Research Paper

Macroscopic Changes Observed after Burning in Incised Wounds on Bones Caused by Sharp and Penetrating Instruments

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ABSTRACT

Background: Stab and incised wounds are frequently encountered in forensic practice. Burned skeletal remains often complicate the evaluation of such injuries, making it essential to understand how fire alters cut marks on bones. This study aimed to investigate macroscopic changes in bones subjected to sharp-force trauma after exposure to high temperatures.

Methods: Three bovine humeri were incised with a 32 cm non-serrated kitchen knife. The length, width, direction, and interrelationships of each incision were measured with a forensic scale, photographed, and recorded. The bones were then burned in open-air conditions using oak wood, without accelerants, at 460–570 °C for 60 minutes. Following combustion, the incisions were remeasured, and pre- and post-burning characteristics were compared statistically.

Results: Despite advanced thermal destruction, most incisions remained macroscopically visible. Heat exposure caused significant increases in incision length and width ($p < 0.05$). Linear fissures radiating from the cuts were observed, and the cut margins appeared sharper and drier after burning. In one specimen, thermal fractures disrupted the evaluation of a distal incision.

Conclusion: Sharp-force trauma marks on bones are not completely obscured by fire and may even become more pronounced. However, heat-related expansion of cut dimensions can lead to overestimation of blade size. These findings emphasize the need for caution in interpreting burned skeletal remains and highlight the importance of further research with larger sample sizes to improve forensic accuracy.

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Introduction

Every year, thousands of people are injured or lose their lives as a result of violent acts. Knives, widely used in daily life in homes and workplaces for various purposes, are more easily accessible than firearms because they are not subject to specific restrictions at the time of purchase. Due to their constant availability, these instruments frequently appear in forensic medicine practice in cases involving injuries related to crimes against bodily integrity.

According to the Violence Map of Turkey prepared by the Umut Foundation in 2022, sharp instruments were used in 616 (15.46%) of firearm-related violent incidents that resulted in homicide, while 3,368 (84.54%) of these homicides were committed with firearms [1]. With the parallel increase in violence, injuries, and deaths caused by sharp and penetrating instruments, they have gained an important place in forensic practice. In a study conducted by Isenhour and Marx in 2007, it was reported that sharp and penetrating instrument injuries are three times more frequent than firearm injuries. However, their mortality is lower [2]. Similarly, according to a news article published in *Hürriyet* on January 27, 2016, the Council of Forensic Medicine in 2014 received 16,872 cases involving sharp and penetrating instruments and 6,168 cases involving firearms, amounting to a total of 23,040 cases of injury, highlighting the comparable prevalence of sharp and penetrating instrument injuries [3].

Because sharp, penetrating instruments are so frequently used, numerous forensic questions are expected to arise during the investigation and prosecution phases. Examples include determining whether the event originated from an accident, homicide, or suicide; establishing the location, number, and characteristics of the wounds on the body; noting the presence of hesitation or defense wounds; and identifying the distinctive features of the knife used.

In some cases, perpetrators attempt to eliminate victims or prevent identification by burning the body, burying it in remote locations, or disposing of it in seas or rivers. In such cases, regardless of the time elapsed since death, the discovered body must be examined very carefully and thoroughly, and all findings related to identity determination and cause of death must be evaluated [4]. Therefore, in cases involving sharp, penetrating instrument injuries, it is important to understand the morphological characteristics of the trauma inflicted on bone by each type of knife and how they act, in order to distinguish the type of knife used and avoid misinterpretation when elucidating the event. Furthermore, given the possibility of body burning, it is also useful to understand how such sharp, penetrating bone injuries may be affected by fire.

This study aims to observe and measure morphological changes in bones caused by sharp, penetrating instrument injuries that occurred in the perimortem period, following subsequent exposure of the bones to fire.

Materials and Methods

Adult bovine humeri (18–24 months), obtained from a local butcher on the same day and free of any additional trauma, were used in this study. After macroscopic examination confirmed the absence of further trauma, incisions were made on the diaphyseal shaft regions of the long bones using a standard kitchen knife. The knife measured 32 cm in total length, with a 20 cm stainless-steel blade, a dorsal thickness of approximately 2.5–3 mm near the handle tapering to 1.5 mm at the tip, and an increased thickness toward the handle. The blade was non-serrated, sharpened on one side, and designed with both edges converging at the tip. The incisions penetrated the periosteum but did not completely traverse the cortical layer, producing damage limited to the outer portion of the cortex (Figure 1).

According to Symes and L'Abbé [5], the most common instrument responsible for sharp-force injuries in forensic cases is a standard kitchen knife. For this reason, a kitchen knife with a pointed tip and double-sloping edges was selected in the present study.

The length, width, direction, and interrelationships of each incision were measured with a forensic scale, photographed, and recorded. Subsequently, each bone was burned separately under open-air conditions using oak wood, without fuel or additives, at 460–570 °C for 60 minutes, as measured by an infrared thermometer. The burning procedure was conducted in a standard 90 L garden incinerator with the front cover removed. To maintain a steady temperature and flame, a combination of coal, wood, and kindling was used. No accelerant was applied to the bones, as this could have left residues and complicated the analysis [6].

After 1 hour of burning, the specimens were immediately photographed, and despite advanced combustion and destruction, the remaining macroscopically visible incisions were remeasured, photographed, and recorded. Charred hard tissues were then examined for discoloration and thermal fractures. The post-burning incision lengths were measured again, and the similarities and differences between

Figure 1. Bones 1, 2, and 3, respectively, before burning.

Table 1. Numbering of the bones and localization of the incisions. The numbering of the bones used in the study, the number of incisions created in each bone, and their locations on the bone are presented. In the first bone, a single incision was made on the central shaft; in the second bone, two incisions were made on the proximal and distal shafts; and in the third bone, six incisions were created on the central shaft at intervals of 0.5–1 cm.

Bone No.	Number and location of incisions	
1	1	incision on the central shaft
2	2	incisions on the proximal and distal shafts
3	6	0,5-1 incisions on the central shaft at 0.5–1 cm intervals

sharp-force injuries before and after burning were evaluated. The obtained data were compared with the existing literature. Table 1 illustrates how the specimens were numbered (Table 1).

Fractures of the bones and the morphological features of the incisions were described. In addition, the pre- and post-burning measurements of incision length and width were compared using the Wilcoxon Signed Rank test. This analysis was performed both for all incisions collectively and for the six incisions created on bone number 3. Statistical analyses were carried out using SPSS version 29.0 (IBM Corp., New York, USA).

Results

It was observed that all bones exposed to heat turned gray after 60 minutes and acquired a markedly brittle structure. Despite the advanced degree of thermal damage, all identifiable incisions remained visible to the naked eye. Due to the effect of thermal fractures, loss of periosteal and superficial cortical tissue was noted in the most distal incision created on the shaft of bone number 3. Therefore, the evaluation was conducted on the remaining five incisions. The incisions on the bones appeared more distinct after burning, and a small number of linear fissures radiating from the cuts toward the periphery of the bone tissue were observed (Figure 2). In particular, the margins of

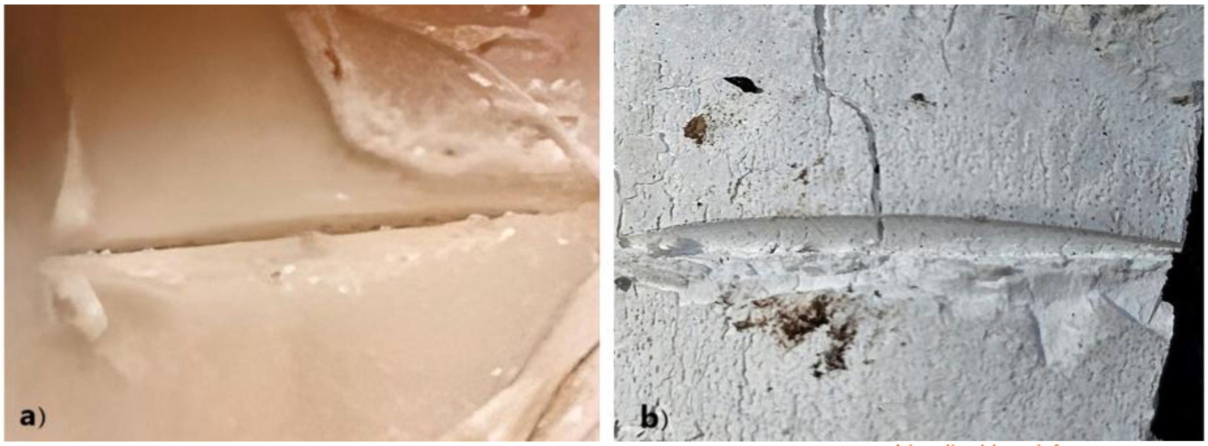

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Figure 2. In bone number 1, the periphery of the created incision (a) shows a linear fissure line (b) oriented perpendicularly to the incision, formed after burning.

the incisions acquired a sharper and drier appearance due to heat, making them more easily distinguishable to the naked eye.

Table 2 presents the changes in the lengths and widths of the incisions on the bones before and after burning. When all incisions were evaluated together, both the lengths and widths of the bone incisions showed statistically significant increases after burning ($p = 0.011$ and $p = 0.017$, respectively). When the same analysis was repeated only for incisions made on a single bone (bone number 3), the lengths again showed a significant increase ($p = 0.042$). In contrast, the increase in widths was not statistically significant ($p = 0.066$) (Table 2).

In addition to the incisions, longitudinal, transverse, curved transverse, step, and patina fractures were also

Table 2. Comparison of measurements of artificial incisions created on bones before and after burning. a: Analysis results for all incisions across the three bones. b: Analysis results for incisions on bone number 3 only. Mean, SD: Standard deviation, W: Wilcoxon test score, Ө: Measurement could not be performed.

Bone No.	Incision Length (Before Burning) (cm)	Incision Length (After Burning)	Incision Width (Before Burning)	Incision Width (After Burning)
1	2	2.10	0.15	0.21
2	2.10	2.30	0.10	0.15
	1.50	1.85	0.08	0.10
3	1	1.30	0.10	0.30
	0.7	1.0	0.20	0.25
	1.6	1.70	0.10	0.10
	1.3	1.50	0.20	0.25
	1.2	1.45	0.15	0.30
	1.0	Ө	0.20	Ө
m ±SS[a]	1.38±0.47	1.65±0.43	0.14±0.5	0.20±0.08
W (p)a	36.000 (0.011)		28.000(0.017)	
mn ±SS[b]	1.13±0.31	1.39±0.26	0.16±0.5	0.24±0.08
W (p)b	15.000 (0.042)		10.000 (0.066)	

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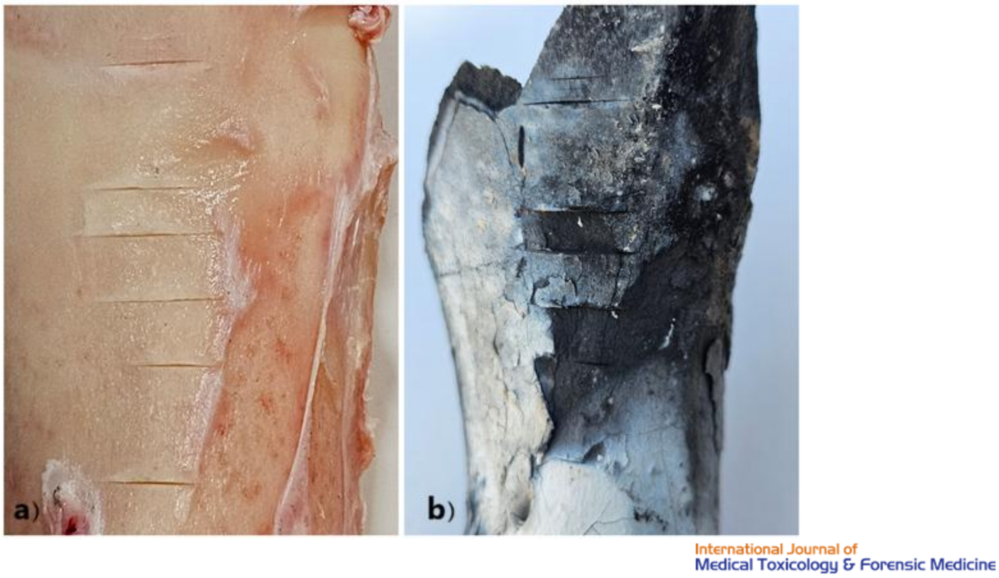

Figure 3. Macroscopic changes observed in Bone No. 3 before burning (a) and in the areas between the incisions after burning (b).

identified in the burned bones. A marked degree of warping was also observed in the bones, which had become particularly brittle due to heat exposure.

Discussion

The results demonstrated that sharp-force trauma marks on bone are not completely obscured by heat exposure and that, with further development of such experiments, there is potential to standardize fracture analysis in burned bones. In the literature, it has been reported that trauma occurring at the time of death may be further exacerbated by heat [7, 8]. This has been attributed to the extension and deepening of existing fracture lines originating from impact points along the bone shaft. Indeed, in a 2017 study using 20 sheep radii, Macoveciuc et al. showed that regions traumatized by sharp instruments became more distinct and more clearly observable after thermal alteration, with an increase in incision depth [9].

Typical changes observed in bone following exposure to fire include weight loss, discoloration, and fracturing. Bone generally first turns black (charred), then gray, and finally becomes completely white (calcined) as organic components are consumed [6, 10-13]. Thermal fractures can be distinguished from trauma-related fractures by their irregular appearance and tendency to follow the bone's microstructure [14].

In our study, observations also revealed a small number of linear fissures extending peripherally from the incisions, attributed to thermal damage to the bone tissue. Thermal damage caused fractures to initiate around the incisions, spreading to larger areas, compromising the overall integrity of the bone, and intensifying the thermal damage in these regions. Moreover, fractures were also observed in non-incised areas due to high heat exposure. This indicates that the effects of cuts and thermal fractures may occur independently. In particular, in bone 3, secondary fractures were observed after burning in the interincisional area (Figure 3).

The observed pattern of thermal damage is thought to be related to deterioration of bone structure and the rapid loss of water content in the affected areas, rendering the bone brittle. Indeed, early studies in the literature support our observations, demonstrating that the dehydration process reduces both the strain at fracture and the energy required for fracture in bone [15-17]. Furthermore, as trabecular bone loses water, its buckling behavior—reflecting its capacity to deform under load—shifts from flexible to brittle, making it prone to cracking [18]. The loss of water and elasticity is therefore expected to increase bone's susceptibility to fracture.

The fractures observed in our study encompassed nearly all types of thermal fractures described by Symes and L'Abbé [5], including longitudinal, transverse, curved transverse, step, and patina fractures. These fractures were also evident in the areas between the incisions in bone 3, which may explain why no significant difference in incision width was observed.

The use of bovine rather than human bone and the application of incised wounds rather than other types of trauma represent important limitations of our study. It is known that while the cortical thickness of the human humerus accounts for approximately one-quarter of the total diameter, the cortical thickness of the bovine humerus accounts for nearly half, with a higher density [19]. Moreover, in real-life scenarios, the long bones we studied are more likely to be injured by sharp-blunt instruments rather than sharp-penetrating instruments. Even if sharp-penetrating instruments wounded them, the puncture characteristics may predominate in such injuries [20, 21]. In addition, in this study, trauma was applied postmortem, without the surrounding soft tissues (muscle, fat, and skin) covering the bone. Therefore, our study is limited in scope, highlighting the direction and characteristics of the observed changes.

Conclusion

Heat exposure led to reduced bone mass and shrinkage, which, in turn, increased the width and length of the incisions. Therefore, when measuring incisions on burned bones, caution must be exercised to avoid overestimating the blade width of the sharp instrument used. The findings from bone number 3 demonstrated that when multiple sharp-force injuries are present on a single bone, localized thermal damage may also become more severe.

The results of this study indicate that, to some extent, the locations of sharp-force injuries can be inferred from thermal damage patterns on skeletal remains; however, the accurate determination of the blade width and length of the instrument remains limited. Additional variables should be examined, and further research is needed to assess the post-burning visibility of sharp-force trauma on bone and to enable more reliable identification of the instrument employed.

Acknowledgment

The authors have no acknowledgements to declare.

Ethical Approval

Ethical approval was not required as the study used only slaughterhouse-obtained bovine bones. This exemption was confirmed by the decision of the Local Animal Experiments Ethics Committee (Saki Yenilli Experimental Animals Production and Application Laboratory, Decision No: 17, Meeting No: 05, 16/06/2025), which stated that procedures involving dead animals or slaughterhouse materials are not subject to HADYEK approval (Article 8/8-k of the Regulation dated 15.02.2014, No: 28914).

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Conflicts of Interest

The authors report there are no competing interests to declare.

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