Compression Plating Versus Intramedullary Fixation of Humeral Shaft Fractures

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Abstract

Most humeral shaft fractures do not require surgery. When operative stabilization is indicated, the surgeon can choose between compression plating and intramedullary fixation. The results after compression plating have been shown to be predictable with respect to healing, alignment, and range of motion of the shoulder and elbow joints. Although complications are unusual with plate fixation, the procedure can require extensive dissection and operative time. Intramedullary fixation offers an alternative to plate fixation, with the principal advantage being a limited surgical dissection. This benefit must be balanced against the reportedly high rate of postoperative shoulder problems seen with antegrade nail placement. Unfortunately, few direct comparative studies have been done to evaluate the various techniques. The authors attempt to clarify and resolve these issues.

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Humeral shaft fractures are preferably treated nonoperatively, most commonly with a functional orthosis. Klenerman[1] demonstrated that function of the upper extremity was not affected by as much as 20 degrees of anterior angulation, 30 degrees of varus angulation, and 3 cm of shortening of the humeral shaft. Sarmiento et al[2] showed consistent and rapid healing of 51 humeral shaft fractures treated with the use of prefabricated braces, with resultant excellent alignment, early restoration of joint motion, and minimal morbidity. Balfour et al[3] later found similar results in 42 humeral shaft fractures treated with functional braces. Since these reports showing the consistent success of nonoperative treatment appeared, authors have strongly recommended closed treatment of humeral shaft fractures unless specific indications for operative intervention exist.

Surgical treatment of humeral shaft fractures should be considered for unacceptable alignment with closed treatment, polytraumatized patients, progressive or new onset of a radial nerve palsy after the beginning of nonoperative treatment, ipsilateral upper extremity fractures, segmental humeral shaft fractures, pathologic fractures, bilateral humeral fractures, and open fractures (Table 1). In these situations, the surgeon can choose from a variety of options, including external fixation, compression plating, and intramedullary nailing. The use of external fixators in humeral shaft fractures should be restricted to injuries with severe soft-tissue compromise and loss. Other humeral shaft fractures are amenable to either compression plating or intramedullary fixation.

This article will focus first on the techniques of compression plating and intramedullary fixation, including the use of implants, patient positioning, operative approach, and details of fixation. The techniques of plating and nailing will then be compared in terms of technical ease and the results documented in the literature. The discussion concludes with a review of the available reports, limited as they are, that directly compare the results of plate fixation with those of intramedullary fixation.

Compression Plating

Compression plate fixation of humeral shaft fractures can be performed for any of the surgical indications listed in Table 1. In fact, before intramedullary nails became widely used, this was the only sur-

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Table 1
Indications for Operative Stabilization of Humeral Shaft Fractures

Inability to maintain reduction
Fracture pattern: comminuted, segmental, displaced
Obesity
Noncompliance or intolerance of orthosis
Prolonged recumbency
Floating elbow
Multiple injuries
Open fractures
Pathologic fractures
Spinal cord injuries
Progressive neurologic deficit
Bilateral humeral fractures
Brachial plexus injury

gical option available. The reasons behind the loss of popularity of compression-plate fixation for fractures of the humeral shaft include difficulties with surgical exposure, concern about the radial nerve, and problems with the technical aspects of plating. When the requisite surgical skills have been mastered, however, plate fixation of the humeral shaft fracture is an elegant and highly consistent method of treatment.

The surgical approach to the humeral shaft is either an extensile anterolateral approach coupled with splitting of the brachialis muscle or a posterior extensile approach in which the dissection begins between the long and lateral heads of the triceps and progresses inferiorly by splitting the medial head of the triceps. With an anterior approach, the radial nerve is posterior to the intermuscular septum and is not routinely exposed unless the dissection continues to the distal fourth of the humerus. With the posterior approach, however, the radial nerve must be identified and protected early in the dissection. For fractures in the upper half of the humeral shaft, the anterior exposure may be extended through the deltopectoral interval. Supine patient positioning is used for the anterior exposure; prone or lateral positioning, for the posterior approach. A sterile tourniquet will minimize blood loss with either approach.

Because the humerus is coupled to the shoulder joint, large rotational forces are placed across the bone. The broad 4.5-mm compression plate with staggered holes was developed specifically for use in tubular bones, such as the humerus, to resist these rotational forces. Theoretically, the in-line nature of the holes in a narrow 4.5-mm compression plate increases the chance of a longitudinal stress fracture when a rotational force is applied (similar to tearing a page at its perforations). The anterolateral application of a plate for upper-shaft and midshaft fractures is relatively straightforward; however, the placement of a broad plate anteriorly on the narrow lateral condyle of the humerus for lower-shaft fractures is technically difficult. Thus, when the fracture occurs in the distal half of the humeral shaft, a posterior approach for placement of a broad compression plate on the flat surface of the posterior humerus is superior.

After open reduction of the fracture, osteosynthesis is most effectively performed with standard AO/ASIF techniques (Fig. 1).[4] These include placement of a lag screw outside or preferably through the plate to achieve compression at the fracture site. If the fracture is too transverse to accept a lag screw, compression should be applied by using either the dynamic compression holes of the plate or the articulated tensioning device. In the rare instance in which a

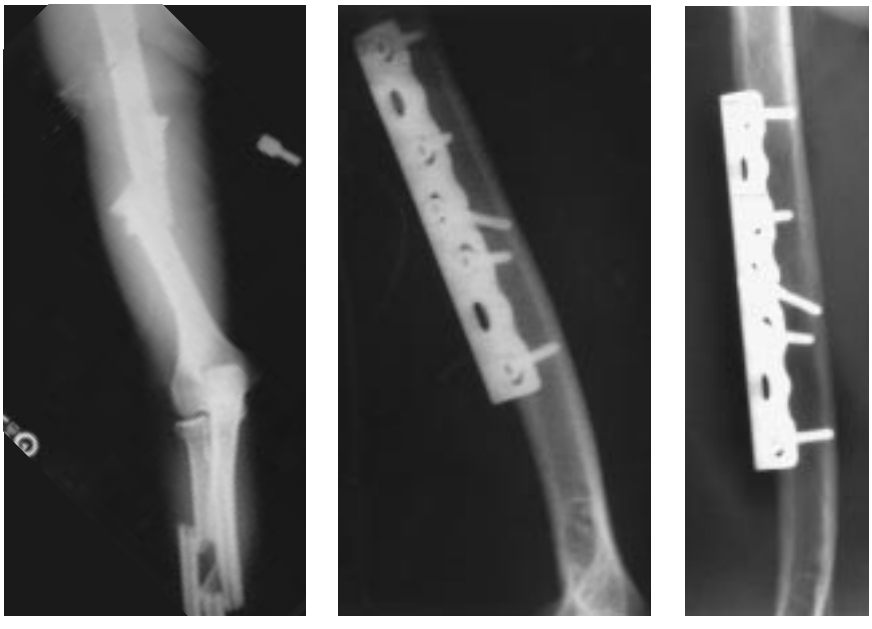

Fig. 1 **A,** Anteroposterior radiograph shows fracture of the ipsilateral humerus and forearm. Anteroposterior **(B)** and lateral **(C)** radiographs show healed humeral fracture after fixation with a broad 4.5-mm plate with use of the AO/ASIF technique.

broad plate is too large for the humerus, a narrow 4.5-mm compression plate will be required. A cancellous bone graft may be helpful if comminution is excessive or fixation is less than ideal, such as in patients with osteopenia.

Intramedullary Fixation

Intramedullary fixation of humeral fractures has gained popularity in recent years for several reasons, including improved image intensification, the introduction of locking humeral nails, relatively percutaneous insertion techniques that obviate the need for large incisions and the need for proficiency in compression-plating techniques, and overall satisfaction with intramedullary nailing for fractures of other long bones. However, this popularity seems to antedate good documentation of the efficacy of the technique. The most important considerations in the decision to use an intramedullary device for a fracture of the humeral shaft include the type, location, and anatomic extension of the fracture and the canal diameter of the humerus. These features will in part determine nail type, direction of nail placement, and whether or not to ream the canal for nail insertion.

A variety of implants have been used for intramedullary fixation of humeral fractures. These can be divided into two general types: multiple flexible nails and single rigid nails with interlocking capability. Although the Rush rod (Berivon, Meridian, Miss) is still occasionally employed, the most commonly used flexible implant in the United States is the Ender nail (Smith & Nephew Richards, Memphis), which is available in 3.5-mm diameter for the humerus (Fig. 2). The goals of treatment with this implant are to fill the humeral canal with multiple nails and to achieve an interference fit, creating both rotational and bending stability.

Ender nails can be inserted in an antegrade manner, but retrograde insertion is more common. The approach is a triceps-splitting exposure centered over the distal humerus. The medullary canal is opened with drill bits or a router 2.5 cm above the olecranon fossa (Fig. 3). Care must be taken to prevent fracturing the distal humerus during nail entry and passage. The radial nerve is not encountered with this exposure, but injury to the ulnar nerve may occur with excessive retraction on the medial side of the incision.

The patient can be positioned either prone or supine. Although there have been reports of the use of overhead traction with supine positioning,[5] most surgeons now employ a radiolucent arm board for prone positioning.[6] One insertion technique possible with supine

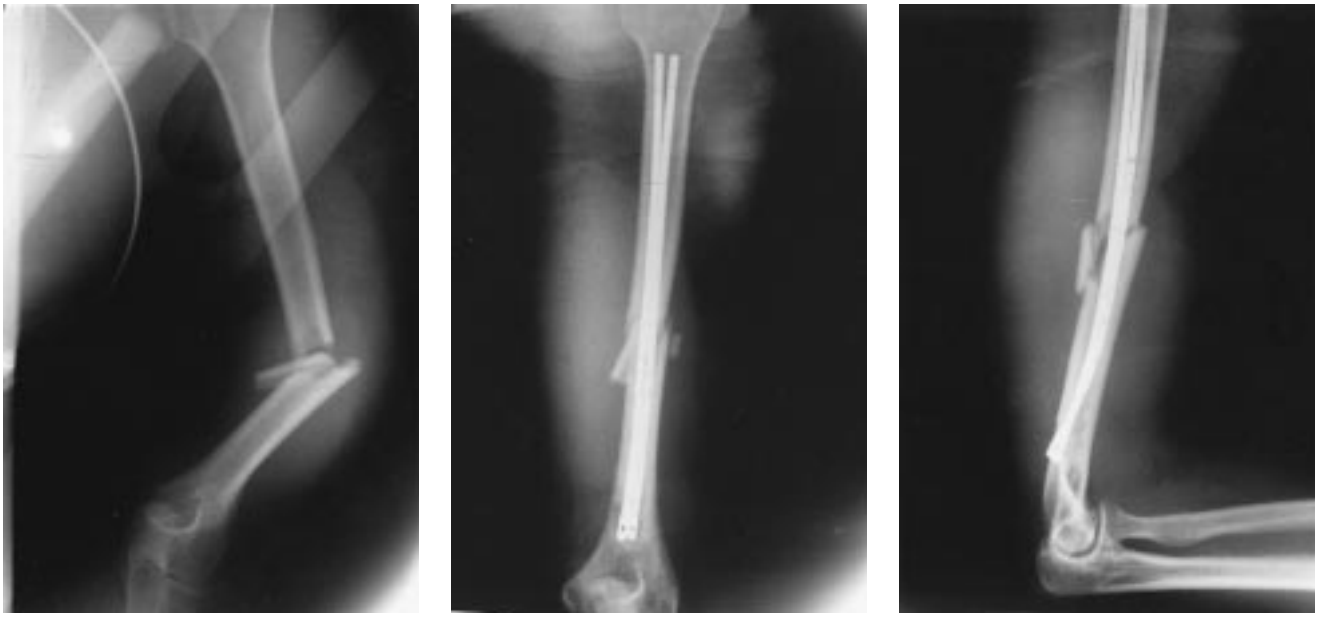

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Fig. 2 **A,** Anteroposterior radiograph shows humeral fracture in a polytraumatized patient. Anteroposterior **(B)** and lateral **(C)** radiographs show fixation of the fracture after retrograde placement of Ender nails.

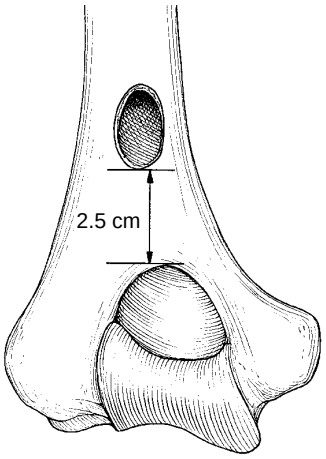


Fig. 3 The proper location and type of opening in the distal canal for retrograde placement of intramedullary nails. The opening should measure approximately 10 mm in width and 20 mm in length.

positioning requires placement of the forearm of the fractured extremity on an over-the-chest arm board connected to the opposite side of the table. The entry portal can then be established and the nails started into the canal. To pass the nails across the fracture site, the elbow can be extended, allowing the humerus to be imaged from the ipsilateral side of the table. Ideally, the tips of the nails will rest in the humeral head when the end of the nail is flush with the bone at the entry portal. Nails should always be passed with care in a humeral fracture and not forced if resistance is met. If nails do not pass easily, consideration should be given to opening the fracture site to confirm that the radial nerve is not blocking the canal.

While nails can be locked at the end with wire or 3.5-mm cortical screws to prevent migration, shortening and/or angulation may still occur in spiral or comminuted fractures because static locking is not possible. Furthermore, in a humerus with a canal diameter of less than 7 mm, insertion of more than one nail may not be possible, and fracture stability may be compromised. Such problems have somewhat limited the use of these implants. At the present time, most surgeons use them in fractures with a transverse or short oblique pattern.

Rigid nails can be inserted in either an antegrade or a retrograde fashion. Antegrade insertion involves opening the intramedullary canal at the proximal end of the humerus in the vicinity of the rotator cuff. Both the optimal location and the proximal method of entry remain controversial. An entry site at the greater tuberosity violates the portion of the cuff with the poorest vascular supply and thus entails a lower probability of uneventful healing. An approach that incises the cuff tendon just lateral to the articular surface of the humeral head, where the vascularity is greater, probably facilitates healing. Some authors have recommended a small skin incision followed by creation of the starting point by fluoroscopic visualization, without formal exposure or subsequent repair of the cuff tendon.[7,8] According to the advocates of this method, if the technique is performed with care, no long-term sequelae result from such a violation of the tendon. Others recommend that the cuff be formally visualized, purposefully incised in line with its fibers, and then repaired; however, this method has not been shown to be superior.[9-11] Problems related to the proximal entry portal remain with antegrade nail insertion. Unfortunately, the literature does not yet provide a convincing answer regarding the optimal technique.

For antegrade nail insertion, the patient is positioned on a fluoroscopy table turned so that the entire chest and shoulder rest over the radiolucent portion of the table. With the upper extremity lying at the patient's side, the shoulder can be imaged in the anteroposterior and lateral scapular planes without manipulation of the arm (Fig. 4). The fluoroscopy unit is usually most conveniently positioned on the contralateral side of the patient. Most fluoroscopes will have to be turned so that the x-ray tube is above the patient.

Interlocking humeral nails have recently become available. In the past, these nails required reaming of the canal to accommodate their larger size. Concerns about damage to the radial nerve during the reaming process have led to the development of implants that are small enough to be inserted without reaming. Many of these nails are solid and have interlocking capabilities both proximally and distally. The Seidel nail (Howmedica, Rutherford, NJ) has an expandable distal fin mechanism that achieves an interference fit at the tip of the nail. The Russell-Taylor nail (Smith & Nephew Richards) has a

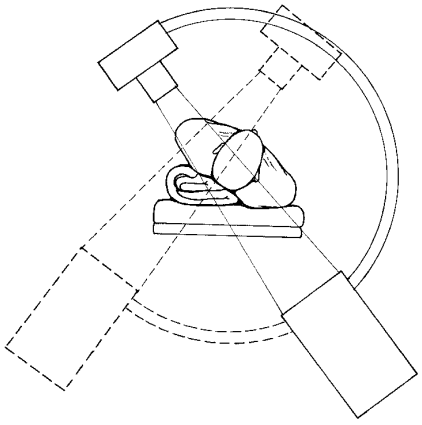


Fig. 4 For antegrade nail insertion, the patient should be positioned on a radiolucent table that allows imaging of the shoulder in the anteroposterior scapular and scapular Y views.

traditional distal locking hole located in the anteroposterior plane, which allows one to avoid the radial nerve during distal interlocking (Fig. 5).

Relative Usefulness in the Treatment of Acute Humeral Shaft Fractures

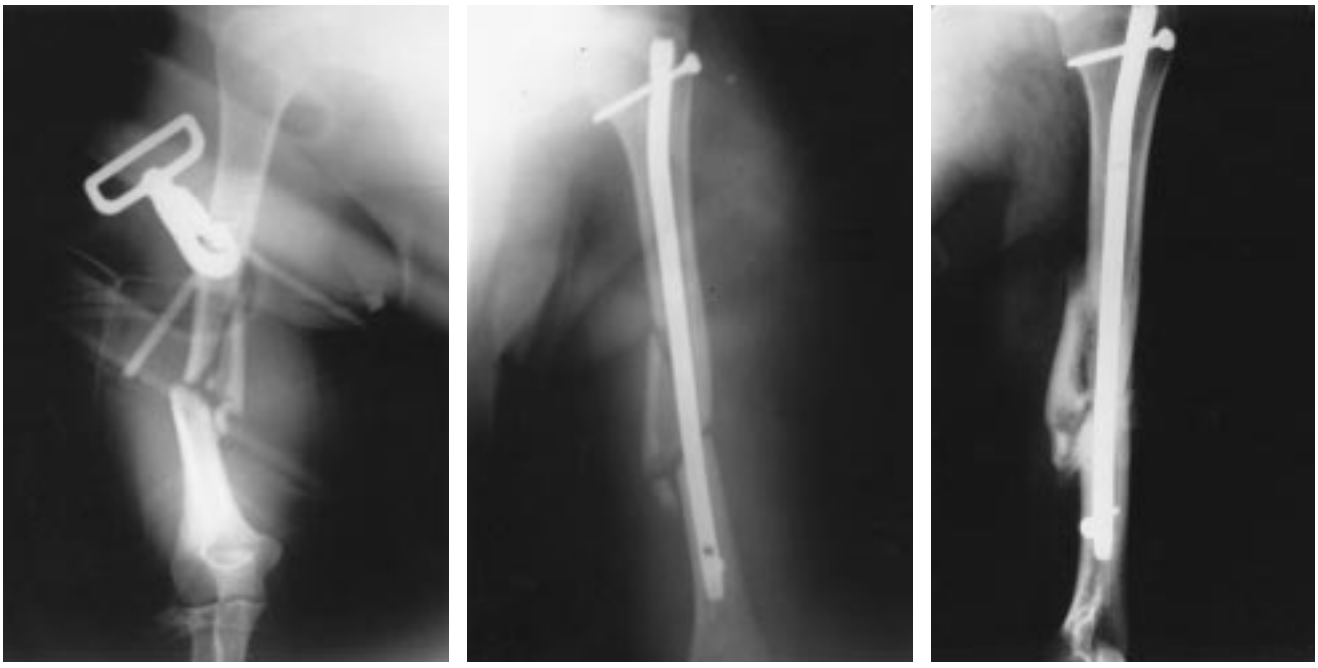
Technical Ease

Definitive evidence does not exist to support the use of one procedure over the other with respect to technical ease. Variables reflective of technical ease include patient positioning problems, total time for the procedure, and amount of blood loss. Unfortunately, the wide variety of techniques available for both plating and nailing of humeral fractures makes direct comparison difficult. This variety is exemplified by the fact that both compression plating and intramedullary nail insertion can be accomplished with the patient prone or supine. As discussed previously, compression plating requires expertise in plate-application techniques. In contrast, intramedullary nailing is essentially percutaneous and involves the use of indirect reduction techniques. Furthermore, compression plating tends toward a smaller incision, shorter operative time, and less blood loss than compression plating.

On the basis of these observations, it may appear that intramedullary nailing would be technically easier. However, much depends on the specific technique of nailing that the surgeon uses. Appropriate fluoroscopic equipment must be available, and the surgeon must be comfortable with closed intramedullary techniques. In addition, if the canal diameter is small, reaming will prolong the procedure as well as cause additional blood loss. If these issues are problematic for the surgeon, compression plating may be favored. Thus, all that can be concluded with respect to the technical ease of treating humeral shaft fractures is that it is surgeon-dependent.

Outcome

The results of surgical treatment of humeral shaft fractures can be measured in a number of ways. Traditionally, investigators have evaluated outcome on the basis of rate of healing, final alignment, range of motion of associated joints, and complications. More recently, a trend toward measuring functional outcome has



A B C

Fig. 5 **A,** Anteroposterior radiograph shows a comminuted humeral fracture in a polytraumatized patient. **B,** Anteroposterior radiograph after fixation with an antegrade interlocking intramedullary nail. **C,** Anteroposterior radiograph obtained at 10 months shows complete union of fracture.

emerged. The ideal study would be one that directly compares techniques by using functional outcome measures. Unfortunately, such studies have not yet been published.

The results of compression-plate fixation of humeral shaft fractures have been reported to be quite good.[12-15] Although both anterolateral and posterior approaches are commonly used, authors have more frequently selected the anterior approach. The combined results of the largest reported series are shown in Table 2. The rates of nonunion and hardware failure necessitating revision ranged from 0% to 7%.[12,16] In nearly all cases, nonunions were successfully treated with revision plating and iliac-crest bone grafting. Alignment after compression plating has been consistently excellent. The most common complications after plating procedures were infection and iatrogenic nerve palsy. Infection rates ranged from 0% to 6%, with the majority of cases being associated with open fractures. Iatrogenic nerve palsy occurred in 0% to 5% of cases and was usually a transient problem that did not require further intervention.

The literature also supports the fact that range of motion of the elbow and shoulder of the involved extremity returns predictably after plate fixation. Patients who exhibited incomplete return of function usually had associated skeletal or neurologic injuries. Thus, compression-plate fixation of humeral shaft fractures appears to be an effective and predictable procedure that restores skeletal anatomy with a minimum of complications and functional problems.

Evaluation of the outcome of intramedullary fixation of humeral fractures must take into consideration the particular technique employed. Several reports concerning the use of flexible implants have been published[5,6,17-19] (Table 3). Stern et al[19] presented one of the earliest series in which Rush pins were inserted primarily in an antegrade fashion. This method proved to have unacceptable rates of nonunion, delayed union, and postoperative shoulder pain. In other series in which Ender nails were used, antegrade insertion caused shoulder dysfunction in 5% to 10% of cases, and even hardware removal did not allow complete return of motion.[5,17] Therefore, a starting point outside the rotator cuff has been recommended when placing flexible nails in an antegrade fashion in order to decrease postoperative complications.[5,17]

Series in which Ender nails, Hackethal nails, and Rush rods inserted with distal starting points were used have shown better outcomes.[5,6,17,18] In these more recent series, the rates of non-

Table 2
Cumulative Data for Compression Plating of Humeral Fractures

Authors	No. of Fractures		Surgical Approach		Functional Problems*		Complications		
	Acute	Open	Anterior	Posterior	Shoulder	Elbow	Nonunion / Hardware Failure	Iatrogenic Nerve Palsy	Infections†
Bell et al[13]	39	14	39	0	0	0	2	1	1(0)‡
Dabezies et al[14]	44	11	13	31	0	0	1	2	0
Heim et al[12]	127	9	103	24	0	0	7	2	4(1)
Vander Griend et al[15]	36	13	36	0	0	0	1	1	2(0)‡
Foster et al[16]	36	9	§	§	0	0	0	0	2(1)‡
Rodríguez-Merchán[23]	20	0	20	0	0	0	0	0	1(0)
Total	**302**	**56**			**0**	**0**	**11**	**6**	**10(2)**

*Problems resulting from the humeral shaft fracture alone.
†Expressed as total number (number of deep infections).
‡All infections occurred after open fractures.
§Anterior approach preferred.

Table 3
Cumulative Data for Intramedullary Fixation of Humeral Fractures With Flexible Nails

Authors	No. of Fractures*	Implant	Surgical Approach	Functional Problems†		Complications		
				Shoulder	Elbow	Nonunion / Hardware Failure	Iatrogenic Nerve Palsy	Infections‡
Brumback et al[5]	63(11)	25 Enders 38 Rush	32 antegrade 24 retrograde 7 epicondylar	3 (antegrade approach)	3 (retrograde approach)	1	0	1(1)¶
Hall and Pankovich[17]	86(10)	86 Enders	34 antegrade 52 retrograde	16° mean abduction loss	0	1§	0	0
Henley et al[6]	49(4)	49 Hackethal	49 retrograde	0	1	1	0	1(1)¶
Peter et al[18]	39(1)	39 Hackethal	39 retrograde	0	0	3	1	0
Rodríguez-Merchán[23]	20(0)	20 Hackethal	20 retrograde	0	0	0	1	0
Total	**257(26)**	**111 Enders 108 Hackethal 38 Rush**	**66 antegrade 184 retrograde 7 epicondylar**			**6**	**2**	**2(2)**

*Expressed as number of acute fractures (number of open fractures).
†Problem related to humeral shaft fracture alone.
‡Expressed as total number (number of deep infections).
§Asymptomatic.
¶All infections occurred after open fractures.

union have ranged from 2% to 9%. Hardware failure was very unusual with the use of multiple flexible nails. Infection occurred in 0% to 2% of cases in which flexible nailing was used (as with compression plating, almost solely in open fractures). Iatrogenic injury to the radial nerve was noted in as many as 3% of cases but was usually temporary. Final alignment in these series was also consistently good, with only rare instances of malunion. These retrograde insertion techniques have not been associated with loss of elbow motion, although implant removal may be necessary due to nail migration.[17] Locking the Ender nail eyelets with a screw or tying the nails together with a single loop of wire has been effective in decreasing the rate of migration.[17]

The use of rigid interlocked intramedullary nails entails similar problems. The results of the largest series in which interlocking nails were used are shown in Table 4. Antegrade insertion resulted in loss of shoulder motion in 6% to 37% of cases.[9,10] Retrograde nailing seems to give more predictable long-term function, and return of elbow motion was not a problem unless there were associated injuries in the same extremity.

With the use of rigid interlocked intramedullary nails, another variable has been introduced—intramedullary reaming. Unfortunately, the effect of reaming on healing and the complications associated with it are unknown. Nonunion has been noted in 0% to 8% of cases of locked intramedullary nailing of the humerus.[7-9,11,20-22] At least one group of investigators found rates of delayed union as high as 20%; exchange nailing was done for several patients but was successful in only 40% of the cases.[10] Malunion, hardware failure, and iatrogenic nerve palsy have all been uncommon in series of humeral fractures treated with interlocking nails.

Direct Comparisons

Three recent studies have directly compared various treatment options for stabilization of humeral shaft fractures. In a prospective study, Rodríguez-Merchán[23] reported the data on a series of patients with humeral fractures treated with either compression plating or retrograde Hackethal nailing. The outcomes in the two groups of 20 patients each were not significantly different with regard to healing and function. However,

Table 4
Cumulative Data for Intramedullary Fixation of Humeral Fractures With Interlocking Nails

Authors	No. of Fractures*	Implant	Surgical Approach	Functional Problems		Complications			
				Shoulder	Elbow	Nonunion / Hardware Failure	Iatrogenic Nerve Palsy	Infections‡	Fracture Propagation
Crolla et al[20]	30(?)	Seidel	30 antegrade	6	0	1	0	1(1)	3
Ikpeme[7]	20(?)	Russell-Taylor	20 antegrade	3	0	1	0	0	1
Riemer et al[11]	28(4)	Seidel	28 antegrade	6	0	0	0	0	0
Riemer et al[9]	40(6†)	Seidel	40 antegrade	2	0	3	0	3(3)§	3
Robinson et al[10]	27(?)	Seidel	27 antegrade	13	2	7	1	2(0)	3
Rommens et al[22]	39(4)	Russell-Taylor	39 retrograde	3	5	2	1	0	3
Total	**184**		**145 antegrade 39 retrograde**	**33**	**7**	**14**	**2**	**6(4)**	**13**

*Expressed as number of acute fractures (number of open fractures).
†Plus three gunshot wounds, which were considered as a separate group.
‡Expressed as total number (number of deep infections).
§All infections occurred after open fractures.

this study suffers from its nonrandomized methodology and small number of patients. In addition, the selection of treatment method was left to the discretion of the surgeon, which may have introduced bias toward certain fracture patterns or injury types, limiting the strength of the conclusions. Nevertheless, the author was among the first to approach the question of plating versus nailing in a comparative manner.

Two recent studies have also approached the fixation question in a comparative way, both testing antegrade interlocking nails against compression plates. Wagner et al[24] presented a retrospective series comparing plating and antegrade locked nailing. Although the rates of healing were similar, a 42% incidence of shoulder symptoms was noted in the patients who were treated with antegrade nailing. Shortcomings of this report include its nonrandomized retrospective technique and the limited sample size for each method of fixation.

Chapman et al[25] presented the data on a series of 70 patients in a randomized prospective study comparing plating and antegrade locked nailing. The outcomes in the two groups were similar. Shoulder dysfunction developed in 10 of the 32 patients (31%) treated with nails. In contrast, the functional outcome after compression plating was consistently good. Although these data have yet to be published in a peer-reviewed journal, they seem to be the best yet that address the question of plate fixation versus intramedullary fixation. Thus, although additional testing is warranted, current comparative studies indicate that compression plating and retrograde flexible nailing give better functional results than antegrade techniques with interlocking nails.

Summary

The standard of care for the majority of humeral shaft fractures continues to be nonoperative management. Compression-plate fixation gives predictably good results but necessitates an extensive exposure and requires expertise in plate-application techniques. Intramedullary fixation with multiple Ender nails can give good functional results but lacks the ability to maintain axial and rotational stability in some fracture patterns. Interlocking intramedullary nails are an attractive alternative for humeral fracture stabilization, primarily because of the limited surgical exposure and secure fixation provided. However, these advantages must be weighed against a high rate of postoperative shoulder problems with antegrade insertion.

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