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Cut mark micro-morphometrics associated with the stage of carcass decay: A pilot study using three-dimensional microscopy

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ABSTRACT

Recent analyses of archaeological collections have suggested that the frequency, location and micro-morphometric characteristics of cut marks produced when cleaning partially decayed bodies are significantly different from butchery of fresh bodies. The present study attempts to verify this hypothesis by performing incisions into pig body parts at different stages of decay, using different hand pressures and two different types of tool. Focus variation microscopy was used for metric evaluations of experimentally produced cut marks. The clearest metric correlation observed was that greater cutting strength produces wider and deeper cut marks. We also observed that in general, when using the same strength, wider and deeper cut marks are produced on bone with less meat due to the decay (i.e. reduction) of organic tissues. It was also observed that liquefying tissues affect the precision of incisions, causing tools to slip on decaying remains. Finally, no clear metric or morphological differences were observed between cut marks produced using unretouched flakes and unretouched blades.

1. Introduction

Cut marks are produced when a cutting tool (made of stone, metal, bamboo, etc.) accidentally strikes the surface of a bone, antler or tooth during defleshing, filleting and disarticulation of a body. They are direct traces of human action and by studying how and why they were made, we can begin to understand a variety of past human behaviours. In the context of carcass processing these include specific butchery tasks, different tool or raw material use, and the determination of handedness of the tool user (e.g. Bello, 2011; Bello et al., 2009; Bonney, 2014; Bromage and Boyde, 1984; Bromage et al., 1991; Domínguez-Rodrigo and Barba, 2005; Greenfield, 1999, 2006; Hillson et al., 2010; Maté-González et al., 2016; Pickering and Hensley-Marschand, 2008; West and Louys, 2007; Wilson, 1982). When cut marks are found on human remains, their study enables the identification of funerary practices such as cannibalism or defleshing (e.g. Bello et al., 2011a, 2015, 2016; Boulestin, 1999; Cauwe, 2001; Cole, 2017; Fernández-Jalvo et al., 1999; Redfern, 2008; Schulting et al., 2015; Turner and Turner, 1999; Wallduck, 2013; Wallduck and Bello, 2016a; White, 1992). In the context of artefact production the study of deliberate cut marks, or engraving marks, can facilitate the reconstruction of chaîne opératoires, the identification of different artistic techniques, and level of expertise (e.g. Bello et al., 2013, 2017; Choi and Driwantoro, 2007; d'Errico and Cacho, 1994; Güth, 2012; Rivero, 2016; Wallduck and Bello, 2016b).

The timing at which cuts are produced after the death of an animal (human or non-human), however, often remains uncertain. Yet determining the length of time between death and butchery has sustained debates related to hunting versus scavenging as a means for carcass acquisition by early hominins (Blasco and Rosell, 2009; Bunn, 1981; Capaldo, 1998; Domínguez-Rodrigo, 1997; Domínguez-Rodrigo and Pickering, 2003; Shipman, 1983) as well as the differentiation of cannibalism from secondary burial practices (Bello et al., 2016; Chacon and Dye, 2007; Diamond, 2000; Hurlbut, 2000; Pickering, 1989; Saladié et al., 2013; Saladié and Rodríguez-Hidalgo, 2017; Wallduck and Bello, 2016a). Determining the time carcasses are accessed, processed, and modified has been mainly supported by the mutual relationship and physical superimposition of cut marks with other bone modifications (e.g. carnivore chewing marks, trampling; c.f. Blumenschine, 1995; Domínguez-Rodrigo et al., 2009; Olsen and Shipman, 1988; Selvaggio, 1994; Lupo and O'Connell, 2002). In the case of human bodies and funerary practices, differences in the location of cut marks (i.e. on labile or persistent joints; c.f. Bello et al., 2016; Duday, 2009; Saladié and Rodríguez-Hidalgo, 2017; Wallduck and Bello, 2016a) has been used as a diagnostic feature. But these methodologies have been often criticised for their qualitative approach and their strong interpretative component. Apart from two recent studies (Bello et al., 2016, and Wallduck and Bello, 2016a), no other research has attempted to directly associate cut mark frequency and micro-morphometric features with the time when the cutting of carcasses occurred.

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It is conceivable that there are measurable differences in the morphological and micro-morphometric characteristics of cut marks produced on fresh and decomposing bodies. These differences might indirectly relate to the amount of meat present on the bones and the force exerted to butcher fresh bodies compared to decaying or desiccated carcasses. Zooarchaeological studies are not in agreement on this subject, and suggest that there is no apparent relationship between cut mark frequency and the weight (or amount) of attached flesh. For instance Lupo and O'Connell (2002) and Pobiner and Braun (2005) concluded, after experimental analyses, that cut mark frequency does not vary consistently with the weight of meat attached to a bone at the time butchery is initiated. Bunn and Kroll (1986) stated that high frequency of cut marks is indicative of hominin access to larger amounts of meat, whereas Binford (1986) proposed that a high frequency of cut marks on long bone shafts indicate butchery of carcasses with relatively small amounts of meat. Bello and co-authors (2016) compared humanly-induced modifications on human and non-human bones from four archaeological sites (one interpreted as cannibalism and three interpreted as funerary defleshing and disarticulation after a period of decay). Results indicated that cut marks produced when cleaning partially decayed bodies are significantly different (in number, location and micro-morphometric characteristics) from cut marks produced during the butchery of fresh bodies. The authors suggested that these contrasts are due to the effects that varying amounts of meat and different degrees of body decomposition have on cutting strengths. We aimed to test this hypothesis by performing an experimental archaeological study that examines whether differences in the frequency, morphology and metric characteristics of cut marks is influenced by cutting strength, type of tool used and amount of soft tissue present on the bone. This last point was verified using two types of body parts with different amounts of meat (shoulders and ribs), and cutting into these body parts at different stage of carcass decay (i.e. as the volume of meat decreases).

2. Material and method

For the purpose of this study, we define 'incision' the action of cutting into a body part, regardless of whether this does or does not produce visible cut marks on the surface of a bone. We use a cut mark representation index ('CMRI') to examine the relationship between the number of incisions produced and the number of cut marks resulting from this action: CMRI = number incisions/number cut marks × 100. The CMRI is calculated in order to estimate the frequency of cut marks in relation to the use of different tools, different hand pressures and the amount of meat present on the bones.

The premise of the experimental study was to produce a series of incisions over a period of time into decaying body parts from organically farmed domestic pigs (*Sus scrofa*) using flint tools. The specimens would be buried and exhumed at regular intervals for the purpose of performing incisions into the meat. Each episode of exhumation is henceforth termed a 'cutting event' (CE). Only slicing incisions (*sensu* Greenfield, 2006), rather than butchery marks (e.g. filleting, skinning, disarticulation marks), were performed in order to reduce and better control the number of variables. To refine the experimental protocols, the study was first preceded by a trial phase conducted on a leg and three ribs of organic pig (pigs are good proxies for human bodies; e.g. Shean et al., 1993). A simple flint blade tool was knapped and the specimens were cut every four days for a period of three weeks. During this trail phase it was ascertained that the leg of a modern domestic pig had too much meat for the experiment, as the decay period would have been significantly protracted. It was decided that shoulders (scapulae) would be used in place of femurs alongside ribs.

For the main stage of experimentation, a total of three racks of 'front' ribs (i.e. the sternal end; Fig. 1A) and nine shoulders (bone-in) of organically farmed pork (Fig. 1B) were utilised. These were slaughtered between six and ten months old (pers. comm. S. Freeman). The decision to select shoulder and rib bones was made in order to compare bones covered by large amounts of meat (the shoulder) with bones covered by less meat (the ribs); mimicking other body parts or different sized animals. Ribs and scapulae also allow the variables of curvature and density to be controlled (c.f. Greenfield, 2006). Two types of un-retouched flint tools were knapped, a blade and flake (Fig. 1C). Each was approximately 60 × 30 and 60 × 50 mm in size respectively. During each cutting event a single flake and single blade were used, both of which were then replaced with new (i.e. sharp) tools for the next cutting event. A field diary was kept throughout the experiment.

A standard protocol was followed for each cutting event. Three parallel incisions were made using a blade and three incisions were made using a flake along the medial side of the scapulae and the exterior surface of the ribs. The same right-handed individual (RW) carried out each incision in the same direction and at the same angle. The nine scapulae and three racks of ribs were divided into thirds, each subset being subjected to different cutting pressures (Fig. 2), replicated by wearing hand weights. The first third (three scapula named specimens 1–3 and three ribs from one of the 'racks' of ribs, known as specimen 10) were cut using normal hand pressure ('NHP'). For the next third (scapulae specimens 4–6 and three ribs from rack specimen 11), a 1 kg hand weight was worn in order to exert greater force in a more controlled manner; termed as moderate hand pressure ('MHP'). For the final third (scapulae 7–9 and three ribs from rack specimen 12) an additional 1 kg (total = 2 kg weight) was added to replicate firm hand pressure ('FHP'). When there was no more space available to perform incisions along the length of the first three ribs in each rack, incisions were made onto the next three ribs, and so on. Notes and photographs were taken regarding the incision locations, to avoid producing overlapping cut marks. After each cutting event was completed, the specimens were weighed and then buried. We buried the specimens in soil with a neutral to alkaline PH value (in order to preserve the integrity of the bone's cortical surface) at a depth of approximately 40 cm. Soil and remains were contained in large plastic boxes. Holes were drilled into the plastic containers in order to allow soil fauna to enter, and chicken wire was attached onto the tops in order to protect the specimens from local carrion fauna (Fig. 1D).

The incisions were performed regularly at four-day intervals during the first month of experimentation (July); totalling six cutting events. For the next two months (August and September) the specimens remained buried. In October the experiment was resumed as before with incisions performed at four-day intervals until no further space was available on the specimens. In total ten cutting events occurred, resulting in 1032 incisions (Table 1). The specimens were then cleaned of any remaining fat or soil on the surface using soapy warm water, and we attempted to de-grease the bones by slow cooking. After cooking, all grease was removed from the bone surfaces, yet it persisted internally within the specimens. It was therefore decided that moulds of the cut marks should be taken ensuring that that the specimens were not brought into a sensitive collections environment at the Natural History Museum (London, UK). A two-component liquid silicone-based dental impression material (President Light Body by Coltene®) was used for mould reproduction. It is an addition-curing high quality material, equivalents of which have been shown to provide excellent copies of surface features with minimal linear shrinkage and to be suitable for micro-morphometric analysis (Bello et al., 2011b).

The experimentally produced cut marks were counted by eye and using a hand lens. A Focus Variation microscope (the Alicona 3D InfiniteFocus microscope, AIFM) was utilised for metric evaluations of the cut marks. The AIFM combines the small depth of field of an optical measurement system with vertical scanning to provide topographical and colour information from the variation of focus (Bello and Soligo, 2008; Bello et al., 2011b). Specimens are illuminated with light delivered through a beam splitter to an objective lens and throughout the field of view (during focus variation) images are captured up to a resolution of 10 nm. The resulting variation in sharpness between each image is utilised for extracting depth information and a dense 3D