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Atypical Gunshot Exit Defects to the Cranial Vault

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ABSTRACT: Cranial exit wounds typically display external beveling, however, variation has been noted in the literature due to keyhole phenomena and pre-existent fractures. Two cases of atypical exit morphology are presented with features mimicking blunt trauma. In both instances radial fractures created by the exiting impact allowed passage without producing exit beveling. A working knowledge of the biomechanics of bone fracture, radiographs and low power microscopy are essential elements for the proper interpretation of such exit wound fractures.

KEYWORDS: criminalistics, ballistics, fracture, gunshot, biomechanics, anthropology

Exit gunshot wounds of the calvarium are typically externally beveled [*1*] and have associated secondary and tertiary fractures that relate to direction [*2,3*] sequence [*4–6*] and velocity [*7*]. Exit wounds differing from the expected morphology have been caused by the rapid progression of entrance associated fractures [*8*]. We have recently examined two shootings with atypical features more characteristic of blunt force than gunshot trauma. The cases will be presented individually followed by interpretation of the fracture patterns.

Case 1

An adult black man was shot in the left occiput by a .38 caliber round nose lead projectile from a distance of six to eight feet. The bullet was recovered beneath the skin of the left brow with an associated complex of fractures as depicted in Fig. 1. Photographs of the external and internal table fractures are seen in Figs. 2*a* and 2*b* respectively. The initial appearance shows none of the typical features of an exit wound, that is, a central defect with external beveling. Instead, two epicenters of radial cracking exist, the first and rearmost point of impact was tangential, causing the plastic deformation and producing a pattern of radial and circumferential fractures with a small piece of lead embedded in the bone, visible only upon radiography. The bullet proceeded anteriorly to strike

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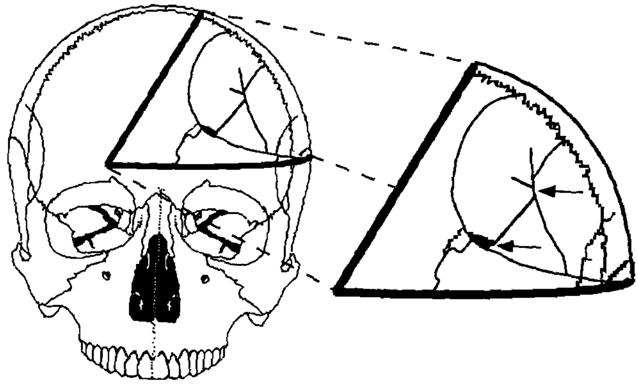

FIG. 1—*Diagram of the fractures associated with the exit gunshot wound from Case 1. The bullet was recovered between the complex of fractures and beneath the scalp.*

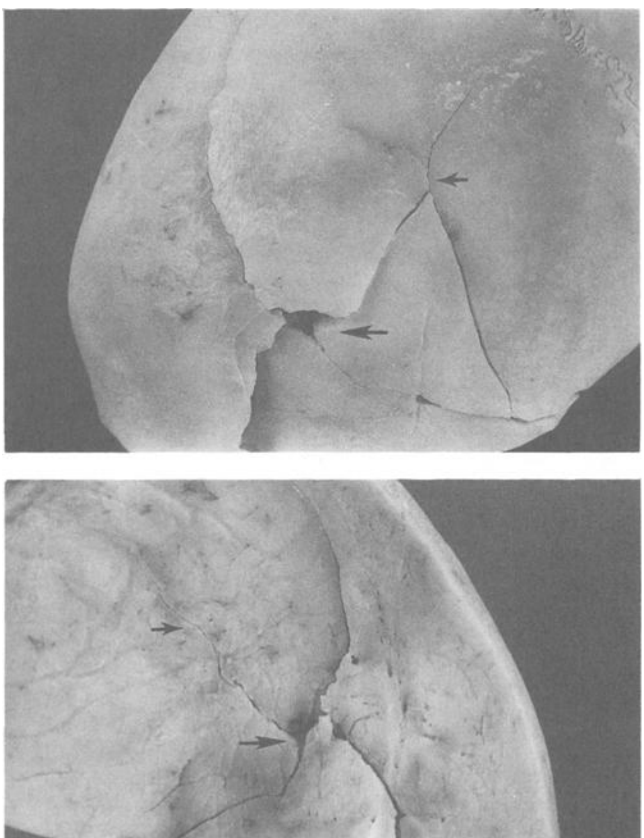

FIG. 2—*Photographs from Case 1 showing the external and internal tables of the exit wound in Figs.* 2a *and* 2b, *respectively. Two epicenters of radial cracking indicating impact sites; the first* (small arrow) *contains a small lead fragment seen only on X-ray, the second* (large arrow) *shows crushing of the inner table, heavier lead wipe and more extensive fracturing through which the bullet escaped. Plastic deformation due to the slow loading and bending of the bone prevent approximation of the wound margins.*

the inner table again, creating the second epicenter with more extensive radial cracking and plastic deformation allowing the bullet to exit through the fracture defect of the first impact. A large amount of metal deposit and crushing of the inner table was noted at this epicenter of exit. The bullet was recovered in the scalp, immediately above the area of crushing.

Case 2

An adult black woman was shot in the nose with a 9 mm pistol. The bullet exited the left occiput and was not recovered. Figure 3 shows the fractures associated with the exit wound, Figs. 4*a* and 4*b* are respective photographs of the external and internal tables. The figures show features very similar to the previous case. An epicenter of curvilinear radial cracking with plastic deformation exists. The internal surface is crushed and contains bullet wipe; combining the appearance of blunt trauma fractures with missile penetration.

Discussion

These two cases demonstrate the continuum of the viscoelastic properties of bone and how they affect fracture morphology throughout the energy and velocity ranges wounding objects deliver to the skull. The viscous nature of bone modifies the elastic properties by making them rate dependent to the effects of loading [*9*]. Slow loading allows the viscous element to yield, permitting strain or stretching of the bone prior to fracture, resulting in deformation. With faster loading, the viscous element has no time to yield to the accumulated forces and fractures resemble shattered brittle materials. Fast moving projectiles produce wounds of expected morphology, that is, external bevel about a central defect with very little to no plastic deformation. Previous authors have demonstrated the effects distraction of entrance associated fractures may have on the exit morphology of gunshot wounds [*8*], the warping or plastic deformation of bone due to slow loading and blunt trauma [*10*] and the association of less extensive fracture patterns with slower projectiles and stress-relieved calvaria [*7*]. Knowledge of such occurrences allows the exit fractures of these two cases to be described as a mixture of blunt and penetrating trauma. The slow moving projectile strikes and focally crushes the inner table at the point of impact, initiating rapidly progressing radial fractures that are then lifted or levered out of position far enough to allow bullet passage without production of the typical externally beveled plug and spall formation. The resulting fracture pattern represents the "missing

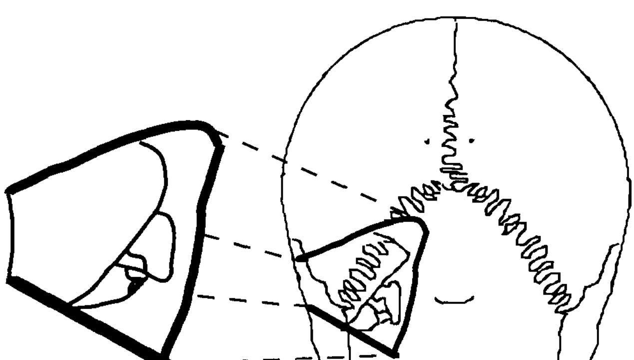

FIG. 3—*Diagram of the fractures associated with the exit gunshot wound from Case 2. The bulle exited completely and was not recovered.*

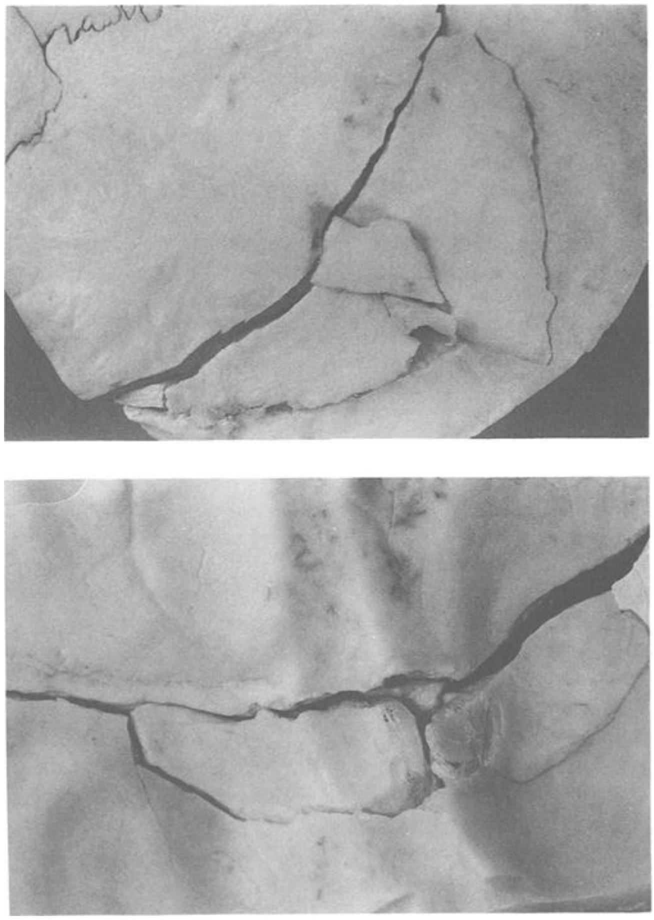

FIG. 4—*Photographs from Case 2 showing the external and internal tables of the exit wound in Figs.* 4a *and* 4b, *respectively. The epicenter of curvilinear fractures and the presence of plastic deformation mimic blunt trauma. The inner table is crushed and contains much bullet wipe indicating the site of bullet passage. This wound demonstrates the nature of the injury, combining blunt force with missile penetration.*

link" between these two fracture mechanisms. Plastic deformation is an uncommonly encountered finding in gunshot entrance wounds, as warpage requires a longer loading time to permanently bend and set the bony tissues. Gunshot wound fractures are generally fast-loading enough to exceed the tensile and compressive strengths of bone before the plastic phase of the stress-strain curve is realized. Thus, most such fractured skulls are easily reconstructed with all fracture margins well approximated. This differs greatly from our experience with fractures produced by manually delivered blows, slowly advancing machinery, and crushing mechanisms. In these cases the process is slow enough that the longer time allows entry into the distal portion of the stress-strain curve where plastic deformation occurs. Reconstruction of these skulls is made more difficult as the fragments will not come together along all margins.

These conclusions are reassuring as a link between the two most common types of directional forces applied to bone: broadly based, low velocity blunt trauma; and focally discriminate, high velocity penetrating trauma. The same physical principles apply in a consistent fashion to bone as a viscoelastic material as they do to the similar properties of elastic mild steel [*11*]. It is the viscosity however, that introduces rate dependent features, thus creating a family of stress-strain curves, one for each rate of loading. Keeping this in mind will aid the interpretation other atypical wounds that evidence a similar morphologic mixture of elastic and plastic fracture patterns.

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