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Sharp and blunt force trauma concealment by thermal alteration in homicides: an in-vitro experiment for methodology and protocol development in forensic anthropological analysis of burnt bones.

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Highlights:

- Non-human bones were subject to sharp and blunt force trauma, followed by burning
- Sharp and blunt force trauma signature were not entirely masked by heat exposure
- In these burnt specimens, it was possible to trace the origin of the trauma impact
- Emphasis is placed on future standardization of fracture experimentation in burnt bone.
- Promotes the use of anthropologists in the recovery of human remains at fire scenes

Abstract

Burning of human remains is one method used by perpetrators to conceal fatal trauma and expert opinions regarding the degree of skeletal evidence concealment are often disparate. This experiment aimed to reduce this incongruence in forensic anthropological interpretation of burned human remains and implicitly contribute to the development of research methodologies sufficiently robust to withstand forensic scrutiny in the courtroom. We have tested the influence of thermal alteration on pre-existing sharp and blunt trauma on twenty juvenile sheep radii in the laboratory using an automated impact testing system and an electric furnace. The testing conditions simulated a worst-case scenario where remains with pre-existing sharp or blunt trauma were exposed to burning with an intentional vehicular fire scenario in mind. All impact parameters as well as the burning conditions were based on those most commonly encountered in forensic cases and maintained constant throughout the experiment. The results have shown that signatures associated with sharp and blunt force trauma were not masked by heat exposure and highlights the potential for future standardization of fracture analysis in burned bone. Our results further emphasize the recommendation given by other experts on handling, processing and recording burned remains at the crime scene and mortuary.

Keywords: forensic anthropology, human remains, burning, sharp force trauma, blunt force trauma, homicide.

1. Introduction

Deaths from sharp and blunt force trauma are common in homicide cases [1-5], particularly in countries where civilian use of firearms is strictly regulated. In England and Wales for instance, 2011-12 homicide data shows that out of 550 homicides, 200 resulted from sharp instruments and more than 100 from blunt trauma [6]. Homicides, whether by sharp, blunt or other type of trauma, are often concealed through burning [7]. In such circumstances, where expertise in burn patterns and differential bone fracture propagation is required, the presence of the forensic anthropologist is advisable [8-11]. Currently, this expertise mainly relies on experimental research investigating perimortem trauma in the absence of thermal alteration or vice versa and forensic casework experience.

In the literature, cremated bone has been examined macroscopically, especially with regard to methods for biological profile estimation [12,13]. Microscopically, bone structure and compositional changes have also been investigated at length [14,15] using specialized analytical techniques such as X-ray diffraction and/or X-ray spectroscopy [16,17], Scanning Electron Microscopy [18,19], Transmission Electron Microscopy [20] and Fourier Transform Infrared [21,22]. In contrast, investigations of full-body burn patterns [23-25] and effects of flesh combustibility [26,27] are scarce, with a limited number of studies analysing remains from crematoria [28,29]; these aspects have been addressed secondarily to, for instance, analysis and weighing of cremated remains for identification [30,31]. With respect to mechanical trauma, blunt trauma research has been extensive, with studies from both clinical and forensic perspectives. Although these mainly focus on head trauma [32,33] and associated computerized models [34,35], they also include analysis of fractures associated with child abuse [36,37], fracture toughness in long bones [38] and autopsy case reports of various accident types [39,40]. Similarly, sharp force trauma has also been thoroughly investigated, with studies addressing stabbing events [41,42], cut marks, weapon edge

striations analysis and metal residues at impact sites using microscopic techniques [43,45] and knife blade [46] and screwdriver tip morphology [47] at macroscopic level. However, experimental research combining both perimortem trauma and thermal alteration is scarce [11,28,48-50], the majority with inadequately controlled testing environments and unevenly distributed sample sizes and demographics.

In light of the current literature, we hypothesized that ‘fresh’ bone trauma morphology and any associated fracturing, although exacerbated by heat, will still be distinguishable from damage produced by thermal alteration due to differential failure mechanism of bone.

Juvenile sheep radii were used in the simulation of a closed-compartment fire [18,50,51] in which calcined human remains recovered presented either sharp or blunt trauma in addition to various types of defects and fractures due to burning. The current sharp trauma experiment simulated a typical cutting action impact produced by a large knife; whilst the blunt trauma experiment simulated a baseball bat impact [33,42]. The methodology was repeatable whereby equipment which allowed proper regulation of the scenario was utilized.

Biomechanically, control of the nature of impact during experimentation is of high importance for an understanding of how and why bone behaves in a particular manner during loading.

The principal objectives of this controlled experiment are: to demonstrate that field experiments can be replicated in a realistic manner in the laboratory and that the variation in the observed thermal defects can be reduced to factors which are pertinent to the variables being tested rather than to factors which cannot be fully controlled in a field experiment. Hence, the main aim is to resolve discrepancies amongst experimental approaches which deter adequate comparison of data sets and which are the cause for current divergence in expert opinion by investigating which types of heat fractures occur and whether this is dependent on the presence of mechanical trauma.. This approach also seeks to promote future

drafting of experimental protocols sufficiently robust to withstand forensic scrutiny, thereby solidifying forensic anthropological expert opinion in the courtroom.

2. Materials and Methods

Samples

Twenty fresh juvenile sheep radii under three years of age (verified by the degree of epiphyseal fusion [52] ~~[73]~~) were purchased from a local abattoir (the sheep were slaughtered on the day the purchase was made). The samples were allocated as follows: two samples for determining optimal experimental conditions, 14 for the applied mechanical trauma and four as controls; the latter group were thermally altered intact and in the absence of previously applied trauma. Specimens were kept in a laboratory freezer and subsequently removed and refrigerated at 4°C for two days for gradual defrosting in advance of the experiment. After defrosting, larger muscle layers were removed using a dissection scalpel and each specimen was photographed and measured.

Sheep was preferred because its frequent use in the literature allowed comparison with other studies [53,54]. Defleshing was carried out because fat, muscle and skin act as fuel themselves [26] and will affect the temperature at which the bone is burnt. Since their proportions can vary between individuals, removing the soft tissue ensured greater temperature uniformity across all specimens.

Mechanical Trauma

Trauma was dynamically applied using an IMATEK Impact Testing System (Imatek® Ltd, Old Knebworth, Herts, SG3 6QJ, UK) equipped with a sensor to control and record load, time, energy dissipation and an experimental chamber within which the test rig and samples were mounted. Fourteen samples were used, seven for the sharp trauma (SFT 1-7) and seven for the blunt trauma experiments (BFT 1-7). The specimens were wrapped in commercially

available cling film to ensure stability during impact and prevent the loss of bone fragments (if produced).

The sharp trauma scenario replicated a cutting action with a large knife, using a striker measuring 2.2x0.01 cm (Fig.1) at a velocity of 4.0 m/s and a total impact mass of 3.703 kg. This corresponded to impact energy of approximately 28 J and a peak force of 3.2-4.0 kN. The blunt trauma experiment simulated a baseball bat impact using a 15 cm long and cylindrical impactor (Fig.2) at a velocity of 6.0 m/s and total impact mass of 4.102 kg; corresponding to approximately 84 J and a peak force of 5.6-7.7 kN.

Each specimen was placed onto three non-deformable sponges, with each epiphysis further secured with plastic tape (Figs.3,4). This ensured that the impactor would always come into contact with the midsection of the anterior surface of the bone shaft, perpendicularly to the long axis of the bone. The purpose was to isolate impact forces to compression and tension and maintain impact angle constant to reduce variability in the resulting defects [55-57]. The correlation between impact generated by the testing system and impact generated by a manually-handled object is as follows: the impact velocity originates from the generated momentum during the hitting action whilst the impact mass is a combination of the actual mass of the object and that originating from the body of the attacker; together, these generate the impact force to which the sample is subjected.

Thermal Alteration

The thermal alteration experimental component reproduced a closed-compartment fire where skeletal remains with perimortem trauma were expected to become fully calcined, fractured and highly fragile [50,51]. A CARBOLITE CWF 110 electric furnace (Carbolite® Gero Ltd., Parsons Lane, Hope Valley, S33 6RB, UK) was used, equipped with adjustable temperature and duration controls and fitted with a peep hole for visualization of specimens during

cremation. Each burning or cremation session followed the same set-up whereby a limestone slab was placed inside the furnace on top of which two ceramic tiles were arranged; the purpose of the limestone slab was to raise the specimens to a level at which maximal heat exposure could be achieved whilst the ceramic tiles were used to extend the surface area for placement of more than two specimens at a time (Fig.5). The controls (CS 1-4) were burned and analysed first to establish a basis of heat defects and fracture patterns for comparison with those to be subsequently encountered in the trauma samples.

The epiphyses of the bone samples subjected to trauma were removed using an automated metallurgical saw (Struers®, Accutom 2) to allow placement of more than two specimens within the furnace, thus simulating cremation of a set of remains. To imitate the insulation effects of soft tissues, specimens were placed inside the furnace at room temperature which was set to increase at an average of 12-14°C/minute to a peak temperature of 820°C (i.e. duration of room-to-peak temperature increase was approximately 58 minutes). The furnace was then turned off and cooled back to room temperature prior to sample removal to prevent fracture formation associated with sudden cooling [14, 29].

The total heat exposure duration was around 7.5 hours; however, duration of specimen exposure was considered as 4 hours; the remaining 3.5 hours were at temperatures less than 200°C which is negligible since no further changes have been previously reported to occur [16,18].

Analysis

The analysis of trauma was approached in a step-by-step manner to ensure adequate prioritization of variables (Table 1). The approach was initially morphological and macroscopic whereby all trauma-associated defects were documented and photographed before and after burning and compared to those observed in the control samples as well as

those previously reported in the literature [24, 58]. Several features were examined and documented as listed in Table 2, such as overall morphology of the injury and a description of the fractured edges.

3. Results

Control Samples: Thermal Alteration Characteristics in the Absence of Trauma

Table 3 presents all morphological heat defects observed in the control samples, illustrated in Figure 6. All samples were calcined with the characteristic colour and presented some degree of fragmentation (the images observed in Figure 6 are after reconstruction). Specimen CS 3 was the only specimen which was fully reconstructed due to the large size of the produced fragments. The most substantial degree of fragmentation in terms of the larger number of fractures and fragments produced, was observed in CS 4.

With the exception of splintering which was absent in CS3, the samples displayed all types of heat defects which have been reported in previously published burned bone experimental research and case studies. However, potential for misclassification of heat-induced fragmentation as blunt trauma exists, as can be observed in two of the control specimens (CS2 and CS4) which present wastage similar to that associated with both sharp force trauma and blunt force trauma. Whilst CS 1 did present wastage due to the loss of several small fragments, the morphology of the wastage sites can be clearly classified as heat-induced rather than mechanically-induced trauma.

The observed patterns of thermal trauma in the control specimens are in accordance with published research [24,49]. The patterns as a result of burning observed in the control group differed from those observed in the BFT and SFT specimens with regard to pattern morphology and the number of fractures. The heat fractures in the control specimens were of

substantial depth with the majority penetrating the entire cortex, sharp and well-defined, particularly the longitudinal ones; their type and morphology correlate with previous studies which also utilized ‘wet’ bone [12,29].

Mechanical Trauma Signatures Pre-Burning

Overall, the morphological defects observed in the sharp force trauma samples were very similar (Table 4A and Fig.7). SFT 1-4, 6 and 7 presented defects typical of incisions: narrow width, superficial/medium depth, minimal/no wastage, absence of hinging and fracture lines. All incisions were V-shaped in cross-section, some of which were associated with raised edges (either on one side of the incision or on both sides) and/or peeling. Unilateral raised-edge morphology was observed in SFT 2 and 7 (Fig.8) while bilateral raised edge morphology was present in SFT 3 and 4, the former also exhibiting peeling (Fig.9). The SFT 5 incision was deeper and associated with hinging and an incomplete transverse fracture line on the posterior half of the bone shaft (Fig.10).

A similar damage pattern was also observed in the blunt trauma samples, whereby the majority sustained complete fractures (Table 4B and Fig.11). BFT 1, 3, 4 and 5 fractures were complete and associated with varying degrees of comminution whilst BFT 7 displayed a complete, simple fracture (Figs.12,13). In contrast, fractures in BFT 2 and 6 (Fig.14) were incomplete and associated with a ‘compression fracture’-like effect at impact site (also noted in BFT 3). Irrespective of fracture type, all fracture ends exhibited a regular, jagged/sharp outline with smooth surface morphology. Secondary or radiating ‘wet’ bone fractures were observed in all specimens and could be traced to a common origin (i.e. impact site), with the majority reaching the medullary cavity. Edge morphology and fracture angle originating from impact site were sharp, with a clearly defined and regular outline and angled relatively parallel to the long axis of the bone.

Mechanical Trauma Signatures Post-Burning

The sharp trauma incision sites were enhanced after thermal alteration and could be observed more clearly and in the specific cases of SFT 1 and 6 specimens the incision depths were exacerbated (Fig.7). Post-burning fragmentation, whether associated to the incision itself or as a result of heat was only noted in SFT 2, 4, 5, and 7. At incision sites, longitudinal and transverse heat fractures were the predominant types of substantial depth (Table 5), the latter producing complete separation of SFT 2 (Fig.15). Morphologically, the fractures exhibited an irregular appearance of overall outline, even and smooth edge surfaces and were angled either parallel to the long axis of the bone or were relatively oblique. Superficial fractures (i.e. they did not penetrate the cortex) were also noted, radiating from larger longitudinal fractures. Step fractures were only observed in SFT 3 and 5; in the former, this resulted in the production of a large fragment whilst in the latter, complete separation at incision site had occurred. Curved transverse fractures were observed on the posterior surfaces of SFT 1 and 3, close to the epiphyseal regions. With the exception of some remnants of raised-edge morphology in SFT 3, no other similar characteristic survived (Figs.16). However, the incision morphology of SFT 7 does indicate the presence of unilateral raised-edge morphology (Fig.17).

With regard to blunt trauma (Fig.11), outline sharpness was lost and surface morphology became rough in appearance, with no discernible regularity and associated with small projections (Fig.18). Except the step fractures observed only in BFT 5 and 6, all expected fracture types were observed and documented (Table 6). These were also irregular in outline with even and smooth surface morphology and were angled either parallel to the long axis of the bone or were relatively oblique. The greatest damage to overall bone integrity resulted from longitudinal fractures, the majority penetrating through the cortex. Curved transverse and patina fractures were superficial, with both types being present only at or in close proximity to the epiphyses. Fissures as described in the sharp force trauma specimens were also observed;

transverse fissures radiated from longitudinal ones and were deeper and longer. A unique pattern was observed in BFT 1, 2, 4-6 whereby a combination of transverse and longitudinal fractures created a 'cross' pattern (Fig.19).

The pre-existing fragmentation was only exacerbated in the samples with 'compression-like' fractures (i.e. resulting from a crushing action), namely BFT 2, 3 and 6. Larger fragments from the remaining specimens were preserved intact; whilst impact site fragments from sample 6 were lost (turned to ash); in comparison those from BFT 2 were recovered in a good enough condition for reconstruction. Qualitatively, heat-induced fragmentation was minimal, presenting as small chips of bone, splinter-like in morphology and originated from the fracture ends of all specimens (i.e. splintering effect) (Fig.20). Therefore, as expected, the overall heat defect and fracture patterns noted in the control samples were different from those observed in the trauma samples. Furthermore, the trauma samples did not present any heat-induced changes which significantly altered the mechanical trauma signatures. The latter were encountered in CS 2 and 4 (Fig.11,21): the defects had a rough appearance but smoothness and morphological regularity were still present and could be observed more clearly in comparison with the blunt trauma defects.

4. Discussion

The present study examined the degree to which concealment of sharp and blunt force trauma can be achieved by thermal alteration, taking into account homicide cases and the involvement of forensic anthropological expertise. The results have shown that signatures associated with sharp and blunt force trauma were not entirely masked by heat exposure and that there is potential for future standardization of fracture analysis in burnt bone given further experimentation of this nature. In the literature, perimortem trauma is exacerbated by heat [59-61] whereby pre-existing fracture lines radiating from impact points extend further along the bone shaft and increase in depth. However, in these studies, existing fracture lines prior to burning were notably different from

heat fractures [12,29] which were sharp, well-defined and the majority penetrating the cortex, particularly the longitudinal ones. Based on these features, it has been possible to 'trace' the origin of the mechanical trauma impact [49,62,63] and distinguish them from post-burning damage. This is an aspect worth mentioning because a higher degree of damage was observed when the ceramic tiles within the furnace collapsed during the heating of specimens CS 2 and 4 resulting in further breakage, although this did not affect the overall fracture pattern. Whilst this is a limitation with respect to the change in position (i.e. 'movement') in relation to the fire, such damage is expected to be a common find in a forensic fire scenario, especially when taking into consideration any further damage sustained during the recovery and transportation of the remains. Thus, heat-related fracture patterns will not be obscured by post-cremation breakage and the latter only occurs along pre-existing penetrating heat fracture lines, exacerbates superficial fracture lines and originates from point of impact. In addition, fragments associated with comminuted fractures were all still recovered in their original shape. This illustrates the importance of laboratory conditions as testing environments: in an open-fire set-up, it is very likely that further fragmentation would have led to the omission of many fragments, thereby providing false data regarding percentage of successful recovery.

The specimen positioning and epiphyseal removal prior to burning are two factors which could have influenced heat fracture patterns in the experimental specimens. Hence, it is not possible to conclude with certainty whether the penetrating longitudinal fractures which extend to the cut ends in the SFT specimens are: a result of direct exposure to heat of the epiphyses or whether they represent an exacerbation of microscopic fractures produced by mechanical trauma or whether they are an indication of the type and severity of the mechanical trauma. In addition, the control and SFT specimens also exhibited secondary fractures of a more superficial depth at perpendicular angles to the primary ones. Since these were absent in the BFT samples, it suggests that the formation of these superficial secondary fractures in the SFT and control

specimens is a means by which additional stress caused by heat accumulation within the cortex is alleviated. The influence of these heat stresses were eliminated in the BFT samples because the overall mechanical trauma damage was much more extensive and altered the effect of the heat-induced stresses along the bone shaft. As such, no superficial secondary fractures were produced at a macroscopic level. It was also interesting to note that fractures normally associated with fleshed remains were present. A rationale often presented in previous research attributes this find to uneven musculature contraction forces produced along the bone as the muscle shrink and ‘pull’ at their points of origin. This is debatable [13] and certainly not applicable herein because trauma samples were sawed off at their proximal and distal ends and defleshed.

Nevertheless, potential for evidence destruction exists, as exemplified by the obliteration of raised-edge morphology in the sharp trauma samples. Similarly, the severity of longitudinal heat fractures in both trauma types has the potential to destroy incision morphology. However, this study has demonstrated that the impact of these aspects can be minimized if appropriate recovery and handling methods are exercised.

5. Conclusions

This study, designed as a pilot to be followed by further experiments, has demonstrated that perimortem mechanical trauma induced by sharp or blunt force can be distinguished from thermal trauma. It has also emphasized that standardization of heat-induced fractures in skeletal remains evidencing perimortem trauma is possible. Hopefully, this study will encourage other researchers to further investigate this approach quantitatively and build towards a standardized experimental protocol for understanding and tackling analysis of burnt remains in a more robust manner. The reconstruction and analysis of the skeletal material utilized herein have been

greatly facilitated by controlled and careful recovery and handling of the remains in an experimental setting; thus further demonstrating the need for a forensic anthropologist and/or archaeologist to be involved in recovery procedures at the fire scene. Knowledge of the location, position, orientation and condition of the remains and any associated evidence will facilitate both the reconstruction of a biological profile as well as assisting in the reconstruction of the events and circumstances surrounding death.

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Figure 1 – Anterior view of the sharp impactor



Figure 2 – Anterior view of the blunt impactor

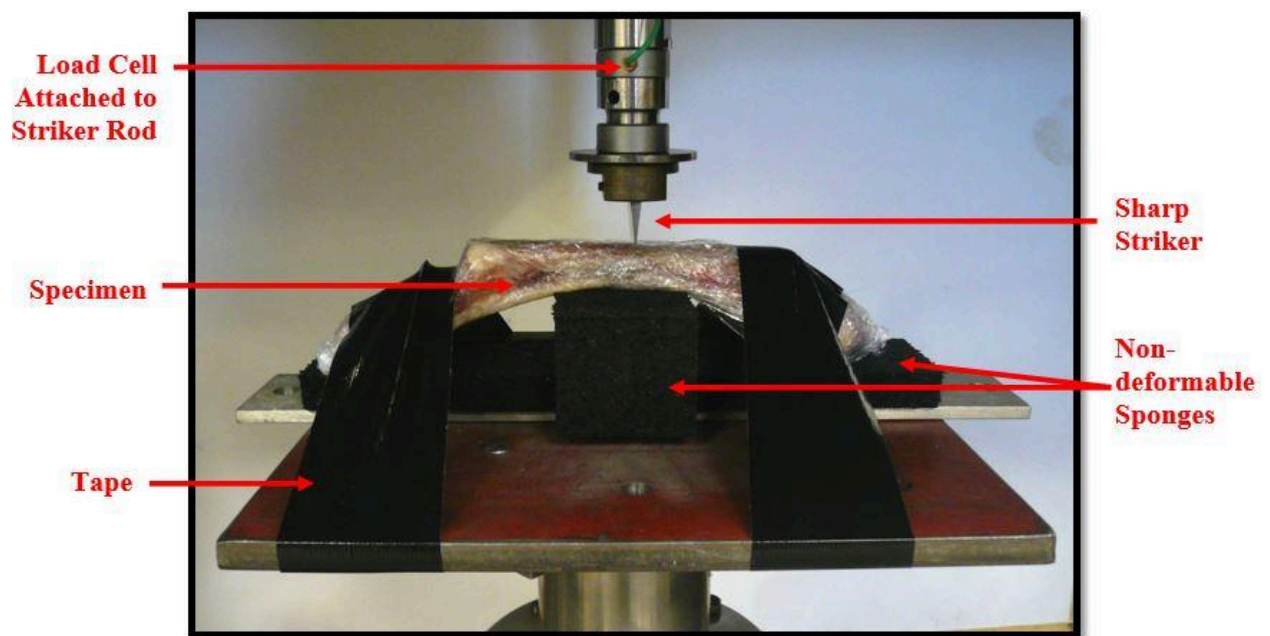


Figure 3 – Lateral view of the sharp force trauma specimen arrangement during impact

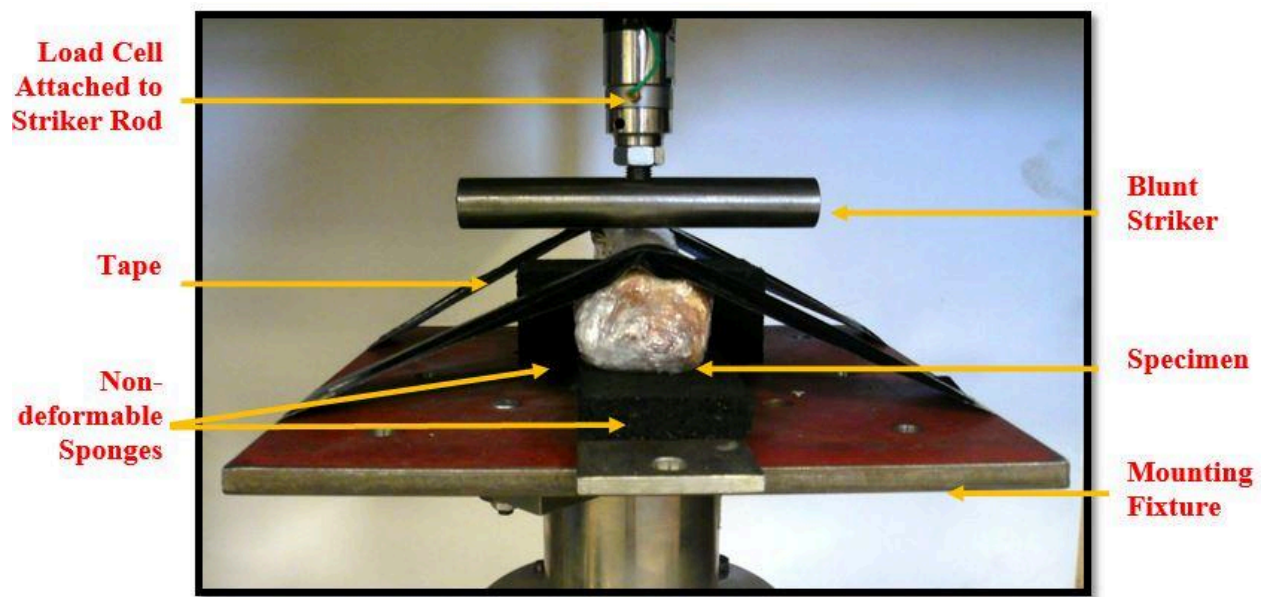


Figure 4 – Anterior view of the blunt force trauma specimen arrangement during impact

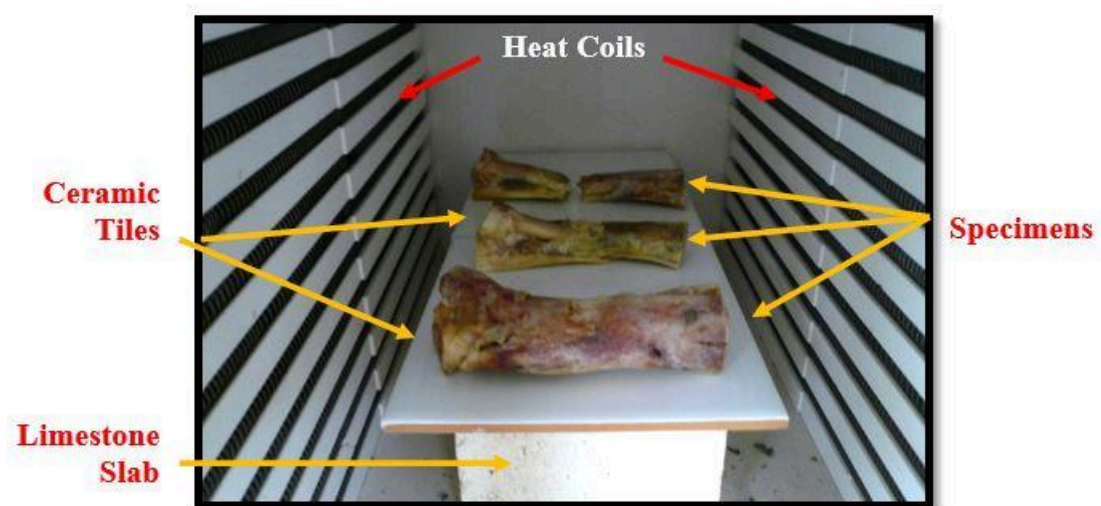


Figure 5 – Example of Specimen Positioning Inside Cremation Chamber

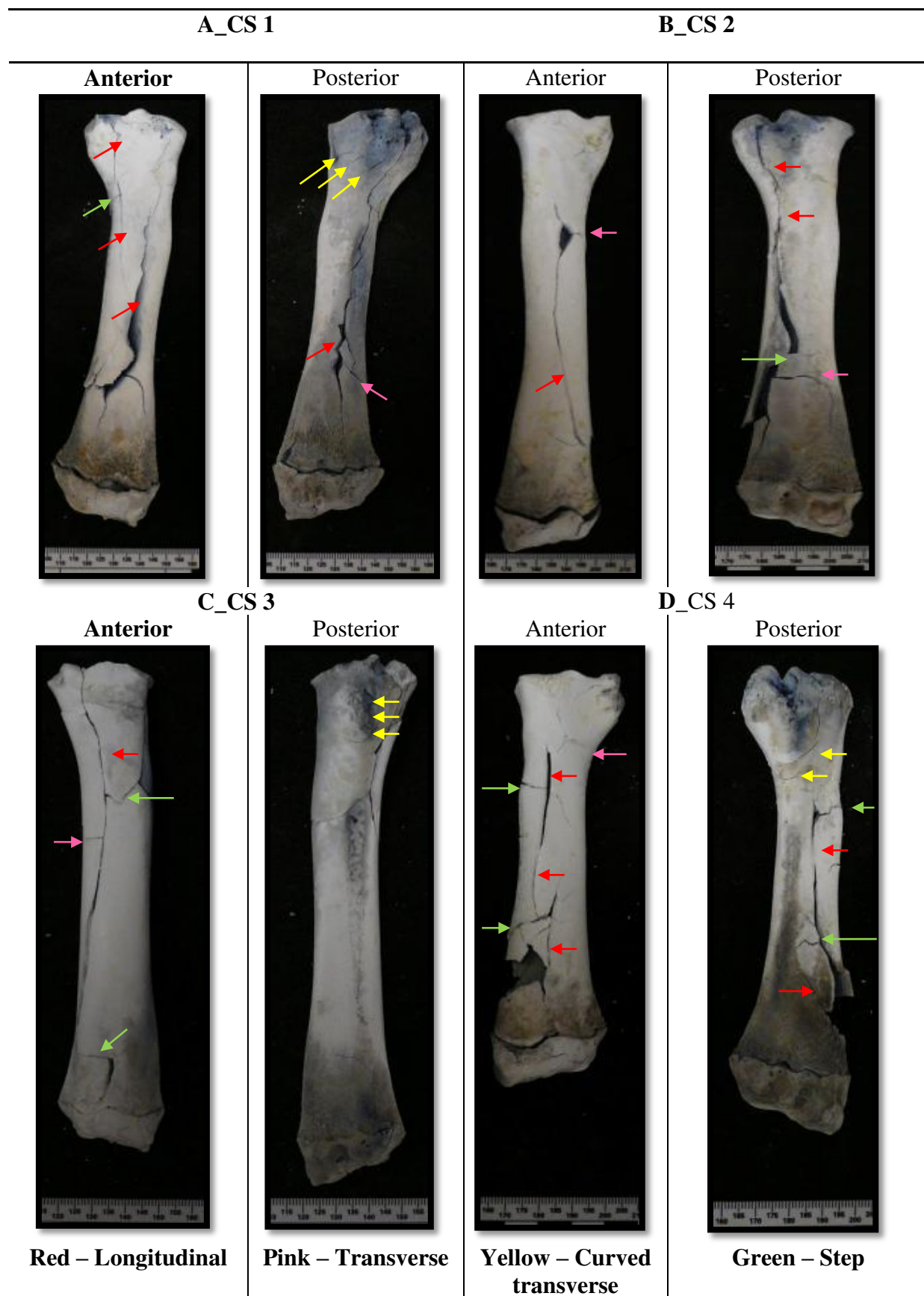


Figure 6 – Heat Fracture Patterns in the Control Specimens

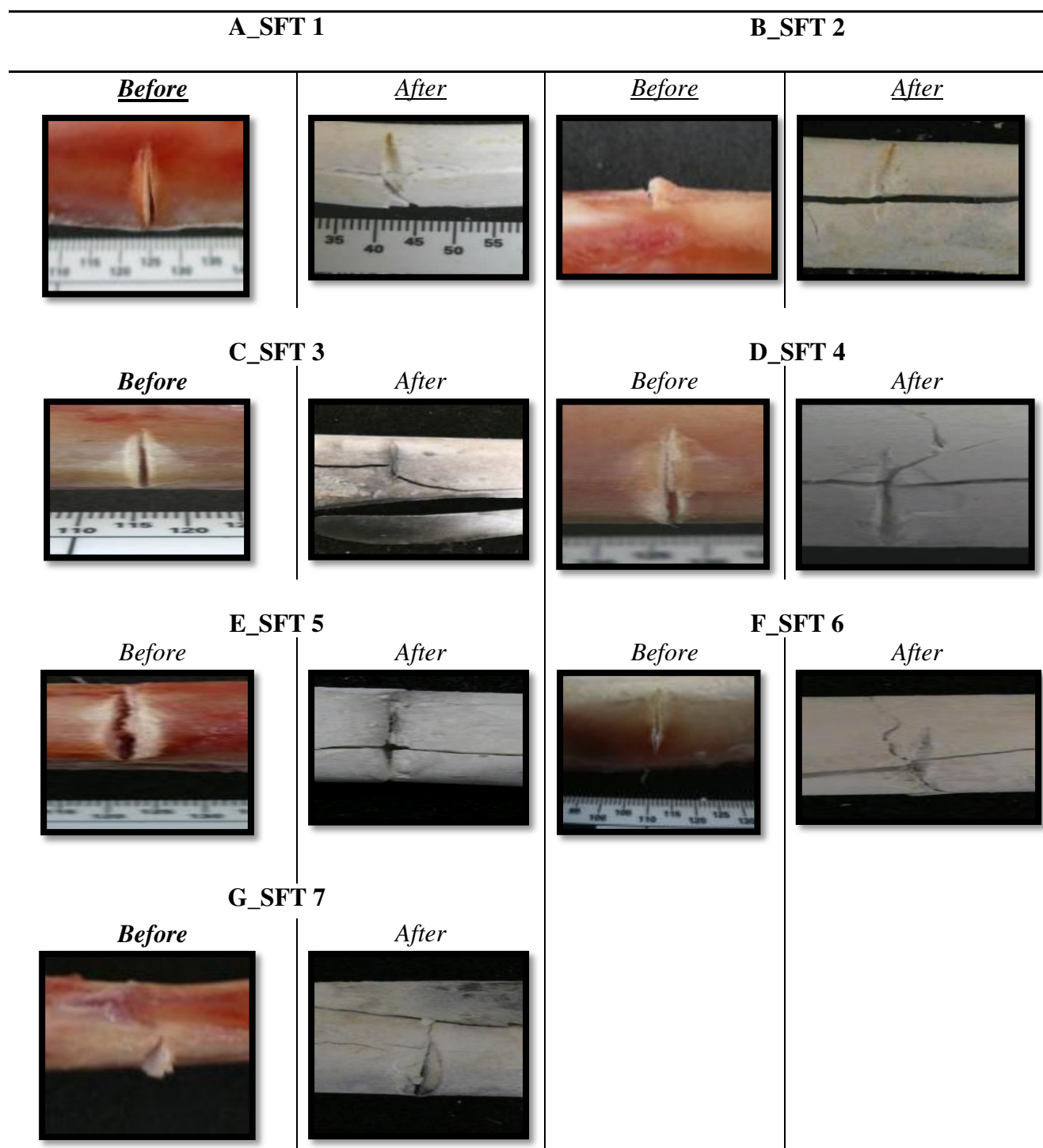


Figure 7 – Sharp Force Trauma Before and After Thermal Alteration: A Comparison



Figure 8 – Example of large bone spur on the right wall of the incision in SFT 2

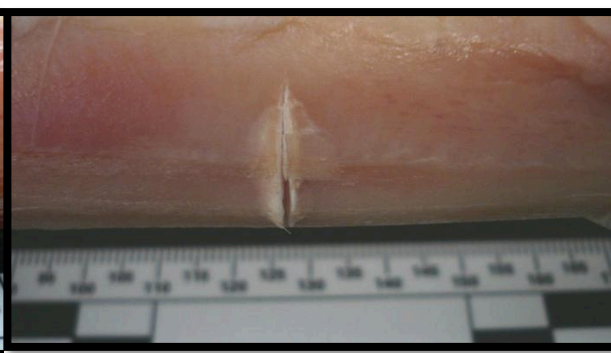


Figure 9 – Example of raised-edge morphology at incision site and peeling (upper right side of incision) in SFT 4



Figure 10 – Sample SFT 5 exhibiting deep incision

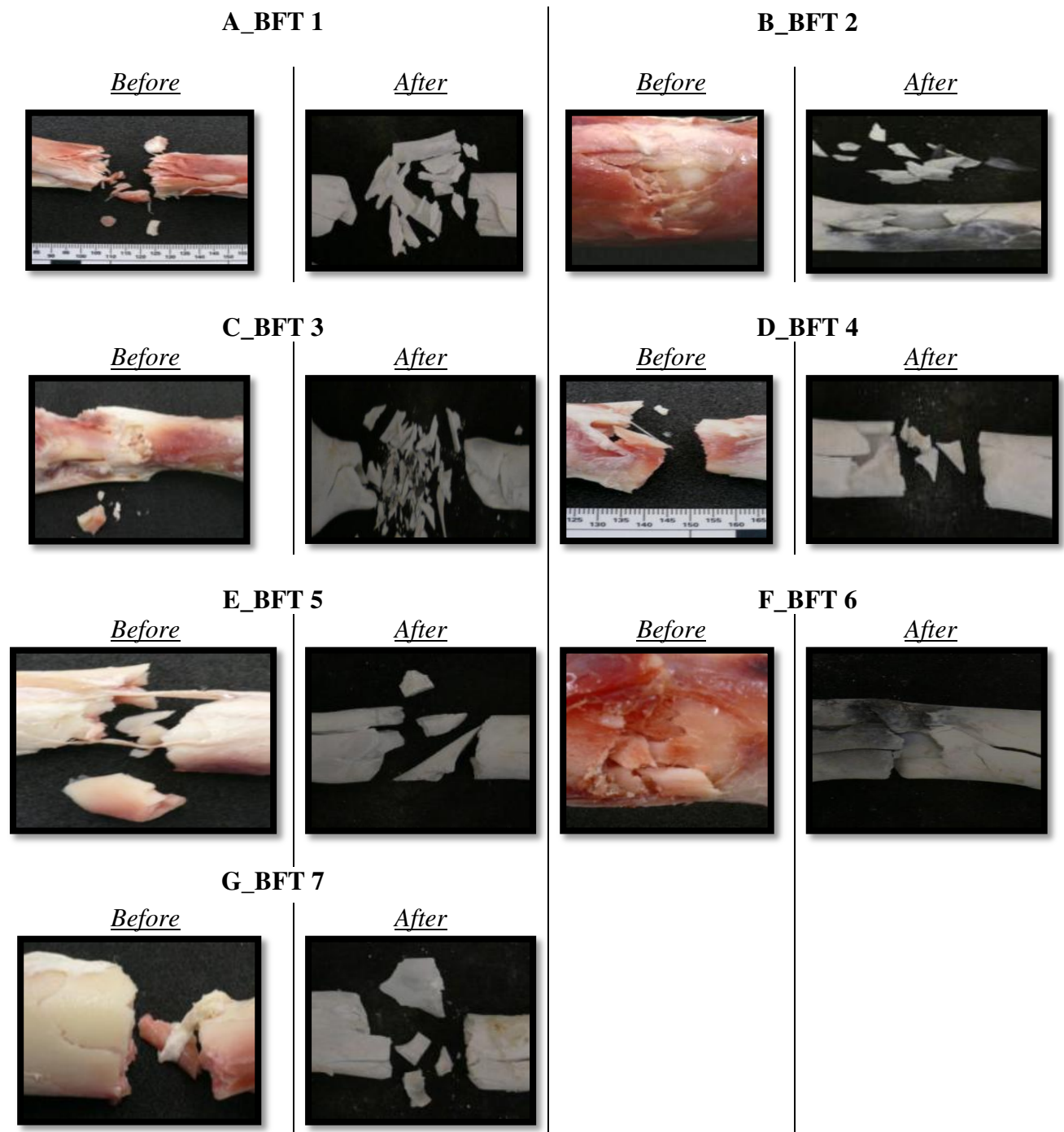


Figure 11 – Blunt Force Trauma Before and After Thermal Alteration: A Comparison



Figure 12 – Example of complete fracture in BFT 1



Figure 13 – Complete, simple fracture in BFT 7



Figure 14 – Example of crushing effect in BFT 6



Figure 15 – Illustration of complete separation of SFT 2



Figure 16 – Raised-edge morphology apparent in SFT 3



Figure 17 – Incision morphology of SFT 7 indicating the presence of a bone spur prior to heat exposure



Figure 18 – Example of blunt outline of the perimortem fracture in BFT 5



Figure 19 – Example of cross-pattern in BFT 1



Figure 20 – Example of heat-induced fragmentation in BFT 1



Figure 21 – Example of splintering effect in BFT 7

Table 1

Independent and Dependent Variables

<u>Independent variables</u>	<u>Dependent Variables</u>
<i>Specimens</i>	
<ul style="list-style-type: none"> Species Age Skeletal element 	Types of heat fractures
<i>Mechanical Trauma</i>	Differentiation between heat and mechanical trauma fractures
<ul style="list-style-type: none"> Specimen positioning and fixation Impact velocity, mass and force Region and angle of strike 	Degree of mechanical trauma concealment
<i>Thermal Trauma</i>	
<ul style="list-style-type: none"> Type of furnace Positioning of specimens Starting temperature Peak temperature Duration 	Occurrence of mechanical trauma-mimicking heat artefacts

Table 2

Pre-burning and post-burning variables examined

<u>Blunt Trauma</u>	<u>Sharp Trauma</u>	<u>Thermal Trauma</u>
Fracture category	Fracture category	Fracture type
Fragmentation severity	Fracture outline	Fracture morphology
Fracture outline	Wastage	Fracture outline
Fracture surface morphology	Secondary fractures	Fracture angle
Secondary fractures		Delamination
		Splintering

Table 3

Types of thermal alteration defects observed in the control specimens

Type of Defect	Specimen (CS)			
	1	2	3	4
Longitudinal fracture	√	√	√	√
Step fracture	√	√	√	√
Transverse fracture	√	√	√	√
Curved transverse fracture	√	√	√	√
*Patina fractures	√	√	√	√
Splintering	√	√	X	√

**Delamination	√	√	√	√
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*present at epiphyseal regions

** present at and around the epiphyseal regions

√ – present

X – absent

Table 4

Summary of BFT and SFT sample characteristics pre- and post-burning

Trauma type	Pre-burning	Post-Burning
<u>A. Sharp Force</u>		
<i>Fracture category</i>	incisions of superficial/medium depth deep incision in SFT 5	incisions in SFT 1-4, 6, 7 enhanced SFT 1 and 6 incision depths exacerbated but no change to overall pattern SFT 5 incision exacerbated and altered into a complete fracture
<i>Fracture outline and morphology</i>	V-shaped	V-shaped
<i>Wastage</i>	absent	present in SFT 2, 4, 5, 7; associated with the incision and/or with heat fractures
<i>Secondary fractures</i>	SFT 5: hinge and partial transverse fracture	SFT 5 secondary fractures exacerbated present in SFT 1-4, 6, 7 as heat fractures and associated with the incision sites and/or specimen extremities heat fractures in SFT 2 and 5 resulted in complete separation at incision site
<i>Peeling</i>	SFT 3	absent in all specimens
<i>Raised-edge morphology</i>	SFT 3, 4	SFT 3
<i>Bone spurs</i>	SFT 2, 7	SFT 7
<u>B. Blunt Force</u>		
<i>Fracture category</i>	complete: BFT 1, 3-5, 7 (BFT 3 impact site associated with compression-like fracture) incomplete: BFT 2, 6 (associated with compression-like fracture at impact)	general pattern of the complete fractures unchanged overall pattern in BFT 6 altered due to ‘ashing’ of smaller fragments
<i>Degree of fragmentation</i>	slight to moderate	exacerbated in BFT 2, 3, 6
<i>Fracture type</i>	transverse; irregular	general pattern unchanged
<i>Fracture outline and surface morphology</i>	sharp; smooth	blunt; irregular/rough to the touch and appearance
<i>Secondary Fractures</i>	present in all specimens	Pre-existing fractures exacerbated by heat fractures; Heat-induced cross-shaped pattern observed in BFT 1, 2, 4-6

Table 5

Heat-induced defects in the sharp force trauma samples

Fracture Type	Specimen (SFT)						
	1	2	3	4	5	6	7
Longitudinal	√	√	√	√	√	√	√
Step	X	X	√	X	√	X	X
Transverse	√	√	√	√	√	√	√
Curved transverse	√	X	√	X	X	X	X
Splintering	X	√	X	√	√	X	√

√ – present

X – absent

Table 6

Heat-induced defects in the blunt force trauma samples

Type of defect	Specimen (BFT)						
	1	2	3	4	5	6	7
Longitudinal fracture	√	√	√	√	√	√	√
Step fracture	X	X	X	X	√	√	X
Transverse Fracture	√	√	√	√	√	√	√
*Patina Fracture	√	√	√	√	√	√	√
Curved Transverse Fracture	√	√	√	√	√	√	√
Splintering	√	√	√	√	√	√	√

*present at epiphyses

√ – present

X – absent



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Sharp and blunt force trauma concealment by thermal alteration in homicides: an in-vitro experiment for methodology and protocol development in forensic anthropological analysis of burnt bones

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