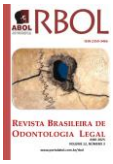
Revista Brasileira de Odontologia Legal – RBOL

ISSN 2359-3466 http://www.portalabol.com.br/rbol



Forensic traumatology

ATYPICAL CRANIOFACIAL INJURY CAUSED BY A FIREARM PROJECTILE IN THE MAXILLARY BONE: CASE REPORT.

Lesão craniofacial atípica causada por projétil de arma de fogo na maxila: relato de caso.

Taylana Ramos PIROCCA[1], Ana Paula Marzagão CASADEI[2], Elisa Cristiana Winkelmann DUARTE[2], Beatriz Álvares Cabral de BARROS[3].

1. Graduated in Dentistry, Federal University of Santa Catarina, Brazil.
2. Department of Morphological Sciences, Human Anatomy, Forensic Anthropology Laboratory/LANFOR, Federal University of Santa Catarina, Brazil.
3. Department of Dentistry, Forensic Dentistry, Forensic Anthropology Laboratory/LANFOR, Federal University of Santa Catarina, Brazil.

Information about the manuscript:

Received: September 13, 2025.
Accepted: December 23, 2025.

Contact author:
Profa. Dra. Beatriz Álvares Cabral de Barros
Delfino Conti, S/N – Departamento de Odontologia - UFSC/CCS – Trindade, Florianópolis, SC, Brazil – CPF 88040-370
E-mail: beatriz.barros@gmail.com.

ABSTRACT

Firearm injuries present a significant challenge for forensic sciences, requiring precise analysis of ballistic mechanisms and their effects on skeletal structures. Forensic odontology has increasingly contributed to examining craniofacial injuries, supporting both scientific interpretation and legal processes. This study reports the forensic analysis of a skeletonized skull with two distinct firearm projectile (FP) trajectories. While classic ballistic signs such as external beveling, radiating fractures, and the Bonnet funnel sign were observed, particular focus is given to an unusual orifice in the left maxilla. This lesion, marked by irregular borders and extensive comminution, deviated from typical entry and exit wound patterns, demonstrating how bone thickness and fragility influence ballistic damage. The sequential assessment of injuries suggested that the first shot occurred at the left temporoparietal junction, followed by a facial shot. The maxillary orifice, in particular, raised hypotheses about the symbolic or practical intent behind the second shot, aligning with literature describing disfigurement practices in homicidal cases. The case highlights the complexity of interpreting firearm injuries in delicate facial bones and emphasizes the importance of detailed osteological examination when faced with unusual presentations. It underscores the value of combining forensic anthropology, dentistry, and ballistics to reconstruct projectile trajectories and develop hypotheses about the dynamics of violent death. Given the increasing circulation of firearms and persistently high homicide rates in Brazil, the study emphasizes the scientific and judicial importance of interdisciplinary forensic approaches supported by thorough documentation.

KEYWORDS

Forensic dentistry; Forensic ballistics; Cranioencephalic injuries.

INTRODUCTION

Forensic ballistics is one of the disciplines encompassed within criminalistics, being responsible for the analysis of firearms, projectiles, cartridges, ballistic trajectories, and the injurious effects caused by gunfire. Its purpose is to contribute to both the reconstruction of

criminal events and to the production of technical evidence in criminal proceedings[1].

In recent years, Brazil has witnessed a significant increase in the number of registered firearms, particularly among hunters, sport shooters, and collectors (CAC)[2]. This scenario has direct implications for both the frequency and severity of firearm projectile injuries, especially those affecting the skull, which are associated with high lethality and survival rates ranging between 7% and 15%[3]. In this context, the importance of forensic traumatology becomes evident, as it is dedicated to the systematic study of bodily injuries, their dynamics, and their legal implications. The analysis of wounds caused by firearm projectiles involves the identification of entry and exit orifices, the internal trajectory, and the estimation of the shooting distance. Such information is crucial for constructing a forensic narrative capable of supporting judicial decision-making[4].

The interaction between forensic ballistics and forensic odontology proves to be particularly relevant in the analysis of craniofacial firearm injuries, given the anatomical complexity of the region and the high incidence of fatal outcomes. In this context, the role of the forensic odontologist involves the examination of bone and dental injuries, the reconstruction of the ballistic trajectory, and the recognition of characteristic impact patterns. In the case analyzed, atypical patterns were identified in an entry orifice with a larger diameter than the exit orifice. This finding highlights the complexity involved in interpreting injuries in thin and irregular bones, such as those of the face, where the absence of beveling is common[4].

CASE REPORT

This study is an observational descriptive case report examining a cranial specimen. The analyzed specimen consisted of a human skull cataloged as “RV4,” obtained through a formal cooperation agreement between the Institute of Forensic Medicine of Florianópolis (Instituto Médico Legal – IML) and the Federal University of Santa Catarina (Universidade Federal de Santa Catarina – UFSC). Under this agreement, skeletal remains of unclaimed individuals, previously interred in municipal cemeteries, are subsequently exhumed and donated to the University for research purposes. The custody, conservation, and management of the specimen are the responsibility of the Laboratory of Forensic Anthropology (LANFOR). The project received approval from the Brazilian Human Research Ethics Committee under the consolidated opinion number CAAE: 48423321.0.0000.0121.

The methodology consisted of a direct visual examination and detailed analysis of the lesions present on the skull, accompanied by photographic documentation. Each wound was described according to morphological criteria (shape and presence of beveling) and topographical criteria (anatomical location). The ballistic trajectory was inferred through the identification of entry and exit orifices, allowing for the determination of the projectile's direction and path.

Photographic documentation was performed using a Nikon D5100 digital

camera equipped with a Sigma 105mm macro lens for Nikon, following the established technical protocol. The skull was positioned on a flat surface, and the ABFO No. 2 photographic scale was used in all images of the orifices to standardize measurements and control perspective. The resulting images serve to illustrate the analysis.

The analysis of the skull revealed good structural preservation, with morphological features consistent with a subadult male pattern. The sutures were well-defined, and most of the bony structures remained intact, except for traumatic fractures consistent with firearm projectile (FP) injuries. The mandible was intact; however, it was not analyzed in this case report.

Four orifices consistent with ballistic injuries were identified, two exhibiting extensive loss of bone substance and two of smaller size with regular morphology.

One of the wounds is located in the left maxilla, just below the fractured left zygomatic bone. It exhibited extensive bone loss, with exposure of the maxillary sinus, loss of part of the anterior wall of the maxillary sinus, affected by the projectile's impact and its kinetic energy. A horizontal, radiating fracture originates from this wound in the left frontal bone, extending to the glabella on the right side and continuing to the temporal bone on the left side, with a small, branching fracture ending adjacent to the left supraorbital notch (Figure 1).

Figure 1 – a) Entry orifice, anterior view; b) Radiating fractures, left lateral view.

The loss of part of the anterior wall of the maxillary sinus could initially confuse the examiner with a possible gunshot wound; however, a regularly shaped orifice is located in the posterior portion of the right parietal bone. It presents a radiating fracture line reaching the lambdoid suture, along with a secondary fracture line in the right parietal bone. This orifice exhibits the characteristic Bonnet funnel sign, with the bevel projecting outward on the external table of the skull, indicating the trajectory of the passing projectile and supporting the conclusion that it represents an exit wound (Figure 2).

Therefore, it can be deduced that the corresponding antagonist orifice, located on the left side of the facial region of the skull, constitutes the entry wound, as it is positioned opposite to it along the trajectory. Thus, this trajectory likely had its entry in the left maxilla, with fracture of the adjacent zygomatic bone, and its exit in the posterior portion of the right parietal bone. The radiating fracture and the presence of the Bonnet funnel sign on the external table support this hypothesis (Figure 3). Despite not being in the conventional morphological pattern, both would result from the same firearm discharge.

The other regular orifice appears to be an entry wound with conventional characteristics and is located at the junction of the parietal and left temporal bones, near the mastoid process. From this point, a long fracture line extends, beginning at the parietomastoid suture and terminating at the sagittal suture (Figure 4). The orifice exhibits the characteristic Bonnet funnel sign, which manifests as a pronounced diastasis on the internal table of the bone on the side opposite to the direction of displacement of the firearm projectile.

Figure 2 – Exit orifice, posterior view of the skull. The Bonnet funnel sign is projected on the external table of the bone.

Figure 3 – Anterolateral view of the second trajectory path.

Figure 4 – Entry orifice viewed from the left lateral perspective: The Bonnet funnel sign is projected on the internal table of the bone (a). From the orifice, a long fracture line extends, beginning at the parietomastoid suture and terminating at the sagittal suture – superior view (b).

The orifice opposite to the one previously described exhibits extensive loss of bone substance and resembles the exit wound of the same shot. It is located on the right temporal bone, extending from the squamous portion of the temporal bone to the region of the zygomatic arch and the right external acoustic meatus. These structures are absent due to the disarticulation of the temporal squama and the loss of bony remnants caused by the projectile trauma (Figure 5).

Therefore, the projectile trajectory entered the left parietal bone near the mastoid process, producing a radiating fracture extending to the sagittal suture. The presence of the Bonnet funnel sign on the internal table confirmed the direction of

entry. The corresponding exit orifice is located on the right temporal bone, with destruction of the temporal squama, zygomatic arch, and external acoustic meatus. This represents the trajectory with a likely left-to-right direction (Figure 6).

The application of Puppe's Rule indicated that the shot entering the left parietal bone occurred first, as its fractures were intersected by the fracture lines resulting from the second shot. Thus, it was possible to establish a chronological sequence of the ballistic events, with the first shot following the lateral trajectory and the second following the facial-posterior trajectory (Figure 7).

Figure 5 – Exit orifice (right lateral view).

Figure 6 – a) Shortest trajectory, anterolateral view; b) Shortest trajectory, anterior view.

Figure 7 – Simultaneous simulation of both trajectories (anterosuperior view).

- The first trajectory, with entry in the left parietal bone and exit in the right temporal bone, exhibits a typical transverse gunshot pattern, with kinetic energy sufficient to produce extensive fractures and the removal of adjacent structures such as the zygomatic arch and the acoustic meatus. The presence of radiating fractures extending to the sagittal suture corroborates the direction and intensity of the impact.

- The second shot, with entry in the left facial region (maxillary area) and exit in the posterior portion of the right parietal bone, presents a longer trajectory with an anteroposterior direction. This less common trajectory may suggest a specific positioning of the victim or a distinct dynamic at the moment of the injurious event. The fracture of the zygomatic bone and the damage to the maxilla indicate a high level of fragmentation resulting from the dissipation of the projectile's energy.

DISCUSSION

The increasing incidence of injuries caused by firearm projectiles (FP) underscores the need for accurate identification and interpretation of these lesions, both in the scientific field and in their broader societal implications. As highlighted by Palhares Machado et al. (2022)[4], the precise characterization of such injuries requires mastery of terminal ballistics principles, especially in forensic contexts.

In the present case, the analysis was performed on a skeletonized skull, which inherently excluded the observation of soft-tissue signs typically associated with firearm injuries—such as abrasion collars, excoriation, bruising, soot deposition, stippling, and tattooing. Their absence is consistent with expectations, as these markers are restricted to fresh cadavers, as reported by Palhares Machado et al. (2022)[4] and Mahoney et al. (2018)[5].

Despite these limitations, forensic anthropology enables the reconstruction of ballistic trajectories by analyzing bone damage. Quatrehomme and Iscan (1998)[6] emphasize that exit wounds in bone are usually more irregular and present external beveling—the Bonnet funnel sign. In the current case, this sign was identified in two orifices, assisting in distinguishing entry from exit wounds, even in atypical scenarios where the entrance displayed a larger diameter than the exit. This finding highlights the interpretative challenges inherent to injuries in thin and irregular bones of the facial region, where the absence of beveling is not uncommon[4].

A particularly relevant aspect of this study concerns the atypical orifice observed in the left maxilla. Unlike the cranial orifices that displayed more classic ballistic patterns, the maxillary lesion presented a comminuted fracture associated with an orifice morphology that did not follow the usual size and beveling standards for entry and exit wounds. The partial loss of the anterior wall of the maxillary sinus could, at first examination, be misinterpreted by the examiner as a firearm projectile exit wound. The irregular borders and extensive fragmentation are consistent with high-energy transfer patterns described by Leite Segundo et al. (2013)[7] and Motamedi (2003)[8] for projectile impacts in facial bones. This anomaly may be attributed to the reduced thickness and structural fragility of the maxilla, which can modify the expected morphology of orifices, as already suggested by Light (1963)[9] when discussing the influence of bone density and projectile deceleration on wound appearance. Thus, the maxillary orifice not only illustrates the variability of ballistic behavior in the facial skeleton but also reinforces the need for cautious interpretation when confronted with atypical presentations. The preservation of the mandible, in contrast, suggests that either the projectile lacked sufficient energy to propagate the fracture further or that the shot impacted a restricted facial area, sparing adjacent structures.

The literature further supports that projectile behavior is influenced by multiple factors, including the density of the tissue struck, the projectile's velocity and shape, and the shooting distance[10-12]. These variables may help explain the atypical morphology found in the maxilla and highlight how ballistic dynamics in facial structures may differ substantially from those observed in cranial vault bones.

Although exceptions to Puppe's Rule have been described[13], its application remains fundamental for inferring the chronology of shots[14]. In the present case, the evidence suggests that the first shot occurred at the left temporoparietal junction, followed by a second shot affecting the facial region. The maxillary damage, in particular, supports the hypothesis of a secondary shot possibly aimed at disfiguring the victim's face. This interpretation aligns with the literature, as Bizhan et al. (2015)[15] reported that cranial firearm injuries have lethality rates exceeding 90%, implying that the second facial shot may have had symbolic or practical intent rather than lethality. Silva et al. (2014)[16] and Cavalcanti et al. (2021)[17] describe such practices as common in extermination crimes or acts of intimidation in Brazil, while Robinson (2019)[18] highlights the high mortality associated with facial firearm injuries even in medicalized contexts.

Quatrehomme and Yscan (1998)[6] noted that bone exit wounds are more irregular than bone entry wounds. In general, they exhibit external beveling in most cranial vault lesions, but not in those of the orbit, maxilla, temporal bone, greater wing of the sphenoid bone, or left side of the occipital bone. However, in the analysis of skull RV4, included in this work, it was observed that the entry wound located on the left side of the face does not behave

traditionally, as its shape is irregular and larger than the exit wound located on the posterior part of the skull.

The observation of the chamfer and external beveling of the bone projecting outwards (Bonnet's Funnel) at the exit wound in question allowed for the identification of the distinction between entry and exit wounds. According to Palhares Machado et al. (2022)[4], differentiating between an entry and exit wound may not be an easy task and is commonly not possible in case of thinner and more delicate bones, such as some facial bones or children's bones. These bones do not have a conformation similar to that of other bones in the cranial vault; the Bonnet's Funnel does not form, and sometimes an irregular-looking lesion will be observed. In such cases, to try to define the entry and exit wounds, the bone edges of fractures produced by gunshot wounds should be analyzed both in isolation (each fracture) and in conjunction with other fractures to try to associate entry and exit wounds, radiating fractures, etc., that may suggest the trajectory of the projectile. These findings, taken together, are capable of demonstrating where the projectile entered, where it traveled, and where it may have finally exited.

The morphological and ballistic assessment of the skull thus revealed evidence consistent with two distinct shots, both exhibiting complete trajectories with entry and exit points. The atypical orifice in the left maxilla was particularly significant, not only because of its irregular features but also because it provides critical insight into the complexity of interpreting facial gunshot wounds. The analysis of radiating fractures, localized bone loss, and ballistic markers such as the Bonnet funnel sign contributed decisively to identifying projectile trajectories and characterizing the injuries. Together, these findings support forensic and judicial reconstructions by demonstrating the high kinetic impact of the shots and the variable morphological expressions they produce in craniofacial bones. The importance of this analysis lies in preventing erroneous correlations, such as classifying entry as exit and vice versa, which could increase or decrease the number of projectiles that struck the skull.

This case underscores the value of integrating forensic anthropology, odontology, and ballistics in the analysis of firearm injuries, especially when soft tissues are no longer present. Moreover, it highlights the importance of systematic methodologies and rigorous documentation as a scientific and legal foundation in criminal investigations. Although this analysis was based primarily on macroscopic examination, complementary imaging methods, such as computed tomography (CT) and magnetic resonance imaging (MRI), continue to prove valuable in assessing firearm injuries, even in decomposed remains or isolated bone fragments[19].

CONCLUSIONS

The present study analyzed injuries caused by firearm projectiles (FP) in a skull provided by the Institute of Legal Medicine (IML). Based on the scientific literature on Forensic Traumatology and Terminal Ballistics, it was possible to describe and

characterize the injuries, identify entry and exit orifices, and estimate the direction and length of the ballistic trajectories within the skull.

The application of technical-scientific knowledge in forensic ballistics enabled the identification of the orifices, including in atypical cases, such as the second shot, which exhibited unusual characteristics in its entry orifice. Furthermore, the use of Puppe's Rule was crucial for establishing the sequence of the shots and the trajectories traveled by the projectiles.

It should be emphasized that prior mastery of ballistic concepts and trauma mechanisms is fundamental for the accurate analysis of firearm projectile (FP) injuries, particularly in identifying exceptions to conventional bone orifice patterns. Experts are encouraged to increasingly incorporate advanced technologies for the detection, identification, and detailed description of injuries, thereby contributing to reliable scientific findings in forensic investigations. Therefore, it is essential to promote academic production and the dissemination of research focused on Forensic Odontology and Forensic Ballistics. Such initiatives significantly contribute to the advancement of knowledge and to the strengthening of the application of these sciences for the benefit of society.

RESUMO

Lesões por arma de fogo representam um desafio significativo para as ciências forenses, exigindo análises precisas dos mecanismos balísticos e seus efeitos nas estruturas esqueléticas. A odontologia forense tem contribuído cada vez mais para o exame de lesões craniofaciais, apoiando tanto a interpretação científica quanto os processos legais. Este estudo relata a análise forense de um crânio esqueletizado com duas trajetórias distintas de projéteis de arma de fogo (PF). Embora sinais balísticos clássicos, como biselamento externo, fraturas irradiadas e o sinal do funil de Bonnet, tenham sido observados, o foco particular é dado a um orifício incomum na maxila esquerda. Essa lesão, marcada por bordas irregulares e extensa cominuição, desviou-se dos padrões típicos de entrada e saída da ferida, demonstrando como a espessura e a fragilidade óssea influenciam o dano balístico. A avaliação sequencial das lesões sugeriu que o primeiro tiro ocorreu na junção temporoparietal esquerda, seguido por um tiro facial. O orifício maxilar, em particular, levantou hipóteses sobre a intenção simbólica ou prática por trás do segundo tiro, alinhando-se com a literatura que descreve práticas de desfiguração em casos de homicídio. O caso destaca a complexidade da interpretação de ferimentos por arma de fogo em ossos faciais delicados e enfatiza a importância do exame osteológico detalhado diante de apresentações incomuns. Ressalta o valor da combinação de antropologia forense, odontologia e balística para reconstruir trajetórias de projéteis e desenvolver hipóteses sobre a dinâmica da morte violenta. Dada a crescente circulação de armas de fogo e as taxas de homicídio persistentemente altas no Brasil, o estudo enfatiza a importância científica e judicial de abordagens forenses interdisciplinares apoiadas por documentação completa.

PALAVRAS-CHAVE

Odontologia legal; Balística forense; Traumatismos cranioencefálicos.

REFERENCES

1. França GV. Medicina Legal. 11th ed. Rio de Janeiro: Guanabara Koogan; 2017.
2. Fórum Brasileiro de Segurança Pública. Anuário brasileiro de segurança pública 2024. São Paulo: FBSP; 2024. Available from: https://publicacoes.forumseguranca.org.br/items/f62c4196-561d-452d-a2a8-9d33d1163af0/full. Accessed 25 Jun 2025.
3. Alvis-Miranda HR, Villafañe RA, Rojas A, Alcala-Cerra G, Moscote-Salazar LR. Management of craniocerebral gunshot injuries: a review. Korean J Neurotrauma. 2015;11(2):35-43. https://doi.org/10.13004/kjnt.2015.11.2.35
4. Palhares Machado CE, et al. Tratado de antropologia forense: fundamentos e metodologias aplicadas à prática pericial. Campinas: Millennium Editora; 2022.
5. Mahoney P, et al. Ballistic impacts on an anatomically correct synthetic skull with a

surrogate skin/soft tissue layer. Int J Legal Med. 2018;132:519–530. https://doi.org/10.1007/s00414-017-1737-9

6. Quatrehomme G, Iscan MY. Gunshot wounds to the skull: comparison of entries and exits. Forensic Sci Int. 1998;94(1-2):141-146. https://doi.org/10.1016/s0379-0738(98)00056-5.
7. Leite Segundo AV, et al. Inclusão do estudo da balística no tratamento dos ferimentos faciais por projétil de arma de fogo. Rev Cir Traumatol Buco-maxilo-fac. 2013;13(4):11-16.
8. Motamedi MHK. Primary management of maxillofacial hard and soft tissue gunshot and shrapnel injuries. J Oral Maxillofac Surg. 2003;61(12):1390-1397. https://doi.org/10.1016/j.joms.2003.07.001.
9. Light FWJ. Gunshot wounds of entrance and exit in experimental animals. J Trauma. 1963;3:120-128. https://doi.org/10.1097/00005373-196303000-00003.
10. Berryman HE, Smith O, Lyman P. Diameter of cranial gunshot wounds as a function of bullet caliber. J Forensic Sci. 1995;40(5):741-745. https://doi.org/10.1520/jfs15377j.
11. Ross AH. Caliber estimation from cranial entrance defect measurements. J Forensic Sci. 1996;41(4):642-645. https://doi.org/10.1520/jfs13966j.
12. Viel G, Gehl A, Sperhake JP. Intersecting fractures of the skull and gunshot wounds: case report and literature review. Forensic Sci Med Pathol. 2009;5(1):22-27. https://doi.org/10.1007/s12024-008-9062-8
13. Amadasi A, Franceschetti L, Amadasi L, Oesterhelweg L. Exception to the Puppe's rule reloaded and a warning in the interpretation of skull fractures: they run even through recent craniotomy burr holes. Forensic Sci Med Pathol. 2025;21(1):341-344. https://doi.org/10.1007/s12024-024-00829-0.
14. Berryman HE. A systematic approach to the interpretation of gunshot wound trauma to the cranium. Forensic Sci Int. 2019;301:27-33. https://doi.org/10.1016/j.forsciint.2019.05.019.
15. Bizhan A, et al. Surgical management of civilian gunshot wounds to the head. Handb Clin Neurol. 2015;127:321-334. https://doi.org/10.1016/B978-0-444-52892-6.00012-X.
16. Silva CJ, et al. Traumatismos maxilofaciais como marcadores de violência urbana: uma análise comparativa entre gêneros. Cienc Saude Colet. 2014;19(1):127-136. https://doi.org/10.1590/1413-81232014191.2059.
17. Cavalcanti AL, et al. Head and face injuries in Brazilian homicide victims: a retrospective study. Ann Maxillofac Surg. 2021;11(1):103-107. https://doi.org/10.4103/ams.ams_158_20.
18. Robinson LA, et al. Outcomes in patients with gunshot wounds to the brain. Trauma Surg Acute Care Open. 2019;4:e000351. https://doi.org/10.1136/tsaco-2019-000351
19. Oehmichen M, et al. Forensic pathological aspects of post-mortem imaging of gunshot injury to the head: documentation and biometric data. Acta Neuropathol. 2003;105:570–80. https://doi.org/10.1007/s00401-003-0683-4