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Diameter of Cranial Gunshot Wounds As a Function of Bullet Caliber

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ABSTRACT: Determination of bullet caliber becomes increasingly important in homicides where the bullet is missing. In cases with entrance wounds to bone that are circular and well defined it may be tempting to measure the defect and offer suggestions about bullet caliber. For this reason, the relationship between wound diameter and bullet caliber was examined using cranial bones from autopsy cases. The minimum diameter of 35 cranial wounds produced by .22, .25, and .38-caliber bullet was measured. The relationship of minimum wound diameter to bullet caliber was examined using a one way analysis of variance. Fisher's least significant difference test revealed no significant difference between .22-caliber and .25-caliber wounds, while the .38-caliber wounds were significantly different ($P < .001$) from .22-caliber and .25-caliber wounds. Variation in wound size resulting from such factors as bullet shape, surface treatment, strength characteristics, loss of gyroscopic stability, intermediate targets, tangential impacts, and existing fractures are discussed. Also, the large variety of calibers available are noted as complicating the prediction of caliber from wound size. In view of these factors caution is recommended in any attempt to determine precise bullet caliber from the minimum dimensions of the cranial gunshot entrance wound.

KEYWORDS: physical anthropology, ballistics, gunshot trauma, forensic anthropology

According to media reports [*1*], the murder rate in the United States during 1993 was 9.3 per 100,000. Handguns were used in 55.4% of all homicides in 1992, which was up from 43.5% in 1982 [*2*]. In cases involving handguns, the bullet has obvious evidentiary value but is frequently not recovered during an autopsy. Bullets may exit and be lost at the scene, may be lost during surgery, or may be absent with skeletal remains. Determination of bullet caliber is important to the investigation, and forensic scientists may be asked to provide caliber estimates by examining tissue wounds in cases where the bullet is missing.

Referring to skin Di Maio [*3*] states that the diameter of the entrance cannot be used to determine bullet caliber. Larger caliber bullets can produce entrance wounds having the diameter of a smaller caliber and vice versa. Wound size is a function of bullet diameter, skin elasticity, and the wound location. Whether the skin is lax or tightly stretched can affect wound size. But when a gunshot wound is in bone, circular, and well defined, it is tempting to assume that wound diameter reflects the dimensions of the bullet. Our experience indicates that some bone wounds closely approximate known bullet caliber, but the potential for predicting caliber from wound size remains undetermined.

We examined the relationship between bullet caliber and cranial entrance wound diameter. In addition, variables that can complicate caliber prediction will be reviewed. These variables are understood by firearms examiners and terminal ballistic experts but are usually unknown or poorly understood by anthropologists.

Methods

Wounds in bone are routinely processed to remove soft tissue and oil and retained as evidence at the Regional Forensic Center, Memphis, Tennessee. Although specimens with wounds produced by many handguns were available, only three bullet calibers were used: .22 ($n = 16$), .25 ($n = 8$), and .38 ($n = 11$). The vaults selected were limited to those with wounds produced by known calibers in which the bullet was recovered and where there was no indication that the entrance wound was produced by a bullet fragment. A total of 35 cranial vaults with gunshot wounds from known weapons met these rigorous selection criteria.

A dial caliper calibrated to 0.001 inch (0.003 mm) was used to measure the wounds. Each entrance wound was measured from the external margin as identified by a sharp circular contour, and the frequent presence of bullet wipe. The maximum dimension of a circular entrance wound was measured, however a wound obviously fractured beyond the dimensions of the projectile was more problematic. In these cases, the defect was closely examined for bullet wipe and remnants of the circular contour from which the measurement could be taken.

Results and Discussion

Wounds produced by .38-caliber bullets were significantly larger than wounds produced by .22-caliber or .25-caliber bullets ($P < .001$). No significant difference was found between wounds produced by .22-caliber and .25-caliber bullets ($P = .360$).

Little difference exists between the wounds produced by .22-caliber and .25-caliber bullets (Table 1). Interestingly, the mean

TABLE 1—*Mean diameters and ranges by bullet diameters (inches).*

Caliber	Mean	Range	SD
.22	0.30	0.22–0.43	0.066
.25	0.28	0.25–0.36	0.037
.38	0.46[a]	0.32–0.72	0.069

[a].38-caliber differs from .22- and .25-caliber wounds ($P < .001$).

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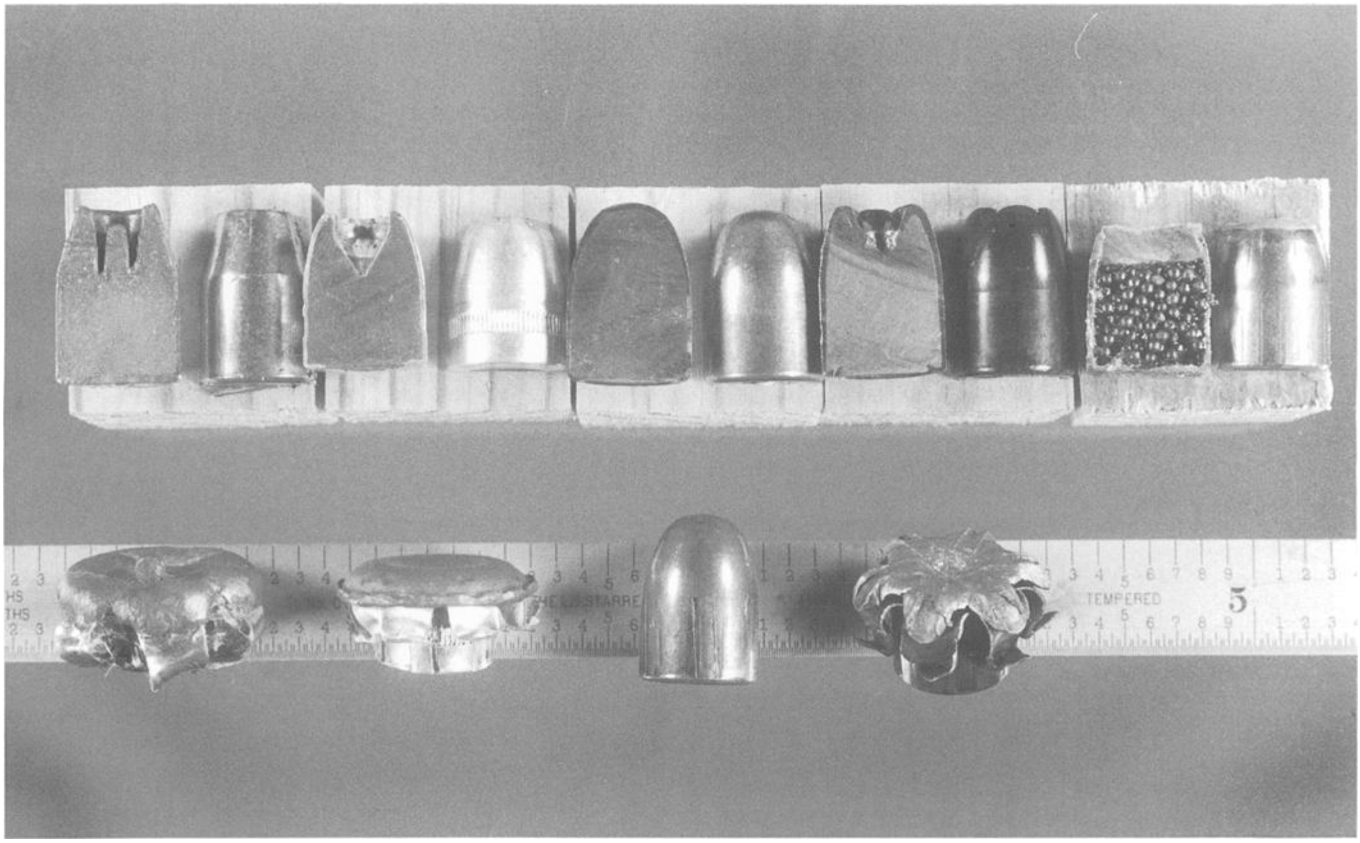

FIG. 1—*Relationship of bullet design to bullet deformation. From left to right, Hydra-Shok® hollow point, Silver Tip® hollow point, military, full metal jacketed, round nose bullet, Black Talon® hollow point, and Glaser® (fragmenting rounds).*

size and range of .25-caliber wounds are less than those produced by .22-caliber bullets. The .38-caliber wounds are clearly larger than those of either a .22-caliber or a .25-caliber. The maximum diameter of a wound produced by a .22-caliber bullet was .43 inch (10.92 mm) while the largest defect produced by a .25-caliber bullet was .36 inch (9.14 mm). However, the minimum diameter of a defect produced by a .38-caliber bullet (.32 inch or 8.13 mm) overlaps with the upper range of both .22-caliber and .25-caliber bullets.

Gunshot entrance wounds in this study were typically larger than the bullet caliber that produced them. However, some wounds were smaller. Also, wound shape varied from circular to oval to irregular. Factors influencing size and shape of gunshot wounds include the loss of bullet yaw angle, intermediate targets, tangential impacts, existing fractures, the large variety of calibers available, and variation in bullet shape, surface treatment, and strength characteristics. Before bullet caliber can be determined from the size of the gunshot wound, these factors must be understood.

The internal surface of a rifle or a handgun barrel is rifled to produce spiraled lands and grooves. These features induce spinning in a bullet as it is propelled along the barrel of a gun. Spin imparts gyroscopic stability to the bullet along its longitudinal axis, making it more accurate in flight.

When a stable bullet enters perpendicular to the target, the result

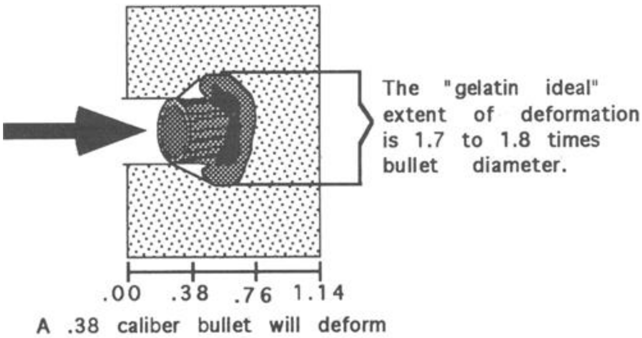

FIG. 2—*Bullet deformation within two calibers of penetration.*

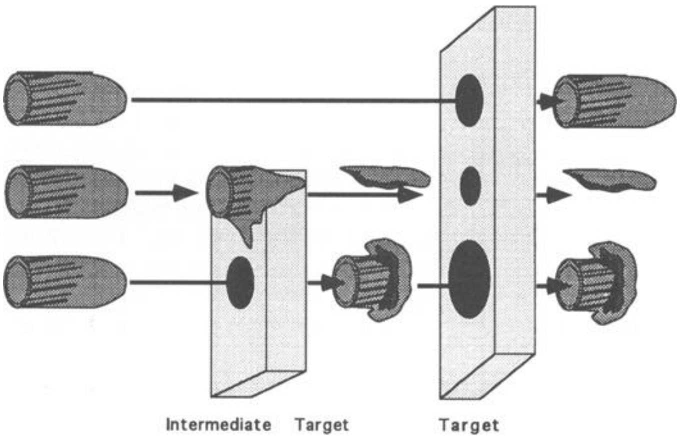

FIG. 3—*The effect of an intermediate target on target defect dimensions.*

is often a circular defect closely approximating the diameter of the bullet. A bullet may become unstable for many reasons including poor quality or heavily fouled guns which may result in a loss of gyroscopic stability. The resulting yaw or precession causes the bullet to impact the target in some way other than nose first which can produce an irregular defect larger than the caliber. Stability can also be lost when bullets of smaller diameter are fired in a larger caliber gun, when the bullet ricochets or strikes an intermediate target, or after traveling an extreme distance.

The angle of incidence of the bullet relative to the target may also affect the characteristics of the gunshot wound. Tangential impacts to the skull typically produce gutter wounds classified according to degree of bullet penetration [*3*]. Class 1 gutter wounds affect the outer table only, without penetration of the vault. Class 2 gutter wounds groove the outer table and fracture the inner table again without entering the vault. In a Class 3 gutter wound, the bullet or a fragment may enter the cranium, leaving an elongated defect. Class 3 wounds, also called keyhole defects, have been described by both Dixon [*4,5*] and Di Maio [*3*].

Keyhole defects occur when bullets impact at an acute angle to form an ovoid wound with fractures radiating ahead of the bullet. As the bullet advances, fragments produced by radiating fractures become elevated, and connecting fractures form perpendicular to the radiating fractures. Bone fragments delimited by these fractures are propelled outward as the bullet passes through. The final defect resembles a keyhole, although some wounds are irregularly shaped. Wounds from tangential shots, as observed in this study, were larger than bullet caliber and often had a morphology that made them more subjective to measure.

Hardness or strength of the bullet and bullet shape also affect wound size and shape. Jacketed bullets have a lead core covered with another type of metal, frequently a copper alloy but sometimes aluminum. They may have a full-metal-jacket (more covered) or a semijacket (less covered) or may be totally encased in electrodeposited metal. Bullets may also be thinly washed with copper or clad in nylon. Jacketed bullets are usually stronger and resist deformation upon striking a target, whereas nonjacketed bullets deform more and produce larger wounds. The presence of a bullet jacket, along with the small sample size, probably explains the narrow range of the .25-caliber wounds relative to the wider range of the .22-caliber wounds. Most .25-caliber bullets have a strong, full metal jacket capable of resisting deformation, while .22-caliber bullets are made of soft lead that deforms more readily.

Bullet manufacturers vary bullet design to address specific needs and to make bullets more effective. Typical designs include round nose, hollow point, wadcutter, semi-wadcutter, fragmenting, exploding, armor-piercing and truncated cone rounds. Figure 1 illustrates the relationship of bullet design to bullet deformation. Each .45-caliber bullet is displayed in longitudinal section, beside a view of the external bullet surface. Bullets fired into 20% ballistic gelatin are displayed on the ruler to illustrate variation in deformation. The Glaser® is a copper alloy container filled with small lead shot that disrupts upon impact with a target, releasing the shot. The full-metal-jacket military bullet showed no deformation after being fired into gel, whereas, hollow points did.

In our experience, bullet deformation typically occurs within 1 to 2 calibers of target penetration. For example, .38-caliber bullets deform within .38 to .76 inch of penetration (Fig. 2). We have found that the "gelatin-ideal" extent of deformation is about 1.7 to 1.8 times bullet diameter.

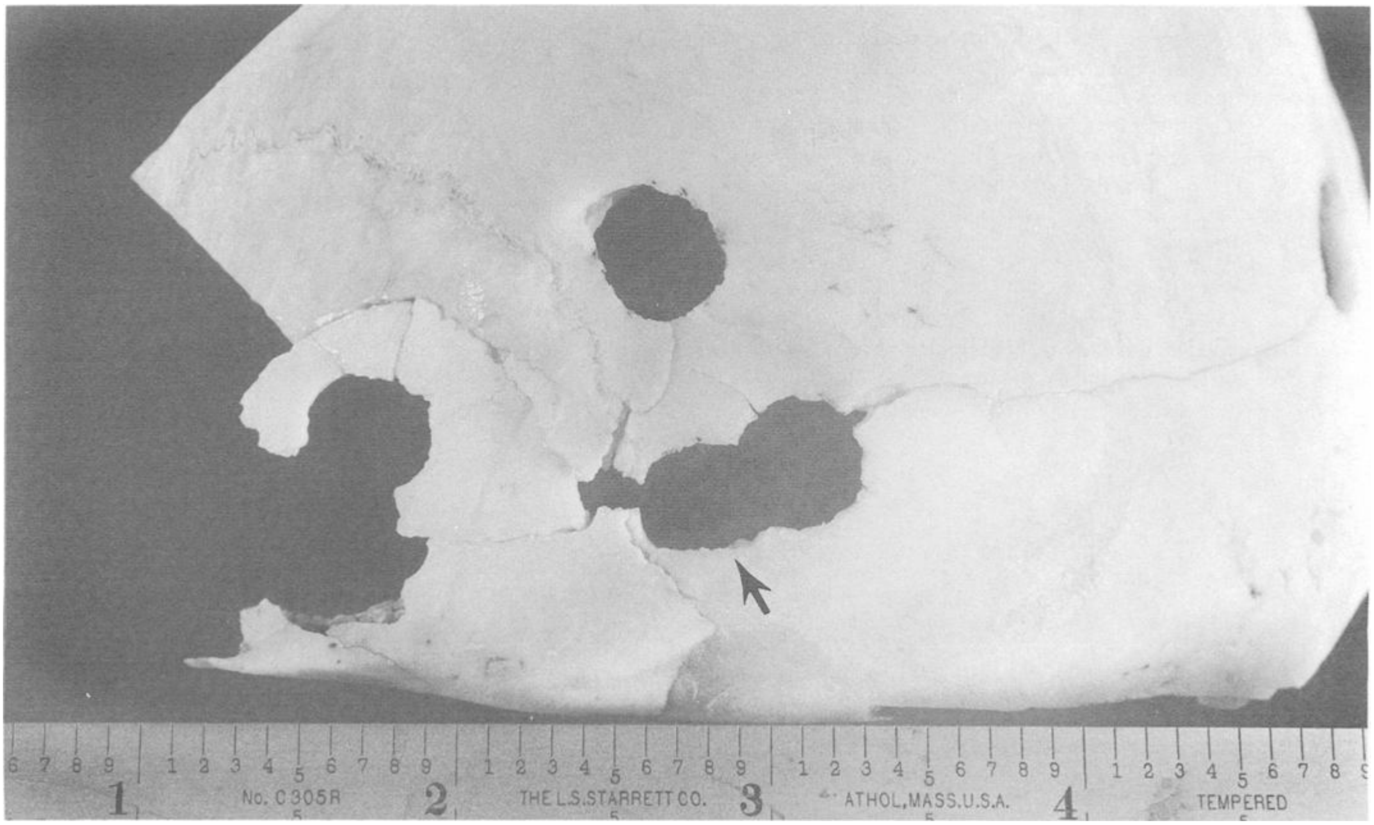

FIG. 4—*Portion of a vault exhibiting five gunshot wounds produced by a .22-caliber gun. The arrow points to the smaller wound, which resulted from the bullet passing through an existing fracture.*

The presence of intermediate targets can result in a defect in the primary target that is larger or smaller than the caliber of the bullet. An intermediate target can be anything: window glass, door, clothing, or the soft tissue overlying a bone. Figure 3 depicts three bullets being fired at a target. The top bullet impacted the target directly, leaving a defect approximating bullet caliber. The middle bullet struck an intermediate target and fragmented, leaving a smaller segment to impact the target. The defect produced by the fragment may more closely approximate a bullet of smaller caliber. The bottom bullet penetrated the intermediate target and deformed or may even have tumbled before striking the primary target. The defects produced by deformed bullets may more closely approximate a bullet of larger caliber.

A bullet entering through existing fractures can result in a wound that appears smaller than the caliber. Figure 4 shows a portion of vault with five entrance wounds from a .22 caliber handgun. One of these wounds is smaller and appears to have been produced by a smaller caliber. However, this particular wound occurred within an existing fracture that radiated from a previous gunshot wound. When the fractured margins of bone are apposed, the wound appears smaller than the other wounds although they are all from the same caliber.

A final hinderance to identifying bullet diameter from defect size is the large number of handgun calibers. With over 36 centerfire calibers in existence, bullets range in size from 2.7 mm (approximately 0.1 inch) to .50-caliber [6]. Although some of these calibers are obsolete, an examination of the relative size of some of the most common, contemporary handgun calibers (for example, .22, .25, .32, 9 mm, .38, .45) illuminates another problem in correct classification. If no other factors are involved, a wound produced by a .22-caliber bullet can perhaps be distinguished from a .32-caliber and definitely from a .45-caliber. But how can a wound produced by a .357-caliber bullet be differentiated from a 9 mm, .38-, or a .40-caliber bullet, or how can a wound produced by a .44-caliber be distinguished from one produced by a .40- or a .45-caliber bullet? Cartridge nomenclature further complicates matters. A .40-caliber and a 10 mm bullet are the same size; a .38-caliber and a .357 magnum fire the same bullet, which measures .357 inch in diameter. Additionally, a .44-caliber measures 0.423 inch and a .45-caliber 0.451 inch.

Conclusion

Wounds produced by a .38-caliber bullet were significantly larger ($P < .001$) than wounds produced by a .22-caliber or a .25-caliber, while no significant difference was observed between defects produced by a .22 and a .25. But, before any determination of bullet caliber from a gunshot defect to bone can be determined, a number of factors must be considered. These factors include the large variety of calibers available, some of which are very close or identical in diameter. Also, bullets vary in shape and surface treatment, causing some to deform and produce a larger wound. The loss of gyroscopic stability may result in a more irregular or larger defect. Intermediate targets can result in a defect that is larger (from tumbling or deformation) or smaller (from fragmentation) than the bullet caliber. Another factor is a tangential shot which results in an irregularly shaped defect with portions that may be larger than the caliber. Finally, bullets that pass through an existing fracture may leave a defect that is smaller than the caliber. With additional research and larger sample sizes, it may be possible to eliminate suspect weapons, but it may never be possible to identify the specific caliber from a single measurement of the defect. Caution is recommended in cases where knowledge of the stated factors is lacking.

Acknowledgment

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