Controlled Compression Nailing for At Risk Humeral Shaft Fractures

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Summary: Compression techniques seem to be the primary factor in determining the success of both plating and nailing techniques for the management of acute fractures and for delayed and nonunion management of these fractures. An intramedullary nail that can provide continual compression (like a plate) and mechanical manipulation of the callous throughout the course of treatment is an ideal device that provides all the advantages of plating and nailing and avoids the noted limitations of both. The UNYTE compression humeral nail is based on the PRECICE intramedullary limb lengthening system. This nail provides the ability to intraoperatively compress a humeral fracture immediately and continue compression in the outpatient setting with the external remote controller. This compression nail allows the surgeon to continually modulate stability through controlled compression and the ability to relengthen if necessary. The capacity to achieve constant compression at the fracture site has demonstrated rapid healing of the "at risk" humerus fracture in this series. We review the current indications for use of this device after its early introduction. In most cases, this was the failure of conservative brace management that presented with a progressive distraction gap and minimal callous formation or those fractures that could not be adequately controlled in the brace with malalignment greater than 20 degrees. The protocol for intraoperative compression using the external remote controller is detailed, as is the outpatient protocol for follow-up. The compression algorithm for progression to full fracture healing is also reviewed.

Key Words: delayed union, humeral non-union, humeral functional brace, compression humeral nail

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INTRODUCTION

Principles of Conservative Management

The treatment of most isolated humeral shaft fractures is commonly with a functional orthosis. Indications for functional brace application include closed diaphyseal fractures without marked distraction between the fragments with or without an initial radial nerve palsy. As well, low-grade open fractures without significant soft tissue damage are also suitable for treatment by closed measures.

The early introduction of function, especially flexion and active extension of the elbow helps to prevent distraction of the fracture. The functional compression of the soft tissues provided by the brace satisfactorily aligns the fragments in most instances. The brace must be adjustable and tightened with Velcro straps to maintain constant compression of the soft tissues and to prevent distal displacement of the fracture. The compression of the soft tissues by the adjustable brace and the dependency of the extremity encourage the correction of angular deformity.

Deformity is more likely to develop in transverse, nondisplaced fractures. As such, patients treated with bracing can expect a possible varus deformity of up to 10 degrees, which is very common. However, valgus and sagittal plane malalignment is rare.[1,2] Failure to obtain acceptable alignment of the fragments calls for abandoning the closed functional treatment modality. This includes fractures that present with and maintain a progressive distraction gap that continues to increase despite active range of motion at the elbow. Residual deformity of up to 20 degrees has been noted by most authors to be cosmetically and functionally acceptable. Fracture malalignment greater than 20 degrees is unsatisfactory and an alternative treatment should be undertaken.[1]

Rationale for Early Operative Treatment

Early studies documented nonunion with functional bracing as a rare complication, occurring in only 1.8%–3.9% of reported cases.[1,2] Mild angulation consisting of varus is the most common deformity with an average angulation of 3–9 degrees reported in most series.

Studies published in the past decade that included more than 50 patients demonstrate a 10%–23% rate of humeral shaft nonunion after functional bracing.[2–5] This is significantly greater than the rate of 0%–2% reported in earlier studies by Sarmiento et al.[2–7] These contemporary series note that location of the shaft fracture dictated the rates of union. Proximal third fractures seem to be the most difficult to treat, with a union rate at 76%. Distal third fractures demonstrated an 85% union rate, and midshaft fractures revealed the highest union rate at 88%.[8] Other factors that have been shown to predispose

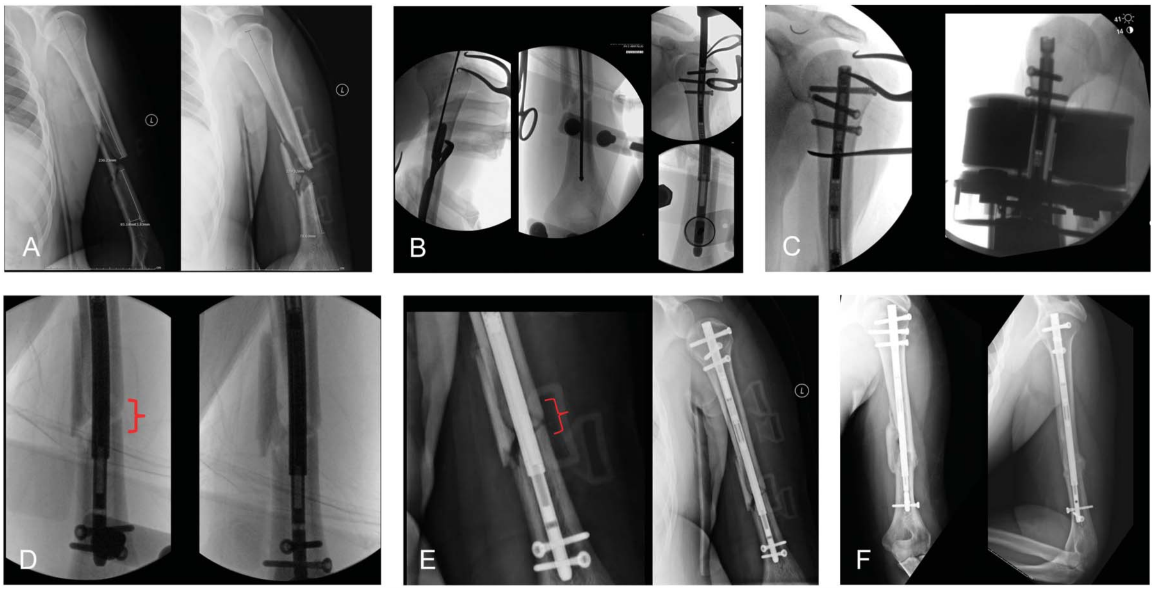

FIGURE 1. A, Grade 1 open humerus fracture treated in a functional brace at 9 weeks after injury, with persistent distraction gap, minimal callous, and gross motion. B, Entry portal guide wire is positioned medial to the tuberosity to accommodate a straight nail. The guide wire is seated into the most distal aspect of the humerus to accommodate the small-diameter 6.5-mm distal nail. The nail is positioned and any residual distraction is manually corrected, followed by static locking. C, Location of the magnet is localized and marked on the skin. The ERC is then placed over the magnet and acute compression carried out. D, Residual distraction is noted and compressed acutely with the ERC. (bracket) Note the closure of the residual fracture gap. E, First postoperative films reveal a small 1.5 mm gap, which is compressed at that time with the ERC. F, Complete healing is present at 11 weeks after nailing.

patients to delayed or nonunion of isolated fractures include highly comminuted shaft fractures (any location), proximal third, and 2-part/short spiral–oblique, and transverse fracture patterns[4–7] (Fig. 1A). The decision and timing to discontinue failing brace treatment in favor of surgery varies widely in the literature.[9]

A systematic review by Papasoulis et al[7] of studies regarding outcomes of nonsurgical management of diaphyseal fractures demonstrated a mean time to union of 10.7 weeks. These results suggest that surgeons should broach the topic of surgical options to patients with fractures that have not healed or are not demonstrating progressive callous formation by 8–10 weeks after injury. This is much sooner than what has been historically recommended.

Defining the Clinical Need for Compression Nailing

Conversion to operative treatment often requires plate fixation or intramedullary nailing. The standard of care is open reduction and internal fixation with rigid compression plating and autogenous bone grafting.[10] Other techniques that have been described include intramedullary fibular strut allograft for atrophic proximal nonunions and dual compression plating for osteopenic humeral shaft nonunions.[11–13] Plate fixation is most common; however, potential issues include difficulties with the surgical exposure specifically regarding the concern for the radial nerve.

Additional technical issues can occur with plate application and the ability to span the length of the humerus to provide adequate stabilization and axial compression.[11,12] Fracture reduction must correct any angular deformity and achieve good joint alignment, with maximal cortical contact and compression to enhance mechanical stability. Depending on the fracture configuration, the plate or lag screw insertion can be prestressed to maximize interfragmentary compression. It is clear from numerous series reporting on the successful plating of humeral nonunions that compression techniques seem to be the primary factor in determining the success of the fixation construct.[14]

Humeral nailing is an attractive alternative to the very invasive approach of plate fixation. However, there are many aspects that limit the potential usefulness of this technique. The procedure initially may seem easy, but fracture reduction and insertion portal technique can be technically demanding to avoid damage to the rotator cuff. Symptoms of shoulder impingement are common especially with nails that have a proximal bend. As well, the distal humeral canal narrows rapidly in the distal third of the humerus. This may limit the useful range of capture area for many midshaft and infra-isthmal fracture locations.

It is very common that after nail placement, the resultant construct is distracted. If the humerus is fixed in distraction, it is almost certain that repeat nonunion will be the result. A recent meta-analysis evaluating surgical results of nonunions demonstrated a union rate of 98% in patients who underwent compression plate fixation with autologous bone grafting (ABG).[15] Only 88% healed with intramedullary nailing using ABG and only 66% healed using intramedullary nailing without ABG. A total complication rate of 15% occurred in the intramedullary nail group. This included recalcitrant nonunion resulting from distraction at the residual fracture site.[15,16]

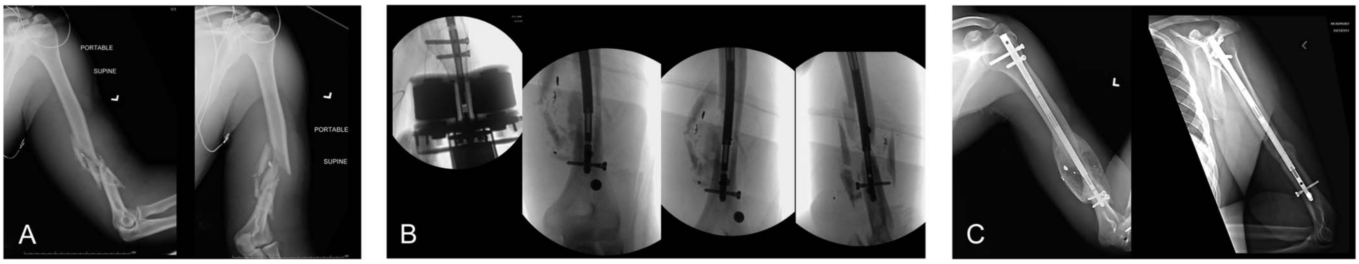

FIGURE 2. A, Highly comminuted distal fracture that failed brace treatment at 15 days postinjury, due to comminution and distal location, precluding acceptable reduction. B, The nail is seated very distally to increase the nail capture area with increased construct stability. The ERC is used to compress across the large zone of comminution to achieve bone-on-bone contact. C, The fracture healed within 9 weeks with continued use of the active compression device. Nine-month follow-up notes extensive callous and obliteration of the fracture lines.

There seems to be a large unmet clinical need regarding the treatment of the "at risk" humeral shaft fracture. It would be desirable to avoid extensile exposures and the potential complications of open reduction and internal fixation. However, the major advantage to plating is the ability to achieve and maintain the constant compression at the fracture site.[16] The capability to modulate mechanics at fracture site by modifying the strain is also a desirable concept. The immediate advantages of intramedullary nailing are the minimally invasive nature of the procedure and the additional advantage that reaming provides to the healing environment.

Rational for Use of the UNYTE System

The UNYTE compression humeral nail is based on the PRECICE intramedullary limb lengthening system.[17] The interlocking humeral nail is a straight nail designed to be inserted through the rotator cuff interval, thus avoiding the insertion of the rotator cuff onto the greater tuberosity. The nail is tapered with the proximal third being 10 mm, the intercalary portion 8.5 mm, and the distal telescoping portion 6.5 mm. This permits the nail to be placed in the far distal portions of the humeral shaft allowing for expanded nail capture and stability (Fig. 1B). The compression nail uses the same technique with a magnetic rod and a motorized external remote controller (ERC) producing a rotating magnetic field. The external magnet causes the drive thread rod to rotate, making the thinner distal nail element telescope into the thicker surrounding nail body. Compression of the nail occurs on interaction of the internal magnet with the 2 revolving magnets within the external controller unit, which can be custom programmed to adjust the compression rate.[17] This provides the ability to intraoperatively compress the fracture immediately and continue compression in the outpatient setting. This allows the surgeon to continually modulate stability and thus facilitate bone healing. The nail can also provide distraction if necessary to restore limb length or provide a compression/distraction stimulus to the fracture site.

Technique

The standard anterolateral incision is made at the apex of the acromion process and the rotator cuff is divided through its tendinous portion. The guide wire is inserted medial to the greater tuberosity. The cannulated entry reamer opens the entry portal and a small reaming guide wire is introduced. Closed or open reduction is achieved and the guide wire passed into the very distal segment of the humerus. The medullary canal is reamed appropriately and the nail is inserted under fluoroscopy (Fig. 1B). Once the nail is seated, any residual distraction can be eliminated with backslapping of the nail or using manual compression. After static locking, the magnet location in the proximal nail is verified under fluoroscopy. The magnet location is marked on the skin with a permanent marker to facilitate placement of the patient controller device (ERC) (Fig. 1C). The fracture site is visualized and any amount of residual distraction is noted. The ERC is used to compress the nail to achieve bone-on-bone contact (compression) and closure of any remaining fracture gap (Fig. 1D).

Our follow-up protocol involves clinical and radiographic examinations at 2-week intervals, beginning the active compression phase of treatment at the first postoperative visit. At this time, new cone down x-ray images should be taken and assessed to measure any residual fracture gap that may be present (Fig. 1E). Using the ERC, the measured gap is actively compressed until the gap is eliminated. This is repeated every 2 weeks until no residual gaps are apparent and callous is visible. With fracture healing, there is normal fracture site resorption and active compression allows for obliteration of these developing gaps. Once cortical contact is maintained and callous visualized, follow-up is at 3-week intervals. The fracture is compressed 0.33 mm only, to maintain continual compression and preload in the construct. Every 3 weeks, the patients are seen and the maintenance 0.33 mm of continual compression is performed until complete union is achieved (Fig. 1F).

Indications

Indications for compression nailing included patients who failed brace management within the first 8 weeks after injury. Persistent distraction gaps, significant deformity >20 degrees, inability to control the fracture with patient comfort concerns, and lack of callous all contributed to early conversion (Fig. 2). Additional indications include patients demonstrating persistent distraction gaps with transverse fracture patterns and gross motion at the fracture site, and persistent pain many weeks after brace application.

CONCLUSIONS

Most of the diaphyseal humeral fractures are treated successfully with functional braces. However, there is a distinct subset of patients where brace treatment is unlikely to end with a satisfactory outcome. The early conversion to a compression nail has demonstrated minimal surgical morbidity and a very quick return to function. The demonstrated union rate is excellent as all patients in our early experience with this nail have healed without any secondary procedures. UNYTE offers a unique solution for complex diaphyseal humeral fractures with specific indications, such as an unresolvable distraction gap, soft tissue concerns limiting brace utility, and fracture instability resulting from comminution, fracture location, or transverse orientation. These results are encouraging and further study is warranted.

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