



Research Article

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Gunshot Fractures to the Limbs: A Review of Fixation Methods

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Abstract

Background: The authors had intensive experience with gunshot fractures in wounded civilian and military in the war against organized crime in Rio de Janeiro. From the many difficulties and controversies, came the necessity to search for scientific evidence to establish management and treatment to these challenging injuries.

Purpose: Make a revision about fixation methods in the management and treatment of gunshot fractures to the limbs.

Material and methods/results: The author researched the combination of the terms "Fractures", "Gunshot", "Treatment", "Fixation" and "Orthopedic Surgery" in MEDLINE, PUBMED, SCIELO and LILACS.

Conclusion: Gunshot fractures Grade Gustillo I and II can be treated with debridement plus immediately/early internal fixation; Fixation methods remain controversial in Gustillo III fractures. More high level studies are necessary to establish protocols in Gustillo III gunshot fractures.

Introduction

Until the 1990s, the United States had virtually all of the published work on firearms injuries and in war situations. This may be due, in large part, to the fact that this country has participated intensively in the last armed conflicts of Humanity since the Second World War. More recently, with the increase in crime, the war against terrorism and the ease of access to military weapons, the treatment of these fractures has become no more exclusivity in situations of war. Studies in Africa, Asia and Latin America [1] presented relevant experiences in the approach to these lesions. The increase in violence in large urban centers around the world has resulted in injuries from firearms being treated in civilian hospitals, particularly in developing countries. In Brazil over the last 30 years, violence, drug trafficking and arms trafficking have grown on a large scale. Fractures from military weapons have been increasingly common in emergency hospitals in large Brazilian urban centers, such as the metropolitan areas of Rio de Janeiro and São Paulo. Epidemiological studies show that more than 40,000 people die each year from firearm injuries [2], most of them young adult men. In developed countries,

especially in the United States, which continue to engage in constant military and combat military activity, treatment protocols are being improved for the most severely injured soldiers, especially in post-amputation rehabilitation and protection. The rehabilitation and rapid return of military combatants to their operational activities has been a reality in the recent Operations in Afghanistan and Iraq [3,4]. The present review article seeks data in the literature for fixation methods

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in the surgical treatment of fractures by firearms.

After the ABCDE Primary Evaluation and Trauma Management, one of the first steps in orthopedic assessment is to investigate the mechanism of trauma and observe the characteristics of the wounds. Historically, gunshot wounds are divided into high and low speed. Results of ballistic studies obtained in the literature have shown that the impact of the lesion on the tissue at the moment of impact, the anatomical site affected, the distance of the shot and the degree of bone comminution [5,6] are more important than the velocity to characterize the injuries. Fackler [5] observed that speed is only one of the severity factors of the lesion and is not considered a single criterion. Long [7] correlated the low speed lesions like Type Gustillo I Lesions and high speed lesions like Type Gustillo III. Classifying these lesions by high or low energy may not give the true dimension of severity and prognosis, with negative consequences for evaluation and treatment. Gustillo's classification for exposed fractures remains the ideal parameter for assessment of severity and prognosis of firearm fractures and should be used to the detriment of others in order to establish conducts in order to avoid serious complications such as infection [8,9]. In a multivariate study

of predisposing factors for deep infection in open fractures Noumi [10] performed in Japan, covering 89 exposed femoral fractures in 88 patients. The study took into account gender, age, Gustillo's classification, AO classification, fracture segment, time and method of intramedullary fixation (milled or unmurtened), debridement time (> or < 6h), polytrauma and floating knee. After evaluating these variables, the authors concluded that the only parameter that acts as predisposing factor of infection is the Gustillo classification (Table 1).

Material and Methods

The authors researched the combination of the terms "Fractures", "Gunshot", "Treatment" and "Orthopedic Surgery" in MEDLINE, PUBMED, SCIELO and LILACS. After this primary research, criteria for inclusion and exclusion were established:

Inclusion criteria

1. Patients that were treated with gunshot injuries to the extremities and limbs
2. Clear description of the treatment

Table 1: Gustillo classification for open fractures.

Gustillo and Anderson classification	
Grade I	Clean skin opening of < 1 cm, usually from inside to outside; minimal muscle contusion; simple transverse or short oblique fractures
Grade II	Laceration > 1 cm long, with extensive soft tissue damage; minimal to moderate crushing component; simple transverse or short oblique fractures with minimal comminution.
Grade III	Extensive soft tissue damage, including muscles, skin and neurovascular structures: Often a high energy injury with severe crushing component.
Grade IIIA	Extensive soft tissue laceration, adequate bone coverage; segmental fractures, gunshot injuries, minimal periosteal stripping.
Grade IIIB	Extensive soft tissue injury with periosteal stripping and bone exposure requiring soft tissue flap closure; usually associated with massive contamination
Grade IIIC	Vascular injury requiring repair.

Table 2: Gustillo I gunshot fractures.

Author/Journal	Population/anatomical Segment	Methods of fixation	Results
Wiss [12]/J Bone Joint Surg Am 1991	Civilian/Femur fractures	Delayed Interlocking Nailing	0% infection; 3.5% delayed union; 12.5% malunion
Bergmann [13]/J Trauma 1993	Civilian/Femur fractures	Immediate Intramedullary Nailing	0% infection
Nowotarski [14]/J Orthop Trauma 1994	Civilian/Femur fractures	Immediate Intramedullary Nailing	0% infection; 2.5% delayed union; 2.5% malunion; 0% nonunion.
Molinari [17]/Cont Orthop 1994	Civilian/Extremity long bone fractures	Immediate (A), early (B) and late (C) internal fixation groups	Infection 2.6% Nonunion 3.3% in each group
Tornetta [16]/J Orthop Trauma 1994	Civilian/Distal femur	Anterograde Intramedullary Nailing	7.8% low valgus deformity; 15.8% low posterior angulation

Long [7]/Clin Orthop Rel Res 2003	Civilian/Injuries to the femur	Immediate or early nailing	No infection
Polat [15]/ Eur J Trauma Emerg Surg 2018	Civilian/Femur Diaphyseal fractures	Immediate debridement and delayed treatment: External fixation (group A) versus Intramedullary Nailing (group B)	Deep infection 5.2% (A); 3.5%(B) Delayed union 10.5%(A); 7.1%(B) Nonunion 2.6%(A) 3.5%(B)
Gonzalez [18]/The Journal of Hand Surgery 1993	Civilian/Hand metacarpal fractures	Early rigid fixation combined fixation with flexible intramedullary nails, k wires and plates.	0% deep infection; 4% superficial infection; 0% malrotation; mild decrease in range of motion.
Kiehn [19]/Plast Reconstr Surg. 2005	Civilian/hand fractures	Reduction and immobilization; Early definitive fixation	8% infection with no difference between the methods.
Komurcu [20] Int Orthop 2008	Civilian/Hand fractures	Immediate fixation for all plate fixation (A), K wire (B) and Ext Fixation (C), Plate + graft (D)	Infection 14.2% (A); 30% (B); 28.5% (C); 10% (D) Nonunion 0% (A, B) 7% (C); 10% (D).

Table 3: Gustillo II gunshot fractures.

Author/Journal	Population/anatomical Segment	Methods of fixation	Results
Long [7]/Clin Orthop Rel Res 2003	Civilian/Injuries to the femur	Delayed Nailing (more than 48h)	43% infection

3. Clear description of the injuries
4. Clear description of the outcomes
5. Articles published after 1980

Exclusion criteria

1. Epidemiologic studies
2. Basic science studies
3. Articles involving patients with skeletal immaturity
4. Spinal injuries

Results

The articles selected for this review were organized in Table 2, Table 3 and Table 4 and they were divided according to the Gustillo Classification. If an article presents clear and relevant data about different types of fractures it can appear in more than one table.

Discussion-Treatment

Gustillo I gunshot fractures

Gunshot Fractures Gustillo I with good alignment and stability tend to be treated conservatively. These fractures are correlated to fractures by low energy firearms. It seems to be a consensus that conservative management is well indicated in less severe lesions. This is very important because

of the antibiotic bacterial resistance and high costs of health administration. Papasoulis [11], in a systematic review, concluded that the use of antibiotics in uncomplicated lesions and with conservatively treated fractures can be ruled out. The antibiotics of choice are cephalosporins, cefazolin, with similar efficacy through intravenous or intravenous administration.

When surgical methods are needed, the treatment of choice is the immediate primary immediate fixation. However, it was observed that until the late 1970's and early 1980's, the conservative treatment of Gustillo I gunshot femoral fractures was still used. In the mid-1980s, comminuted and unstable femoral shaft fractures, including firearms, were being treated by intramedullary nail. Plates and screws had a higher incidence of deep infection due to larger incisions and exposure of soft tissues and external fixators had infection with pin traction and problems with knee rehabilitation and bone healing. In the 1990's, Wiss [12], Bergman [13] and Nowotarski [14] published non-comparative retrospective studies assessing the treatment of gunshot-induced femur fractures by early intramedullary nailing, all with good results and low rates of complications. The main limitation of these studies was the low level of evidence.

Gunshot femur fractures Gustillo type I are quite prevalent and their treatment has some controversy. Polat [15] analyzed 107 low energy gunshot-induced diaphyseal femur

Table 4: Gustillo III gunshot fractures.

Author/Journal	Population/anatomical Segment	Methods of fixation	Results
Dar [23]/Ulus Trauma acil Cerrahi Derg 2009	War fractures by firearms	External Fixation	0% malunion
Olasinde [24]/South African Orthop Journal 2012	Civilian/Inferior extremities fractures	Delayed Intramedullary Fixation and bone grafting	15.2% infection
Dubravko [25]/J Trauma 1994	Military/Extremities Fractures	External Fixation	7.7% osteomyelitis 35% tract pins infection
Kaguru [26]/East and Central African Journal of Surgery 2004	Military/War extremities fractures	External Fixation	3.2% pseudoarthrosis; 16.1% osteitis; 1% tetanus.
Dahabra [27]/J Trauma 1994	Military/Extremities fractures	External Fixation	23% wound infection; 10% pin tract infection
Lerner [28]/Clin Orthop Relat Res 2006	Military/war lower limbs fractures	Ilizarov External Fixation	90% good results
Possley [29]/J Trauma 2010	Military/Tibial fractures	External Fixation	77% successful
Amaral [30] Orthop Rel Res 2003	Civilian/Forearm fractures	External fixation (A) vs. cast (B)	A-57.1% Satisfactory; B-58.3% satisfactory.
Nikolic [31] Injury 1999	Military/Subtrochanteric fractures	External fixation (A) versus plaster of Paris (B)	Complications overall: 65%; infection: 15%; malunion: 10%. A-65% (delayed healing and nonunion; B-86.7% (contractures)



Figure 1: Transfixing Gustillo I gunshot fracture of the proximal femur a sciatic nerve neuropraxis treated with pelvifemoral external fixation at a trauma hospital in Rio de Janeiro. (Author's archive).

fractures, comparing delayed external fixation and delayed nailing and no differences were found between these methods. Tornetta [16] retrospectively assessed 38 patients with distal femoral fractures by firearms in an average period of 24 months operated with anterograde intramedullary nail and obtained consolidation and early mobilization in all cases with rates of 22% of deviations greater than 5° of angulation. Molinari [17] and Long [7], in comparative studies with femoral firearm fractures in civilians, had good results treating them with immediate intramedullary nail and low infection rates in cases with lower exposure bone (0% to 2%). Molinari performed a comparative analysis of 121 Gustillo I long-bone firearm fractures in a New York City hospital, placing them in three groups according to the internal fixation time (immediate, precocious and late). No difference was found and the study concluded that early internal fixation is related to the reduction of hospital stay. Long studied 100 fractures of the femoral diaphysis and classified according to the level of contamination in 1, 2 and 3. Immediate fixation was performed in fractures of Grade 1 with infection rate equal to 0%. Polat [15] analyzed 107 grade I diaphysal femur fractures, comparing late external fixation and late fold, and no differences were found between these methods.

In some Gustillo I gunshot fractures, depending on the circumstances and other injuries associated, the treatment with external fixation can be done, especially when there are other injuries associated (Figure 1). In the war against crime in Rio de Janeiro, many conflicts are fought in places of high contamination and difficult access, near hills, forests and open air sewers. In addition, there are reports of drug traffickers who put feces in their armaments and projectiles to increase the contamination of wounds. Primary internal osteosynthesis may be at high risk of complicating infection, even in Gustillo I fractures.

On many occasions, it is not the degree of contamination of the fracture by firearm that determines the surgical technique, but the anatomical site. Fractures of the upper limbs by firearms present a very small amount of studies when compared to the inferior limbs. Nevertheless, some articles can be pointed out to be relevant to establish management in Gustillo I upper limb gunshot fractures. Gonzalez [18] performed definitive stabilization in 64 cases of Gustillo I firearm hand fractures in 49 patients. The patients were initially approached with debridement, antibiotic therapy and immobilization. After an average of 3 days, definitive reconstruction with rigid fixation was performed. There were no cases of deep infection and 1.38% of surface infection. The shortening occurred on an average of 1.4 mm. The mean final angle was 1°. The mean metacarpophalangeal foramen amplitude was 65°; the interphalangeal was 72° and the distal 60°. Kiehn [19], in a retrospective descriptive study, pointed immediate definitive fixation methods and the best choice for definitive fixation in hand fractures by low energy firearms. Komurcu [20] compared osteosynthesis with plate and fixation with kirschner wires in hand fractures by low velocity firearms, in a total of 76 patients, 51 metacarpal fractures and 41 proximal phalangeal fractures. There were no significant differences between the methods used. The infection rate was 10.5%,

being 1.3% of deep infection and 9.2% of deep infection.

Gustillo II gunshot fractures

Gustillo grade II firearms fractures can be considered as of intermediate severity. Long [7], when discussing the treatment of firearm fractures with wounds greater than 2 cm, emphasizes the importance of meticulous debridement and finds a 43% infection rate in these fractures. Comparing fracture complications with wounds less than 2 cm (0% of infection) with greater than 5 cm (50%), Gustillo II fractures would have more similarity to Gustillo grade III fractures than Gustillo grade I fractures. Regarding the technique of surgical fixation, Long recommends an early definitive fixation (less than 48 h) in grade 2 and late fixation in fractures grade 3. If the results of this study are correlated with the classic works of Gustillo and Anderson, it can be said that Gustillo II grade fractures with wounds bigger than 1 cm and smaller than 2 cm, without bone devitalization may have a more conservative treatment, like Gustillo I. Those Gustillo II grade fractures with wounds bigger than 2 cm and tissue devitalization should have a more aggressive treatment, like Gustillo III. It is recommended in cases of doubt, look at other criteria to define the best approach, such as the time taken to hospital care, the circumstances and the anatomical site where the victim was shot. Table 3 shows articles about Gustillo II gunshot fractures

Gustillo III gunshot fractures

There is a consensus that meticulous debridement plays a key role in grade II and III Gustillo gunshot fractures, apparently more important than the initial the method of fixation in the primary management [7,21]. The fractures by Gustillo grade III firearms are related to higher energy injuries, more serious and with greater potential of complications, more common in victims of injuries of armaments of military use and explosives. The meticulous debridement plays a key role in fractures grade II and III Gustillo apparently more important in the initial assessment of the method of fixation. In war situations, the difficulties of access and transportation of wounded victims to centers of great trauma and the high destructive capacity of military weapons tend to suffer from more severe fractures. It can be said that there is a strong correlation between these high energy lesions and Gustillo's grade III fractures. There seems to be a tendency to perform damage control with external fixation in war zones and heavy urban armed conflicts (Figure 2).

Harwood's [22] concept of damage control was eventually applied to firearms fractures in the United States, which was already used in war environments, but without this designation. The main complications that are avoided are Respiratory Insufficiency, Fat Embolism and Venous Thromboembolism. The time for this conversion, so that there are no infectious complications, depends on the patient's evolution and their inflammatory and metabolic response to the trauma, but should not exceed 14 days. Nevertheless, Dar [23] conducted a prospective study with 41 patients with femoral gunshot fractures grade III of Gustillo. In the initial approach, external fixation was performed followed by intramedullary nailing.



Figure 2: Gustillo type IIIC fracture of the proximal humerus by AK47 Rifle treated by damage control using external fixation and K wires (author's archive).

The mean conversion from placement of the external fixator to the closed intramedullary nail was about 26 days, with 100% of union. Olasinde [24] obtained good results in more severe gunshot fractures with delayed intramedullary fixation and bone grafting. The Table 4 below grouped studies that mention fractures by grade III firearms.

Dubravko [25] published, after attending FPA victims in the Croatian War, a study with a casuistry of 116 fractures, including 31 of femur, the lesions were treated by external fixation and the general incidence of osteomyelitis of 7.7% and 35% infection in the path of the pins. In war conflicts, the authors recommended external fixation.

Kaguru, et al. [26], in a study carried out in Congo, Africa treated 62 patients with limb war injuries with external fixation and venous antibiotic therapy and concluded that external fixators war limb injuries with fractures.

When performing a retrospective study in the conflicts in Jordan, Dahabra [27] recommends that 60 patients with

FAP fractures defended the use of external fixation for these lesions, regardless of fracture severity.

Lerner [28] widely use the external fixator in their reports to the victims of bomb attacks in Israel and, in an analysis of 47 patients with 64 fractures of the lower limbs in a war environment, treated the fractures with tube-to-tube external fixator at one moment, converting them to the Ilizarov type external fixator as definitive treatment after 5 to 7 days. At the end of the follow-up, more than 90% of the fractures were consolidated. Possley [29] had a 77% successful treatment of combat-related open tibia fractures with external fixation.

In Brazil, Amaral, et al. [30], in a comparative study with 26 patient's evaluated complex fractures of the forearm by high energy firearms treated with external fixator and immobilization. 57.1% of the patients treated with external fixator and 58.3% of those treated with plaster had satisfactory results. Among the patients treated with external fixation, 21.4% had infection, 14.3% had pseudoarthrosis and 7.2%

had compartment syndrome. Among the patients treated with cast immobilization, 16.7% developed functional loss of supination and 8.3% with pseudoarthrosis. The group treated with external fixator had improvement in flexion-extension movements of the wrist. The study concludes that the ideal course is the initial use of orthosis until it is possible to perform rigid osteosynthesis.

The fixation methods are controversial in fractures by firearms Gustillo grade III and this is observed by the lack of standardization and studies with a high level of evidence to establish management and treatment protocols of this type of injury. The literature seems to a tendency to external fixation in war injuries and internal fixation in fractures in civilian hospitals. Nevertheless, controversies still remain. Nikolic [31] had poor results in subtrochanteric war gunshot fractures with external fixation. More recently, Fang [32], in a meta-analysis comparing intramedullary nail and external fixation in Gustillo grade III tibial fractures was not conclusive about the best choice, but points that surgeons subjectively prefer external fixation followed by nailing, giving much attention to infection and sometimes forgetting that this procedure can also raise infection rates, because of reoperation, more time of hospitalization and higher malunion rates. As a matter of fact, more comparative studies with high level of evidence are necessary.

Conclusion

Immediate and early treatment with internal fixation can be recommended to Gustillo I gunshot fractures and uncomplicated Gustillo II gunshot fractures. As it can be observed, there is still controversy about the best technique to be used in exposed fractures type III of Gustillo. In the civilian environment, trauma centers tend to indicate immediate debridement and internal fixation as soon as soft tissue conditions are better. In war fractures by firearms, there seems to be a tendency for external fixation followed before internal definitive fixation and in some centers definitive external fixation. More studies with high level of evidence need to be published to establish protocols.

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