of *Pongo* had low DA at the Triquetrum-TFCC

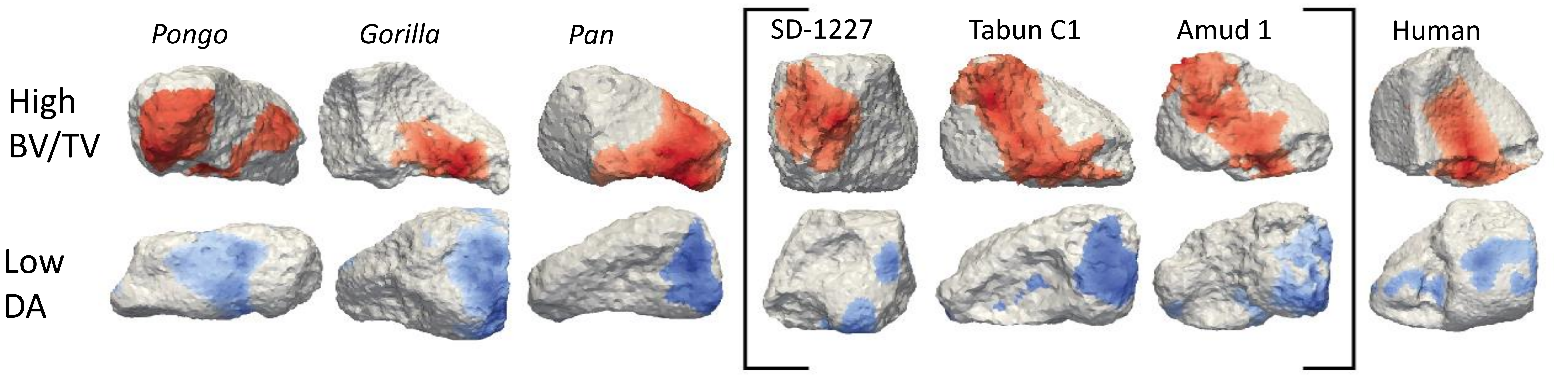

Fig. 4. Bone distribution of one representative individual from each extant group, and each Neanderthal (inside square brackets). Top row shows the top 20% of BV/TV in red. Dorsal is up, left is the lunate articulation and right is the hamate articulation. Bottom row shows DA ≤ 20% in blue. View is of the proximal surface, dorsal is up.

Conclusions

Previous studies of trabecular architecture in great apes have often shown high degrees of variation both within and between species [6,7]. The results of this study exhibit **relatively consistent inter- and intraspecific patterns of bone architecture.**

In ***Gorilla*, *Pan*, humans and Neanderthals,** there was consistently greater BV/TV at the triquetro-hamate joint relative to the triquetro-lunate. This may indicate greater force transfer with the hamate relative to the lunate.

The architecture in **Neanderthals appeared to have a similar distribution to humans**, suggesting similar force transfer.

Pongo has distinct soft and hard tissue morphology at the ulna side of the wrist [1]. In this study they show a different pattern of bone architecture to the other great apes. ***Pongo* exhibits greater bone volume at the triquetro-lunate joint** which may reflect a reliance on the lunate for force transfer to the ulna. ***Pongo* did not consistently exhibit low DA** at the proximo-radial triquetrum, possibly due to a **reduced capacity to transfer force due to the under-developed TFCC**.

In all taxa except *Pongo*, the TFCC insertion site showed low DA. If force transfer with the **synapomorphic TFCC results in characteristic isotropic trabeculae patterns**, this would be a powerful framework in which to analyse fossil taxa whose radiocarpal joint configuration is unknown. Further research including non-hominoid primates would benefit this hypothesis.

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