Lo SCALPELLO (2020) 34:67-73
doi number: 10.36149/0390-5276-011

Appropriateness of fixation methods - Trauma Meeting 2019: humeral diaphysis

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Summary

Humeral shaft fractures account for about 1-3% of all fractures in adults and are classified according their location, open or closed status and the pattern of fracture lines. Conservative treatment with functional bracing has been the most widely accepted treatment option in the last decades, however an increasing number of patients is treated surgically. This article overviews the indications, pros and cons of the most used fixation methods.
Plates and nails are the most used devices, have widely overlapping indications, mostly depending on surgeon's preference. Plate fixation can be used for almost all humeral fractures and represent the best option for transitional fractures (proximal or distal shaft), particularly those with intra-articular involvement. MIPO techniques combines the advantages of plates with less soft tissue impairment. Fractures associated with nervous lesions deserve special considerations: the need to explore the radial nerve can drive the choice of implant more than the fracture itself. Intramedullary implants are the best option for pathological fractures of the humeral shaft, and can appropriately replace plates fixation for middle third or proximal shaft even with intra-articular simple patterns. External fixation is rarely indicated, mainly for damage control and/or extensive soft tissue damage.

Key words: diaphyseal humeral fractures, intramedullary nailing, plates, MIPO, ORIF

Received: February 3, 2020
Accepted: February 28, 2020

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Conflict of interest
The Authors declare no conflict of interest

Funding
None

How to cite this article: Guindani N, Castelli CC. Appropriateness of fixation methods - Trauma Meeting 2019: humeral diaphysis. Lo Scalpello 2020;34:67-73. https://doi.org/10.36149/0390-5276-011

Introduction

Humeral shaft fractures account for 1-3% of all fractures in adults. Although conservative treatment with functional bracing has been the most widely accepted treatment option [1,2], a growing number of cases are currently treated with surgery. The increasing widespread of surgical indications has, as usual, many factors. On one hand, young and high demanding patients looking for a *restitutio ad integrum* as soon as possible, on the other increasingly low demanding patients with poor bone stock (osteoporosis, pathologic fractures, geriatric patients…) with an even greater need for faster recovery and no immobilization [2,3].
All fixation methods have been described over the years for humeral shaft fractures, although the most used are plates and intramedullary nails; external fixators play a role in open fractures. This article overviews the indications, pros and cons of the most used fixation methods in traumatology.

Epidemiology

Humeral diaphyseal fractures have a typical two-peak incidence: the first in the 2nd-3rd decades (usually following a fall, or high energy accidents) and the latter around the 7th-8th decades (usually a low energy trauma) [4]. Young males with high energy

trauma are typical in the first peak, and the M:F ratio is similar in the second peak. Smoking and female gender independently increase the healing time.
The commonest associated injury is transient radial nerve palsy (10-12% of all closed shaft fractures). In case of post -traumatic radial nerve deficit with closed injuries, the problem is almost always a transient neuropraxia; about 95% recover spontaneously and primary exploration is usually not indicated [5,6]. On the contrary, when radial palsy is associated with open fractures, a higher frequency of nerve lesions imposes surgical exploration and repair [2].
Other commonly associated injuries are ipsilateral shoulder or forearm lesion; the coexistence of multiple injuries, either in the same limb or in the contralateral one, is normally an indication for surgical treatment.

Classifications

The AO-OTA is the most common classification system [7], although recently Garnavos proposed a simpler classification [8]. Basically, all classification systems consider the morphology of the fracture (simple, one/two additional fragments or comminution) and the location (proximal, middle or distal third). In addition, Garnavos leave an additional class for transitional fractures extended to the joint (Fig. 1) [8].
Soft tissue lesions can be described according to Gustilo-Anderson [9] and/or Tscherne [10], which are the most widely used by all Authors.
A variety of scores is available when in doubt for amputation, as MESS, LSI, NISSSA and the Hannover scale, although they were intended especially for lower limbs and, as is common knowledge, in the upper extremities every attempt should be made to save the limb. Therefore, scoring systems are mostly of limited value in clinical practice to manage an individual situation [2].

Indication for surgical treatment

Nonoperative treatment is still the method of choice for most humeral shaft fractures, using some form of fracture bracing [1,2,4]. Humeral diaphyseal fractures have a good prognosis with conservative treatment [1], which is to be expected in both comminuted and simple fractures; indeed simple transverse fractures are a relative contraindication for conservative treatment [2,11]. In adults, < 20° angulation anteriorly and 30° varus, < 40° rotation and < 30 mm shortening are considered adequate displacement at bone consolidation, reaching good to excellent outcomes and 95% union rates [1,2,11].
Typical indications for surgical treatment are open fractures, polytrauma, bilateral fractures, complex fracture patterns and/or combinations of the upper limb traumatic lesions, transverse fractures, associated neurovascular injuries and neurological diseases (e.g. Parkinson, ICP, etc.), obesity. However, a wide range of overlapping indications leave the choice to surgeons and patients [2-4].

Plates

Information gathered from the AO group are milestones regarding this topic. Careful planning and application of AO principles is paramount before approaching any fracture, but this is beyond the aim of this work.
The first problem to solve is how to reduce the fracture and this is largely independent from the fixing devices, although, the surgical approach needed for reduction influences the choice of the implant. Secondly, the same plate allows to obtain absolute or relative stability and can be used as compression, protection, or bridging tool, giving more options for different situations. Obviously, it should be decided before surgery, which is the best option for each case [12].
The upper limb is not weight bearing; however, it has a large

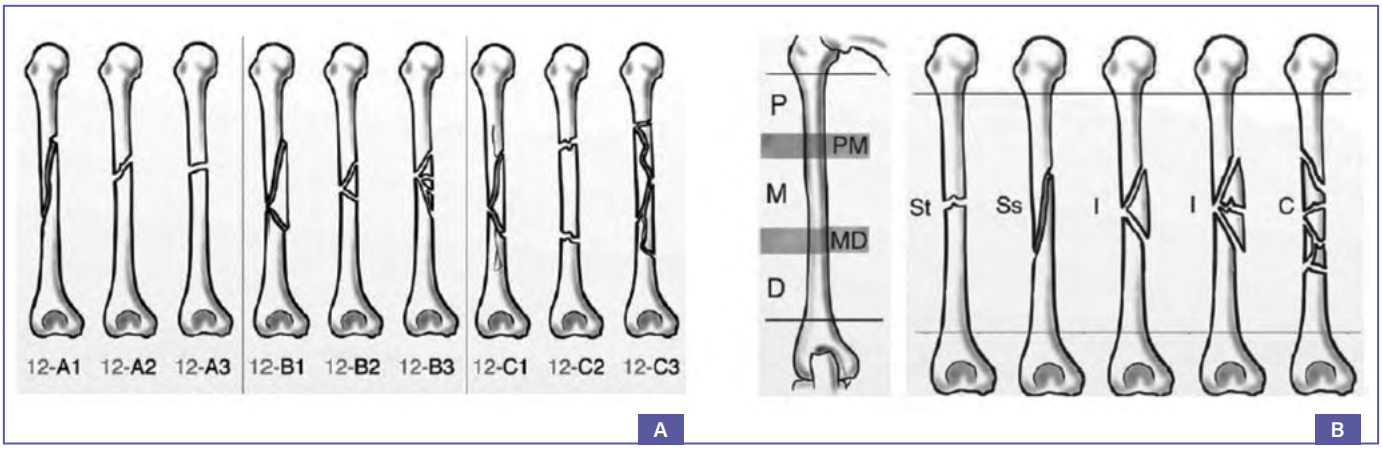

Figure 1. AO-OTA and Garnavos classifications.

rotational excursion and because of this, it is advisable to use long plates to cushion the torsional moment. For this reason, it is advisable to use 4.5 mm plates, with 8 cortexes on each side of the fracture. Dedicated 4.5/3.5 mm precontoured plates are available for transitional fractures. Plates may be implanted for every surgical approach; the choice is mostly a matter of soft tissue and reduction. In general, antero- or anterolateral approaches are more used in proximally extended fractures, posterior or lateral for distal ones (Fig. 2a-e) [4].

In poor quality bone and accounting for large rotational forces, locking screws are preferable and should be bicortical. When ORIF is required, plating enables to reduce and hold articular or periarticular fragments.

Although sometimes technically demanding, results are predictable. According to published reports of 600 humeral plating procedures, a 92-98% union rate could be obtained, the infection rate is less than 1% and iatrogenic radial nerve palsy is 3%. More than 97% of these patients achieve good functional results [13].

Minimally invasive plate osteosynthesis (MIPO)

In the last 20 years, MIPO of humeral shaft fractures using two or three small incisions became popular, similar to techniques described for lower limb [2,4]. This method, however, has been considered with great caution because of neurovascular structures at risk, for the radial and musculocutaneous nerves. Many studies have dealt with this subject reporting good outcomes with few complications, with union rates around 95% [14-17].

As for traditional ORIF, generally for MIPO an anterior/anterolateral or lateral approach were chosen for proximal fractures, lateral or posterolateral approach was used to treat distal humeral shaft fractures [15].

The lateral approach has three windows: proximal, through the deltoid for the insertion of the plate, in the middle to allow the passage between the biceps and triceps muscles, and distally for visualization of the radial nerve and fix the plate [4]. While it was concluded that MIPO is a safe and efficient procedure for humeral shaft fracture treatment, with high union and low complication rates, although in distal third elbow flexion contracture could be a problem and might indicate the need for a formal elbow rehabilitation protocol [14,15]. Despite clinical evidence that MIPO is safe for diaphyseal humeral fractures, anatomical studies have pointed out the the risk for nerve injury (radial and musculocutaneous) is tangible and should not be underestimated [18,19].

MIPO or ORIF?

This is a reiterate question in traumatology. As usual, the problem is primarily a matter of reduction and secondly of fixing method. Thus, one should consider suitable for this question only fracture pattern liable of closed reduction. Once again, planning is paramount and a *plan b (*switching from MIPO to ORIF) must be considered. Given these premises and looking for EBM, two meta-analyses have described better results with MIPO, namely concerning complications [20,21].

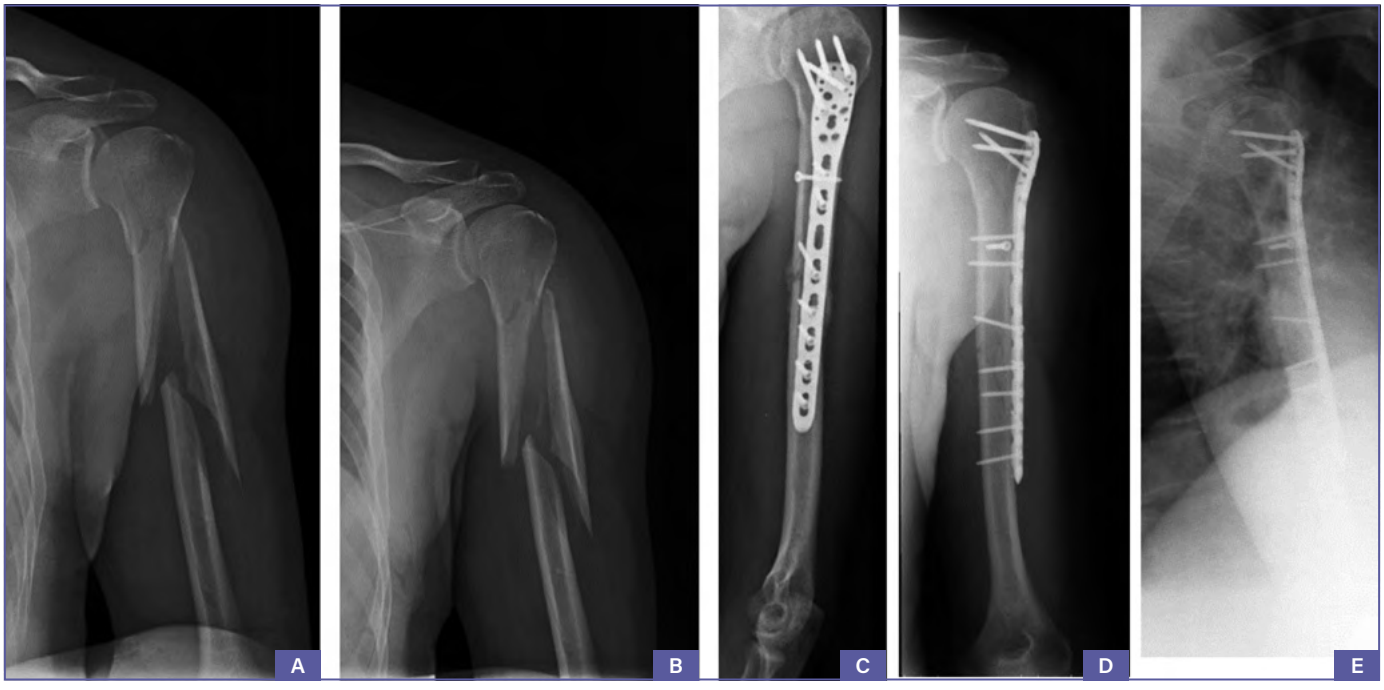

Figure 2. AO-OTA 12-B2(A) + 11-B1.1, treated with plate (ORIF). Post-operative check and follow-up at 3 months.

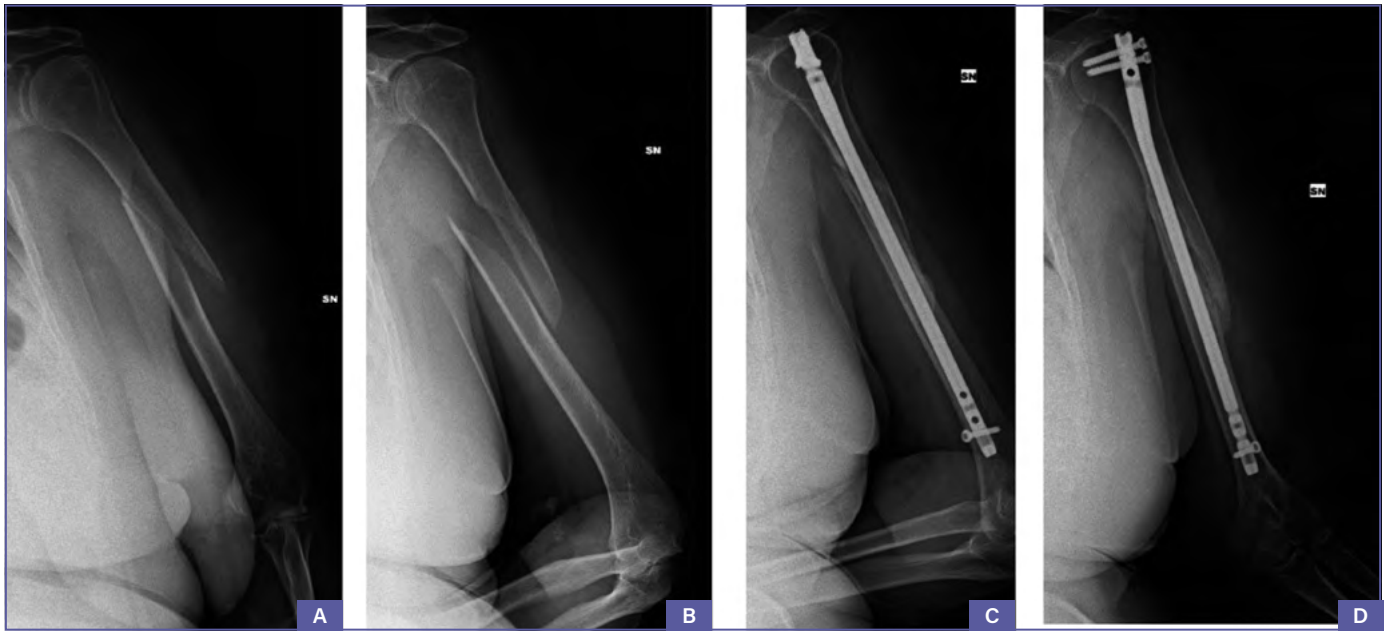

Figure 3. 12-A1(B), treated with IMN. Follow-up at 6 months.

Intramedullary nails (IMN)

IMN are the gold standard treatment option for pathological fractures of the humeral shaft [22]. In addition, segmental fractures and obesity are considered relative indications for IMN, even if there is a large indication overlap between IMN and plates.
Pre-operative planning for intramedullary nailing is not different from other techniques. The peculiar condition is that IMN can be inserted either antegrade or retrograde, each one reamed or unreamed. In any case, IMN are more frequently inserted in an antegrade fashion, as retrograde nailing is technically more challenging and has a higher risk of iatrogenic distal humeral fracture (Fig. 3a-d).
Recent designs include smaller diameter nails, with more locking options (overall proximal), so that these designs allow the treatment of transitional fractures, extending into the proximal humerus. On the contrary, if such implants are not available, to use simpler IMN the fracture must be located between the surgical neck and the transition between shaft and distal metaphysis. Obviously, closed nailing does not allow intraoperative visualization of the radial nerve, for this reason in our centre we do not usually use IMN for closed fractures associated with radial palsy.
Good to excellent results in 95% of cases are expected for both consolidation and functional outcomes [2,4].

External fixation

External fixation (EF) has a limited role for acute humeral diaphyseal fractures, and is used mainly during the damage control setting and/or open fractures with extensive soft tissue and bone loss. As plating and nailing have been advocated even in low grade open injuries, indications for EF are even more limited [4].
For external fixation, a unilateral, half-pin frame is enough for fracture stabilization and a "delta-shaped" frame can be used to achieve more stability. If any of the pins are close to neurovascular structures, limited open placement of the pins is recommended. Concerning the conversion to definitive treatment, plating after 2 weeks is a safe and effective time window for patients with multiple injuries or severe soft tissue [23].

Plating or nailing?

Plating and IMN have up to date widely overlapping indications. In two prospective randomized trials comparing plating and locked IM nailing 20 years ago, similar union rates were reported, although there was a higher complication rate in the IMN group [24,25]. In the last years, however, the trend has in favor of IMN [26-29]; a good example of this orthopedic *customs and traditions* drift can be appreciated matching the 7th and 9th edition of the Rockwood and Green's Fractures in Adults [4]. New IMN designs and established surgical know-how, progressing from the first decades, could be the basis of this trend. Concerning time to healing, both plates and IMN showed no differences, however intramedullary nailing was significantly associated with shoulder pain and stiffness and plating was significantly associated with elbow stiffness especially in distal third fractures, but not with elbow pain [26].
Shoulder joint impairment is also the main problem with antegrade nailing: in a study designed to compare the functional out-

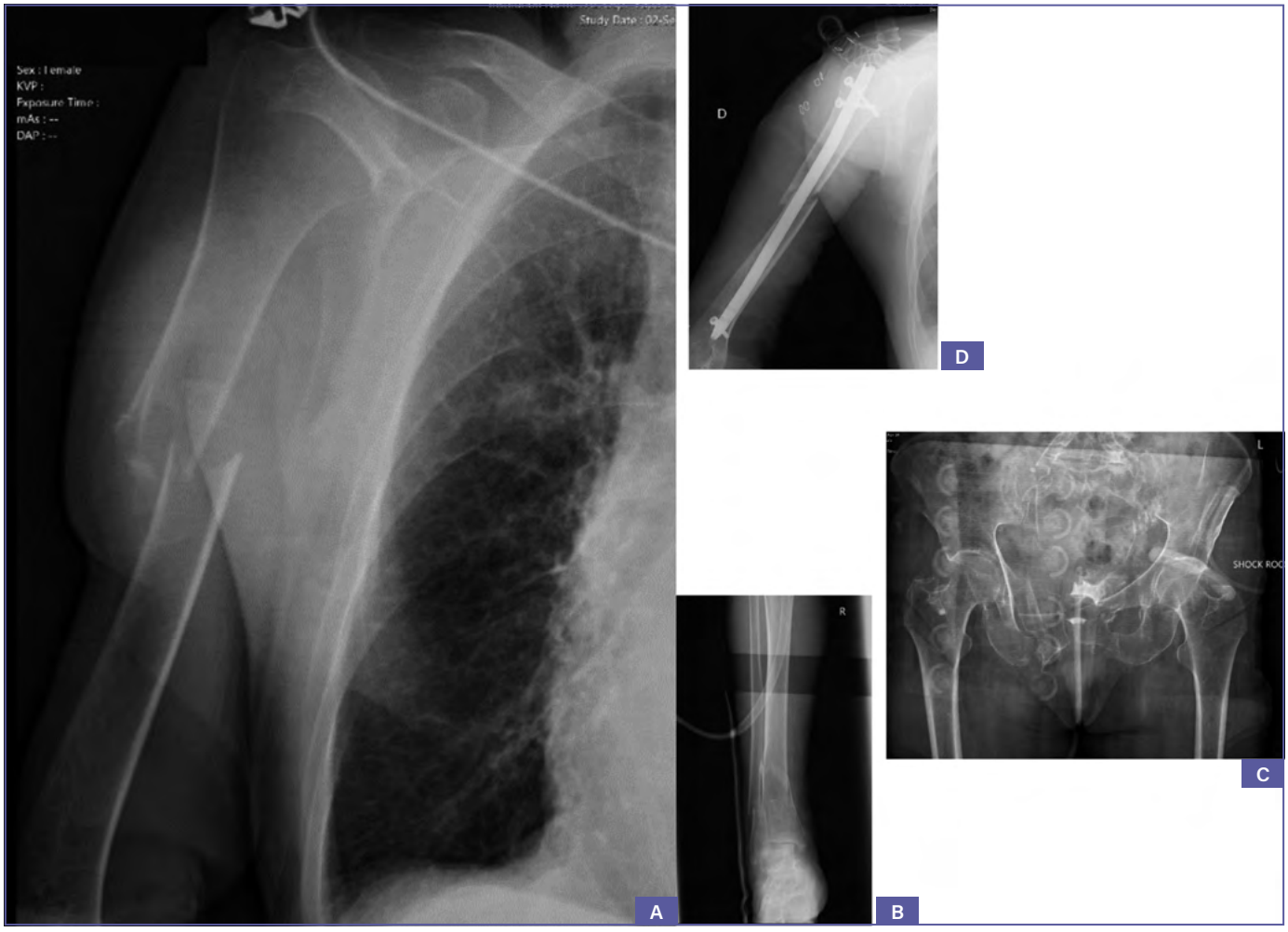

Figure 4. AO-OTA 12-A3(B) in a polytrauma geriatric patient with pronounced osteoporosis. In the post-operative x-ray (D), note the large diameter nail whitout implant-bone fit in the wide medullary canal.

comes of the shoulder joint anterograde IMN and ORIF with DCP showed no statistically significant difference in shoulder pain, functional scores, or isometric strength parameters between the two groups [30]. Exactly the opposite conclusions were described by Li et al., which showed that after IMN patients had lower shoulder functional scores, a decreased range of shoulder motion and a greater degree of malrotation [31]. In a recent study, MIPO seemed overall better with respect to nonunion, functional outcomes and rate of complications [32], nevertheless, the available data concerning plating and IMN have not given conclusive results [20], therefore allowing for further considerations on the surgeon and case, taking into account their personal experience and patients' needs.

Special consideration for osteoporosis

The choice of the implant in osteoporotic bone is always difficult. Bone weakness and potential fixation failure are the principal concerns, and in addition these patients often have many co-pathologies and need fast recovery for many reasons [4]. IMN is a good option, because it is a long load-sharing implant. However, in osteoporotic bone the medullary canal is often so wide, that no IMN can provide adequate fit and the only fixed points are the few screws through the nail (Figs. 4-5). More recently, humeral nails have been designed with threaded screw holes in order to provide more stability. Locking plates are theoretically advantageous in osteoporotic fractures, supplying a wider fixing area [33-36].

Conclusions

Concerning surgical treatment of diaphyseal humeral fractures, both plates and nails are adequate options.

In our center, given the indication for surgical treatment, we prefer following options:

- for the proximal 2/3 of the humeral shaft IMN (MIPO on-

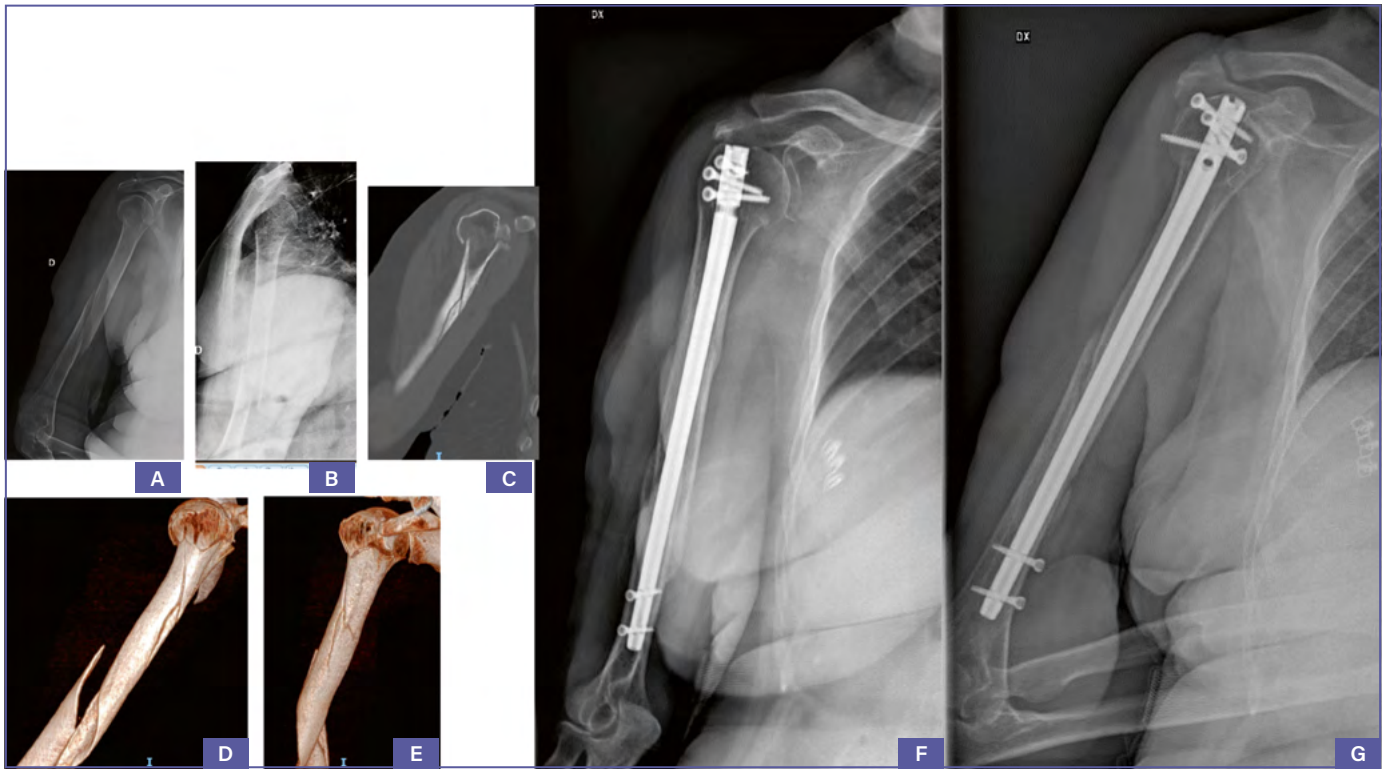

Figure 5. AO OTA 12-A1(A→B) + 11-B1.1, geriatric patient. This bifocal fracture underwent closed reduction and IMN fixation. Follow-up at 1 month.

ly for selected patients), the same for transitional proximal humerus fractures, according to fracture pattern. IMN are always reamed and blocked. Relative contraindications concerning the rotator cuff are considered (e.g. the need to use crutches, wheelchair chronically…);

- the distal third is preferably approached with plates, in osteoporotic bone, as far as possible, with 4,5mm LCP plates and at least 4 bicortical locking screws on each side of the fracture. Precontoured 4.5/3.5 mm plates are used for distal transitional fractures. In case of nerve palsy, ORIF with plate is preferred.

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