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Anthropic fractures and human tooth marks: An experimental approach to non-technological human action on avian long bones

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ABSTRACT

Anthropic fracture of avian bones has received scarce experimental attention. Prehistoric bird consumption is assumed from references in studies of lagomorphs or small mammals, despite the fact that avian bones are quite different from those of mammals and rodents. Their consumption by humans can be addressed experimentally. This paper presents the results of a study in which fresh chicken (*Gallus*) thighs were fractured using hands and teeth, with no technological assistance. Results showed that fractures are different from those of larger animals, resulting in the proposal of a new classification of fragments. The location of the fracture influences its line and angle and, above all, the ensuing splintering. The fracture types and characteristics of notches, tooth marks, scores and depressions have led the authors to propose a model of fragmentation and marks that can be applied to avian remains at archaeological sites.

1. Introduction

The focus of prehistoric archaeology on the causes and forms of bone breakage is due to the traditional protagonism of bone assemblages in the interpretation of African Pliocene and Pleistocene sites and the ensuing controversies in scientific literature (e.g., Dart, 1957; Binford, 1981; Shipman et al., 1981; Binford and Todd, 1982). Many authors have primarily focused on the differentiation between fresh and dry bone material at the time of fracture, the identification of the taphonomic agent(s), and the detection of human presence and its differentiation from other biological, physical and chemical agents (Haynes, 1983; Todd and Rapson, 1988; Cruz-Uribe, 1991; Oliver, 1993; Lyman, 1994; Fisher, 1995; de Ruiter and Berger, 2000; Selvaggio and Wilder, 2001; Alcántara et al., 2006). As a result, there has been a predominance of experimental and ethnoarchaeological approaches, discussed below.

Experimental bone fracture with the direct or indirect use of hammer stones began some time ago (Biberson and Aguirre, 1965; Sadek-Kooros, 1972; Noe-Nygaard, 1977), and has been successfully used with animals of different sizes to ascertain the particularities of human action when accessing the bone marrow (e.g., Capaldo and Blumenschine, 1994; Pickering and Egeland, 2006). In the late 1960s, C.K. Brain conducted an experiment with the Hottentot community, and described the fractures and other bone modification produced during caprine consumption (Brain, 1967, 1969). Although he was not the first researcher to study the results of contemporary human consumption (White, 1953), the influence of Brain's work can be seen in subsequent ethnographic observations of Ache (Jones, 1983), Kua, Dassanetch (Gifford-González, 1989), Nunamiut (Binford, 1978) and Bofi communities (Landt, 2007). Thanks to these studies, we know that humans can consume meat without recourse to technology, using only our hands and teeth (Martínez, 2009; Fernández-Jalvo and Andrews, 2011; Pickering et al., 2013; Saladié et al., 2013).

With regard to the dichotomy (Lyman, 1994; Alcántara et al., 2006) between the use or avoidance of technology, dynamic fracture (by humans with a hammer) versus static force exerted by teeth (fracture by carnivores), oral/manual anthropic fracture can

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be defined as being static in dental pressure but dynamic in hand movements. This is particularly relevant to the palaeoeconomic role of small animals (lagomorphs, birds and tortoises) for two reasons: a) technology is not indispensable in their processing and consumption, and b) the recent revision in scientific literature of the relevance of small game in Pleistocene societies (e.g., Díez et al., 1995; Laroulandie, 2005; Pérez-Ripoll, 2006; Landt, 2007; Blasco, 2008; Sanchis and Fernández Peris, 2008; Blasco and Fernández Peris, 2009; Lloveras et al., 2009; Martínez, 2009; Blasco et al., 2011, 2013; Cochard et al., 2012; Fa et al., 2013).

The detection of human consumption without technological assistance is thus highly relevant in prehistoric archaeology. In this context, the present authors have conducted an experiment that sheds light on the debris generated by humans during their consumption and fracture of avian bones. Several studies have analysed avian bone fracture and consumption, with a particular focus on the signs resulting from the disarticulation of the elbow joint (Laroulandie, 2000, 2005; Laroulandie et al., 2008), the removal of the epiphysis by chewing (Blasco and Fernández Peris, 2009) and traces of cooking or exposure to fire (Spenneman and Colley, 1989). None of the above analyzed the traces of bone fracture by human teeth after raw meat consumption. Our results facilitate the typification of human intervention at an archaeological site and permit inferences about hominid diet and choice of food species.

2. Materials and methods

Fifty-seven femora from 40 day old *Gallus* were chewed raw by volunteers (32 men and 25 women aged between 18 and 57 years). These specimens were subadults because complete growth of *Gallus* takes place at 24 weeks (Thomas et al., 2014). However, these diaphyses are not porous and 60% of the bones ($n = 34$) support distal epiphyses. Moreover, domestic fowls mature quickly and their bones reach large dimensions in a few weeks (Williams et al., 2000). In this sense, radiographic and anatomic studies using *Gallus gallus domesticus* show that the width and thickness of femora diaphyses do not undergo major variations during growth (Breugelmans et al., 2007). After the growth stage, there is only an increment in bone length and a cartilage reduction.

Femora were chosen because they are the most meat-rich, robust and easily identified bird bones (Ericson, 1987). Unlike humerii, they have a minimal pneumatisation and contain abundant, high quality marrow (Higgins, 1999), particularly females (Monks, 1981). Femora are thus the parts most likely to be opened by human groups to access their content. Each femur was processed by a volunteer who was asked to remove the flesh with their teeth and break the bone without recourse to any type of technology. The uncooked flesh was only removed to access the bone, without being ingested by the volunteers.

After processing and initial inspection, the bones were boiled without any product to remove any remaining meat and fat. A Nikon SMZ 645 binocular microscope was then used to analyse the fractures and human tooth marks. In all cases, measurements were taken with an electronic calliper (numbers in millimetres down to two decimals).

We adapted existing terminology to our work, samples and requirements. The following variables were noted in the analysis of the bone breakage surfaces: outline (transversal or curved), angles (oblique, right or mixed) and texture (smooth or jagged) (Villa and Mahieu, 1991). We also generated a morphological typology (Fig. 1), classified as:

1) Transversal, subdivided into simple transversal (T1), columnar transversal (T2), transversal with peak (T3), irregular transversal (T4), transversal with one (TL1), two (TL2) or more steps (TL3).
2) Curved, subdivided into: simple curved (C1), columnar with step (C2) and curved with peak (C3).
3) Longitudinal (L) and
4) Transversal-curved (TC)

In addition, we analysed the point of bone breakage. Each bone epiphysis (articular end) was considered as a unit, noting the break development at two points (nearest and furthest distal condyles). Only one break point was noted in the case of incomplete breaks. To simplify the data interpretation, optimise reference to biomechanical levels and facilitate the comparison of the same anatomical level in individuals with different maximum lengths, these metric classes were transformed into percentages of maximum bone length. We then simplified the data by taking femur length an 100% and the breakage point (in mm from distal end) as the percentage to be calculated. These breakages points (%) were grouped into five percentile classes, distributed evenly across each 20% of the maximum length (0–20%, 21–40%, 41–60%, and 81–100%). Fracture notches (Capaldo and Blumenschine, 1994) were studied and their maximum width noted wherever possible. We distinguished four morphotypes: U, double U (Fernández-Jalvo and Andrews, 2011), V and W.

Existing classifications of human tooth marks were used to distinguish different types of damage such as pits (depression on bone cortical zone caused by dental pressure), punctures (perforations with depression edges) and scores (scratches caused by tooth drag against the bone surface) (Maguire et al., 1980; Binford, 1981; Shipman et al., 1981; Landt, 2007; Saladié et al., 2013). We noted maximum length, maximum width and alignment of scores in relation to the bone axis (transversal, oblique or longitudinal).

Finally, we considered it necessary to define the intrinsic properties of the bone in order to ascertain the extent of its influence on the breakage points. We therefore also analysed bone quantity at each individual level. Bone quality is due to two main factors, the bone material and the section size and shape. In this study we analysed two inalterable and perdurable aspects: size and shape. To obtain cross-section slices, CT scanning of three fresh avian femoral specimens was performed at the University of Burgos (Spain) with a YXLON Compact X-Ray industrial multi-slice computed-tomography scanner. The specimens were aligned along the bone's long axis with the proximal epiphysis in a superior position. Scanning parameters were 0.130 mm pixel size, 0.2 mm interslice, 160 Kv and 4 mA. Slices were obtained as a 1024 × 1024 matrix of 32 bit Float format with a pixel size of 0.18 mm. The computed tomography (CT) images were visualized with a commercial software package, Mimics v.16™ (Materialise, NV, Belgium). The bones were then cut evenly into 20 slices as Ruff and Hayes (1983) made in humans, from level 0 at the distal epiphysis to 100% at the most proximal end. Given that all three individuals were subadult, we checked for the starting point of the cortical bone compaction in order to ensure an accurate geometrical analysis. All femora were compact between 20% and 70% of the bone length. This facilitated the definition of the limits of our cross-sectional levels.

Selected cross-sections were subsequently imported to Autocad (Autodesk, USA) for further analysis. The geometric properties defined for each cross-section were Cortical Area (CA), Total Area (TA) and Percentage of Cortical Area (%CA). These three parameters show the axial resistance to impact load (Fioretti et al., 2011).

3. Results

We recovered 141 fragments of 57 skeletal elements consumed by the group. The volunteers were able to completely break 51 bones (89.5%), resulting in 101 fragments with epiphyses. We also

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