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"HANDS-ON ARCHAEOLOGY": AN EXPERIMENTAL PROGRAM BASED ON BONE TOOL ASSEMBLAGES CREATED DURING THE *OSSEOUS INDUSTRY* COURSE, UNIVERSITY OF ALGARVE (FARO, PORTUGAL).

"Arqueología práctica": programa experimental basado en conjuntos de herramientas óseas creados durante el curso de Industria Ósea, Universidad de Algarve (Faro, Portugal).

"Arkeologia Praktikoa": hezurrezko tresna multzoetan oinarritutako programa esperimentala, Hezur Industriaren ikastaroan sortua, Algarveko Unibertsitatean (Faro, Portugal).

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Patrícia Aleixo (**)
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Marina Évora (****)

Abstract

The aim of this paper focuses on the analysis of osseous raw materials through experimental archaeology. The lack of studies on experimental archaeology at the MSc degree in Archaeology from the University of Algarve gave way to the creation of a brand-new course based on *Osseous Industry*. The main goal of this study was to provide a better understanding and interpretation of the traces left on bone tools during the emergence of *Homo sapiens* in Europe. The results of this work include femur bone needles from swine (*Sus domesticus*), an arrow and harpoon head antler from red deer (*Cervus elaphus*), and a comb antler from fallow deer (*Dama dama*). This approach gained knowledge by experience and a broader view about a hypothetical image of how human communities used to live. The implementation of the experimental activity is an important empirical function in the studies of archaeology, though often is overlooked. We hope that this work can provide an example of how fundamental an experimental approach to archaeology is for filling gaps in our knowledge about the past.

Keywords

Experimental Archaeology, Osseous Raw Materials, Femur Bone Needles, Arrow and Harpoon Head Antler, Comb Antler.

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Resumen

El objetivo de este trabajo se centra en el análisis de materias primas óseas a través de la arqueología experimental. La falta de estudios sobre arqueología experimental en el Máster de Arqueología de la Universidad de Algarve dio paso a la creación de un nuevo curso basado en la *Industria Ósea*. El objetivo principal de este estudio fue proporcionar una mejor comprensión e interpretación de las huellas dejadas en las herramientas óseas durante la aparición del *Homo sapiens* en Europa. Los resultados de este trabajo incluyen agujas de fémur de cerdo (*Sus domesticus*), flecha y arpón de asta de ciervo rojo (*Cervus elaphus*) y peine de asta de gamo (*Dama dama*). Este enfoque brindó el conocimiento adquirido por la experiencia y una visión más amplia sobre una imagen hipotética de cómo solían vivir las comunidades humanas. La implementación de la actividad experimental es una función empírica importante en los estudios de arqueología, aunque a menudo se pasa por alto. Esperamos que este trabajo pueda proporcionar un ejemplo de cuán fundamental es un enfoque experimental de la arqueología para llenar los vacíos en nuestro conocimiento sobre el pasado.

Palabras Clave

Arqueología Experimental, Materias Primas Óseas, Agujas de Hueso de Fémur, Flecha y Arpón de Asta, Peine de Asta.

Laburpena

Lan hau, arkeologia esperimentalaren bidez, hezur-lehengaien azterketara bideratuta dago. Algarveko Unibertsitateko Arkeologia Masterrean arkeologia esperimentalari buruzko azterketa ezak *Hezur Industrian* oinarritutako ikastaro berri bat sortarazi zuen. Ikerketa honen helburu nagusia, Europan *Homo sapiensa* agertu zenean hezur tresnetan utzitako aztarnak hobeto ulertzea eta interpretatzea zen. Lan honen emaitzak honakoak dira: txerri femur orratzak (*Sus domesticus*), orein gorrien adar gezia eta arpoia (*Cervus elaphus*) eta adarzabel orrazia (*Dama dama*). Ikuspegi honek esperientziatik lortutako ezagutzak eta gizakien komunitateen bizimoduaren irudi hipotetiko baten ikuspegi zabalagoa eskaintzen zuen. Jarduera esperimentala ezartzea, funtzio enpiriko garrantzitsua da arkeologia azterketetan, nahiz eta askotan ahaztu egiten den. Lan hau iraganari buruz dugun ezagutzaren hutsuneak betetzeko, arkeologiaren ikuspegi esperimentala zeinen funtsezkoa denaren adibide dela espero dugu.

Hitz-gakoak

Arkeologia Esperimentala, Hezurrezko Lehengaiak, Femur Hezurrezko Orratzak, Adarrezko Gezia eta Arpoia, Adarrezko Orrazia.

1. Introduction

The MSc degree in Archaeology from the University of Algarve, Portugal, has been advocating scientific development in this area. Faculty directors and professors specialized in archaeology have sought to expand the development of this science by introducing different subjects, as well as by intensifying further training for the students. Besides theoretical courses, the MSc degree in Archaeology has now several methodological and empirical courses that will help provide vocational qualifications for the graduates. One of the newly created courses under this improvement is the *Osseous Industry* course supervised by Dr. Marina Évora, researcher of the *Interdisciplinary Center for Archaeology and Evolution of Human Behavior* (ICArEHB). The aim of this course is that the graduates acquire a technical sense of bone and antler manufacture, and develop innovative work and independent research by using the methodologies and models related to technology as an archaeological discipline.

Humans have used fragments of osseous materials to create tools since early Prehistory. Nevertheless, "it was only in the Upper Paleolithic, in Europe, that these raw materials became an important technological element, used in the manufacture of several kinds of tools that hunter-gatherers used in their daily tasks" (GAUDZINSKI *et al*., 2005; ROSELL *et al*., 2011). Most of these manufactured tools were the results of a systematic work. Artisans knew the mechanical properties of each raw material, and they recognized the importance of their usage as tools. Therefore, most artisans carefully chose a predetermined function before the process of manufacturing, such as needles made from cortical bones (BORAO, 2010: 180-181). The Solutrean in Iberian Peninsula represented a continuation of technological innovations that started during the Gravettian; among these innovations were needles with proximal perforations (ÉVORA, 2015b). In 1979, Stordeur published an important study on needles from the Magdalenian, which highlighted perforations with an emphasis on technological analysis, but also addressing the typology, morphology and marks of use / recycling of this type of utensil (BORAO, 2010).

"Another similarity to Southern Iberian archaeological sites is the fact that during the Gravettian there is a high frequency of projectile points, as opposed to the Solutrean and, to a lesser extent the Magdalenian" (SALGUEIRO *et al*., 2010). The lower frequency of osseous projectile points in the Solutrean, and in some phases of the Magdalenian, are not solely attributed to a climate change, but to an alteration of choices in hunting and fishing with osseous raw materials (ÉVORA, 2015b). According to the data of Upper Paleolithic archaeological sites in Portugal, archaeologists recovered a small assemblage of artefacts made from red deer antlers and mammal bones (ÉVORA, 2013; 2015b). Among these artifacts, specific tools such as "projectile points and wedges were preferably made of antler, which is more suitable to resist to direct impacts [...]" (ÉVORA, 2015b: 173). The barber point/harpoon head is a distinctive element in the Mediterranean Magdalenian in Iberia Peninsula, appearing at 16.800 cal BP and disappearing at around 13.700 cal BP (ÉVORA 2015b: 68). This period marked the limit of the Upper Magdalenian phase (*idem*). However, the barbed points/harpoon heads found in the archaeological record show variabilities in the morphological arrangement (BORAO, 2010).

In addition to bone raw materials, antler from red deer was equally explored with different methods throughout the Upper Paleolithic in Southern Iberia (ÉVORA, 2015a). However, this exploration shows a variability in the production of mammal bones and antlers. Why? The answer lies in the possible differences between the mechanical properties of both materials. These properties are influenced by the amount of mineralization found in the biological component of the osseous raw materials (CURREY, 1999). The composition of antler raw materials is similar to that of bone but is less mineralized. For this reason, it is much more resistant to impacts and has greater elasticity, which is why antler projectile points have been found at a larger number in the archaeological record (CURREY, 1999; ÉVORA, 2013). For example, in archaeological sites located near the coastal zones, such as Vale Boi (Portugal) and Cendres (Spain) (ÉVORA, 2013). Furthermore, cervid antlers were also used in the following Neolithic. The archaeological record indicates a limited used of fallow deer antler. The reasons behind that preference could be related to the availability of this species and to the mechanical and physical properties of the antler, as it does not allow the production of a vast variability of tools (ARAMPATZIS, 2019). Bone and antler combs are common in Neolithic (e.g. Cova de les Grioteres, Barcelona, Spain). However, according to Provenzano (1991) combs are also used as a tool to ornament ceramic, but more often during the Chalcolithic than Neolithic (e.g. Espargueira archaeological site, Amadora, Portugal) (SALVADO, 2001), indicating the use of the Neolithic combs for hairdressing.

In this experimental program, the raw materials used are two femurs from domestic swine, to produce bone needles, antler from red deer to manufacture an arrow and harpoon head, and finally, an antler from fallow deer to produce a comb. To obtain these tools, we try to recreate the techniques used by our ancestors with auxiliary materials, such as flint tools, quartzite, greywacke and Silves' sandstone core. This study demonstrates the importance of experimental archaeology to decipher past human behavior.

2. Experimental archaeology on osseous raw materials

Archaeology briefly means the study of humankind's past activities. This multidisciplinary science is based on the material remains left by our ancestors, which are recovered during archaeological surveys and excavations (BICHO, 2006). Upon finding material remains, archaeologists face decision-making processes and go through the evaluation of sample strategies. Archaeologists use several methods to help them understand the events that happened in the past. One of these methodologies is experimental archaeology (SEMENOV, 1985). However, what is experimental archaeology? Coles shares a coherent thought on the meaning of experimental archaeology, "any honest effort to understand ancient artifacts is by actually working with them" (COLES, 1979: 11-12). According to Mathieu (2002: 1) experimental archaeology is a "controllable imitative experiment to replicate past phenomena […] in order to generate and test hypotheses to provide or enhance analogies for archaeological interpretation". The most important aspect of experimental archaeology is to understand the space, form and material of certain artifact or way of life (reproduction of fire pits and cooking methods) (ALDEIAS *et al.*, 2016). However, it is important to understand that experimental archaeology is not mainly about the research of artifacts *per se*. The true aim of this methodology is to find out more about the past human behavior behind these artefacts (COLES, 1979).

For the creation of tools and adornments in prehistory, human communities used many kinds of raw materials, *e.g. stones, wood but also hard animal remains* such as bones, deer antlers, ivory and shells. Osseous artifacts formed an important part of the every-day tool kits (ÉVORA, 2015a). Unlike wood, bone is tough and adaptable. Human communities of the past used bone raw materials to make a variety of tools. With slights modifications, a piece of bone could transform into several different tools, while other types of raw materials required more work to reach a desired form (ÉVORA, 2013).

Bones are softer than most stones and harder than wood. As mentioned above, the hardness and resilience of bones makes it particularly useful for the manufacturing process. When bones are extracted directly from the animals, the remaining freshness allows for an easier production, by either splitting, breaking or splintering (ÉVORA, 2015a). "On drying, bone regains stability" but is less likely to survive impacts, bending and twisting (STONE, 2005: 9). The manufacturing process of bone tools is varied, from a simple method to a more sophisticated technique. Among the simple and most common techniques found is by breaking the bone on an anvil with a large hammer stone (SEMENOV, 1985). For the creation of a specific bone tool, the manufacturer would not only use direct percussion, but also grooving in order to outline the intended form on the bone (BLUMENSCHINE *et al*. 1996). During prehistorical times, this method was often used with sharp stone tools such as flint splinters (DAUVOIS, 1977). A more recent analysis suggests that burins have been used as flint tools on the manufacturing of osseous materials (KUFEL-DIAKOWSKA, 2011). In order to segment a bone into several pieces, the manufacturer could use a stone knife with a serrated bifacial edge, use a flake tool, and in other cases, use a discarded core or burin in indirect percussion to predetermine the breaking point. Other specific work such as regular perforating of the bone can be achieved by lithic borers either handheld or attached to shafts (BLUMENSCHINE *et al*. 1996). On the other hand, grinding and sharpening were often done with a sandstone abrader (*idem*).

Antler is tough and resilient, and often used to create tools, especially since the beginning of the Upper Paleolithic (AVERBOUH, 2000). Unlike bones, antler is relatively more resistant, and its shape varies among individual cervid (ÉVORA, 2015a). "Antler differs from other bones in that it grows quite rapidly and does not usually develop osteotones, which are tubes of highly mineralized bone that form along blood vessels running lengthwise on the bone. Antler also contains more collagen and less mineral than bone" (STONE, 2005: 9). Unlike bone, the high collagen content in an antler remain means that "it can be soaked and the shape altered somewhat" (STONE, 2005: 10). Antler was often used as flint knapping tools and for projectile components such as sagaies and foreshafts (ÉVORA, 2015a; D'ERRICO, 1993). Antler tips were used as pressure flakers, sometimes cut and drilled to make tapering arrow points (*idem*).

A variety of artifacts made of bone and antler were found thanks to archaeological survey and excavation. The tools created by our ancestors witness the daily activities of hunter-gatherers, and later agro-pastoral communities. Among these tools are projectile points, harpoons, knives, fishhooks, needles, bows and arrows, awls, beads for necklaces, flutes, ceramic ornaments, combs, among many others (COLES, 1979; BICHO, 2006).

3. Materials

3.1. Raw materials

The raw materials used in the experimental program consist of two femurs from swine, antler from red deer, and antler from fallow deer.

The two femurs of swine derived from a butcher shop in the city of Olhão (Figure 1a). Both femurs show an epiphysis fusion, meaning both swine were adults. The two femurs were apparently still fresh, with the evidence of soft tissues attached to the bone surface, marrow still filling the longitudinal cavity within the diaphysis, and noticeable traces of blood left. The red deer antler originated from the head of an embalmed juvenile red deer mounted to a plaquette (Figure 1b). This juvenile red deer derived from the Jura mountainous regions between Switzerland and France, as it was purchased locally. Beside the head, the paws were equally embalmed on the wood frame. These presented the lack of an epiphysis fusion pattern. Finally, the antler from *Dama dama* was recovered in Montemor-o-Novo, Alentejo and is from an adult individual (Figure 1c).

3.2. Auxiliary materials

In order to create tools from osseous raw materials, it is necessary to use several auxiliary materials to helps us reach a desired form (COLES, 1979). Lithic tools are one of the main provisions in the production of bone and antler tools (ÉVORA, 2015a). Therefore, the experimental activity took into account the type of lithic tool flakes, mainly flint flakes, used in the manufacturing of bone and antler tools through fracturing and extraction techniques.

Figure 1. Macroscopic pictures of raw materials: a) Femur from domestic swine (*Sus domesticus*), b) Embalmed juvenile red deer (*Cervus elaphus*), c) Palmate of fallow deer (*Dama dama*).

The auxiliary materials used in the bone working activity from the two swine femurs consisted mainly of flint tools: flint tool A, B, C (Figure 2) and a quartzite core (Figure 3a) as well as a red deer antler piece. Flint tool A was chosen for challenging and time-consuming techniques such as longitudinal grooving and bipartition. The flint tool B allowed for detailed techniques such as scraping and incision. Due to its pointy edge, flint tool C was used for incision techniques. The quartzite core was used for fracturing and abrasion techniques. An antler remain from red deer was used as a support for the bone breakage of one femur. The production of red deer antler tools also included flint tools, namely flint tool D and E (Figure 2), and a greywacke core (Figure 3b). Flint tool D was mainly used for scraping and incision while flint tool E had multiple uses; such as longitudinal grooving, splitting and incising. The greywacke core was used for indirect bipartition as a hammer, and for the final shaping of the tools through abrasion. Finally, for the fallow deer antler the auxiliary materials were the following: flint tools F, G, H and I (Figure 2) and quartzite and Silves' sandstone core (Figures 3c, d). The flint tool F was used for incision and grooving. Flint tools G, H and I were also used for grooving, because during this process the edges of flints were not getting sharp due to hardness of the antler. Quartzite and Silves' sandstone core was used for abrasion.

4. Methods

4.1. Fracturation and extraction techniques

According to Évora (2015b: 170), "there are few fracturing and shaping techniques recognized in the archaeological record of the Upper Paleolithic in Portugal". The experimental program applies most of these techniques in the production of bone and antler tools (ÉVORA, 2015b: 171-172).

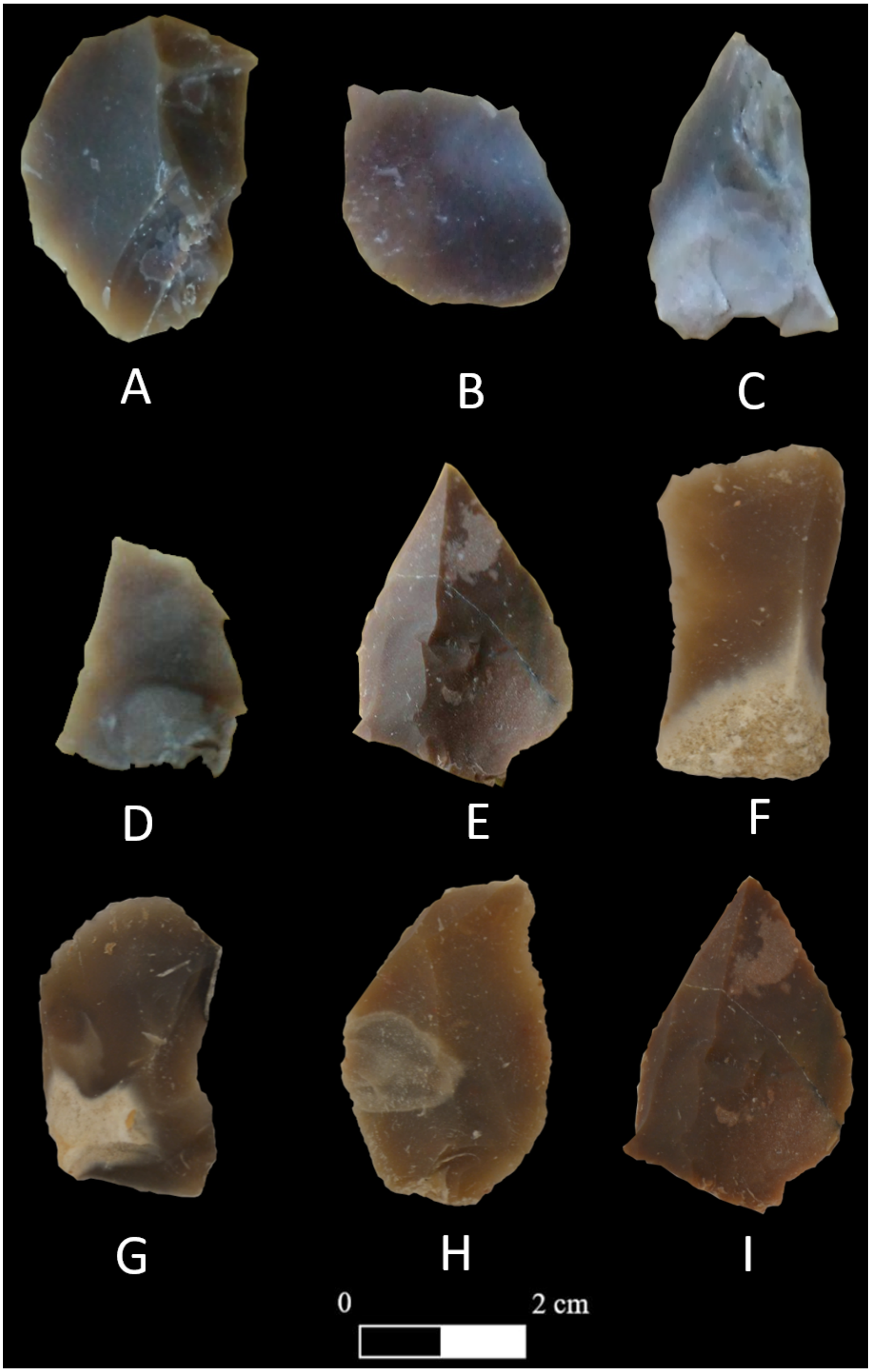

Figure 2. Flint tools A, B, C, D, E, F, G, H and I.

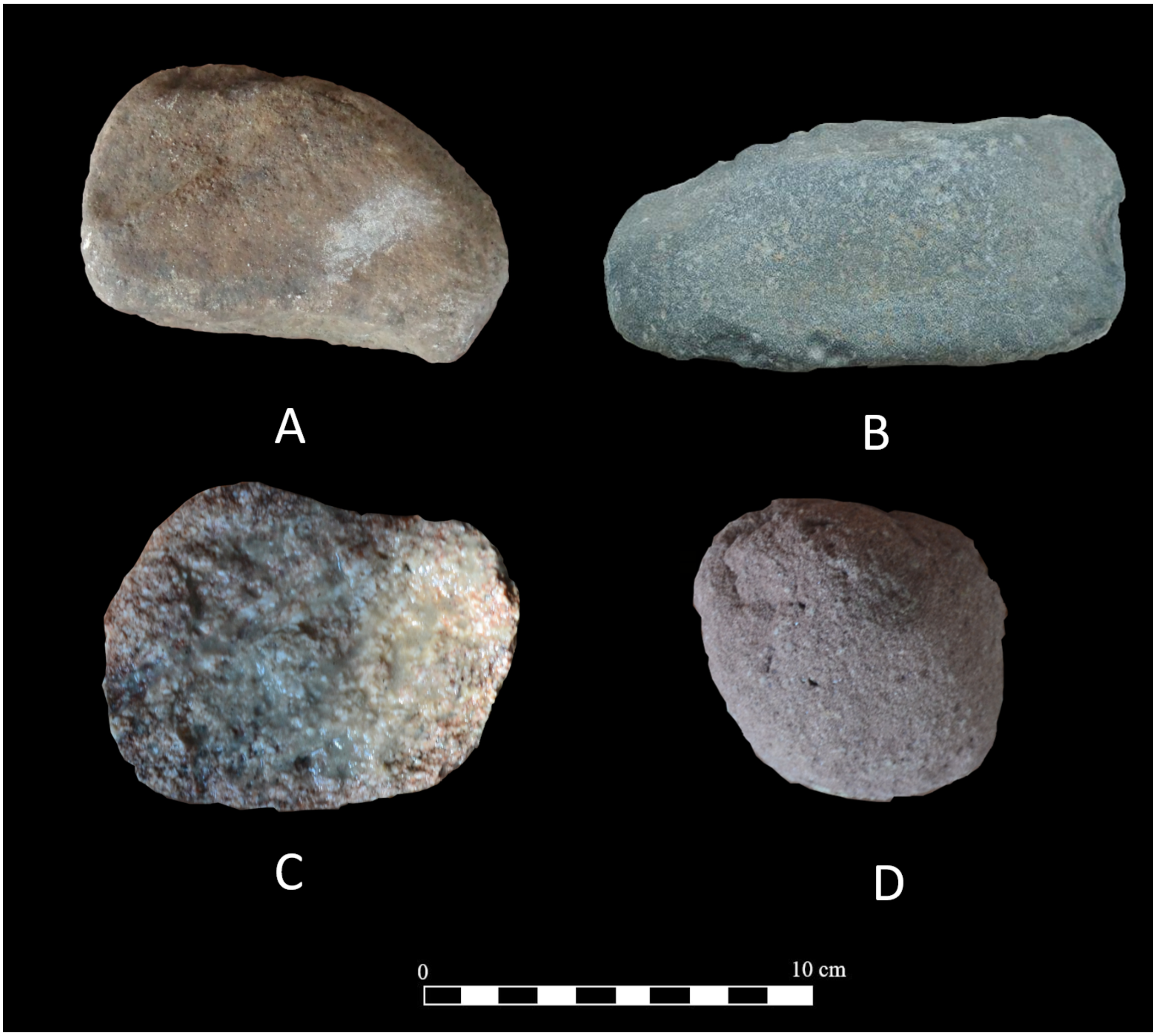

Figure 3. Quartzite core A, Greywacke core B, Quartzite C and Silves' sandstone core D.

- Fracturing: the anthropic action of breaking a bone or antler.

- Sectioning: a way to obtain a support with its full section in which part of its morphology is intact, this technique can be applied transversally to the long axis of the bone or antler.

- Grooving and bipartition: the creation of a longitudinal groove parallel to the long axis of the bone with a lithic tool, making a uni / bidirectional movement leaving a cross-section in U or V-shape. Depending on the active edge of the lithic tool, when the groove is deep enough an intermediate tool (made of bone or antler with a bevel as an active part or a lithic splintered piece) is used to help separate both parts of the bone or antler.

- Scraping: the action of using a retouched or non-retouched lithic tool, on the surface of a bone tool to regulate the surface until obtaining the desired shape.

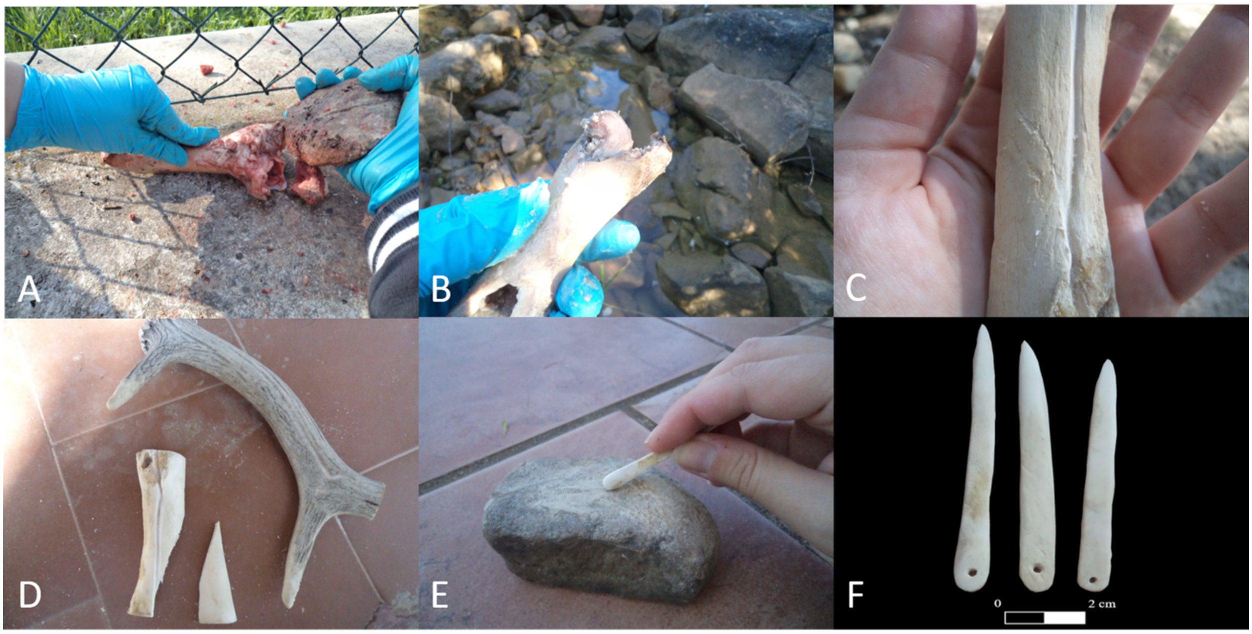

Figure 4. Steps during the bone manufacture: a) Compact bone fracture with stone core, b) Subtraction of the bone marrow in a local riverside, c) Incision in the longitudinal axis of the bones, d) Irregular-shaped fragment: result of bipartition with antler intermediate tool, e) Abrasion of the fragment with a quartzite core, f) First experimental result: three bone needles.

- Abrading: the action of eliminating small particles of material by rubbing it on an abrasive, which can be a soft stone, leather, sand, sand and water or sand and leather.

- Incising: a line that is rectilinear, transversal or diagonal to the longitudinal axis of the artifact, made on the bone surface usually by the lateral edge of a non-modified flint blade, usually its cross-section is V or |/ and it is not as deep as a groove.

4.2. Manufacturing

In order to follow a systematic route for the manufacturing of bone needles, the experimental program focused on the technological evidence found in Southern Iberia during the Upper Paleolithic. In order to follow these rules, a model was used as reference, namely the bone needles from the Magdalenian period of *La Cova de les Cendres*, Alicante (BORAO, 2010: 180). The bone working procedure consisted in the following steps:

1. *Removal* of the periosteum and soft tissues in the diaphysis and both epiphysis with a stone flint. The removal of the periosteum proved to be difficult because the membrane was too attached to the outer surface of the bones. Time: 32 minutes.

2. *Fracturing* on the proximal epiphysis and distal epiphysis of both femurs with the help of a stone core (Figure 4a). Unsuccessful approach when using the stone core in a horizontal position to fracture the distal epiphysis. Once the core was in a vertical position, the fractured area exhibited some results, but not immediately. The movements were repeated for seven times more. The fracturing process on the proximal epiphysis was much faster than the distal epiphysis, with just three movements to the full breakage of the compact bone. Time: 103 minutes.

3. *Subtraction* of the marrow still filled in the longitudinal cavity within the diaphysis (Figure 4b). The subtraction of the marrow was done with the help of two wooden sticks found in the local vegetation, by scraping and pulling the

marrow outwards. The small pools of water from the local riverside aided to the cleansing of the bones. Both bones were set to dry on the nearby rocks. Time: 17 minutes.

4. Incision in the longitudinal axis of both specimens (Figure 4c). The initial objective was to create four vertical lines along the diaphysis, in order to extract four equal fragments. The bidirectional movement was the selected procedure performed during this activity with the usage of flint tool B. Time: 62 minutes.

5. Longitudinal Grooving applied in the parallel to the long axis of the bones above the incision marks. With the help of flint tool A, the first specimen was split into four different fragments. Because of the force applied, one of the fragments broke, becoming unworkable for the next steps in the experimental activity. A similar technique was applied to the second specimen; however, the diaphysis was split in half, as opposed to the four splitting fragments found in the first specimen. Time: 293 minutes.

6. Bipartition using an intermediate tool made of antler to act as an active part to split the bone. This method was applied for the second specimen, whose diaphysis was split in half. With the help of flint tool A inserted in the remaining deep incisions, force was inflicted by using the intermediate tool made of antler to help separate both parts of the bone. However, the results were unsatisfactory. Both pieces broke when the force was applied (Figure 4d). Reasons include too much force with the intermediate tool and/ or weak longitudinal grooving in the bone. Time: 13 minutes.

7. Scraping through the surface of the remaining bone fragments in order to remove portions of the material. This method was accomplished by using flint tool B to obtain the desired shape of Upper Paleolithic bone tools. This process was carried out with a low to intermediate force in a unidirectional movement. Time: 96 minutes.

8. Abrasion on the remaining fragments by rubbing it on a quartzite core (Figure 4e). This part of the experiment consisted of bidirectional and circular movements in the lower part of the fragments in order to give a semicircular shape on the edge. In the proximal area, whose goal was to create a fine point, the quartzite core proved to be ineffective. This difficulty delayed the manufacture of the tool shape. Time: 243 minutes.

9. Incision to create small perforations in the distal area of the bone tool. The flint tool C was used to create incisions due to its sharp pointy edge. The movements were circular, exerting some force to pierce through the compact bone. Time: 124 minutes.

The single red deer antler was used extensively for this experimental work, resulting in two different antler tools, a projectile point (arrow) and a barber point/harpoon head. The projectile point follows a general pattern, without much emphasis on a Southern Iberia example. The barbed point/harpoon head, in contrast, follows the example of the Magdalenian barbed points/ harpoon heads from the *La Cova de les Cendres*, Alicante (BORAO, 2010: 181-182). It is important to refer that the antler of the red deer consisted of a very hard material as consequence of the long embalming. To pre-handle the raw material, water soaking was used to change the material properties. 4 to 5 hours were used for the antler on water soaking before the experimental class. This process provided a better handling of the raw material. The production of the blanks of both antler tools followed these steps:

1. Extracting of the antler in the embalmed red deer mounted to a plaquette. Due to the hardness of the embalmed animal, it was not possible to extract the antler with a flint tool or chisel. In order to successfully extract the antler, a wood saw was used instead. Time: 40 minutes.

2. Incising longitudinal frame in the shape of the later blank on the antler tool D. The aim was to create a long incision line with a bidirectional

Figure 5. Steps during the antler arrow manufacture: a) Result of the indirect bipartition technique, b) Long fragment chosen for harpoon (A), and short fragment chosen for projectile point (B), c) Incision in the longitudinal axis of the fragment B., d/e) Cutting mark at the distal end of the wood branch (D). Vegetable fibers from weeping willow (*Salix babylonica*) (E), f) Second experimental result: Arrow with an antler projectile point.

movement, in order to determine the splitting area. Time: 100 minutes.

3. *Grooving* in the formerly incised furrow was applied with bidirectional and unidirectional movements. The flint tool E was used for these movements, as greater force was applied on the extraction technique. Time: 52 minutes.

4. *Wedging* using flint tool E as an intermediate splintered piece and whose distal end was put into a grooved furrow, while the greywacke core was used as a hammer to smash against the flint tool in order to extract the fragment. The results proved to be half-satisfactory. The extraction was incomplete, as the distal end of the antler remained intact (Figure 5a). Time: 13 minutes.

5. *Wedging* using flint tool E, and subsequent human force by using both hands, to separate both fragments of the antler raw material (Figure 5b). Time: 7 minutes.

After the extraction and bipartition of the antler remain, the manufacture process of the antler projectile point for the creation of an arrow is shown in the several steps below:

6. *Scraping* with the help of flint tool D on the surface of the antler fragment B. This technique consisted mainly of bidirectional and unidirectional movements in order to accomplish the desired form. Time: 36 minutes.

7. *Abrading* with a greywacke core with bidirectional and circular movements to achieve the sharp proximal imagery of a projectile point. Time: 82 minutes.

8. *Incising* in the longitudinal axis of the fragment B for the creation of a projectile point with a bevel (Figure 5c). This technique had the support of the flint tool E to create the bevel incision. Time: 18 minutes.

9. *Assemblage* of thin wood branches from a local riverside to create the arrow shaft. The

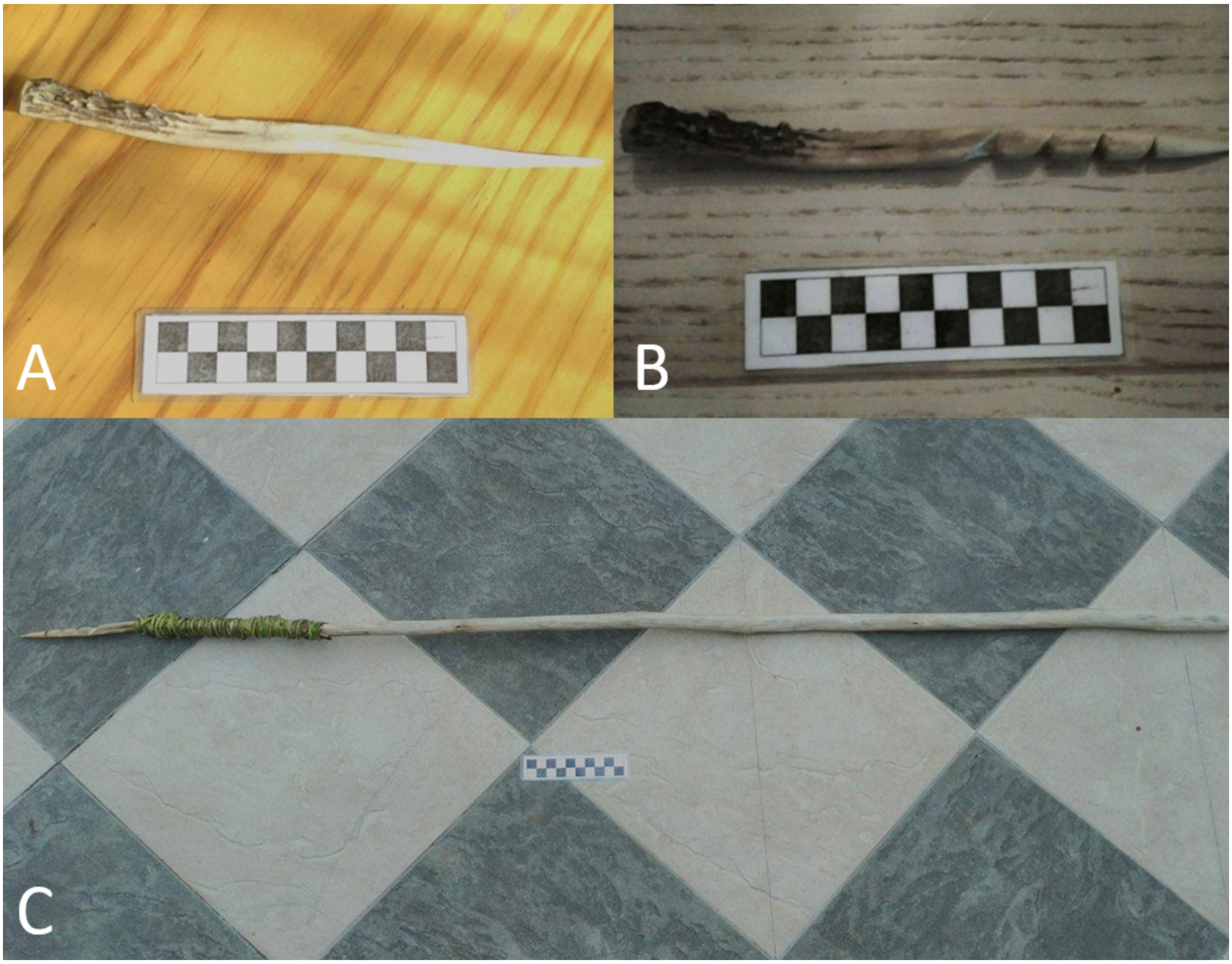

Figure 6. Steps during the antler harpoon head manufacture: a) Abrasion result on the antler fragment A with a greywacke core, b) Four triangular claws shaped with incision, grooving and indirect bipartition techniques, c) Third experimental result: Antler harpoon head.

extraction of wood was done in bidirectional and unidirectional movements with the usage of Flint Tool E. A small furrow was deepened into the distal end of the arrow shaft to allow an attachment on the beveled end of the projectile point. In order to attach the projectile point to the respective wooden branch, vegetable fibers from a weeping willow (*Salix babylonica*) were wrapped around the shaft (Figures 5d, e). This process was relatively simple and efficient. Time: 63 minutes.

The manufacture of the antler harpoon head consisted of the following steps:

1. Scraping with the help of flint tool D on the surface of the antler fragment A. Unlike the scraping of the projectile point, this technique took longer to be achieved because of the larger sizer of this antler fragment. This technique consisted mainly of bidirectional and unidirectional movements. Time: 48 minutes.

2. Abrading with a greywacke core using circular and bidirectional movements along the longitudinal axis of the antler fragment A (Figure 6a). Time: 35 minutes.

3. Incision, Grooving and *Wedging* to create four triangular barbs using bidirectional and unidirectional movements (Figure 6b). Incision and grooving were accomplished with the usage of flint tools D and E along the longitudinal axis of the antler fragment A. Flint tool D and the greywacke core used as hammer were utilized to create four triangular barbs. Time: 100 minutes.

4. Assemblage of thin wood branches were used for the shaft of the harpoon head in accordance with step 9. Time: 21 minutes.

A comb made from fallow deer antler was produced in this experimental program using the same/comparable techniques as for the points. It is important to mention that the complete antler (primary block) was previously sawn, forming several fragments (secondary blocks). The chosen part of the antler was the palmate, for being flat, an ideal feature to produce the comb. The comb was produced from the compact tissue. During all these steps, the antler was previously soakened in water for several hours, due the hardness of this raw material. The antler comb working procedure consisted in the following steps:

1. Incising with the usage of flint tool F. The aim was to determine the unnecessary area of the antler, with a bidirectional movement (Figure 7a). Time: 5 minutes.

2. Grooving to remove the unnecessary remains to produce the comb with bidirectional and unidirectional movements with flint tools F, G, H and I, because as mentioned before, due to hardness of the antler, the edges of flints became unusable (Figure 7b). Time: 240 minutes.

3. Abrading to remove small particles of the antler surface by rubbing it on two abrasives: quartzite core and Silves sandstone core. Quartzite core was more effective. This technique was used on the ends of the antler with bidirectional and circular movements (Figure 7c). Time: 20 minutes.

4. Incising creating guidelines to produce the fagged area of the comb, with bidirectional movement. For this step flint tool F was used. Time: 12 minutes.

5. Grooving on the incision guidelines produced in the previously step, with bidirectional and unidirectional movements with flint tools F, G and I (Figure 7d). Time: 360 minutes.

6. Incising to make the ornamentation of the comb with flint tool F. Small circles of 10 mm diameter and short lines with an approximal length of 20 mm were incised into the regulated surface. These symbols can often be observed on Neolithic combs and are interpreted as idols (lines=body; circles=eyes). Time: 20 minutes.

5. Results

The manufacturing process of osseous tools in the presented experimental program followed the rules of the *chaîne-opératoire* concept: "(1) to reconstruct the reduction sequence of bone technology, (2) identify which raw material was used (i.e. antler or bone) and (3) from which species was recovered" (ÉVORA, 2015b: 182). This technological analysis of utensils in osseous raw materials was based in the identification of several techniques used in different stages of the *chaîne-opératoire* concept (AVERBOUH, 2000).

As shown above, fracturation and extraction techniques were the skills selected to produce bone and antler tools (ÉVORA, 2015b). These skills are the result of human action in the transformation of osseous raw materials and are found in all stages of this production (acquisition and preparation of the osseous raw materials, modification, treatment and use) (GOUTAS, 2005; TEJERO, 2009).

Three bone needles were produced using one of the swine femurs (Figure 4f). These were constructed according to prehistoric data and techniques, as seen in the Methods section (BORAO, 2010; ÉVORA, 2015b). Although similar, the bone needles show different sizes, length and asymmetrical perforations in the distal end. Despite these irregularities, these bone needles

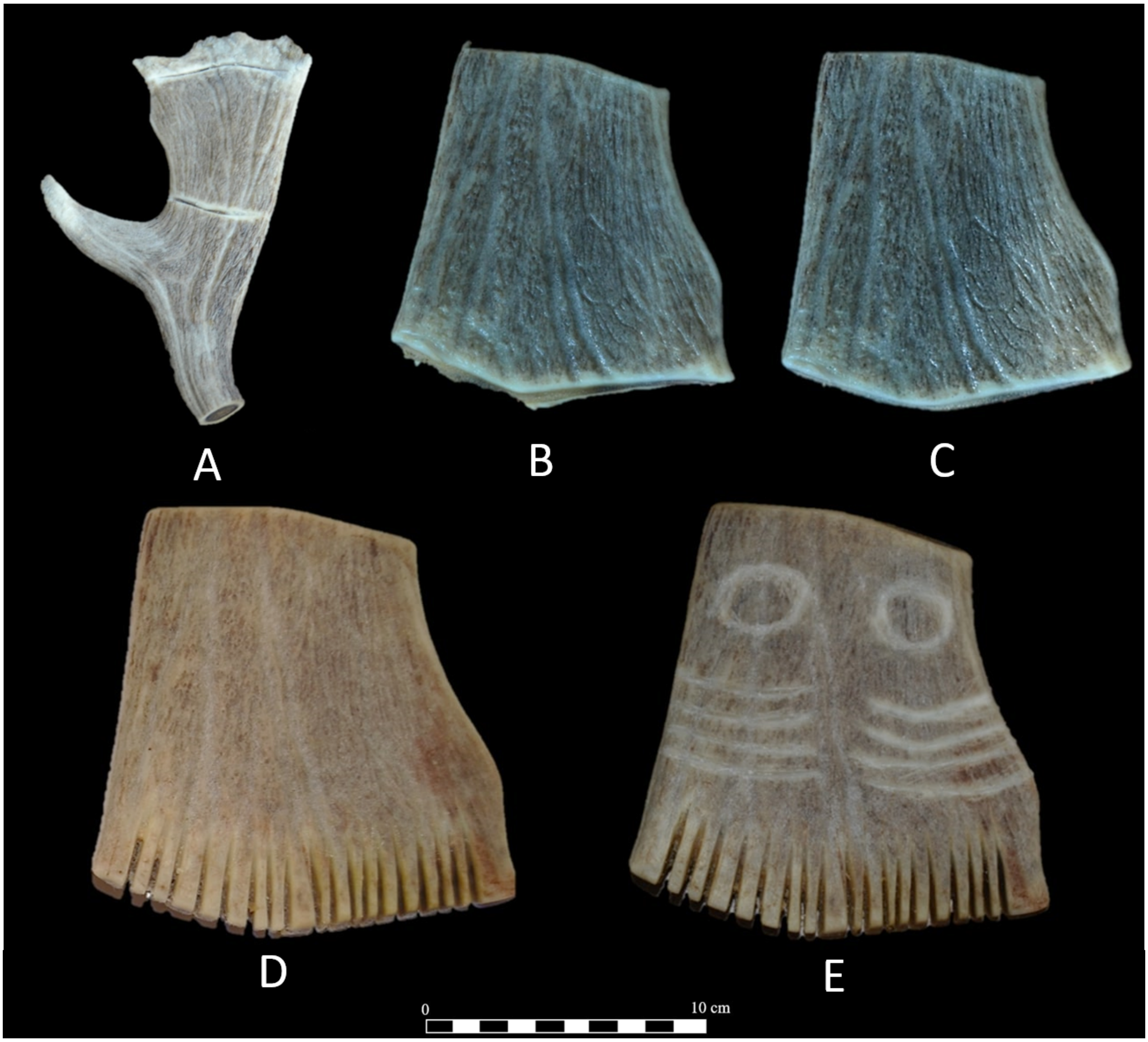

Figure 7. Steps during the antler comb manufacture: a) Incision in horizontal line of the antler remain, b) Grooving on the antler remain, c) Removal of small particles through abrasion, d) Grooving in the fagged area of the soon-to-be antler comb, e) Fourth experimental result: Antler comb.

were effective during the testing tool functionality, such as making of nets and sewing reeds. To segment the second femur, a different technique was used to test the variability of different manufacturing processes. The manufacture of a longitudinal grooving in the parallel to the long axis of the bone was followed by the application of the indirect percussion. This application was conducted with the usage of a red deer antler remain. This remain acted as a hammer. However, the results were not satisfying. The bone broke in an irregular shape by diverging from the line of the incision mark (Figure 4d). A second attempt showed the same results. The bone segmented in four irregular pieces. Due to the angular sharp edges and uneven forms, the four pieces were discarded. Reasons include too much force with the hammer and/or a not so deep longitudinal grooving in the bone. It was not possible to know how much time elapsed from the death of the animals until the purchase of fresh bones. Given its freshness and consumption rules for health, it is believed that not much time as passed since the slaughtering of both swine adults.

The manufacture of the red deer antler gave way to the creation of an arrow with an antler projectile point (Figure 5f). The projectile point shows a regular sharp edge without a noticeable oblique line. The distal end presents a single-beveled mark. The surface of the distal end shows traces of incision marks to better attach the projectile point around vegetable fibers. Despite the success in the manufacture of this antler tool, the short duration of the *Osseous Industry* course was the main reason why a bow was not created. Therefore and because no bow was accessible, we did not test the functionality of the arrow.

A harpoon head from red deer antler was produced with the fracturation and extraction techniques explained above in the Methods section (Figure 6c). The harpoon head shows four uneven triangular barbs in a uniserial line. Due to the difficulty maneuver of the hard material, it was not possible to create convex barbs as represented by the Magdalenian barbed points/harpoon heads from the *La Cova de les Cendres*, Alicante. Thus, a simpler and easier work was conducted, resulting in small-sized barbs with rounded tips. Despite the lack of sharp barbs, the functionality of the antler tool saw an efficacious result. While it was not possible to experiment the tool in an environment with suitable activities, such as fishing or hunting, it was possible to interact with and fire the weapon (e.g. flinging action comparable to a throwing spear). Several steps were repeated, such as fire the weapon with bare hands, grab it and retract.

The antler of fallow deer resulted in a successfully produced comb (Figure 7e). Incision marks present two circles in the proximal end and eight concave lines in the middle of the palmate, four in the left side and the remaining four in the right side. These short lines show an over-all uniform pattern, with just a few irregularities at the side ends. Different sized teeth at the distal end of the antler comb shows the difficulty in creating gaps on the hard material with a flint tool. The wide-sized teeth decreased the functionality of the artifact when pulling through the hair. This feature did not allow proper grooming and styling of hair, therefore, the antler comb proved to be ineffective. Smaller and thinner teeth should have improved the comb's functionality.

A use-wear analysis was conducted in a macro perspective only. Given the hard properties of bone and antler, the lithic tools present a high chipping edge, mostly due to scraping. Flint tools A, B, F, G and H present negatives with ledge termination, while flint tools C, D, E and I show an edge loss, mostly at the point end, after the manufacture process had finished. The direct percussion in bone has made chipping wedges, but it did not happen the same in antlers, as it presents few traces. We observed a stigmata pattern on the surface of both bone and antler. This pattern, the *stria*, indicates a longitudinal movement, mainly unidirectional, on the surface of the worked material with a lithic tool. The *stria* shows a depth in the femurs, but it is not so evident in the antlers. According to Évora (2005b: 201), "micro-wave patterns" occur when the *stria* is made with "retouched lithic tools". However, no microanalysis was applied, preventing us from identifying possible micro-wave patterns.

6. Discussion and conclusion

The experimental program of the *Osseous Industry* Course provided an understanding of why experimentation is a key aspect of artefact studies. The students gained practical experience of experimentations related to archaeological and taphonomic processes and the manufacturing of a range of material culture through reproduction. It is important to observe that, while experimental archaeology asserts to whether archaeologists' interpretations are realistic and plausible, it can also lead to artificial results, difficulties in artifacts' replication, subject to human error, and manipulation of variables, which is not always seen as completely objective. Despite the cons of experimental archaeology, this interdisciplinary science gives a broad range of analysis, assessment and interpretation useful for archaeological research.

For this reason, this practical analysis gave the students a new perspective on osseous raw materials, and above all, to understand the difficulty on which the past human communities had in the acquisition of these osseous materials. Pressure to achieve products was probably one of the main reasons of these limitations, given the time spent on the manufacture of each utensil. This experimental program revealed how the production of osseous industries is extremely complex and challenging, especially when none of the students had expertise and knowledge about experimental research. In addition, the human communities of the past are generally seen as very basic by many, but in a wrong way. This research proved that these communities were far more complex. This analysis also helped the students improve their "eyes". In other words, knowing how to distinguish osseous materials from other artifacts present in archaeological sites. This new assessment may prove to be useful in future excavations. Despite some limitations during the analysis, such as time-consumption and unintentional fractures of the studied raw materials, the students' knowledge has increased, as this course provided an essential platform for the students' growth as future archaeologists.

These results show how important experimental archaeology is in the education of future archaeologists. It allows the students to explore experimental archaeology's potential as a powerful science and an effective educational tool. The dynamics given by this interdisciplinary course can provide a strong grounding for a wide range of careers, not only those related to archaeology but also in wider fields such as teaching. This interdisciplinary science can provide a broader spectrum: the dissemination, be it to the research community and/ or to the wider public. Unfortunately, experimental archaeology continues to be an undervalued science. Few universities' degrees offer courses in experimental archaeology. One of the main reasons for this gap is the lack of specialized researchers in this field of science. Other reasons may include priority of other courses, and the lack of recognition from the scientific community.

We sincerely hope that this work can provide an example of how fundamental experimental archaeology is in the archaeological research, and how important it can be for the graduates to develop skills and methods that could be useful for their career.

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