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A study of the morphology of gunshot entrance wounds, in connection with their dynamic creation, utilizing the "skin–skull–brain model"

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Abstract

The goal of this study was to document the dynamic effects created within, and the developing mechanisms of a gunshot entrance wound to the skin utilizing high-speed photography and the "skin–skull–brain model". The high-speed photography was taken with an Imacon 468/Hadland-Photonics camera. Full metal jacketed, 9 mm Luger projectiles were fired at the target model from a distance of 10 m. During the evaluation of the "skin–skull–brain model", it was possible to show that injuries inflicted to this model are fully comparable to the morphology of equivalent real gunshot entrance wounds. It has been possible to document and study the dynamic process of the "bullet–skin-interaction" in the gunshot entrance wound. The development of the morphologic terms of the entrance wound are discussed. In combination with high-speed photography, this "skin–skull–brain model" is a perfect tool for the documentation and the study of the dynamic development of gunshot entrance wounds in the skin.

Keywords: Forensic science; Skin–skull–brain model; Head model; Entrance wound; Gunshot; Ballistic; High-speed photography

1. Introduction

In order to be able to understand the reciprocal actions between projectile and tissue, interdisciplinary knowledge is prerequisite. The behavior of a projectile in the human body is comprehensible only with a thorough understanding of biophysics. Apart from their substantial forensic scientific importance, this biophysical knowledge and an understanding of physical reactions are also important factors in the consideration of the best surgical procedures to be performed upon the gunshot victim. Consequently, it is important for the surgeon to know prior to planning an operation what bone and soft tissue (organ, blood vessel, and nerve) damage can be expected due to the wound channel and the extent of the temporary cavity in the body.

In forensic practice, the morphology of a gunshot wound plays an important role when considering the following questions: is it an entrance wound or an exit wound? From what distance and direction was the gunshot fired? And, what was the type of projectile? An exact understanding of the dynamic development of entrance gunshot wounds is necessary for obtaining forensic reconstructive conclusions. In this regard, however, to date there is no medical consensus.

Also, the terminology of the morphologic changes in the entrance wound, which terms often reflect the assumed causes of the changes, is not completely uniform. The most highly regarded textbooks and scientific papers [1–11] specify the following characteristics for the entrance wound by distant gunshots. Because the morphologic terminology has its origins in German language [10], the original German terms are subsequently included in parentheses (Fig. 1).

- In the center of the wound is a substance defect (in German "Substanzdefekt"), i.e. a "hole" in the epidermis/skin with a diameter approximating that of the penetrating projectile.

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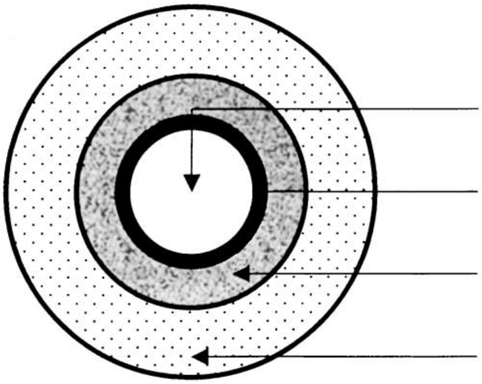


Fig. 1. For a overview and because the morphologic terminology of the entrance wound by a distant gunshot is not completely uniform and has its origins in German language beside the English terms also the original German terms are subsequently included in parentheses.

- Around this substance defect is a ‘‘ring of dirt’’, a feature known as bullet wipe or bullet wipe-off (in German ‘‘Schmutzring/Abstreifring/Randschwärzung’’). This occurs when black powder residue, gun oil, or dirt on the surface of the projectile is rubbed off the projectile onto the skin during the course of penetration [3,10]. Frequently, the dirt ring at the edge of the bullet hole can be differentiated from dried blood only under magnification.
- A further finding is the abrasion ring or margin abrasion (in German ‘‘Schürfsaum/Vertrocknungssaum/Dehnungssaum’’), which develops symmetrically, and concentrically around the substance defect during the head-on impact of the projectile and is generally 1–3 mm wide. In the case of tangential impacts, the abrasion ring is asymmetric in appearance, ‘‘cap shaped’’, and the semilunal abrasion or the broadest width points toward the gunshot's origin. Usually, the development of the abrasion ring is attributed to the contact of the skin with the exterior of the projectile [1,2,4,9].
- Around the entrance wound, a reddish–bluish bruising of the skin appears. This is called the contusion ring (in German ‘‘Kontusionssaum/Kontusionsring’’). The development of this finding is also attributed to various origins [1,2,4,5,6,10,11].

So, in the case of a distant range gunshot wound, there is still no complete consensus as to how and when the wound's individual morphological characteristics develop in the skin. Naturally, it is always the final, static state of the gunshot wound that is evaluated. Therefore, it is necessary to investigate the dynamic development of a gunshot wound. Today, experiments with human corpses are no longer ethically justifiable. Experiments with animals also present ethical problems, and the results of animal experiments are not necessarily transferable to humans.

The goal of this study, based upon physical experiments with a ‘‘skin–skull–brain model’’ [12], is to high-speed photographically document the development of the entrance wound in its dynamic process, and to establish fundamental data for clarifying this dynamic development.

2. Material and methods

2.1. Model

A physical ‘‘skin–skull–brain model’’ was developed, which simulates the structures of the human head [12]. Upon it, experiments with reproducible results and without associated ethical concerns can be conducted.

2.2. Firing distance/ammunition

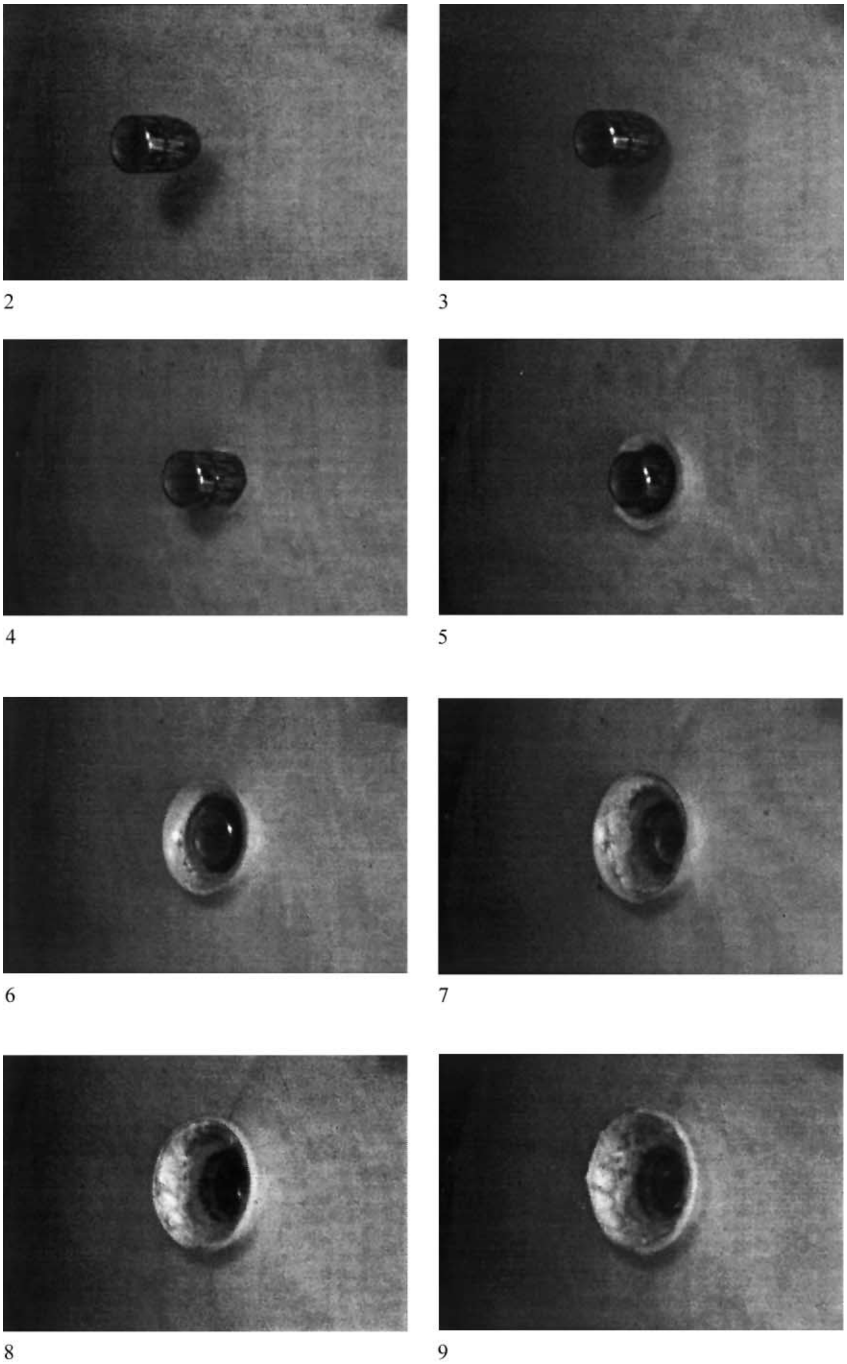
Handgun shots were fired at the ‘‘skin–skull–brain model’’ from a distance of 10 m. The ammunition used was 9 mm Luger, full metal jacket bullet with a mass of 8 g and a muzzle velocity of approximately 350 m/s.

2.3. Recording technology

The high-speed photographic recording was made with an Imacon 468/Hadland-Photonics camera. The photographic technicians came from the ‘‘Group for High-speed Measurement Techniques, Ballistics and Detonics Laboratory (FA 26), Armament Group’’, of Thun, Switzerland. The high-speed camera takes a series of eight pictures, at a maximal frequency of 50 million pictures per second. These eight digitally recorded photographs can then be evaluated successively in their dynamic operational sequence.

3. Results

Figs. 2 and 3 show the projectile before just before it strikes the ‘‘skin–skull–brain model’’. The projectile was fired from a weapon with a right spin (rifling), as evidenced



Figs. 2–9. Dynamic development of gunshot entrance wound in the ‘‘skin–skull–brain model’’. High-speed photography by Imacon 468/ Hadland-Photonics camera, frame speed frame up to 50 million pictures per second. Time delay between two following pictures in the series is 16 μs (16×10^{-6} s)! Copyright of the pictures by Ballistics and Detonics Laboratory, ‘‘Group for High-Speed Measurement Techniques’’, GR Thun, Switzerland.

by the diagonal grooves and ridges along the length of the projectile.

Fig. 4 shows the point of the projectile, 16 μs (16×10^{-6} s !) later, just penetrating and deforming the synthetic skin. The direct contact between the projectile and the outwardly bulging skin is clearly evident.

In Fig. 5, again 16 μs (16×10^{-6} s !) later the projectile, has penetrated the skin up to half of its length. The skin has spread further away from the point of impact, is bulging outwardly more than in Fig. 4, and now has no contact with the projectile.

In Fig. 6, the projectile has already completely penetrated the skin. The skin has spread even further away, and the bulging is more pronounced.

Figs. 7–9 show how the synthetic skin stretches outwardly ever more in a cone shape, with the ridge edge becoming thinner and thinner.

To reiterate, immediately upon contact with the head of the projectile, the skin moves laterally away from the projectile, and outwardly, in a cone shape, opposite the projectile's direction of travel. Direct contact between the synthetic skin and the projectile takes place only during the penetration of the projectile point.

The diameter of the cone-shaped temporary entrance hole increases especially after the penetration of the projectile. Particularly interesting is that the skin bulges ever increasingly outward. The skin is accelerated thus both laterally and outwardly opposite the projectile's direction of flight. The temporary entrance hole, far larger than the projectile's diameter, contracts after the passing of the projectile and in consequence of the damaged skin to about the original diameter of the projectile.

4. Discussion

The development of the entrance wound has been extensively discussed in forensic literature. Sellier may have presented the most promising information for understanding the development of the entrance wound resulting from a distant gunshot [10]. His experimental findings with human skin were documented with slow motion photography (exposure rate of 70,000 pictures per second).

4.1. Central substance defect

Based upon his dynamic documentation of the formation of the entrance wound in human skin, Sellier considered the following two factors to be responsible:

- the primary factor is the tissue destruction caused by the projectile penetration, and
- the secondary factor is the tissue compression brought about by the skin's radially spreading reaction to the impact.

The development and evaluation of the synthetic skin revealed the fact that the skin reacts with more than just—as Sellier's work described it—elastic characteristics.

We believe that besides elastic characteristics (as we know from wound ballistics experiments with ordnance gelatin) the skin also exhibits plastic characteristics (as we know from wound ballistics experiments with glycerin soap). Therefore, the central and primary portion of the central substance defect resulting from the direct traumatization by the projectile head, equates to a total tissue destruction, and occurs at the moment when the projectile head impacts the skin (Fig. 4).

The peripheral portion of the central substance defect is the result of irreversible compression of the tissue due to the concentric misalignment of the skin brought resulting from the projectile impact.

4.2. Bullet wipe-off/"ring of dirt"

Wounds from distant gunshots characteristically display a surrounding discoloration, a so-called "ring of dirt" (residue (oil, black powder, dirt) rubbed off as the projectile passed through the skin). Our experiments with the model produced results that fully concur with Sellier's conclusions from his experiments with human skin [10]. The projectile leaves a residue of contaminants upon the surface of the skin where it comes into contact while impacting and passing through. This transferred residue comes from the head of the projectile, up to where the projectile body begins (Fig. 4). As the high-speed Figs. 5–8 show, the body of the projectile has no contact with the edges of the entrance wound. The "ring of dirt" must, therefore, have been deposited by the bullet's head.

This finding also proves that the primary, direct effect of the bullet (head) upon the entrance wound cannot extend beyond the outside diameter of the bullet wipe-off/"ring of dirt"!

4.3. Abrasion ring

One school of thought teaches that the abrasion ring results from the depression of the skin in the direction of the bullet's flight [2]. The contrary point of view that the postulated depression of the skin does not play a role in the development of the abrasion ring is supported, however, by Sellier's experiments with human skin and by our high-speed photographs of the "skin–skull–brain model" [10].

Other authors are of the opinion that the head of the projectile pushes through the skin in such a manner while penetrating that the environment is abraded and the abrasion ring results [9]. According to previous remarks, however, the dirt ring forms the outer limit of that range in which the projectile comes into direct contact with the skin. Consequently, beyond the development of the dirt ring, the projectile-to-skin contact does not clarify the development of the abrasion ring.

Sellier is of the opinion that the abrasion ring, which often has a diameter greater than that of the projectile, does not come from the projectile's contact with the skin [10]. He could show, based upon his experiments with human skin, that in the course of the gunshot penetration some fine particles of tissue or blood fly outwards in a conical pattern, opposite the direction of the projectile's flight. These minute particles are to be found only in the space between the skin surface and the projectile. He postulated that these small backspattern themselves, flying almost tangentially to the surface of the skin, damage the adjacent skin surface. We don't agree with Sellier's interpretation. These almost microscopically small tissue or blood particles have so little mass that, even at high velocity, they possess practically no degree of the energy that would be required to abrade the skin in such a short span of time.

Based upon our investigations, we postulate that the development of the abrasion ring is due primarily to the massive, temporary overstretching of the skin adjacent to the penetration area, i.e. the skin within and extending up to the edge of the outwardly bulging temporary crater (Figs. 6–9). The massively overstretched skin—concentric to the bullet hole and the "ring of dirt"—dries up and subsequently appears as dried out, abraded skin; i.e. the abrasion ring (from commonly known morphology, this corresponds to the stretch marks left in the groin of the pedestrian who was struck in the buttocks by a speeding motor vehicle).

So the morphologic and dynamic background of the as abrasion ring is not an abrasing but an overstretching or dilatating.

In his histological examination of experimental, orthograde, postmortem gunshot wounds to human skin, Pollak found in the epidermis of the outer area of the abrasion ring strips and pieces of tissue which he thought looked like "old, worn out wallpaper hanging down from a wall" [7,8]. We believe that our hypothesis of the overstretching and dilating of the skin explains these histological findings. So, in conclusion a better term for the morphologic sign of the so called abrasion ring would be "dilation mark" or "stretch mark".

4.4. Contusion ring

The so-called "contusion ring", another sign of the entrance wound, is often found where skin closely covers bone, but this sign is not always present.

The temporary skin opening—greater in diameter than the outside diameter of the projectile—and the outwardly (opposite the direction of the projectile's flight) bulging skin are, in regards to the development of the contusion ring, analogous to the temporary wound cavity in soft tissue. It is well known that as a result of the temporary wound cavity in the soft tissue, blood vessel, nerve, and organ damage (even bone fractures) can occur some distance away from the wound channel.

As Figs. 7 and 8 show, the skin outside and peripheral to the edge of the cone-shaped crater is also stretched. Within this wound area, overstretching of the skin in living organisms leads to bleeding beneath the skin and, occasionally, to mostly circular tears in the skin. This finding is called the "contusion ring" (in German, "Kontusionsring/Kontusionssaum").

The experiments with the "skin–skull–brain model", and the high-speed photographic documentation show the promising possibilities of experimental simulations utilizing body part models in the field of wound ballistics.

Non-biologic models of body tissues are very well suited for wound ballistic research.

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