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Differences in Gunpowder Tattooing on Pig Head Wounds Caused by a .380 Pistol and a .38 Revolver – A Forensic Research in South Brazil

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Authors' contributions

"This work was carried out in collaboration between all authors. Authors MMF, RNO and FD designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors MR and FD managed the analyses of the study. Authors GCR and RPB managed the literature searches. All authors read and approved the final manuscript.

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Short Communication

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ABSTRACT

Aims: To analyse the differences in gunpowder tattooing on pig head wounds caused by a .380 pistol and a .38 revolver.
Study Design: Observational prospective cross-sectional.
Place and Duration of Study: Department of Forensic Dentistry, Brazilian Dental Association – Section of Rio Grande do Sul, between March and July 2017.
Methodology: A .38 revolver (Rossi®, São Leopoldo, Rio Grande do Sul, Brazil) and a .380 pistol (Bersa®, Buenos Aires, Argentina), and their respective ammunition (CBC®, Rio Grande do Sul, Brazil), were used to produce gunshot wounds in the head of 4 *Large White* adult pigs in South

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Brazil. The firearms were positioned by systematically modifying the distance between the muzzle and the target – from 5 to 20 cm. Photographs were taken from each gunshot wound using a standard scale. The gunpowder tattooing area and perimeter were measured and registered for comparison between firearms. Qualitatively, the visibility of the tattooing surface was directly compared between firearms.

Results: The tattooing surface produced by the firearms varied considerably within the distances between 5 and 20 cm. In specific, the tattooing surfaces increased proportionally with the distances. More visible and well-defined tattooing surfaces were produced by the pistol.

Conclusion: In practice, forensic investigators may find clues of the shooting distance by analysing the tattooing surface in gunshot wounds.

Keywords: Firearm; gunshot wound; gunpowder tattooing; facial injury; forensic medicine.

1. INTRODUCTION

The World Health Organization (WHO) estimates that nearly 2.3 million violent deaths were caused by firearms in the world in 2015. This scenario is even more evident in developing countries, such as Brazil, in which homicides rates increased accordingly. In this context, studies on firearm projectiles and gunshot wounds became more important to investigate and understand the causes of deaths in the routine of medico-legal institutes [1].

In Brazil, the post-mortem exams performed in the head and neck may involve both medical pathologists and forensic dentists. Specifically for dentists, the forensic activity in the criminal, civil and administrative fields is supported by the Law number 5.081/66 [2]. Yet, the normative resolution 63/2005 of the Brazilian Federal Council of Dentistry consolidates the guidelines in Forensic Dentistry. This document states that forensic dentists must search for the truth and justice during daily activities and highlights that their knowledge may be applied also for ballistic purposes (art. 64) [3]. Based on that, forensic dentists must be updated and aware of the scientific technology related to Ballistics, especially the ballistic phenomena that are produced with criminal intentions and affect the head and neck [4].

Besides that, the identification of gunshot residues on the human body in firearm related fatalities may be essential for the evaluation of gunshot wounds and for the analysis of the shooting distance [5].

The present research aims to investigate the tattooing phenomenon observed in gunshot wounds produced in pig heads by different types of firearms positioned within different distances from the target.

2. METHODOLOGY

This research was conducted after approval of the local Committee of Ethics in Research, under the protocol number 034/2015. All the practical procedures involving firearms were performed in South Brazil by trained professionals with the supervision of the local Military and Police units.

Two types of firearms were used in the present research, a 2-inch-barreled .38 revolver (Rossi®, São Leopoldo, Rio Grande do Sul, Brazil) and a 3-inch-barreled .380 pistol (Bersa®, Buenos Aires, Argentina), with their respective ammunition (CBC®, Rio Grande do Sul, Brazil). The firearms were used to produce gunshot wounds in the head of 4 Large White adult pigs. These animals were used due to the similarity of their hard and soft tissues with human tissues. All the animals were previously killed for commercial purposes. No animal was killed during this study.

Eight shots were performed – 4 in the left side of the head (facial region) with the revolver and 4 in the right side with the pistol. The 4 shots were performed increasing the distance between the firearm muzzle and the target. Specifically, the first, second, third and fourth shots were performed within 5cm, 10cm, 15cm, and 20cm of distances, respectively. For every shot, the analogue side of the pig head was protected with a tissue to avoid contamination with gunpowder.

Photographs were taken of the gunshot wounds to allow the measurement of the vertical and horizontal dimensions of the gunpowder tattooing surface. The measurements were taken with a scale considering the outermost point of the tattooing surface passing through the gunshot wound. The perimeter of the tattooing surface was traced combining the outermost points of the vertical and horizontal (Fig. 1).

The estimated area of the tattooing surface was also calculated and quantified in mm². The calculation was based on the mean radius ratio of the tattooing surface (vertical radius + horizontal radius / 2). The vertical radius was traced from the centre of the gunshot wound to the outermost point of the tattooing surface in the vertical direction, while the horizontal radius was traced from the centre of the gunshot wound to the outermost point of the tattooing surface in the horizontal direction (Fig. 2).

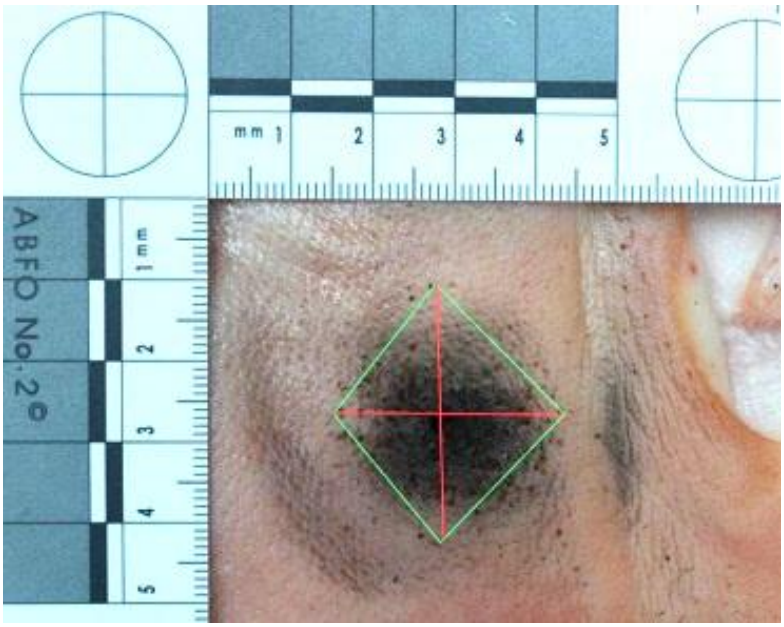

Fig. 1. Vertical and horizontal measurements (red) and the perimeter (green) of the tattooing surface

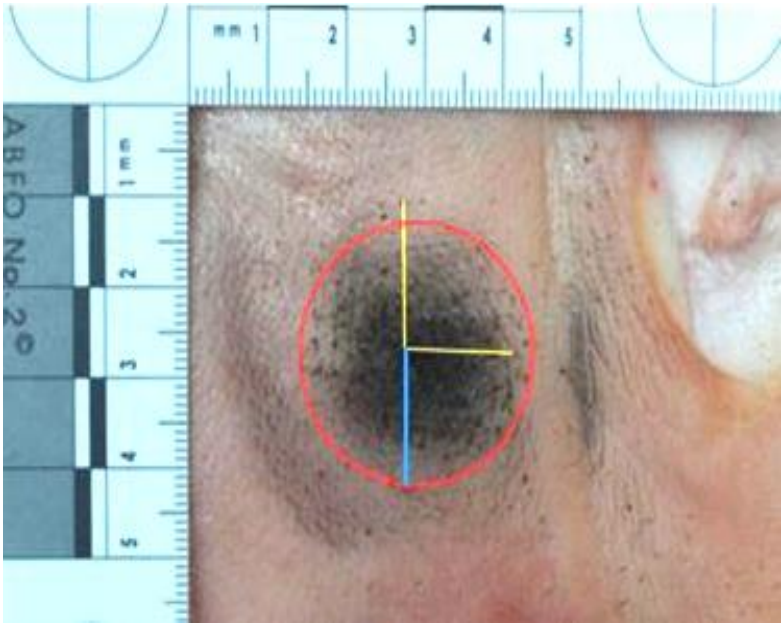

Fig. 2. Vertical and horizontal radius (yellow), mean radius (blue) and the estimated area of the tattooing surface (red)

3. RESULTS

Table 1 shows the quantified measurements taken from the pig heads considering the vertical distances (dv) and horizontal distances (dh), and their respective perimeters, using the revolver and the pistol positioned differently within the 4 set ups from the target (Table 1).

Table 2 shows the quantified vertical radius (rv) and horizontal radius (rh), the mean radius (rm) and the tattooing surface area, produced by the revolver and the pistol, positioned differently within the 4 set ups from the target (Table 2).

Fig. 3 illustrates the tattooing surface area produced by the revolver and the pistol, positioned differently within the 4 set ups from the target.

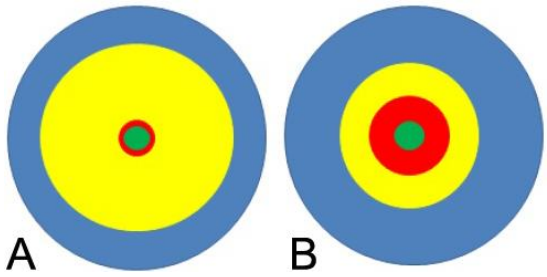

Fig. 3. Tattooing surface area produced by the pistol (A) and the revolver (B), positioned differently within 5 cm (green), 10 cm (red), 15 cm (yellow) and 20 cm (blue) from the target

4. DISCUSSION

The present research was founded and justified on the increasing trend of violent deaths caused by firearms in developing countries. The two types of firearms used to produce gunshot wounds in the pig heads were chosen because those are the most powerful calibers allowed for revolvers (.380) and pistols (.38) in the civil context [6].

The outcomes observed within this research suggested that larger tattooing surface areas are observed positioning the firearm more distant from the target. Despite larger, the area from longer distance shots present less intense tattooing marks. The opposite was also observed. More evident and concentrated tracing of unburned gunpowder were found in gunshots closer to the target. Similarly, Espíndula [7] observed an increase in the vertical and horizontal dimensions of the tattooing surface area and its respective perimeter, both for the revolver and the pistol [7]. These characteristics were corroborated by Tochetto [8] and Vanrell [9]. The first explains that the tattooing surface is produced by the larger (solid) particles of unburned (or partially burned) gunpowder and small fragments of the projectile that penetrate the target (skin). In general, these particles are not removable after washing. In the present research not only the tattooing surface was observed clearly, but also the charring surface – caused by highly heated gas in contact with the skin, and the deposition of soot from the

Table 1. Measurement of vertical and horizontal distances and their respective perimeter

Distance	Pistol			Revolver		
	dv	dh	Perimeter	dv	dh	Perimeter
5	35	40	100	30	27	76
10	57	57	160	65	58	172
15	142	150	412	118	78	280
20	149	163	440	127	87	300

Distance from gun to target (cm); vertical distance (dv), horizontal distance (dh) and perimeter expressed in mm^2

Table 2. Measurement of the radius and the tattooing surface area

Distance	Pistol				Revolver			
	rv	rh	rm	area	rv	Rh	rm	Area
5	25	22	23.5	1.734	18	13	15.5	754
10	28	33	30.5	2.920	40	33	36.5	4.183
15	70	76	73	16.733	48	47	47.5	7.084
20	85	82	83.5	21.892	72	60	66	13.677

Distance from gun to target (cm); rv: vertical radius (mm); rh: horizontal radius (mm); rm: mean radius (mm); area expressed in squared mm^2

propellant combustion process. The second explains that the diameter of enlargement of the tattooing surface grows progressively until the moment in which each particle looses kinetic energy. More specific, it is estimated that a distance of 35cm between the firearm and the target may disperse completely the potential tattooing particles, hampering the formation of a visible tattooing surface. The present outcomes confirm the literature, revealing an increased level of dispersion in the particles shot most distant from the target. However, is important to note that any barrier positioned between the firearm and the target, such as a pillow, would detain the particles generating a tattooing surface on the barrier and not on the target. Despite logic, this knowledge is fundamental to understand the dynamics of firearm injuries and forensic criminal investigations [9].

Knowing the dynamics of firearm injuries benefits the forensic criminal investigations by indicating the distance between the firearm and the victim, the angulation of the firearm, the type of firearm and ammunition. Additionally, the tattooing surface indicates reliably the entrance wound of the injury, because this surface is not imprinted in the exit wound. The type of gunpowder affects directly the color of the tattooing surface. In general, dark surfaces are observed with black gunpowder, while a more variable coloring is observed with pyroxilated gunpowder. The shape of the tattooing surface varies according to the angulation of the firearm Tochetto [8]. Firearms positioned perpendicular to the target generates uniform circular tattooing surfaces around the entrance gunshot wounds. On the other hand, angulated gunshots produce smaller and more intense tattooing surfaces in the side less inclined [10]. In the present research, only perpendicular gunshots were performed. Consequently, only uniform circular tattooing surfaces were produced on pig skin.

Yet in relation to the tattooing surfaces in the distances of 5cm and 20cm, the revolver and the pistol produced a similar area, respectively. However, within a distance of 10cm the revolver produced an area considerably larger than the pistol. The opposite was observed within 15cm, when the pistol produced the larger area. Apparently, the mechanics behind this phenomenon is not clear. Tables 1 and 2 reveal no proportion between the distances used in the present research set up and the area/perimeter of the tattooing surfaces. In other words, if the distance is increased from 5 to 10cm (100%) the increase in area/perimeter will not follow the same proportion (increase in 100%).

The results of the pistol effect can be compared with the study of Lepic et al. [11], which stimulates further studies in this area: considering comparing the bullet entrance injuries produced by the pistols tokarev, makarov and glock 19 with common ammunition at distances of 25, 50, 75 and 100 cm were observed that the following differences in the diameter of the soot deposit pattern and in the maximum distance out to which the soot was visible, in the distribution and the density of the gunpowder residue particles on the cloth targets and in the distribution and the depth of penetration of the gunpowder particles on the skin targets. The results were similar on the cloth and on the skin targets.

In addition, results of the study of Turillazzi et al. [5] introduces the elemental analysis of the gunshot residues on human body by inductively coupled plasma atomic emission spectrometer analysis performed on skin samples, confirming very high concentrations of PB, SB, and BA in the close-range shots and low concentrations of these particles in the intermediate and distant shots. In particular, the concentration of SB, BA, and PB were significantly different from loose values when the firing distance was 100–150 cm for both the 9, 21 and the 7.65 mm calibres, stimulating the second step in our research.

This study corroborated the previous scientific literature in the field [12] by highlighting the importance of investigating the dynamics of gunshot wounds in function of the anatomic place shot and the firearm caliber [13-15]. More specifically, understanding the different tattooing outcomes from gunpowder may contribute to the forensic practice by indicating the shooting range and eventually distinguishing between homicides and suicides. Future studies should be performed with different firearms, distance settings and advanced statistical analysis.

5. CONCLUSION

Based on the exposed, the presented study showed that tattooing surfaces produced by the revolver and the pistol increased vertically and horizontally following the increase in the distance from the target. The revolver produced larger tattooing surface areas compared to the pistol within 10cm from the target, while the pistol produced larger tattooing surfaces within 15cm. These findings may support forensic

investigations in practice by providing clues of the shooting distance.

CONSENT

It is not applicable.

ETHICAL APPROVAL

This research was conducted after approval of the local committee of ethics in research, under the protocol number 034/2015.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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