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Gunshot residue patterns on skin in angled contact and near contact gunshot wounds

T. Plattner[a,*], B. Kneubuehl[b], M. Thali[a], U. Zollinger[a]

[a]*Institute of Forensic Medicine, University of Berne, Bühlstrasse 20, 3012 Berne, Switzerland*
[b]*Defence Procurement Agency, MoD, Ballistics and Detonics Lab, CH-3602 Thun, Switzerland*

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Abstract

The goal of this study was the reproduction of shape and pattern of gunshot residues in near contact and contact gunshot wounds by a series of experimental gunshots on a skin and soft tissue model. The aim was to investigate the shape and direction of soot deposits with regard to the muzzle according to different muzzle-target angles, firing distances, type of ammunition and weapon and barrel length. Based on a review of the literature and on the results of the experiments the authors could make the following statements of gunshot residues in angled contact and close contact gunshot: (1) gunshot residues on the target surface can be differentiated in a ‘‘inner’’ and ‘‘outer powder soot zone’’; (2) the outer powder soot zone is much less visible than the inner powder soot zone and may lack on human skin; (3) with increasing muzzle target distance both inner and outer powder soot halo increase in size and decrease in density; (4) in angled shots the inner powder soot halo shows an eccentric, elliptic shape which points towards the muzzle, regardless of ammunition, calibre and barrel length; (5) the outer powder soot points away from the muzzle in angled contact and close contact shots.

Keywords: Ammunition; Target; Muzzle; Muzzle-target angle; Gunshot residues

1. Introduction

Gunshot residues on the skin of a victim are important evidence for reconstructive questions in the forensic investigation of cases involving gunshot wounds [1]. Powder soot may help to differentiate between entrance and exit wounds, draw conclusions on the muzzle-to-target distance and on the muzzle-target angle [2–4]. The pattern of gunshot residues is influenced by various factors including the distance between muzzle and target, target, weapon and ammunition parameters and the muzzle-target angle [3–5]. When the barrel is pointed perpendicular to the target surface (muzzle-target angle $\beta = 0^\circ$ (Fig. 1)) powder soot will be arranged in a more or less circular zone around the entry wound, its diameter increasing with increasing distance from muzzle to target [6]. When the muzzle is firmly pressed on the skin (contact shot), no soot or only a small amount of soot will be found around the entrance wound. Since the muzzle is sealed by skin, the majority of soot will be found underneath the skin in a wound-pocket caused by the propulsion of gases [1,2]. When the barrel is held at a acute angle to the skin (muzzle-target angle $> 0^\circ$ (Fig. 1)), the gunshot residues show an eccentric (elliptic) shape. A review of the relatively scarce literature on this subject shows contradictory statements on the direction in which the major part of the gunshot residues would point to with regard to the direction of the barrel. According to Hofmann–Haberda [7] the major part of the oval powder soot zone points *away* from the muzzle whereas Spitz [8] states that the major part of the gunshot residues would likely be pointing towards the muzzle. Ballistic experiments by Elbel [9] showed that the pattern would depend on the barrel length: short barrels would produce a soot halo pointing towards the muzzle whereas in long barrelled weapons (rifles) the major part of the powder soot would point away from the muzzle. Di Maio [2] on the other hand states that in angled contact wounds, the majority of the powder soot will point *away* from the shooter whereas in near contact wounds the eccentric powder soot residues will be arranged in the opposite direction thus pointing *towards* the muzzle.

* Corresponding author. Tel.: +41-31-631-84-11.
E-mail address: plattner@irm.unibe.ch (T. Plattner).

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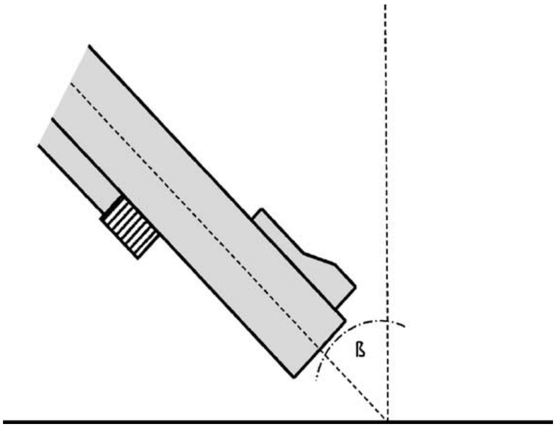

Fig. 1. Muzzle-target angle (β).

The problem in question may have practical consequences for the forensic reconstruction of bullet trajectories in contact and close contact gunshots. The determination of bullet trajectories on a victim may cause problems, as any forensic pathologist knows. In cases involving multiple gunshot wounds as well as in cases where a reconstruction of the bullet path is not possible (massive destruction by deformed projectiles and bone fragments) it may be difficult if not impossible to determine the direction from which the weapon was fired. In such cases gunshot residues on the skin could be valuable clues.

The authors tried to reproduce the shape of gunshot residues by a series of experimentally produced angled near contact and contact shots on a skin and soft tissue model. The aim was to investigate the powder soot pattern according to different muzzle-target angles, firing distances, type of ammunition and weapon and barrel length.

2. Methods and materials

Gunshots were fired in a special facility for ballistic experiments with the weapon securely mounted on a gun carriage. As targets we used naturally tanned calf skin leather fixed on soap and gelatine blocks to simulate skin and underlying soft tissue. Three different types of ammunition and weapons were used: 38 Spl. LRN metal piercing revolver cartridges fired with a Smith and Wesson revolver, 9 mm Luger full metal jacket pistol cartridges with a SIG Pistol P 210, and 22 L.R. cartridges. All shots were fired with nitrocellulose based propellant (NC-powder). The barrel length of the 22 L.R. weapon was exchangeable. We used barrels with lengths of 150, 250 and 650 mm. In the contact shots, the muzzle was firmly pressed to the surface slightly impressing the leather and the underlying soap/gelatine thus reproducing a realistic situation of a close contact gunshot in which the skin would be pressed against surrounding soft tissue or skull bone. In the near contact shots firing distances of 5, 10, 15 and 20 mm measured from the rim of the muzzle to the target surface were chosen. Muzzle-target angles were 0° (perpendicular to target surface), 20, 30, 45 and 60°. A high speed digital film camera was used to examine the development and shape of the powder cloud. Gunshot residues were stained by rhodizonate to reveal lead particles not visible by the naked eye [10,11].

3. Results

In the majority of the experimental shots gunshot residues were visibly arranged in two different zones as described by di Maio [2]. Around the entrance hole they showed a prominent and dense black powder soot halo (‘‘inner powder

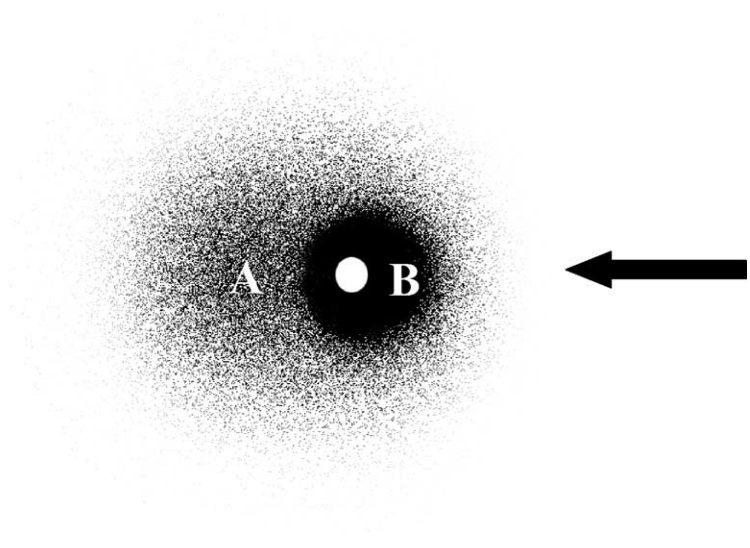

Fig. 2. Gunshot residue pattern on target surface in angled contact and close contact gunshots: (A) outer powder soot zone; (B) inner powder soot zone. Black arrow indicates direction of bullet.

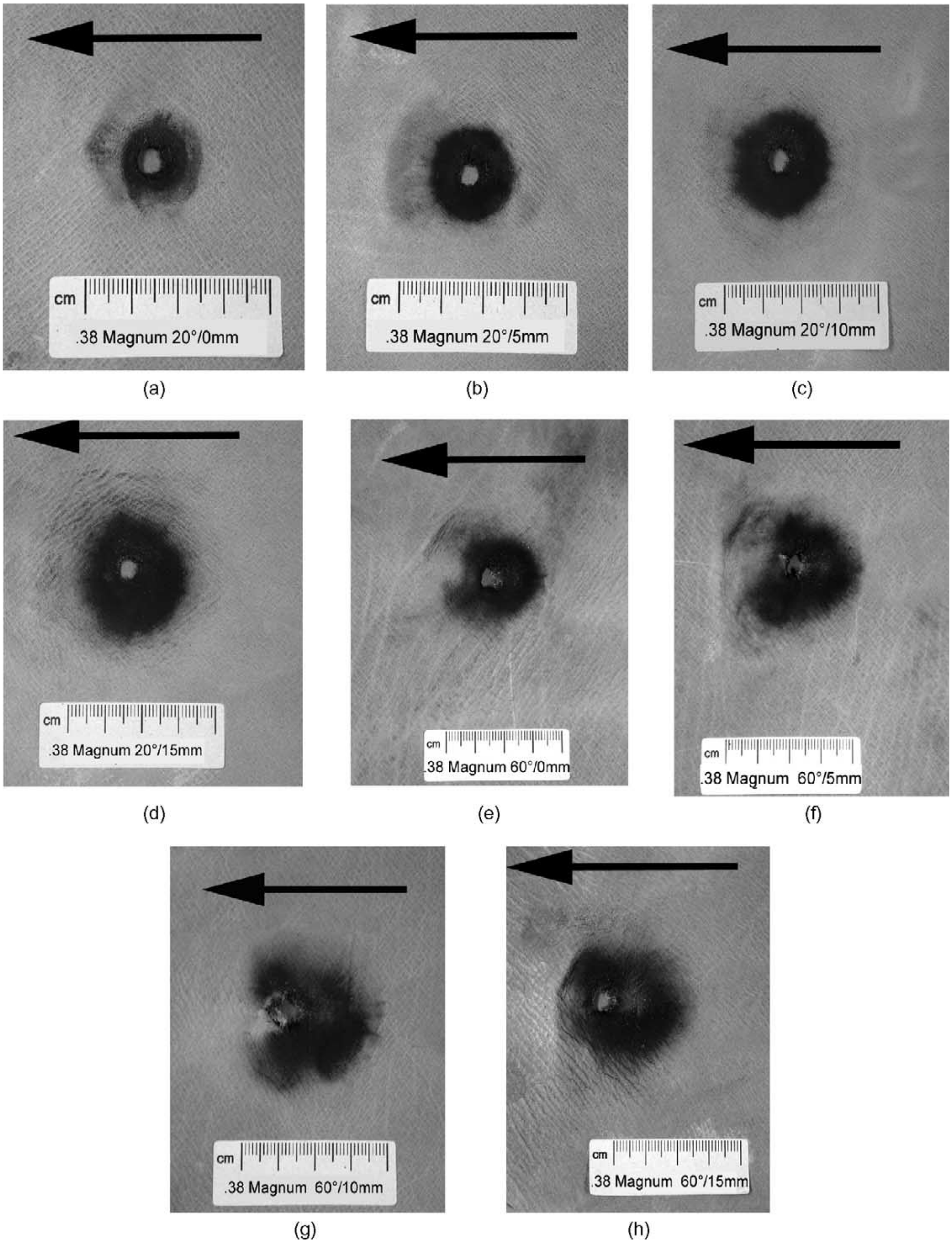

Fig. 3. Series of experimental shots with 38 Spl. LRN metal piercing revolver cartridges fired with Smith and Wesson revolver. Arrow indicates direction of bullet: (a) muzzle-target angle $(\beta) = 20^\circ$, muzzle target distance $(d) = 0$ mm (contact shot); (b) $\beta = 20^\circ$, $d = 5$ mm; (c) $\beta = 20^\circ$, $d = 10$ mm; (d) $\beta = 20^\circ$, $d = 15$ mm; (e) $\beta = 60^\circ$, $d = 0$ mm (contact shot); (f) $\beta = 60^\circ$, $d = 5$ mm; (g) $\beta = 60^\circ$, $d = 10$ mm; (h) $\beta = 60^\circ$, $d = 15$ mm.

soot zone'') which was clearly demarcated and surrounded by a larger, grey and barely visible cloud-like powder soot halo (''outer powder soot zone'' (Fig. 2)). In all shots the inner powder soot zone had an oval shape and became less dense and wider with increasing muzzle-target distance (Fig. 5). In small angled shots the inner powder soot zone was nearly circular (Fig. 3) whereas with increasing barrel-target angle β it adopted a eccentric and oval pattern (Figs. 3–6). In all angled shots, regardless of ammunition, weapon and barrel length, in contact and as well as in near contact wounds, the major part of powder soot residues of the ''inner powder soot zone'' viewed

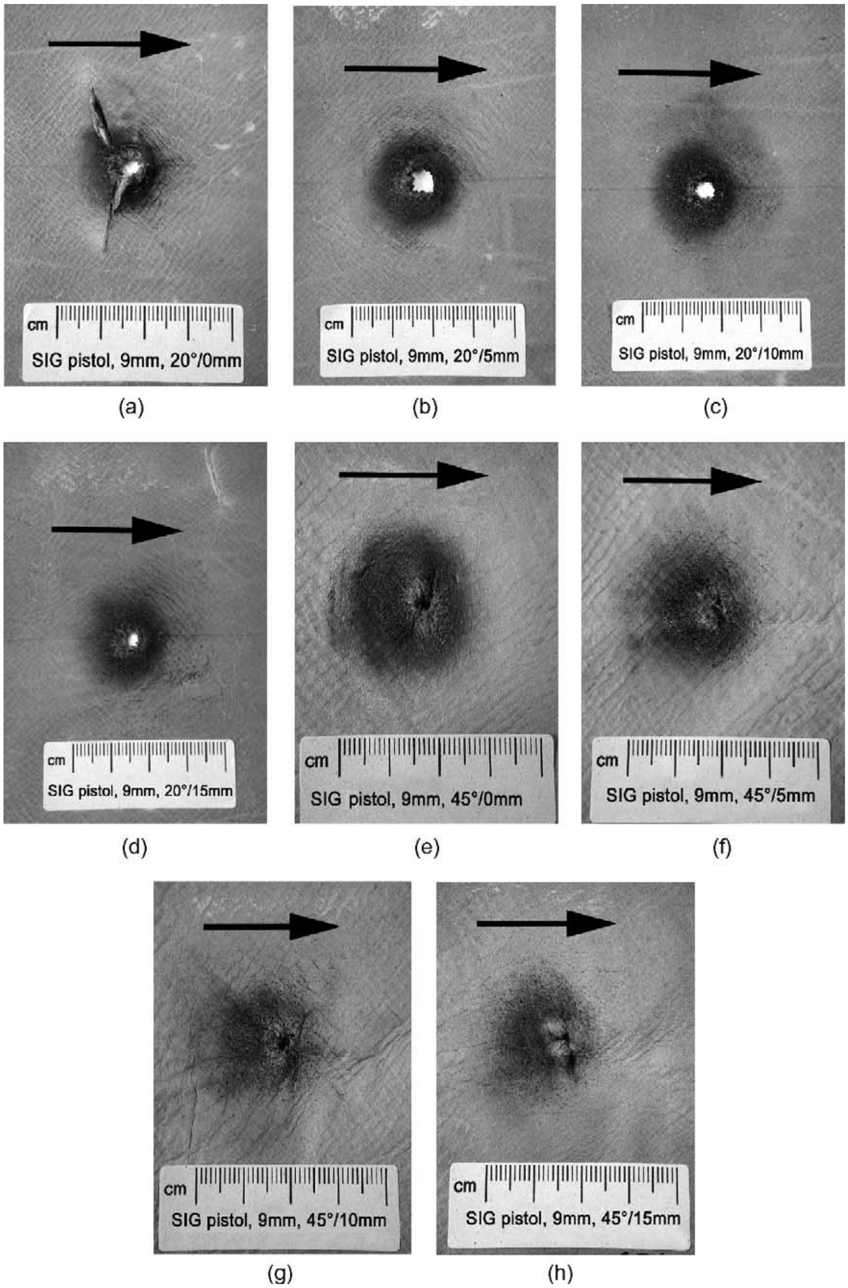

Fig. 4. Series of experimental shots with 9mm Luger full metal jacket pistol cartridges fired with SIG Pistol P 210. Arrow indicates direction of bullet: (a) muzzle-target angle $(\beta) = 20^\circ$, muzzle target distance $(d) = 0$ mm (contact shot); (b) $\beta = 20^\circ$, $d = 5$ mm; (c) $\beta = 20^\circ$, $d = 10$ mm; (d) $\beta = 20^\circ$, $d = 15$ mm; (e) $\beta = 45^\circ$, $d = 0$ mm (contact shot); (f) $\beta = 45^\circ$, $d = 5$ mm; (g) $\beta = 45^\circ$, $d = 10$ mm; (h) $\beta = 45^\circ$, $d = 15$ mm.

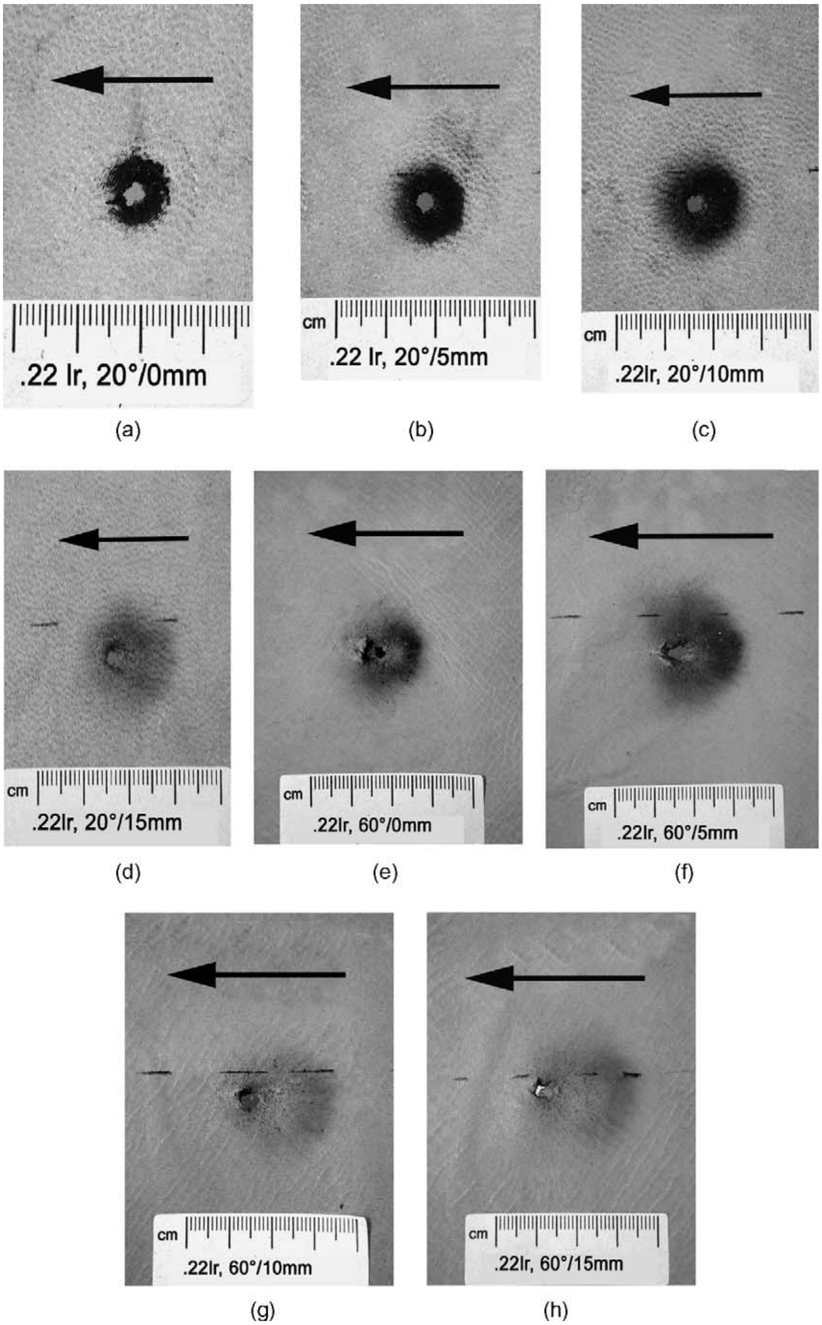

Fig. 5. Series of experimental shots with 22 L.R. cartridges fired with 150mm barrel. Arrow indicates direction of bullet: (a) muzzle-target angle $(\beta) = 20^\circ$, muzzle target distance $(d) = 0$ mm (contact shot); (b) $\beta = 20^\circ$, $d = 5$ mm; (c) $\beta = 20^\circ$, $d = 10$ mm; (d) $\beta = 20^\circ$, $d = 15$ mm; (e) $\beta = 60^\circ$, $d = 0$ mm (contact shot); (f) $\beta = 60^\circ$, $d = 5$ mm; (g) $\beta = 60^\circ$, $d = 10$ mm; (h) $\beta = 60^\circ$, $d = 15$ mm.

from the entrance hole was pointing *towards* the muzzle (Figs. 3–6). With increasing muzzle-target angle the entrance hole was ''migrating'' away from the muzzle towards the rim of the inner powder soot zone (Figs. 3–6). The ''outer powder soot zone'' was not as clearly defined and demarcated as the inner powder soot zone and showed circular, oval or pear-like shapes. In some shots the outer powder soot halo was not visible but could be demonstrated by the means of rhodizonat staining. In our experiments the ''outer powder soot zone'' pointed *away* from the muzzle thus having an opposite behaviour as the inner powder soot zone (Figs. 2–6).

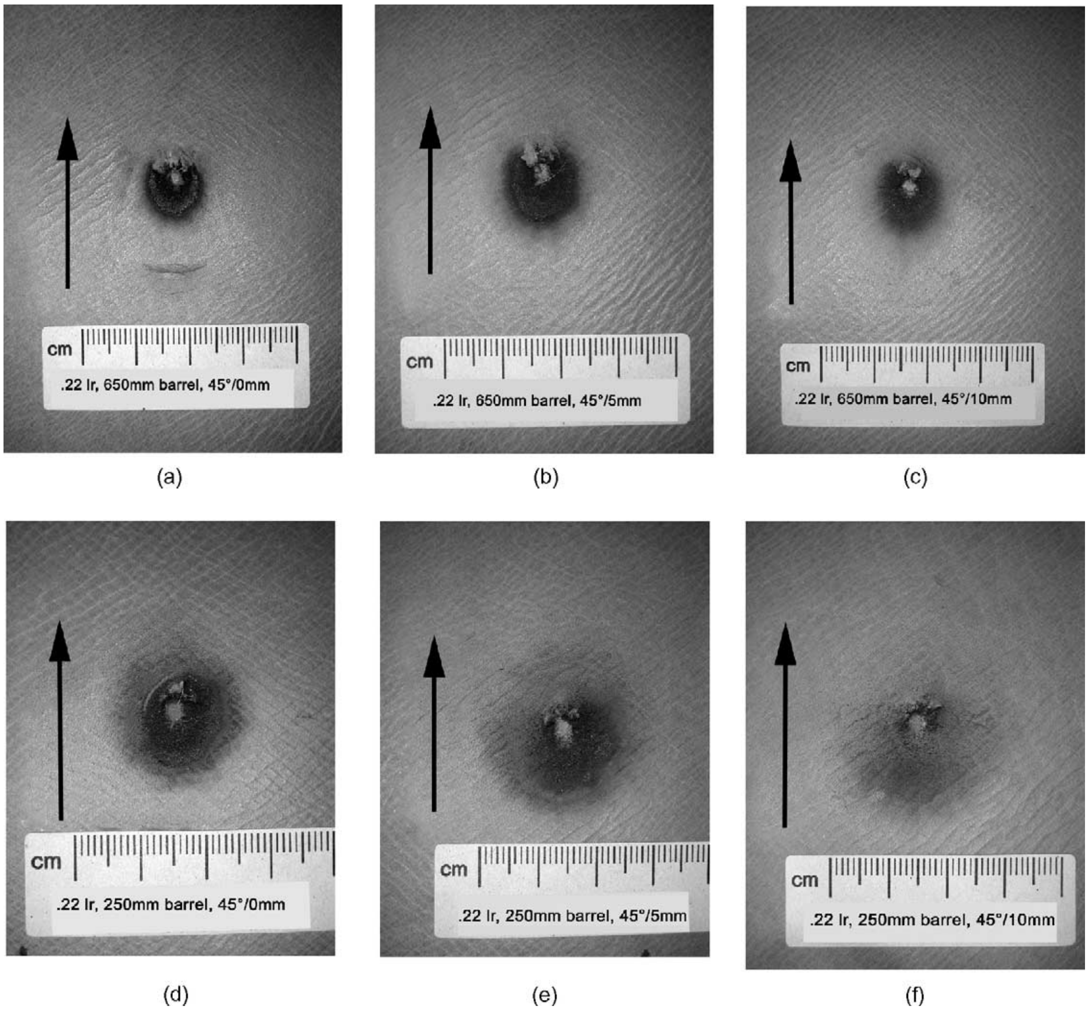

Fig. 6. Series of experimental shots with 22 L.R. cartridges fired with 250 and 650 mm barrel. Arrow indicates direction of bullet: (a) muzzle-target angle $(\beta) = 45^\circ$, muzzle target distance $(d) = 0$ mm (contact shot), 650 mm barrel; (b) $\beta = 45^\circ$, $d = 5$ mm, 650 mm barrel; (c) $\beta = 45^\circ$, $d = 10$ mm, 650 mm barrel; (d) $\beta = 45^\circ$, $d = 0$ mm (contact shot), 250 mm barrel; (e) $\beta = 45^\circ$, $d = 5$ mm, 250 mm barrel; (f) $\beta = 45^\circ$, $d = 10$ mm, 250 mm barrel.

The powder residues produced by 38 Spl. cartridges, 9 mm Luger pistol cartridges and the 22 L.R. cartridges differed only in the amount and size of powder residues due to the different amount of propellant. Shapes and patterns of soot according to muzzle-target angle and firing distance were comparable in all shots (Figs. 3 and 4). The 650 mm barrel showed more densely concentrated powder residues around the entrance hole than the shorter barrels (150 and 250 mm (Fig. 6)). The 650 mm barrel produced denser and smaller inner powder soot zones than the shorter versions (Fig. 6). Based on high speed film sequences we can confirm, that the shape of the powder soot cloud emerging from the muzzle is different in long and short barrelled weapons as described by Elbel. The 650 mm barrel produced a cylindric to cone shaped powder cloud whereas the 250 mm barrel showed a mushroom shaped powder cloud. This would account for the different shape of the gunshot residues produced by the long and short barrels. The observations of Elbel concerning the different orientation of the eccentric powder soot halo in long and short barrels could however not be reproduced. The eccentric inner powder soot residues always pointed towards the muzzle regardless of the barrel length.

4. Discussion

As a result of the study the authors conclude that the orientation of gunshot residues around the entrance wound on contact and near contact wounds may indicate in which direction the barrel was held with respect to the target surface. The phenomenon of the opposite location of the major part of gunshot residues in contact and near contact shots as well as a dependency of the orientation of soot from the barrel length could not be reproduced by our experiments.

It is important to differentiate ''outer'' from ''inner powder soot zone'', since they show a opposite orientation with regard to the muzzle. In a small number of the experimental shots, only the ''inner powder soot zone'' was visible whereas the ''outer powder soot zone'' could only be demonstrated by rhodizonat staining. We presume, that this would apply for human skin as stated by Di Maio.

It should be discussed if the nature of the propellant would have an influence on the gunshot residue pattern. In all our experimental shots NC-powder ammunition was used. The description by Hoffmann–Haberda made in 1911, however, probably refers to results produced by black powder. Black powder produces more gunshot residues than nitrocellulose and may therefore produce a more prominent outer powder soot zone than NC-powder. Hoffman made no differentiation of inner and outer powder soot zone. This may explain why our results seem to contradict the descriptions by Hoffmann. The experiments by Elbel, on the other hand, were conducted both with black powder as well as smokeless powder. Elbel saw no difference in the gunshot residue pattern produced by black powder- and smokeless powder ammuntion.

Based on a review of the literature and on our experiments the following statements of gunshot residues on human skin in angled contact and close contact gunshot wounds can be made

1. Gunshot residues on the target surface can be differentiated in a inner and outer powder soot zone.
2. The outer powder soot zone is much less visible than the inner powder soot zone and may lack on human skin.
3. With increasing muzzle target distance both inner and outer powder soot halo increase in size and decrease in density.
4. In angled shots the inner powder soot halo shows an eccentric, elliptic shape which points towards the muzzle, regardless of ammunition, calibre and barrel length.
5. The outer powder soot points away from the muzzle in angled contact and close contact shots.

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