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Gunshot Entrance Wound Abrasion Ring Width as a Function of Projectile Diameter and Velocity

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ABSTRACT: The relationships between gunshot entrance wound abrasion ring widths versus projectile diameter and velocity, using foam-backed deer hides as targets, were investigated. At a fixed velocity, abrasion ring width increased with increasing projectile diameter but decreased in proportion to the central defect diameter. For fixed-diameter projectiles, very slow and high velocities produced minimal abrasion width. Maximal abrasion width occurred at intermediate velocities.

The authors postulate that abrasion width is a function of the ratio of projectile velocity and the maximum deformation velocity of the target skin. The largest abrasion width occurs when the ratio is one. Using a projectile velocity known to produce maximum abrasion width at an initial warm temperature, then decreasing the target deformation velocity by cooling, produced the expected results of decreasing abrasion width.

KEYWORDS: criminalistics, wound ballistics, abrasion rings, gunshot wounds

During the course of preparing a previous report regarding the similarities and dissimilarities of field-tipped arrow and gunshot entrance wounds, we observed various relationships between the projectile diameter and velocity versus the size and relative prominence of the entrance wound abrasion ring [*1*]. Abrasion rings appeared larger with larger projectiles than with smaller projectiles. We also noted that very slow-moving projectiles produced little, if any, abrasion ring. Unfortunately, we were unable to find any relevant literature addressing the relationships of projectile diameter and velocity to the entrance wound abrasion ring size.

Since projectiles of very high velocity are known to produce minimal abrasion rings [*2*], the authors propose that, with a fixed-diameter projectile, the abrasion ring width will increase from very small with slow projectiles, will peak with intermediate velocity projectiles, and then will decrease again as the projectile velocity increases. The explanation for this phenomenon is unknown; however, we propose that it can be found by looking at the relationship between the projectile velocity and the deformation velocity of the target membrane (skin). Procedures which would decrease skin deformation velocities (deformability), such as cooling, should have the effect on abrasion ring width of increasing the projectile velocity. Thus, projectile velocities producing maximum abra-

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sion ring width at warm temperatures should show decreasing abrasion ring width with falling skin temperatures.

The relationship between projectile diameter and abrasion ring width (assuming fixed velocity) was less clear from our previous work. The current project was also undertaken to see what relationships (if any) exist between projectile diameter and both the abrasion ring width and the relative abrasion ring width (abrasion ring outer diameter divided by the central defect diameter).

Methods

Firearm projectiles used to determine the relationship between projectile diameter and abrasion ring width were specially loaded rounds of the following types and velocities: .22-250 (536 m/s), .270 (526 m/s), .30 carbine (523 m/s), .357 magnum (502 m/s), .44 magnum (499 m/s), and 20-gage shotgun slug (477 m/s). Projectile velocities for the entire project represent five shot averages measured 6 m from the muzzle using an Oehler Model 33 Chronotac chronograph.

The relationship between projectile velocity and abrasion ring width was explored using .22 caliber projectiles of the following types and velocities: .22 CB (213 m/s), .22 long rifle (318 m/s), .22 magnum (414 m/s), and .22-250 (536, 627, 761, 850, 1095, and 1225 m/s).

Targets were obtained from fresh road-kill deer and consisted of shaved rectangular pieces of deer hide averaging 20 by 15 cm with a 1 to 2-cm-thick layer of underlying fat or muscle. The hides were prepared by placing them over correspondingly shaped pieces of 4-cm-thick, soft foam rubber pads so that 2 to 3 cm of hide extended beyond the edges of the foam rubber pad. The hide-pad complex was supported by a 0.3-cm-thick sheet of plywood. The peripheral edges of the hide, along with the plywood sheet were then nailed onto an underlying wooden frame. Shots were fired into the central, nondistorted portion of the hide target. The muzzle to target distance was 3 m. The shooting was done in two sessions with five shots taken in each category per session (with the exception of the second session where no 20-gage shotgun slugs were fired). The outside air temperature (OAT) was 5°C during the first session and 18°C during the second session. A third shooting session used .22-250 ammunition with a projectile velocity of 761 m/s. The OAT was −10°C. Groups of five shots were fired into a hide as it cooled from room temperature. Shots were fired at hide temperatures of 20, 14, 6, 4, and 0°C. Additional shots were fired into a frozen hide packed in dry ice (−78°C).

Recorded from each entry wound was a total abrasion ring diameter (A) and a central defect diameter (D), as illustrated in Fig. 1. Measurements were done using calipers and a millimetre rule, with individual results reported to the nearest 0.5 mm. For each wound, the ratio of A/D was determined as a measure of the relative prominence of the abrasion ring versus the size of the central wound defect. The abrasion ring width for each wound was calculated as $(A - D)/2$. For each category of projectile diameter or velocity A/D and $(A - D)/2$ results were calculated as either five- or ten-shot averages.

Results

The relationship between the projectile diameter and abrasion ring width (assuming a constant projectile velocity) is shown in Fig. 2, both as an average of the two shooting sessions and individually. The overall trend suggests that abrasion ring size increases with increasing projectile diameter.

As shown in Fig. 3, the relative prominence of the abrasion ring, however, appears to decrease with increasing projectile diameter.

The relationship between the abrasion ring width and constant diameter projectile

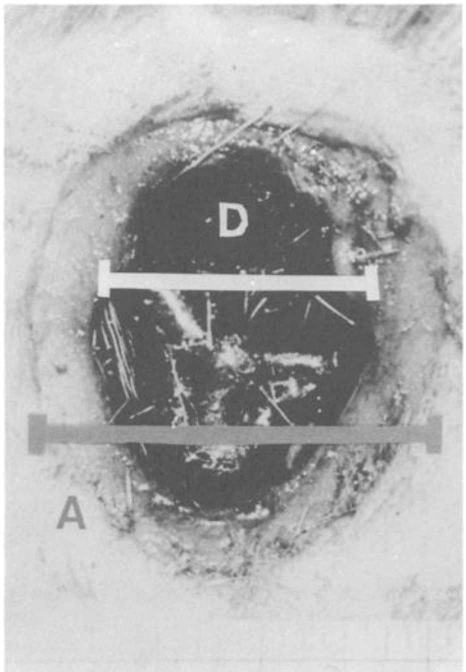

FIG. 1—*Gunshot wound with markers delineating the measurements used in this study.* A = *abrasion ring diameter;* D = *central defect diameter.*

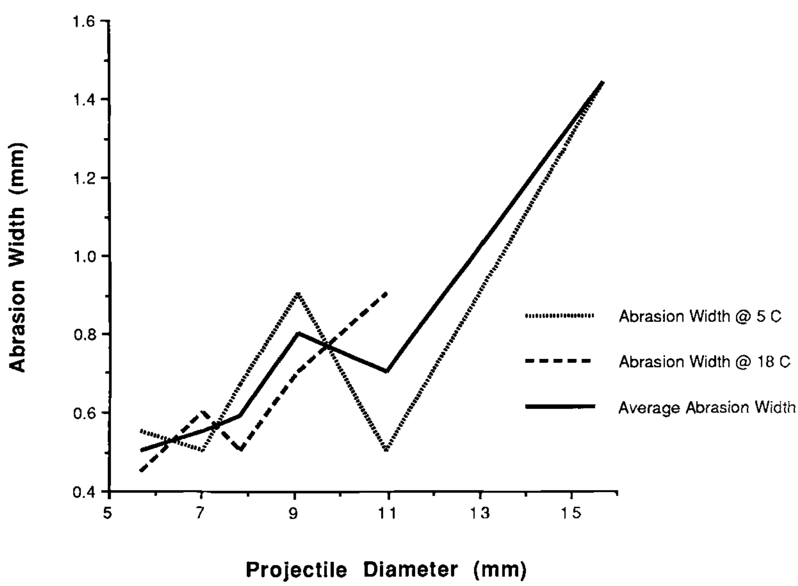

FIG. 2—*Relationship between the projectile diameter and the abrasion ring width, with constant projectile velocity.*

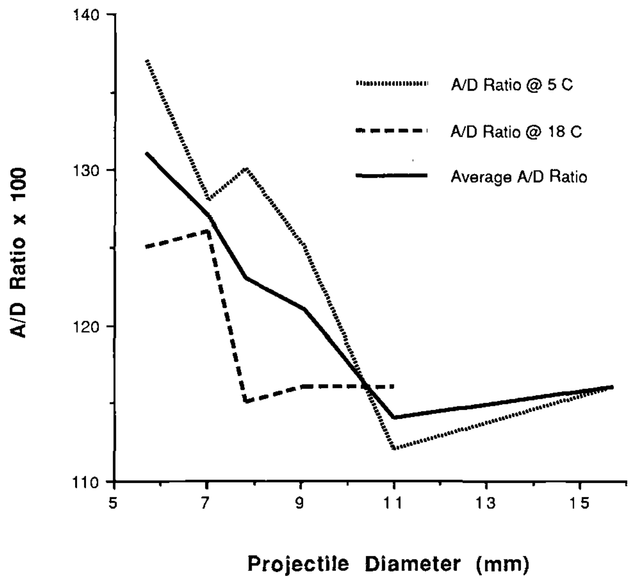

FIG. 3—*Relationship between the projectile diameter and the relative abrasion ring width* (A/D), *with constant projectile velocity.*

velocity is shown in Fig. 4. As predicted, low and high-velocity projectiles had small abrasion rings, while intermediate-velocity projectiles had peak abrasion widths. The trends between the shooting sessions were similar, but the warmer session produced larger abrasion rings (particularly for higher velocity projectiles) and a higher velocity for the peak abrasion width in comparison with the cooler shooting session. The two sessions, however, were statistically not significantly different. The relationship between the relative abrasion ring prominence (*A/D*) and the velocity had the same shape and general trend as depicted in Fig. 4.

The relationship between temperature and abrasion width (assuming a constant projectile diameter and velocity) is shown in Fig. 5. The abrasion ring width increased with increasing temperature, with the most dramatic change occurring for temperatures close to but above 0°C. At −78°C, the average abrasion ring width was only 0.05 mm.

Discussion

The results from this study show, as might be expected, that at a fixed velocity, the abrasion ring width increases with increasing projectile diameter (Fig. 2). Although the abrasion ring for a larger diameter projectile will be larger than that for a smaller projectile, the study shows that, in relation to the central defect, the abrasion ring width proportionally decreases with increasing projectile diameter (Fig. 3).

From our previous work [*1*] we had observed that slow projectiles leave little abrasion rings. High-speed projectiles are also known to produce small abrasion rings [*2*]. Given the above, the current study confirmed our hypothesis that abrasion ring width would increase and then decrease with progressively increasing fixed diameter projectile velocities (Fig. 4).

Although the explanation for the above phenomenon is unclear, we propose that it represents a function of the deformability of the target membrane relative to the velocity of the projectile. From our experience, nondeformable target membranes (for example,

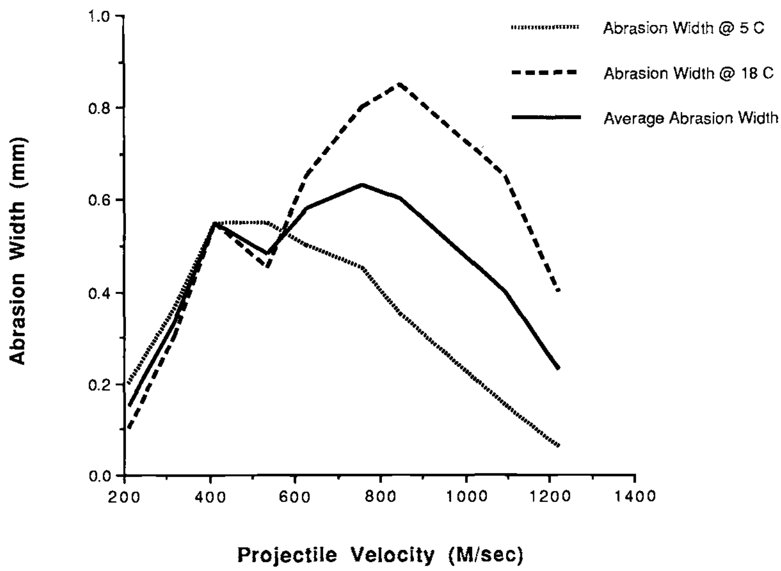

FIG. 4—*Relationship between the projectile velocity and the abrasion ring width, with constant projectile diameter.*

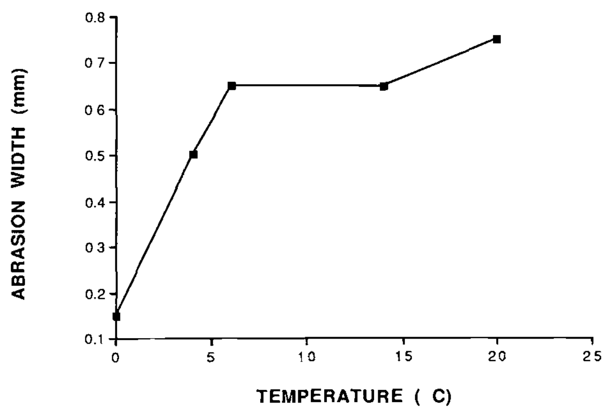

FIG. 5—*Relationship between the temperature and the abrasion ring width, assuming constant projectile diameter and velocity plus maximum abrasion ring width at the warmest temperature.*

wood, glass, frozen tissue, and so forth) are not associated with the creation of significant abrasion rings when struck by bullet projectiles. Very thin target membranes also may behave as nondeformable targets when the speed of the projectile is such that penetration/perforation occurs prior to any meaningful deformation of the membrane. Target membranes also may be rendered nondeformable if they are maximally stretched/deformed prior to projectile penetration.

We believe that in the instance of very slow or very fast projectiles, the absence of significant abrasion ring formation is due to the lack of deformability of the hide target membrane. With very slow moving projectiles, the target is nondeformable due to maximal deformation of the hide prior to penetration of the projectile (Fig. 6*a*). With very

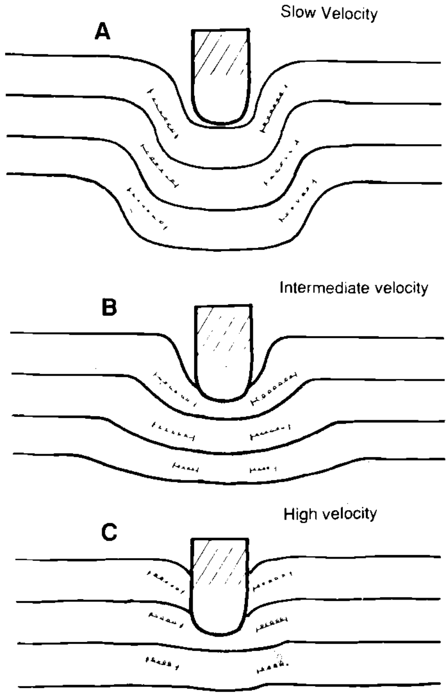

FIG. 6—*Graphic representation of projectile—target (skin) interaction illustrating maximal full thickness deformation with a slow-velocity projectile producing a minimal abrasion ring* (A), *differential target deformation at various layers producing a maximal abrasion ring* (B), *and minimal deformation (rapid penetration) for high-velocity projectiles producing a minimal abrasion ring* (C).

high velocity projectiles, the target membrane behaves like a thin membrane and becomes nondeformable by virtue of the rapid penetration of the projectile (Fig. 6*c*).

With intermediate-velocity projectiles, however, the deformation speed of the membrane and the projectile velocity are similar, allowing deformation of the membrane to occur prior to projectile penetration. As shown in Fig. 6*b*, once the membrane is allowed to deform there will be differential deformation of the membrane between the outer and inner layers. This differential deformation will allow the abrasion ring produced by the projectile shoulder to retract away from the main body of the central defect.

The presence or absence of an abrasion ring therefore appears to be related to the deformability of the membrane. With intermediate-velocity projectiles, the size of the abrasion ring also is a function of the projectile velocity versus the deformation velocity of the membrane. The abrasion ring width should peak when the projectile and maximum membrane distortion velocities are equal.

Figure 4 shows that the effect of decreasing the maximal target distortion velocity (deformability) should be that of shifting to the right on the graph (Fig. 4) or increasing the projectile velocity. In this study, we decreased the membrane distortion velocities (deformability) by cooling the target hides and thereby reducing their elasticity as the fatty tissue became less fluid. If a projectile velocity is chosen which initially produced a maximal abrasion ring on a warm hide and the velocity is fixed, cooling the hide should produce the effect of increasing the projectile velocity, that is, decreasing the abrasion ring width (see Fig. 4). Indeed, that was the observed effect (Fig. 5).

From Fig. 4 we see the same temperature effect as in Fig. 5. As would be expected, the maximum abrasion width on the warmer shooting day occurred at a higher velocity than on the cooler shooting day. The relationship between abrasion width and temperature was less clear with fixed projectile velocities and varying projectile diameters (Fig. 2). The abrasion width maxima, shown in Fig. 4, may vary for projectiles of different diameter. Thus, for a given velocity, the abrasion ring width observed for one diameter projectile may be to the left or right of the velocity, producing maximal abrasion width size for another projectile diameter. Decreasing the temperature would actually be expected to increase the abrasion width for a left shift and decrease the abrasion width for a right shift (as shown in Fig. 5).

Our study indicates that the character of an abrasion ring produced in a gunshot wound of entrance depends on the projectile velocity and diameter, along with the temperature of the target skin. Obviously, the projectile shape, relative trajectory, thickness of the target skin, and intermediate targets are other potentially very significant variables that were not specifically addressed in this study. We hope, however, that understanding some of the variables involved in the formation of abrasion rings will assist in the interpretation of gunshot entrance wounds.

Acknowledgments

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