GUNSHOT WOUNDS OF THE LOWER EXTREMITY: PRINCIPLES AND MANAGEMENT

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In order to properly manage most gunshot wounds involving the lower extremity, the podiatric surgeon should possess an understanding of missiles and their specific destructive effects. Wound ballistics involves the scientific study of the effects that a projectile has upon its target tissues. Many factors influence a projectile's wounding potential, including bullet or missile design and composition, velocity and target range, as well as the density of the tissues encountered and cavitation.

MISSILE DESIGN AND COMPOSITION

Most civilian gunshot wounds are caused by low velocity handguns, shotguns, and rifles, and less commonly by machine guns. Low velocity weapons generally use bullets made of lead alloy. At higher velocities the lead alloy may deform secondary to friction and heat (melting). For this reason many bullets are jacketed with copper or other metals with higher melting points in an effort to stabilize the projectile's configuration and increase its penetration capacity. Bullets can be fully-jacketed or partially jacketed. Partially jacketed bullets display a soft lead (or other metal alloy) tip, which allows deformation or mushrooming upon impact with the tissues. Bullets can also be manufactured with a hollow tip or even an exploding tip or detonator. Bullets that deform upon impact rapidly transfer kinetic energy to the tissues, thereby increasing wounding potential.

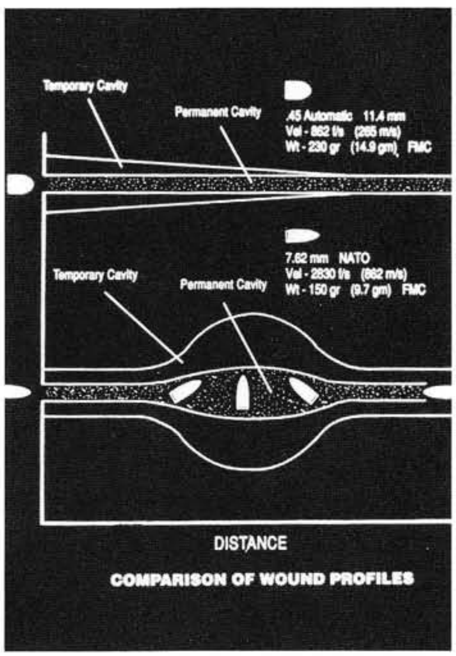

Fig. 1. Comparison of wound profiles for two different projectiles (reproduced from *J Trauma* 28: Supplement No. 1, 1988.)

VELOCITY AND KINETIC ENERGY

A bullet's kinetic energy also greatly determines the missile's wounding capacity. (Fig.1) Remembering that: $KE = 1/2\ mv^2$, it can be shown that doubling the bullet's mass increases the kinetic energy by a factor of two. Whereas, doubling the bullet's velocity increases the kinetic energy by a factor of four. Most civilian weapons project bullets at an average velocity between 1000-2000 ft/sec^2, whereas high velocity projectiles typically display an average velocity greater than 2000 ft/sec^2. Kinetic energy is also dissipated as the projectile courses toward the terminal target, thereby decreasing the wounding potential. For this reason, wounds inflicted at close range are typically more destructive.

TARGET TISSUES, PATH AND CAVITY

The local effect of a bullet wound depends largely on the phenomenon of cavitation. Upon impact with living tissues, kinetic energy is transferred from the missile to the target structures and a shock wave propagates through the body part. Low density tissues deform by stretching and bending, thereby rapidly forming a water vapor-filled temporary cavity that displays a negative pressure at the point of bullet entry. This negative pressure can pull debris and bacteria into the wound at both the entry and exit sites.[1] As the round passes through the body part, the soft tissues recoil in an elastic fashion and the temporary cavity eventually collapses, leaving a smaller permanent cavity. The temporary cavity may actually pulsate as the forces equilibrate prior to establishment of the permanent cavity. Temporary cavitation often causes tissue damage that is not localized to the immediate proximity of the permanent cavity, therefore careful inspection at the time of surgical debridement is necessary.

High density tissues are typically less resilient, and a rapid transfer of kinetic energy to these tissues may result in shattering. Bone tends to deform in a drill-hole fashion secondary to low velocity bullet wounding, and usually shatters secondary to high velocity wounding. A bullet that fragments or deforms upon impact, or one that displays projectile instability (yaws, spins, or tumbles) will usually create a large path and cavity. Similarly, dense tissues (especially bone) can become secondary missiles following transfer of kinetic energy from the bullet, thereby creating their own path and cavity and further increasing the projectile's wounding potential.

SURGICAL MANAGEMENT

An appropriate history should be obtained, and the victim stabilized systemically, and locally at the site of the gunshot wound. Tetanus prophylaxis should be administered and radiographs obtained. If no further studies (angiogram, CT scans) are required, a through surgical debridement should be undertaken in the operating room. The authors also recommend initiating intravenous antibiotic prophylaxis (cefazolin), although this is controversial in the management of low velocity injuries.[2,3] The authors feel that all gunshot wounds are contaminated and warrant the administration of an appropriate antibiotic, especially those wounds involving necrosis and bone destruction. Moreover, we recommend taking a conservative approach to osseous reconstruction, and often perform only debridement (including packing with antibiotic-impregnated PMMA beads) and stabilization of skeletal defects during the initial surgery. This is followed by definitive skeletal reconstruction, often requiring autogenous bone grafting and skin grafting, performed several days after the initial debridement, after confirmation of negative intraoperative microbiology reports. (Fig. 2 A-E) This two-stage technique is more time consuming and may be more costly in the initial phases of treatment when compared to one-stage treatment protocols, however we believe that it decreases the likelihood of encountering significant morbidity related to osteomyelitis and/or bone healing defects secondary to low velocity gunshot wounds of the lower extremity.

Fig. 2A. Low velocity 9 mm gunshot wound in young male. Oblique radiograph shows round retained in plantar vault and comminuted defect of fourth metatarsal base.

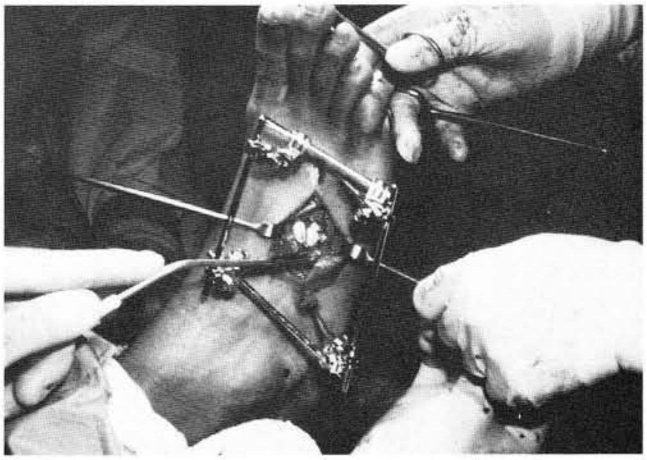

Fig. 2B. Initial surgical management using debridement and packing with antibiotic-impregnated PMMA beads, and skeletal stabilization with small external frame.

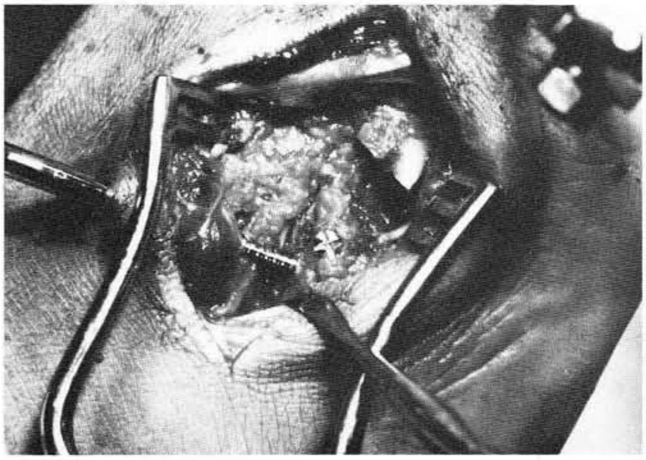

Fig. 2C. Definitive osseous reconstruction three days after initial debridement, displaying large segmental defect of metatarsal base region.

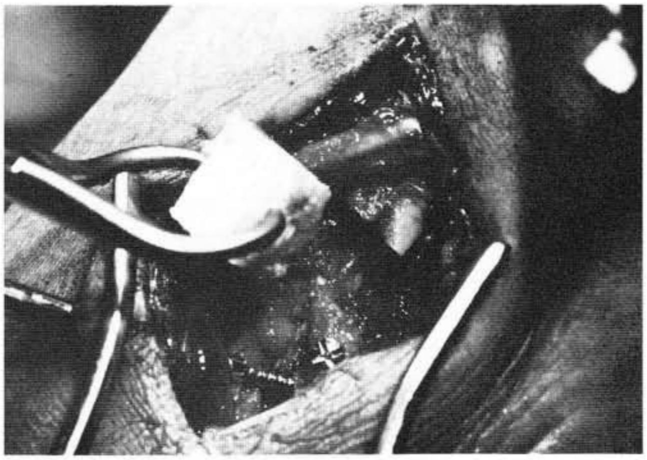

Fig. 2D. Autogenous corticocancellous bone graft harvested from ipsilateral calcaneus used to reconstruct metatarsal base..

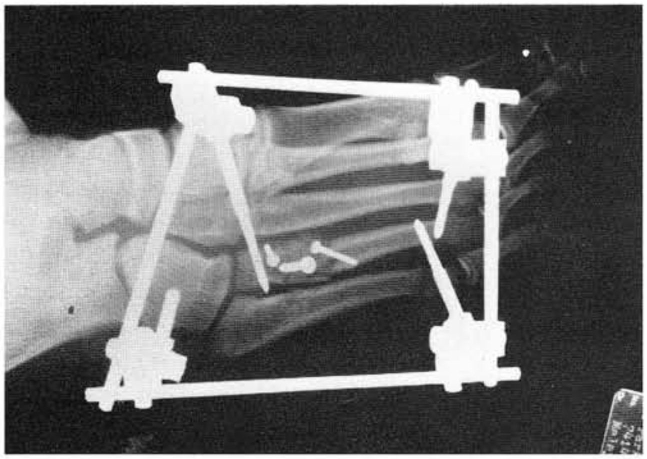

Fig. 2E. Oblique radiograph showing combination of external and internal fixation devices used in definitive reconstruction.

REFERENCES

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