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Focus on Caustic Acid Substances and Bone Tissue: What Forensic Anthropologists and Pathologists Should Pay Attention To

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Commentary

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Abstract

The interaction between caustic acid substances and a human body is typically observed in forensics as a means of concealment and destruction. In this regard, the literature is sparse, and the few studies that have been conducted have been primarily on animal bones. However, since it has been shown that the complete dissolution of a body in acid is more of a theoretical occurrence than a real one, we sought to focus on this particular aspect and to gather the latest findings from the literature. It has been shown that traces of human teeth and bones can still be effectively detected even after immersion in acidic substances through Scanning Electron Microscopy with Energy-Dispersive X-ray (SEM/EDX) analysis. Furthermore, compact bone has been identified as the best substrate for investigating the human nature of acid-immersed bone remains. Thus, it is necessary for forensic anthropologists (and, of course, pathologists) to be aware of the critical issues involved in approaching a body immersed in acid, as well as the analyses that can be performed to uncover the clues that may lie in microscopic traces that can be easily overlooked.

Keywords: Scanning Electron Microscopy; Forensic Investigations; Anthropology

Introduction and Contextualization

In forensic science, anthropologists and pathologists frequently encounter cases in which human remains are concealed. The most important are burial in an unusual or inaccessible place (forest, cave, high mountains) [1], dismemberment [2], charring [3], throwing the weighted body into the open sea or a pit [2], and burying the body wrapped or packed in large bags or plastic sheets [4]. Another method that should not be neglected is dissolving the body in corrosive substances [5]. All these procedures have the common goal of preventing the discovery or recognition of the body and eliminating any traces of the killer on the victim; when applied over a long period of time, they can also lead to skeletonization of the body, which makes the assessment of the post-mortem interval even more difficult [6]. However, of these procedures, only one, immersion in corrosive substances, has such destructive potential that it can lead to apparent complete dissolution of the body [5]. In this scenario, especially acidic substances can be used. Unfortunately, the data currently available in the literature does not allow us to estimate how frequently this phenomenon occurs. This would certainly be worth further investigation in future studies. In any case, among the most frequently used acidic substances the best known are sulfuric acid (H_2SO_4) more or less diluted [5], nitric acid (HNO_3), hydrofluoric acid (HF) [5], aqua regia (HNO_3 +3HCl) [7] and finally hydrochloric acid (HCl) [8]. Most of these substances are widely used in household, industrial and agricultural applications. They can be in liquid, granular, paste, or solid forms, with concentrations varying from 5-40% for liquid compounds to 100% for solid forms. Generally, a strong acid has a pH of about zero to 3 [9].

The chemical mechanism controlling physical destruction by caustic acid substances is well known [10]: in the initial stages of the process, it is almost impossible for the organic components to mix sufficiently with the acid because the interaction between the body and the acids is limited to diffusion at the exposure surface. Nonetheless, the process of organic hydrolysis with the degradation of proteins and adipose tissue is rapidly initiated because the human body is essentially composed of components that are all sensitive to the action of acids and are proton donors (free hydrogen ions), such as water, fat, proteins, and bone minerals [11]. Moreover, due to the notoriously poor solubility of fats in aqueous solutions, the hydrolysis of this organic component can be slowed down, leading to their accumulation and recovery of fat fragments at the end of the process [5]. A stronger reaction occurs when the acid, after reaching the bone mineral, penetrates deeper through its pores and channels, degrading the bone apatite and leading to the precipitation of the poorly soluble calcium phosphate. Throughout the process, the interaction of the water contained in the tissue with the acid results in extreme heat generation, increasing the temperature of the solution. This phenomenon leads to further damage to the tissue, which has already been damaged by the dehydration caused by the acid [11].

Forensic Challenges

After immersion of a body in caustic acid substances, pathological forensic diagnosis is particularly challenging and complicated because very little biological material remains and no analytical criteria have yet been reported in the literature. In practice, however, it is only theoretically possible to completely dissolve a human body without a trace within a few days, as it has been shown that microscopic residues can be preserved and detectable even after some time [5]. Of all the biological tissues of the human body, bones in particular are characterized by greater resistance to the corrosive action of acidic and corrosive substances: as a result, they dissolve more slowly than soft tissues, which makes them more suitable substrates for forensic investigations, because they are more likely to be detected in these cases. In addition to microscopic bone fragments, gallstones or artificial parts such as prostheses or implants can also be found. On these, if recovered, micro-traces of the application of this type of caustic acid substances can still be detected after a long time [5]. One technique that is particularly useful for highlighting the bone nature of small fragments of material that are not fully dissolved by acid and are not macroscopically recognizable as such, is Scanning Electron Microscopy With Energy-Dispersive X-ray (SEM/EDX) analysis [5,12]. Specifically, this technique has been successfully applied in three different cases, with one case of body destroyed in hydrofluoric acid and two others in a mixture of hydrochloric and sulfuric acids [5].

To evaluate the possibility of detecting microscopic bone fragments even after apparently complete dissolution in corrosive substances, an experimental study was conducted with pig bones immersed in acidic and basic liquids for 5 to 70 days. The residual fluids were analyzed through various techniques, including SEM-EDX, revealing microscopic remnants of partially digested bone, thin-walled structures, and recrystallized calcium phosphate [13]. Another successful application of SEM/EDX involved the detectability of human molar remnants after exposure to 37% hydrochloric acid, identifying them as such by recognition of the molar cementum [8]. All of this thus confirms the extreme importance and significance of this method in pathological forensic investigations [14] of bone substrate [15].

The literature, to date, on the analysis and interpretation of bone remains after immersion in caustic acid substances is not very helpful and consists almost exclusively of studies performed on animal bones [16,17]. With respect to human tissue, there are a few reports, one on teeth [8], one on bone tissue [18], and one on both of them [19]. Hartnett KM, et al. [19] performed only a macroscopic study by dissolving teeth and a human femur in 31.45% HCl, observing its complete dissolution within 19 h. On the other hand, Gentile et al. [18] performed the first both macroscopic and histological study on human bones after immersion in caustic acid substances. In detail, the destruction of spongy and compact bone fragments (skull bone, rib, vertebrae, and femur) was experimentally studied in hydrochloric acid at two different concentrations of 10% and 37%. Overall, the destructive effect of the 37% hydrochloric acid was greater, and the specimens completely dissolved after a maximum of 24 hours; in contrast, macroscopically recognizable fragments were still present in the 10% hydrochloric acid after 72 hours. Different degradation kinetics were also observed for bone fragments in the two cases, with fragments from rib and vertebra (predominantly spongy bone) being less resistant to acid corrosion than those from skull and femur (predominantly compact bone). Differences were also noted in the ability to histologically determine the bone nature of the specimens and their human origin: in the 10% acid, the bone nature of the sample was detectable up to 24 hours after immersion, whereas in the 37% HCl this was possible only up to 4 hours. Overall, histologic diagnosis of human bone tissue may no longer be possible even if macroscopic fragments remain, and the time frame for this is variable and depends on the substance used.

Similarly, the possibility to extract genetic material from remains that have been immersed in corrosive acid substances is also severely compromised over time. However, it has been shown in animal models that DNA profiling of acid-treated body parts, particularly cortical bone, is still possible at advanced stages of corrosion, even when the morphological methods used in forensic anthropology and dentistry can no longer be used for identification [10].

Conclusion

Even in scenarios where the destruction of a body in corrosive substances appears to be complete, the literature is consistent in emphasizing that complete dissolution of a human body is a theoretical rather than a real possibility. In particular, traces of human teeth and bones can still be effectively detected even after immersion of a body in acidic substances through SEM/EDX analysis. Furthermore, compact bone has been identified as the best substrate for investigating the human nature of acid-immersed bone remains. For this reason, it was deemed interesting to focus on this particular aspect. Indeed, it is imperative that forensic anthropologists (and, of course, pathologists) be aware of the potential that may be hidden even in microscopic traces that may be carelessly overlooked.

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