Int. J. Oral Maxillofac. Surg. 2014; 43: 1445–1458
http://dx.doi.org/10.1016/j.ijom.2014.07.013, available online at http://www.sciencedirect.com

International Journal of Oral & Maxillofacial Surgery

Review Paper
Trauma

Wound ballistics of firearm-related injuries—Part 1: Missile characteristics and mechanisms of soft tissue wounding

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P. K. Stefanopoulos, K. Filippakis, O. T. Soupiou, V. C. Pazarakiotis: Wound ballistics of firearm-related injuries—Part 1: Missile characteristics and mechanisms of soft tissue wounding. Int. J. Oral Maxillofac. Surg. 2014; 43: 1445–1458.

Abstract. Firearm-related injuries are caused by a wide variety of weapons and projectiles. The kinetic energy of the penetrating projectile defines its ability to disrupt and displace tissue, whereas the actual tissue damage is determined by the mode of energy release during the projectile–tissue interaction and the particular characteristics of the tissues and organs involved. Certain projectile factors, namely shape, construction, and stability, greatly influence the rate of energy transfer to the tissues along the wound track. Two zones of tissue damage can be identified, the permanent cavity created by the passage of the bullet and a potential area of contused tissue surrounding it, produced mainly by temporary cavitation which is a manifestation of effective high-energy transfer to tissue. Due to the complex nature of these injuries, wound assessment and the type and extent of treatment required should be based on an understanding of the various mechanisms contributing to tissue damage.

Keywords: Wound ballistics; Gunshot wounds; Missile injuries; Ballistic injuries; High-energy missile trauma.

Accepted for publication 21 July 2014
Available online 13 August 2014

''Dans les champs, le hasard ne favorise que les esprits préparés'' (In the field [of observation], chance favours only the prepared mind)

Louis Pasteur

The wounding power of firearms is an important issue in penetrating trauma, both war and civilian,[1–6] and as such it may also affect surgeons with little knowledge or concern about weapons and their effects. The study of these effects produced by missiles has been termed 'wound ballistics',[7] indicating its subordination to the science of projectile motion. In this context, the term missile implies small projectiles capable of tissue penetration because of their energy rather than their shape.[8] Wound ballistics examines the relationship between the properties of the missile and the severity of the resultant wound, and the role of the various mechanisms of ballistic penetration in the production of tissue damage.[9] These aspects apply to battle casualties, the majority of which are caused by munition fragments rather than bullets,[1,10–13] as well as to ballistic injuries seen during peacetime.

In both of these environments, the maxillofacial region represents a prominent location for missile injuries,[14–17] but it is mainly due to civilian firearm violence that this area often appears as an intentional close-range target, whether the consequence of assault or suicide attempt.[18–21] In the face, the close anatomical relationship of soft and hard tissues results in a complex pattern of firearm-related injuries,[22] with comminution of bone and teeth as a common feature.[23,24] Furthermore, the amount of non-viable tissue following ballistic trauma remains a critical concern, especially when primary reconstructive procedures are contemplated.[18,25,26] Although the assessment of the unique consequences of these injuries is a subject of surgical judgement, an understanding of wound ballistics can provide the basis for interpretation of the mechanism of tissue damage with respect to its extent along the wound track; in this way the surgeon is also prepared for potential complications.[25–28] In this paper, the first of two, we present the wounding effects of small arms projectiles on soft tissue. In the second part, the pathophysiology and ballistic aspects of maxillofacial missile injuries are discussed.

Wounding agents

Firearm-related injuries among the civilian population are commonly inflicted by handguns, rifles, and shotguns.[18,29,30] These weapons are included under the military term ‘small arms’,[31] and are generally defined by their type and calibre (diameter).

Handguns and rifles

Both handguns and rifles are rifled firearms. Rifling is an important feature of all firearms except shotguns, indicating a series of spiral parallel grooves cut into the bore (the inner surface of the barrel).[18,29–35] Calibre refers both to the diameter of the bore and the bullet maximum diameter.[36–38] It is expressed either as a decimal fraction of an inch (with the nought in front of the decimal point usually omitted) to designate American and British weapons and cartridges,[29,31,37–39] or in millimetres based on the metric designation system,[29,38–40] which is the standardized method for sizing military ammunition.[31,35,38]

Handguns are of two major types, revolvers and auto-loading pistols. They are the most frequently used type of firearm in civilian conflicts.[6,18,31,41,42] Common handgun calibres range from .22 to .45 in. (Fig. 1). The more rarely encountered submachine guns are truly automatic weapons typically using handgun ammunition.[31,33]

Rifles are the most powerful of the commonly encountered small arms,[31,41,42] and they are categorized into two main classifications, those for military use, called assault rifles, and the hunting rifles.[42,43] Assault rifles use ammunition of smaller calibre than most handguns and are capable of firing either single shots (semi-automatic fire) or in bursts (fully automatic fire) through the use of a selector level. Most renowned are the Russian AK-47 (Kalashnikov; calibre 7.62 mm) and the American M16 (calibre 5.56 mm). Civilian versions of assault rifles, such as the AR-15 edition of the M16, normally lack the fully automatic mode.[42]

Fig. 1. Examples of pistol ammunition. From left to right: .38 Super; 9-mm Luger; .40 Smith & Wesson (S&W); .45 Automatic Colt Pistol (ACP). The former two are essentially of the same diameter, but the .38 Super is more powerful as indicated by its considerably longer cartridge case containing larger propellant charge. Note also the truncated ‘semiwadcutter’ (SWC) configuration of the .40 S&W compared to the more common round nose shape of the other bullets. (One cent coins are shown for comparison.).

Ammunition

The cartridge (round of ammunition) is the functional unit of firearm ammunition, renewed for each firing. The bullet is the part of the cartridge that hits the target and does not refer to a complete round of ammunition. The round consists of the cartridge case containing the propellant (‘powder’), with the bullet mounted on the open end of the case and the primer incorporated into the opposite closed end (base or head).[18,30,31,37,44]

Combustion of the powder ignited by the primer produces rapidly expanding gases which propel the projectile out of the cartridge case and down the barrel of the gun.[37] During its acceleration, the bullet attains two types of motion simultaneously, forward translation and also rotation on its longitudinal axis (spin) as it encounters the grooves of the rifled bore (Fig. 2).[44] Spinning serves to gyroscopically stabilize the bullet during its flight, thus increasing both its range and accuracy.[3,31,33,34,36,43–46]

Most bullets are composed primarily of a lead alloy, but lead-free (non-toxic) metallic bullets are also available.[31,38] Bullets are either solid or jacketed. Jacketed bullets have a core of lead or mild steel covered by a coating (jacket) of a harder metal, such as cupronickel or a steel alloy,[30,31,36,38,39] and they come in two basic constructions.[47] Partially jacketed (semi-jacketed) bullets have the tip either simply left exposed (‘soft-point’) or hollowed out (‘hollow-point’); they typically flatten or ‘mushroom’ when striking soft tissue with sufficient velocity,[31,48] hence they are known as expanding bullets. Full metal jacketed (FMJ) bullets, also known as ‘ball ammunition’, have the jacket enclosing the tip to prevent it from such deformation.[22,31,38,41–43,47,49] Rifle bullets are jacketed in order to prevent the soft lead core being stripped and deposited in the rifling at the high velocities accomplished.[31,47]

An unfortunate term for expanding bullets is ‘dum-dum’.[48] It essentially refers to a modification of the official military FMJ .303 British rifle bullet, made for the British Indian Army in 1897 at the Dum-dum arsenal near Calcutta. That