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Research Article

Management of Third Fragment in Femoral Shaft Fractures: A Personal Algorithm

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Abstract

Background and Aim of the Work: Third fragment is often referred as cause of non-union or delayed healing in high-energy femoral shaft fractures. The purpose of this paper is to assess how third fragment features, such as fragment size, his angulation and displacement degree or a reverse fragment, can affect fracture healing, as well as the surgical technique applied, and to develop a decisional algorithm.

Research Design and Methods: From January 2005 to December 2022, the authors report their own experience above a total of 70 femoral shaft fractures with third fragment treated with both close and open reduction approach, analysing two cases with different approach and comparing it to literature.

Results: A total of 70 patients with presence of third fragment with a mean follow-up of 16.9 months (range 6–33 months) met the inclusion criteria. Patients were divided in four group (1A, 1B, 2A, 2B) according to dimension of third fragment and displacement and surgical approach.

The best fracture healing was recorded in fractures with fragment shorter than 5 cm and displaced less than 1 cm (group 1A-1B), while the poorest one was recorded in fracture with fragment longer than 5 cm and with displacement > 2 cm and/or reverse fragment (Group 2A-2B). Among Group 2's patients the best outcome was in patients with open reduction approach.

Conclusion: Third fragment in femoral shaft fracture is still an unsolved challenge daily facing orthopaedic surgeon. Far from settling a specific approach, literature begins to define the usefulness of the open reduction for the third fragment management. Many Authors proved that in general management of a third fragment having specific characteristics performing an open reduction would improve the outcome in terms of fracture healing with a reduced risk of consolidation defects. However, currently there are still no univocal guidelines or appropriate decision-making algorithms. For that reason, we propose a new algorithm about management of femoral shaft fractures with a third fragment based on its characteristics.

Keywords: Third Fragment; Non-Union; Femoral Shaft Fracture; New Algorithm

Introduction

Femoral shaft fractures are usually due to high-energy trauma and often associated to other major trauma [1], which could potentially lead to life-threatening sequelae, so prompt intervention and careful management lead to the best patient outcomes.

Surgical treatment timing of these fractures usually consists of immediate stabilization with a provisional external fixator, according to the principles of Damage Control[3], and their subsequent conversion, exploiting the so-called window of opportunity, in internal fixation with an intramedullary nail, which represents the gold standard surgical treatment [2]. Some authors propose a direct nailing as part of Early Total Care approach [20]. Among the complications, non-union and delayed healing can occur in 1-20% of all surgically treated fractures and they are related to both specific fracture's features and surgical technique [3].

About specific fracture features the most important are Type B or C according to AO/OTA classification system [4], patient's age and comorbidity, intra-isthmic fractures, exposed fracture, interfragmentary gap and comminuted fragment, third fragment's length and its angulation (standard X-rays views), third fragment's maximum displacement and rotation from cortical bone (standard X-rays views) [5].

About surgical technique there are several important aspects to consider such as the choice of the nail diameter (indicated a nail diameter ≥ 10 mm) [6], the ratio between intramedullary nail length and femur (indicated a nail/femur ratio of 90%), non-reamed vs reamed nailing technique. In this paper we represent our overall experience in management of third fragment in femoral shaft fracture, in consideration of own clinical practice of all the authors. The main aim is to contribute to the creation of an algorithm of surgical treatment that can guide and clarify therapeutic process.

Material and Methods

From January 2005 to December 2022, a total of 240 femoral shaft fractures have been treated in Authors' referral hospital, of which 38% have been classified as 32.B and 14% as 32.C, according to AO/OTA classification, totally in line with data reported by literature [7].

Femoral shaft fracture was defined as the portion of bone between a point 5 cm distal to the lesser trochanter and a point 8 cm proximal to the adductor tubercle.

The inclusion criteria were chosen through a careful review of medical charts and serial radiographs, and parameters such as demographic data (age 18 – 64 years old), fracture patterns (presence of third fragment), postoperative courses and union rates were recorded and construed.

Exclusion criteria was age out of the range, presence of major vascular damage, exposition more than 2 Gustilo-Anderson, smoking patient.

Generally, we have mainly used a closed reamed nailing technique, using both straight and anatomical nails, antegrade approach depending on the fracture pattern, and always exploiting the largest nail diameter available in 63% of patient.

We have rarely used an open approach to third fragment, only 27%, preferring an indirect reduction technique, to avoid affecting healing biology.

The surgery has always been performed in a supine decubitus on trauma bed with tractioned limb, using nails with a diameter of 10 or 11 millimetres.

An intraoperative evaluation of the lesser trochanter profile of healthy side has been done, using an image intensifier, to perform a correctly rotated nailing of femur [8].

Clinical evaluation and radiological follow-up program have been unrolled, with post-operative standard X-rays made at 1 month, 3 months, 6 months and 1 year, until complete consolidation. When necessary, a pre-operative CT-Scan was conducted for correct assessment of fracture pattern in the pre-operative planning, and a post-operative CT-Scan for the assessment of reduction obtained, if not well identifiable with conventional radiology.

Results

A total of 70 patients with presence of third fragment with a mean follow-up of 16.9 months (range 6–33 months) met the inclusion criteria. There was 44 male and 26 female, average age 39.8 ± 19,6 (range 18-64). We performed always a reamed anterograde femoral nailing, and we divided patients in four groups:

- Group 1A with a fragment shorter than 5 cm, with displacement less than 1 cm<2cm treated with closed nail (37 patients) 52.9%.
- Group 1B with a fragment < than 5 cm with displacement less than 1 cm<2cm treated with opening nail (12 patients) 17.1%.
- Group 2A with fragment longer than 5 cm and with displacement > 2 cm or reverse fragment treated with closed nail (14 patients) 20%.

- Group 2B with fragment longer than 5 cm and with displacement > 2 cm or reverse fragment treated with opening nail (7 patients) 10%.

The best fracture healing was in fracture with fragment < than 5 cm and displacement less than 1 cm (Group 1A – 1B), with a union rate of 94,6% and a mean union time of 8.3 months for Group 1A patients and a union rate of 91,7% and a mean union time of 8.5 months for Group 1B patients.

The poorest fracture healing was in fracture with fragment greater than 5 cm and with displacement > 2 cm and/or reverse fragment (Group 2A – 2B), with a union rate of 78.6% and a mean union time of 15.8 months in Group 2A patients and a union rate of 85,7% and a mean union time of 12.8 months in Group 2B patients.

Some patients needed a surgical revision: 5 patients needed a renailing (1 in group 1A, 3 in Group 2A, 1 in Group 2B), 1 needed a bone graft e renailing (Group 2A).

Delayed healing was observed in a total of 12 patients (8 in Group 2A, 3 in Group 2B, 1 in group 1A), with a mean healing time of (15-22 months), with a long period of not bearing, persistence Trendelenburg effect and low quality of life but with healing at the end.

We also reported 2 infections, 1 in group 1 B resolved with oral antibiotic and 1 in group 2B resolved with antibiotic and renailing (Table 1).

	Group 1A (n = 37)	Group 1B (n = 12)	Group 2A (n = 14)	Group 2B (n = 7)
Union rate (%)	94,6%	91,7%	78,6%	85,7%
Mean union time (months)	8,3	8,5	15,8	12,8
Delayed union	1 (2,7%)	/	8 (57,1%)	3 (42,9%)
Surgical revision (n and type)	1 renailing (2,7%)	/	3 renailing (21,4%) 1 renailing + bone graft (7,1%)	1 renailing (14,3%)
Complications	/	1 (8,3%)	/	1 (14,3%)

Table 1

Discussion

Femoral shaft fractures classified as 32.B and 32.C (Figure 1), according to AO/OTA classification, are characterized by a third fragment, which represents a cause of consolidation defects. In this sense, the historical orthopaedic definition of non-union is a completely non-consolidated fracture 6 months after surgical or conservative treatment, while according to Food and Drugs Administration (FDA) non-union is defined as a fractured bone that has not completely healed within 9 months of injury and that has not shown progression towards healing over three consecutive months on serial radiographs. Furthermore, some Authors, considering cortical bone circumferentially, define non-union as a lack of consolidation in 3 cortical out of 4 in standard X-rays view 10 months after surgical treatment or if a new surgery is necessary [9].

On the role of third fragment in consolidation defects, it has been proved that some of its characteristics play a key-role, such as fragment length (indicated as average value of longitudinal length in standard X-ray views), its displacement degree (the maximum value of the distance between cortical bone shaft surface and the fragment in standard X-rays views), its angulation and rotation as well as the characteristics of a reverse fragment (Figure 2) [10]. All these features have been the objects of our paper.

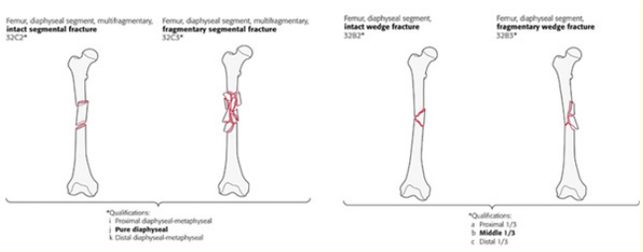

Figure 1: OTA Classification of femoral shaft fractures.

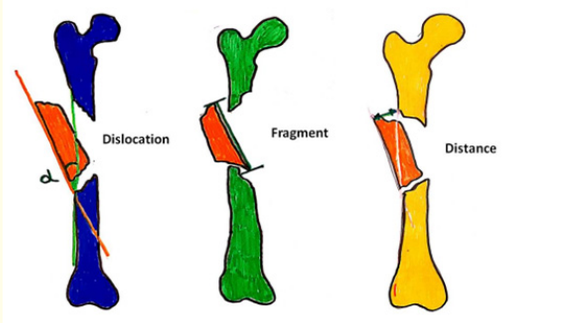

Figure 2: A. Fragment angulation, B. Fragment length, C. Fragment distance

An., *et al*. [11] focused on displacement degree, while Lee., *et al*. [12] have reported a higher risk of non-union when third fragment is longer than 8 centimetres and displaced between 10 and 20 millimetres, thus recommending an open reduction. Lin., *et al*. [13] have shown how a greater displacement than 10 millimetres and the presence of a reverse fragment are a negative prognostic index of non-union or delayed healing, due to the throttling of vascular system caused by fragment rotation that can determine fragment necrosis and its reabsorption, thus widening the interfragmentary gap.

Shuo Yang., *et al*. [14] classified displacement into four grades: grade I (displacement less than a third of the diameter of the shaft), grade II (greater than a third of the diameter and less than two thirds), grade III (greater than two thirds of the diameter), grade IV (fracture fragment turnover) he poorest fracture healing was for the grade IV displacement, while the healing was moderate in the grade II and III displacements, to highlight the importance of the dimension of the third fragment.

Hamahashi., *et al*. [5] analysed 13 cases of femoral shaft fracture treated with open reduction employing cerclage wiring for third fragment and about 50% of them showed non-union, even if the sample is not considered homogeneous in terms of fracture pattern and length. Burc., *et al*. [15], otherwise, reported about 10% of failure in open reduction treated fractures, perfectly in line with failure rates of closed reduction.

In 1987, Fitzgerald., *et al*. [16] reported excellent results in cerclage technique for comminuted third fragment in femoral shaft fractures. About vascular damage caused by cerclage, it has been also proved a damage rate of 1,59% in proximal femoral shaft fractures and 7,14% in distal femoral shaft fractures [17] and mainly for percutaneous cerclage techniques. Furthermore, the histological and anatomical of the femoral vascularization study by Pazzaglia., *et al*. [18] suggested that the periosteal vascular supply is circumferential, rather than longitudinal, with multiple musculoperiosteal vessels feeding the periosteal layer. For this reason, some authors, including Tzu-Hao Wang., *et al*. [19], affirm that cerclage must be absolutely taken into consideration in case of complex fractures with the presence of markedly displaced and rotated third fragment, not reporting statistically significant negative outcomes in terms of healing. when compared to closed nailing. In the proximal femur open reduction of the third fragment is strongly recommended due to the high risk of complications [21].

Discussing our experience, we will examine two cases treated applying an opposite approach of closed and open reduction of third fragment, to offer a critical interpretation of them.

The first case is about an adult male who reported a femoral shaft fracture with associated pneumothorax and head trauma. The fracture was initially classified as 32.B, according to AO/OTA classification, with a rotated third fragment 8 cm length, immediately stabilized with a temporary external fixator (Figure 3).

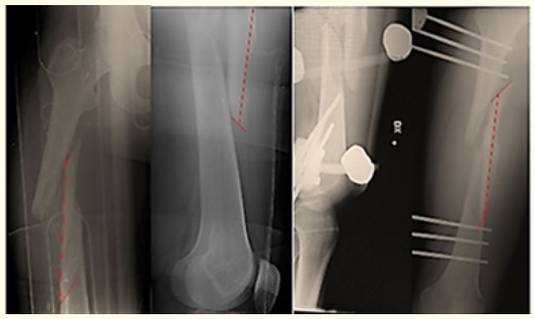

Figure 3: Temporany stabilization of femoral fracture.

During the window of opportunity, the temporary stabilization was converted in a closed intramedullary nailing. However, while removing external fixator, multiple fragmentation of third fragment was already noted in intraoperative fluoroscopy. Therefore, the fracture was newly classified as type 32.C (Figure 4).

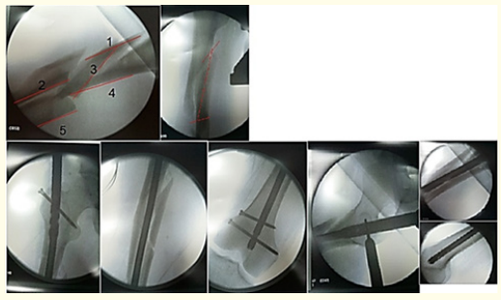

Figure 4: Fluoroscopy and standard X-rays showing multifragmentary fracture with a third fragment longer than 5 cm, displaced more than 1 cm, angulation, rotated and managed with closed reduction and intramedullary nailing.

Post-operative standard X-rays showed that third fragment was about 8 centimetres long, completely rotated. It also was displaced more than 1 centimetre, with an interfragmentary gap of about a half centimetre and an angle > 10° (Figure 5). Radiological outcome was supported by post-operative CT-scan (Figure 6).

It had been clinically and radiologically followed up until complete healing and callus entirely incorporating third fragment, about 16 months later surgical treatment (Figure 7). The case previously reported, proved that a close management of Group 2 A fractures could delay fracture healing for a long time.

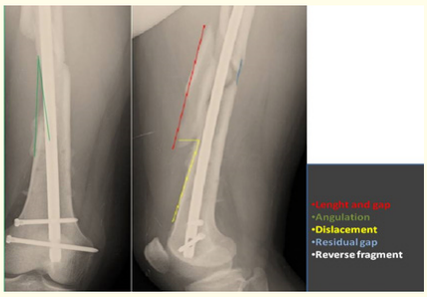

Figure 5: Post-operative X-ray.

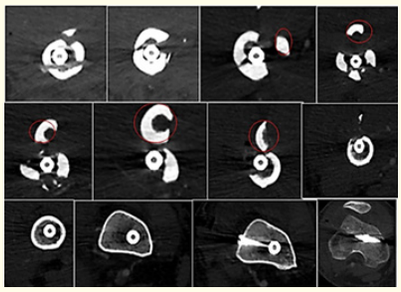

Figure 6: CT-scan showing dislocation and fragment size.

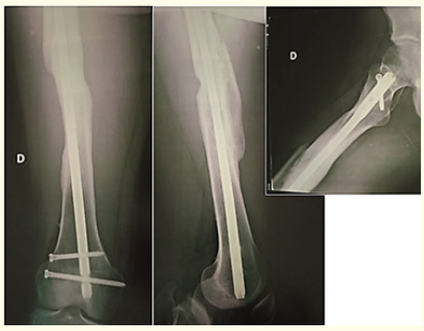

Figure 7: Fracture union at 16 months.

The second case is about a 21-year-old female, polytrauma, coming from another hospital, with bilateral type 33.C femoral shaft fractures, one of which was open fracture type 1 Gustilo-Anderson, immediately stabilized applying a bilaterally external fixator and then transferred to intensive care unit.

Even if an only post-operative X-rays image was performed, it is evident that third fragment is bilaterally shorter than 8 centimetres length, but completely rotated and markedly displaced, for more than 1-2 centimetres, group 2B.

Third fragment characteristics, which could lead to a highly difficult closed intramedullary nailing, and fractures morphology, presenting a high risk of bilaterally consolidation defects, steered to an opposite surgical approach (Figure 8).

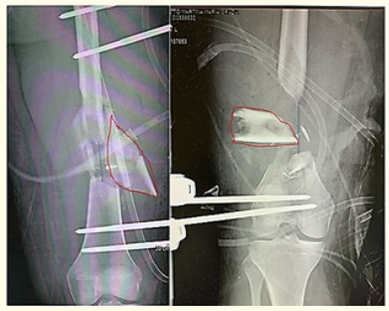

Figure 8: Bilateral femoral fracture treated with external fixator with third fragment lesser than 5 cm long but rotated and displaced more than 2 cm.

So, it was performed an intramedullary nailing with an open reduction of third fragment and cerclage. It had been radiologically followed up until bilaterally complete consolidation, about 10 months later (Figure 9).

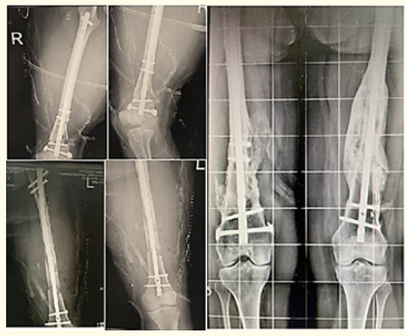

Figure 9: Open reduction to approach third fragment and bilateral consolidation at 10 months.

Third fragment in femoral shaft fracture is still an unsolved challenge daily facing orthopaedic surgeon. It represents an object of debate between those who propose closed reduction to not affect healing biology and those who propose, instead, an open reduction for better management of the fragment itself.

Far from settling a specific approach, literature begins to define the usefulness of the open reduction for the third fragment management. In this sense, the clinical cases under examination and the opposite choice of approach to the third fragment demonstrate how an open reduction must not be completely demonized, although this represents a violation of the fracture site and an alteration of healing biology. It has been widely proved that in general

management of a third fragment having specific characteristics, such as complete rotation, 1-2 centimetres displacement, 5-8 centimetres length, as well as its anatomical site, performing an open reduction would improve the outcome in terms of fracture healing with a reduced risk of consolidation defects. However, currently there are still no univocal guidelines or appropriate decision-making algorithms, as already reported by Vicenti., *et al*. [10], supported by the scientific community, to make orthopedic surgeon decision easier and to avoid legal issue. in the proximal femur open reduction of the third fragment is strongly recommended due to the high risk of complications

In this lack of uniqueness, it adapts to our study and the decision-making algorithm developed by us for a purely internal use and not as an international reference experience, based on our own experience and on current literature data (Figure 10).

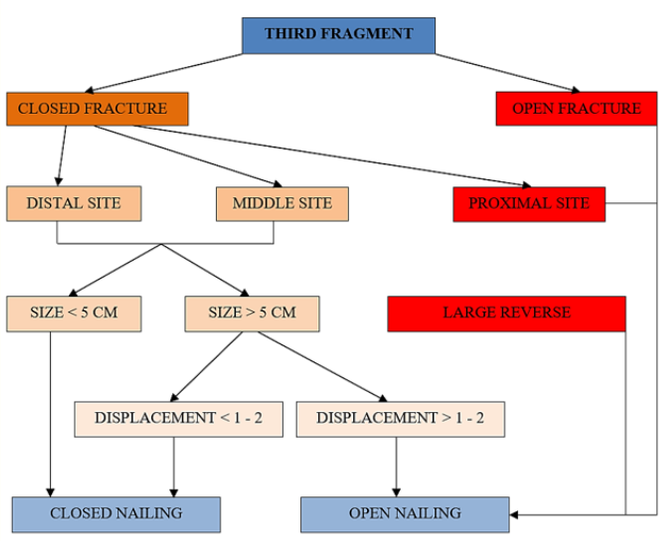

Figure 10: Personal algorithm used by Authors.

Conclusion

Third fragment in femoral shaft fracture is still an unsolved challenge daily facing orthopaedic surgeon. Far from settling a specific approach, literature begins to define the usefulness of the open reduction for the third fragment management. Many Authors proved that in general management of a third fragment having specific characteristics performing an open reduction would improve the outcome in terms of fracture healing with a reduced risk of consolidation defects. However, currently there are still no univocal guidelines or appropriate decision-making algorithms. For that reason, we propose a new algorithm about management of femoral shaft fractures with a third fragment based on its characteristics.

Conflict of Interest

Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article.

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