CASE REPORT

The role of maxillofacial radiologists in gunshot injuries: a hypothesized missile trajectory in two case reports

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Gunshot injuries are an emerging form of trauma that oral radiologists increasingly have to deal with. There are two main types of gunshot injuries: high-velocity and low-velocity bullet injuries. The outcome of high-velocity gunshot injury is usually fatal; however, a non-fatal low-velocity injury to the maxillofacial region is more likely to be encountered by the oral and maxillofacial radiologist. It is therefore important to up-to-date knowledge of ballistic science and its implications in the field of maxillofacial radiology. The ability of oral and maxillofacial radiologists to predict the missile trajectory will aid the assessment and localization of the damage caused by the bullet and its splinters. Predicting the missile trajectory may also be of help to law enforcement agencies and forensic scientists in determining the type of firearm used and direction of fire. This article, which examines two cases, attempts to highlight to the oral radiologist this emerging form of trauma and its implications.

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Introduction

Firearm-related injuries are the second leading cause of injury-related deaths in the United States.¹ More than 50% of all gunshot injuries are related to suicide attempts, and approximately 14% of all gunshot-related assaults will result in maxillofacial injuries.¹ Although there has been an increase in the incidence of gunshot wounds to the face,^{2–4} missile-related craniofacial injuries are still not as common as those to other regions of the body.^{5–7}

Bullet injuries are divided into high-velocity ($> 2000 \text{ ft s}^{-1}$) and low-velocity ($< 2000 \text{ ft s}^{-1}$).⁸ A high velocity bullet is likely to lead to quick and fatal injury to the victim, whereas a low-velocity bullet may result in a non-fatal injury. It is, therefore, more likely that the oral maxillofacial radiologist will encounter low-velocity bullet injuries to the maxillofacial region.

Low-velocity firearms mainly include handguns and shotguns. Low-velocity injuries differ from those of other missile injuries owing to the large spectrum of damage; the pellets scatter as they hit and travel

through the body, thereby multiplying the damage along its course.⁹

The pathological effects of the gunshot wound will depend not only on the calibre of weapons but also on the quantity of energy transferred; rate of transfer and energy flux, which is influenced by the range of shot; type of shot (size and weight of pellets); impact velocity; and body tissue resistance.¹⁰ The extent of tissue damage from gunshot wounds also depends on the track the missile follows after it hits the body. Knowledge of ballistics and forensic sciences will therefore help the radiologist in assessment and localization of the damage caused by the projectile. The aim of this article is to create awareness in the field of oral radiology regarding gunshot injuries and to hypothetically trace the path followed by the missile inside the body.

Case reports

Case 1

A 40-year-old man reported to the Oral and Maxillofacial Radiology unit with a gunshot injury and complaints of a dull aching pain on the left side of his face. The patient was conscious, co-operative and well

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orientatd. Clinically, a 1-cm-wide entry wound could be seen on the left side of the face approximately 1 inch superior to the lower border of the mandible. There was no evidence of an exit wound. The patient's pulse, blood pressure and respiratory rate were all within normal limits. There were no signs of active bleeding or pus discharge from the entry wound. Intraorally, there was no swelling, signs of laceration or ecchymosis.

A panoramic radiograph (Figure 1) revealed a concentration of bullet splinters around the left side ramus and posterior body region. Splinters were seen extending from the lower first molar region to the angle of the mandible and from the maxillary tuberosity region to the inferior border of the mandible. A step deformity along the inferior border of the mandible was also noted. The posteroanterior (PA) mandible (Figure 2) projection revealed splinters from the inferior border of mandible to the subcondylar region.

Axial sections (Figure 3) showed multiple pellets involving the body and the ramus of the left side of the mandible. Some splinters were seen in the adjacent labial soft tissue.

An attempt was made to project the course and trajectory of the missile on a three-dimensional (3D) image of another, non-trauma, case (Figure 4).

The hypothesized path revealed that the missile was directed to the lower left first molar region with the nozzle directed superiorly. This is supported by the fact that the splinters are more concentrated on the superior aspect of the left side. The missile fractured the buccal cortical plate but could not penetrate the lingual cortical plate; hence, there was no damage to the internal structures. The evidence of fracture of the ramus suggested that the impact of the missile was taken by the mandible.

Case 2

A 58-year-old male reported to the Oral Maxillofacial Radiology unit for radiographic evaluation of a bullet injury. The patient was hit by a stray bullet on the right side of the face during a civil riot. The patient complained of dull pain on the right side of the face

and partial trismus. The patient appeared well orientated and his vital parameters were within normal limits. On palpation, splinters of bullet could be felt on the right side of the face.

A panoramic radiograph (Figure 5) revealed a defect at the right ramus of mandible and rounded angle of mandible, suggesting malunion of the fractured segment of bone. A concentration of bullets was seen in the region of right angle of mandible and spread around the ramus and posterior body of the mandible. Some splinters were also seen lying in close proximity to the posteroinferior border of the maxillary sinus. There was approximately a 4 × 4 cm bony defect extending from the left upper central incisor region to the second premolar region with very small splinters of bullets present along the distal wall of the defect. At the defect depth a midline fracture of the palate was noted. Some splinters had also lodged themselves in the left condylar and ramus region. A PA mandible projection (Figure 6) confirmed the concentration of bullet splinters along the right ramus, body and maxillary region and a dent along the right ramus of the mandible.

A CT scan was performed to obtain a detailed picture of bony architecture and missile trajectory. Axial, coronal and sagittal images (Figure 7) revealed large concentrations of splinters in the bone around the right angle of the mandible. The posteroinferior border of the right maxillary sinus showed discontinuity, which indicated a fracture. At the area of discontinuity a few small splinters were seen. Some bullet pellets were also seen in the soft tissue medial to the ramus. Stray splinters were also seen on right side soft tissue of the neck at the level of the C3 vertebra. A discontinuity was noted at the junction of the floor and medial wall of the left maxillary sinus. A crater-like defect was seen in the anterior maxillary region.

Axial images demonstrated stray splinters buccal to the alveolar bone around the left upper premolar region and one splinter to the left mandibular region medial to the medial pterygoid plate.

A Dentascan (Figure 8) confirmed the splinters around the bone at the angle of mandible. The coronal

Figure 1 Panoramic view showing bullet splinters spread around the left ramus and posterior body of mandible

Figure 2 Posteroanterior mandible projection showing pellets around left inferior border to the subcondylar region of the mandible

image also showed discontinuity along the postero-inferior border of the right maxillary sinus. Stray splinters were seen around the alveolar bone in the left maxillary molar region.

A 3D reconstructed image of a non-trauma case was used to superimpose the course of the trajectory (Figure 9). It was hypothesized that the bullet was

Figure 3 CT scan showing multiple pellets in labial soft tissue involving the body and the ramus of the left side of the mandible

Figure 4 Projected missile trajectory of Case 1, shown on a scan of a different, non-trauma, case. A, anterior; F, foot; L, left; R, right

directed from the right angle of the mandible, causing fracture at the angle and another fracture at the ramus of mandible. The bullet then travelled through the soft tissue medial to the ramus, hitting the maxillary bone at the maxillary sinus region. The bullet fractured the postero-inferior border of the maxillary sinus. A splinter entered the sinus and terminated its course at the postero-inferior border of the maxillary sinus. It could be hypothesized that the patient's lower jaw dropped down and was pushed towards the opposite side owing to the impact of the bullet. Splinters passed through the oral cavity, dispersed in various directions and hit the palate on the left side first molar region. The splinters fractured the palatal bone and some terminated buccal to the left alveolar mucosa. One splinter also found its way through the oral cavity to the posterior pharyngeal wall and finally at the level of the C3 vertebra.

After tracing the missile trajectory it was noted that the bullet did not damage any vital structures. The impact of the velocity was mainly taken by the angle of the mandible.

Discussion

Bullet injuries are different from other trauma-related injuries. Traumatic injuries are usually located only in the area of impact, whereas a bullet, as it enters the body, forms splinters that magnify the damage in the direction of the bullet. The damage that a bullet creates is therefore unpredictable. To assess this damage, the basics of ballistics need to be well understood.

The extent of tissue damage in gunshot wounds depends on the distance at which the gun is fired, the missile track, and the bullet structure size and velocity. A maxillofacial radiologist would usually be called upon to assess and localize the damage caused by a low-velocity bullet as these bullets normally lead to non-fatal injuries in the maxillofacial region.

Figure 5 Panoramic radiograph showing a concentration of pellets in the right angle and body of mandible, posteroinferior border of right maxillary sinus and fractured palate (arrows)

Ballistics is a branch of science that deals with natural laws governing projectiles and their predictable performance.¹¹ As a projectile enters the body the

Figure 6 Posteroanterior mandible projection showing pellets around the right angle of mandible and some in the soft tissue at the level of the C3 vertebra

different layers of tissue behave differently according to their specific property.

Injury to the dermis causes abrasion, impaction of particulate matter and contusion. At closer range, burning, implantation of powder or residue may occur and could result in a tattoo. It then enters the muscle. Muscle is elastic and may sustain deformation as much as four times the diameter of the projectile. The shape of deformation will be similar to that of the temporary cavity. On a cellular level the muscle becomes devitalized and necrotic. The projectile may then encounter vital structures such as nerves and vessels. Vessels may be ruptured, crushed or sheared and spasm may occur. These injuries may result in haemorrhage and formation of haematomas and thrombi. On a cellular level, damage may occur to all three layers of the vessel wall.¹² Finally, the bullet will meet bone, which differs drastically from soft tissue in its architecture. The minimal velocity needed to fracture a bone is 65 ms^{-1} .⁸ Bone is very inelastic and its reaction to the bullet will depend on the type of bone encountered. Impact with cancellous bone will result in a drill hole-type defect, whereas cortical bone or teeth will shatter. The resulting fragments can act as secondary projectiles and may pose an aspiration risk.¹³ Surgical removal of the splinters will depend on the accessibility of the site where they are lodged. The maxillofacial surgeon should consider leaving splinters close to vital structures alone as the literature is still ambiguous on ammunition-related plumbism and neurotoxicity of copper.¹⁴

The two cases presented here are unique as we have attempted to predict the course of the missile trajectory. An earlier attempt to reconstruct the missile trajectory was made by Bumbasirevic *et al.*¹⁵ A 3D reconstructed image of a non-trauma case was selected mainly because the reconstructed image of the bullet injury led to many artefacts, which would make study difficult. Several types of imaging may be helpful in diagnosing the extent of injury and treatment planning.

Figure 7 CT scan images confirming the fracture of the right lateral pterygoid plate, pellets lingual to the right ramus area, some pellets in the right soft tissue at the level of the C3 vertebra and fracture of posteroinferior border of right maxillary sinus

Figure 8 Dentascan showing rounded right angle of mandible and defect in upper anterior region

Panoramic radiography may be used as a gross screening radiograph. Multislice CT should also be performed to obtain multiple views with greater detail of vital structures and possible visualization of the missile fragments. Cone beam CT (CBCT) scans may be an important tool as this would lead to fewer artefacts. However, it needs to be noted that with the limited field of view offered by CBCT the extent of damage caused by a bullet injury could never be completely assessed. Moreover, in developing countries, such as ours, CBCT facilities are scarce and expensive.

The projection of the missile trajectory in Case 1 indicated that the missile was directed at the first molar region of the left side; which was also indicated by the entry wound. The missile was also directed upwards as more splinters are seen superior to the entry wound and there are very few splinters scattered inferior to the wound. A small-calibre missile of comparatively low velocity (more than 65 ms^{-1}) caused the injury and crushed the mandible. The missile also missed the facial artery and other vital structures near the angle of mandible as the entry wound was superior to the level of facial artery crossing the lower border of mandible.

Figure 9 Projected missile trajectory for Case 2

Moreover, the firearm nozzle was directed superiorly, thereby missing the facial artery.

In Case 2, the projection of a single missile trajectory was made from the lateral and the posterior aspect. The projection was made from two different planes so that the damage to the external, as well as the internal, structures could be shown. This demonstrated that the missile was directed at the angle of mandible of the right side, as is shown by the relatively higher concentration of splinters at the angle of the mandible. The splinters were spread in all directions and

terminated at various sites, namely, at the maxillary sinus of the right side; alveolar bone at the left upper molar (through the oral cavity); and in the right side neck soft tissue at the level of the C3 vertebra (through the posterior pharyngeal wall). A relatively high-velocity missile (higher than that used in Case 1) was used. This is demonstrated by the fact that the bullet fractured the mandible, passed through the oral cavity and fractured the palate and posteroinferior border of the maxillary sinus of the left side. The missile did not encounter any vital structures along its course. The patient did not, therefore, have any neurological or other complications.

In conclusion, as Hough¹⁶ previously reported, “the only rule regarding the science of ballistics is that the bullet follows no rules”. Not all gunshot wounds are the same. Gunshot injuries will vary depending on the type of bullet used, the distance from which the bullet was fired, type of shot (size and weight of pellets), impact velocity and body tissue resistance. With an increase in the incidence of gunshot injuries to the maxillofacial region, it is important for the oral radiologist to be familiar with shotgun ballistics. The two cases reported emphasize that knowledge of ballistic sciences will help the radiologist to assess the damage and localize the bullets and its splinters.

Our report illustrates that knowledge of the path of the missile track is critical for assessment of the damage and management of the patient with a gunshot wound. The unpredictable nature of the bullet also emphasizes the importance of projecting the missile trajectory. A missile trajectory-tracing software program could be an important tool in the diagnosis and management of patients with bullet injuries.

Disseminating expertise in our journals and continuing education programmes will be key to the understanding of gunshot injuries and their implication in the maxillofacial region.

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