

Original research paper

Functional outcome in surgical management of diaphyseal fracture of humerus treated by intramedullary interlocking nail in adults: A prospective study

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Abstract

Background: General incidence of humeral shaft fractures remain in the area to 1% to 2% of all fractures. Shoulder & elbow stiffness, non-union and mal-union are commonly seen with conservative treatment. Open reduction and internal fixation with plate and screws require extensive soft tissue stripping and high rates of radial nerve palsy. An interlocking intra medullary nail system is an effective and less invasive method with fewer complications. The aim of this study is to document the clinical outcome and complications associated with the use of intramedullary interlocking nail in acute diaphyseal fractures of humerus.

Methods: 30 cases of acute humeral shaft fractures in adults more than 18 were treated by closed reduction and internal fixation by Intra Medullary Interlocking Nail September 2019 to April 2020 at Vijayanagara institute of medical sciences Ballari and followed for a minimum of 6 months. Outcome was assessed by using criterion done by ROMMEN *et al.* series.

Results: All patients were followed up for an average of 6 to 8 months. Our series consisted of 30 patients, 19 male and 11 females. Mean radiological union in weeks was 13.6. There was one nonunion and one delayed union in our study.

Conclusion: Based on our experience and results, antegrade technique is safe & reliable technique for treating acute humeral shaft fractures. The advantages of intramedullary nailing are minimal surgical exposure, better biological fixation, minimal disturbances of soft tissues and early mobilization of neighbouring joints Interlocking nailing also avoids complications like lack of rotational control, migration of nail and requirement of supplementary bracing.

Keywords: Intra medullary interlocking system; Humeral shaft fracture, Rommen's *et al.* grading

Introduction

General incidence of humeral shaft fractures remain in the area to 1% to 2% of all fractures ^[1] occurring in the human body and 14% of all fractures of the Humerus ^[2]. For thousands of years some form of external splintage was the only option for management of fractures. It is obvious that little has changed in the treatment of diaphyseal humeral fractures since ancient times, as humeral fractures heal within a short time. During the treatment patients are mobile whereas shoulder and elbow joints compensate for some malalignment. However, patients in

modern times demand faster union rates and earlier return to preinjury activities while preserving functionality and motion of nearby joints. Many authors preferred conservative management with hanging arm cast [3, 4]. Shoulder and elbow stiffness, non-union and malunion are commonly observed with such conservative methods [5]. Open reduction and internal fixation with plate and screws requires extensive soft tissue stripping. It also requires mobilization of radial nerve during surgery with high rates of radial nerve palsy [6], cortical osteopenia with its complications are commonly seen after plate fixation [7]. Use of only intramedullary nails, have the disadvantage of rotation of 2 fracture fragments. Instability with proximal migration of nail, with subsequent stiffness of shoulder [8]. An interlocking intramedullary nail system has the advantage of stability and early functional recovery with fewer complications [9]. Since fracture treatment in general, strives for complete and early recovery of the limb function with solid union [10], intramedullary fixation of humeral shaft has gained in popularity [11]. Because of less soft tissue trauma and stable fixation, interlocking nail system have dramatically broadened the indications for humeral medullary nailing [12] and antegrade nailing is the most commonly used method [13]. Though the healing time of fractures in conservative and surgically managed patients are same, the later, maintain nearly normal lifestyle during most of this healing period, without limitation by splints, casts or braces and can return to their work sooner [5]. This makes the patient to earn his livelihood earlier and indirectly reduces his economic burden. Thus, interlocked nailing of humerus is an attractive treatment option for patients with fracture of the humeral shaft where operative fixation is required [14]. This study is an attempt to determine the efficacy of interlocked intramedullary nailing in the treatment of humeral shaft fractures.

Materials and Methods

Our prospective study consists of 30 cases of traumatic diaphyseal fracture of humerus admitted to VIMS Hospital attached to Vijayanagar Institute of Medical Sciences, Ballari September 2018 to April 2020. The work was approved by institutional medical ethics committee. A written informed consent was obtained from all the patients.

1. Inclusion criteria

- Acute diaphyseal fracture of the humerus.
- Age above 18 years.
- Osteoporotic bone.
- Segmental diaphyseal fractures.
- Compound fractures of Gustilo's Type I.

2. Exclusion criteria

- Compound fractures of Gustilo's Type II & III.
- Fractures involving lower 3rd shaft of Humerus.
- Age less than 18 years.
- Medically unfit for surgery.
- Fractures with neurovascular deficits.

All cases were admitted, careful history was elicited to reveal the mechanism of injury and severity of trauma. General and local examinations were done, and Care was taken to detect shock and any associated injuries. The clinical diagnosis was confirmed radiologically by taking x-ray of humerus including shoulder and elbow, in antero-posterior and lateral views. A U-slab was given with a cuff and collar to all patients.

After treating the associated injuries and obtaining physician's opinion (if required), patients were posted for surgery at the earliest. Patients were subjected to a thorough pre-anaesthetic evaluation and type of anaesthesia decided. Clinically the nail length was calculated on the normal arm, by measuring the distance between the angle of the acromion to the lateral epicondyle and 3 cm was subtracted from the measurement. Patients were given injection Tetanus Toxoid IM and injection Cefotaxime I gm IV preoperatively along with other pre-operative orders.

Operative procedure

The interlocking humeral nail can be inserted retrograde or antegrade and is designed for reamed and unreamed insertion. The nail is available in diameter of 6 mm, 7 mm and 8 mm. The 6mm is a solid nail and 7 mm, 8 mm are cannulated nail.

Antegrade humeral nailing by closed method

The patient is maintained under brachial block/general anaesthesia for the procedure. The whole of the affected upper limb and the axilla is prepared. The surgery is done with the patient in supine position with a sandbag under the affected shoulder for better exposure of the entry site. The whole arm segment is painted and draped in order to keep the limb free ^[15].

Entry point

Through the lateral approach for the proximal humerus an incision is made. It starts 1 cm anterior and lateral to the point of acromion (Fig 1). The incision extends 3 cm distally. This exposes the multi-pinnate deltoid muscle, which is split along its fibres. Care is taken not to damage the axillary nerve, which is on an average 4.56 cm distal to the acromion. This exposes the white glistening rotator cuff, which has to be split at the tendon of supraspinatus just medial to its insertion into the greater tuberosity. This being a very vascular site heals better. The vascularity may interfere in the field of surgery. This exposes the entry point site just medial to the great tuberosity (Fig 2). It can be seen per operatively as a depression of the anatomical neck. The entry point can also be checked by image intensifier. The entry point is opened up with a sharp awl and reamed up to 9 mm diameter.

Approach

Through the lateral approach for the proximal humerus an incision is made. It starts 1 cm anterior and lateral to the point of acromion. The incision extends 3 cm distally. This exposes the multi-pinnate deltoid muscle, which is split along its fibres. Care is taken not to damage the axillary nerve, which is on an average 4.56 cm distal to the acromion. This exposes the white glistening rotator cuff, which has to be split at the tendon of supraspinatus just medial to its insertion into the greater tuberosity. This being a very vascular site heals better. The vascularity may interfere in the field of surgery. This exposes the entry point site just medial to the great tuberosity. It can be seen per operatively as a depression of the anatomical neck. The entry point can also be checked by image intensifier. The entry point is opened up with a sharp awl, guide wire passed (Fig 3), fracture reduction done, entry reaming done then sequential reaming done up to 9 mm diameter (Fig 4). This prevents the development of hoop stresses at the entry point while insertion of the nail. The nail whose dimensions have been determined by pre-operative radiograph is mounted on to a jig. The size of the nail can be reconfirmed by using a guide pin and checking under an image intensifier.

Insertion of nail

The nail, mounted on to the jig, is inserted through the entry point into the bone. At the fracture site is negotiated across the fracture ends under the guidance of the image intensifier since 6mm nails are solid nails so they are passed directly under the guidance of image intensifier. 7mm/8 mm nails are cannulated so initially guide wire is passed across the fracture, serial reaming done and then the nail is inserted. The nail can be tapped in order to push it deep into the humerus so that it does not protrude into the articular surface. Care has to be taken while choosing the nail in order to avoid the oversized nail which may end up in splintering the distal fragment.

Distal locking

This is done by image control using a 3.9 mm self-taping screw by free hand technique. Under image guidance the location of the distal locking slot is noted, a stab incision is made on the anterior of the arm. Both the biceps and the brachialis are split to reach the anterior surface of the humerus. Under image control, the bone is drilled using 2.9 mm drill bit and locking is achieved using 3.9 mm screw passed anteroposteriorly. This can also be achieved using a distal locking jig.

Proximal locking (Fig 5)

This is achieved by using 3.9 mm self-tapping locking screws. This is applied by using the jig and the screw is passed lateral to medial. Care has to be taken to avoid the axillary nerve, which is situated on an average 4.56 cm distal to the acromion. The screw slot can be predrilled with 2.9 mm drill bit. The fracture site can be compressed by back slapping the nail after insertion of the distal locking screw.

Closure

The rotator cuff has to be repaired using a non-absorbable suture. All the wounds are closed in layers. After sterile dressing limb may be immobilized with U slab for two postoperative days.

Operative images



Fig 1: Incision for entry point



Fig 2: Entry point with bone awl

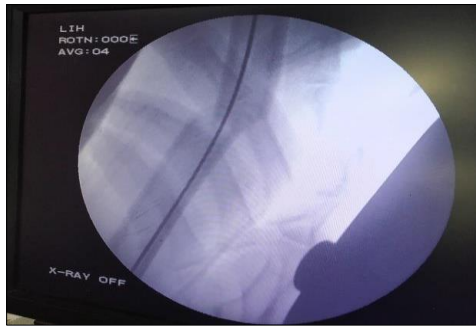


Fig 3: Guide wire passed at fracture site

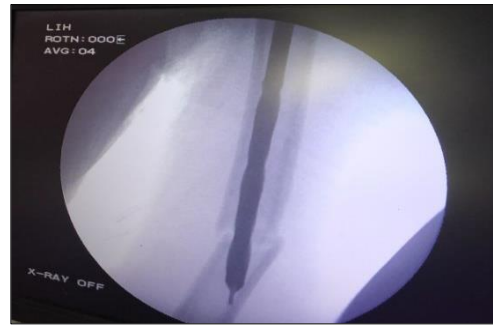


Fig 4: Reaming

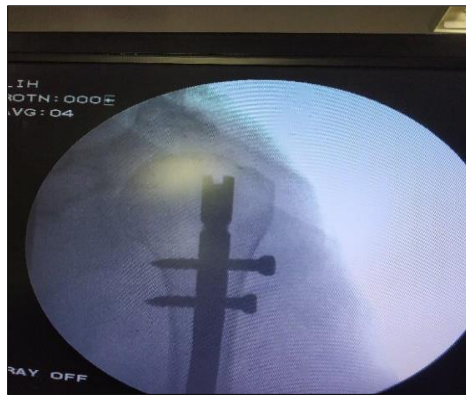


Fig 5: Proximal locking (c arm)

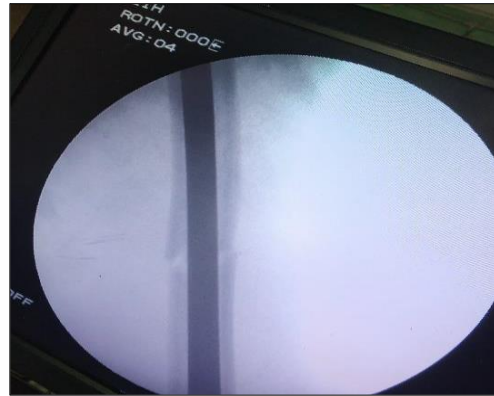


Fig 6: Nail passage at fracture site

Post OP care

Patients were given U-slab for first two days after surgery. IV Antibiotics were continued for 5 days. Patient was examined for any post-operative radial nerve palsy after 1 day of surgery. Wound was inspected and assessed and dressings changed on the 3rd post-operative day. Active movement of wrist and hand were started from the first post-operative day. After two days U-slab was removed and a cuff and collar sling was given and active elbow flexion and shoulder circumduction exercises were started. Active rotation of the arm against resistance was discouraged, until fracture union was seen radiologically. In patients where distal locking was not done, the sling was continued for 4 weeks. Patient were discharged on 6th post-operative day. X-ray of the humerus full length including the shoulder and elbow was taken before discharge and checked for satisfactory alignment of the fracture and proper placement of the nail and locking screws. Suture removal was done usually on 12th post-operative day. In our series, none of the patients had post-operative radial nerve palsy, and no cases had deep infection after the surgery. All the wounds healed without any complications.

Follow up

The patients were called for the follow ups at monthly intervals for the first three months after the surgery. Afterwards, the patients were followed at 2 monthly intervals, up to 1 year whenever possible. At each follow up, clinical and radiological assessment was done for the fracture union and the shoulder and elbow functions evaluated. X rays were obtained in AP and lateral views and signs of union were looked for. Any post-operative complications if present were noted. The fracture was considered to be radiologically united, when there was no visible fracture line and evidence of callus bridging at the fracture site was seen. The final evaluation was done at 6 months after the surgery and the functional outcome were assessed

by modified Rommen's *et al.* criteria ^[16].

Assessment of end result

The final assessment of the patients for the study purpose was done at the end of 6 months on the basis of the following modified criteria derived from Rommen's *et al* series ^[16]. Clinical signs of union were considered to be present when the patients had no pain at the fracture site and could use their arm without pain. The results were graded excellent, good, poor as follows.

Excellent

- Good Clinical and radiological union.
- Less than 10% loss of range of motion of shoulder and elbow joints.
- No significant subjective complaints.

Good

- Good Clinical and radiological union.
- 10-30% loss of range of motion of shoulder and elbow joints
- Minimum subjective complaints.

Poor

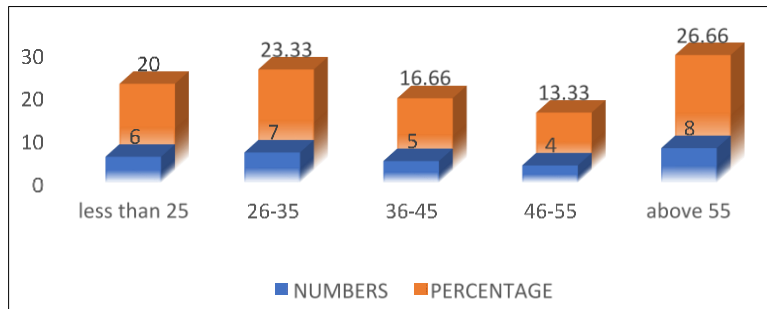
- No signs of union radiologically and clinically.
- Greater than 30% loss of range of motion. of shoulder and elbow joints.
- Moderate subjective complaints.

Results

The present study consists of 30 cases of fracture of the diaphyseal of the humerus treated surgically by closed reduction and internal fixation using intramedullary interlocking nail by antegrade technique using image intensifier September 2018 to April 2020. All the patients were available for follow-up.

Table 1: Age distribution

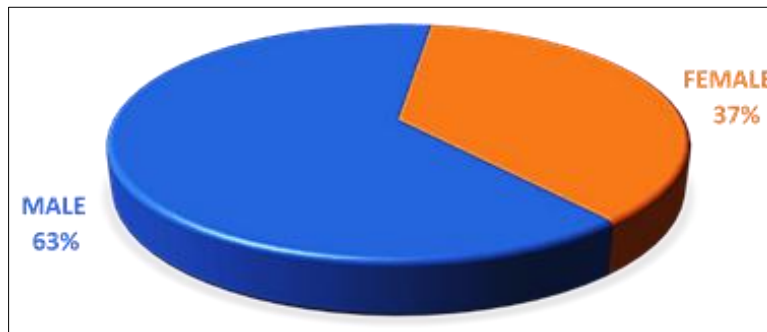
Age Group (in years)	No. of cases	Percentage
Less than 25	6	20
26-35	7	23.33
36-45	5	16.66
46-55	4	13.33
Above 55	8	26.66
Total	30	100



Graph 1: Age Distribution

Table 2: Sex distribution

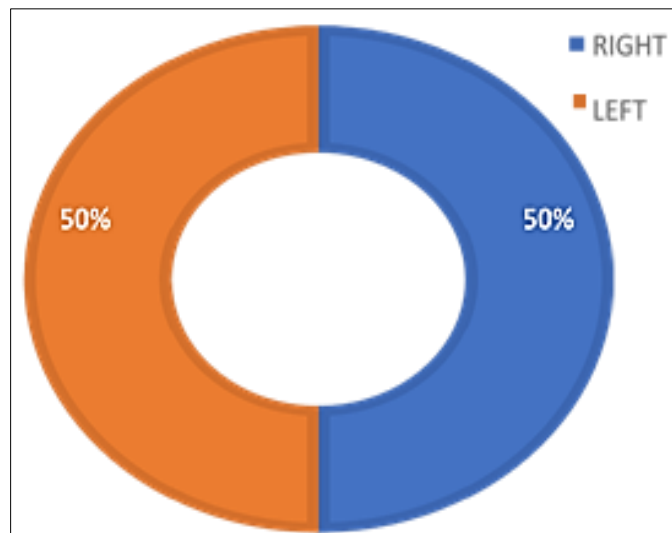
Sex	No. of Cases	Percentage
Males	19	63
Female	11	37
Total	30	100



Graph 2: Sex distribution

Table 3: Side affected

Side	No. of Cases	Percentage
Right	15	50
Left	15	50
Total	30	100



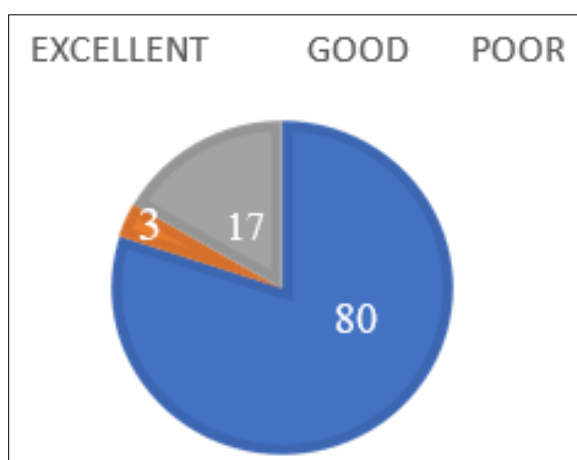
Graph 3: No. of cases

Table 4: Mode of injury

Mode of injury	No. of Cases	Percentage
Road traffic accident	18	60
Accidental fall	10	33.33
Assault	2	6.66

Table 5: Distribution of functional outcome among study subjects

		Frequency	Percentage
Functional outcome	Excellent	24	80
	Good	1	3.3
	Poor	5	16.6



Graph 4

Table 6: Pattern of fracture

Pattern of fracture	No. of Cases	Percentage
Transverse	11	36.66
Oblique	11	36.66
Spiral	5	16.66
Comminuted	3	10

Table 7: AO Classification

AO subclass	Frequency	Percentage
A1	5	16.66
A2	11	36.66
A3	11	36.66
B3	1	3.33
C1	2	6.66

Table 8: Duration for union and range of movement a) Mean duration for radiological union

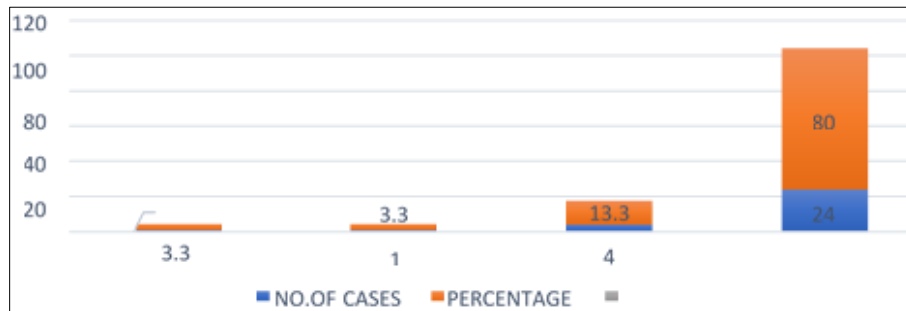
	Mean	Standard Deviation
Radiological union in weeks	13.6	2.23

Table 8b: Distribution of range of movements among study subjects

		Frequency	Percentage
Range of movements	Full	24	80
	Restricted	6	20

Table 9: Distribution of complication among study subjects

		Frequency	Percentage
Complications	Delayed union	1	3.3
	Non-union	1	3.3
	Impinge	4	13.3
	Nil	24	80



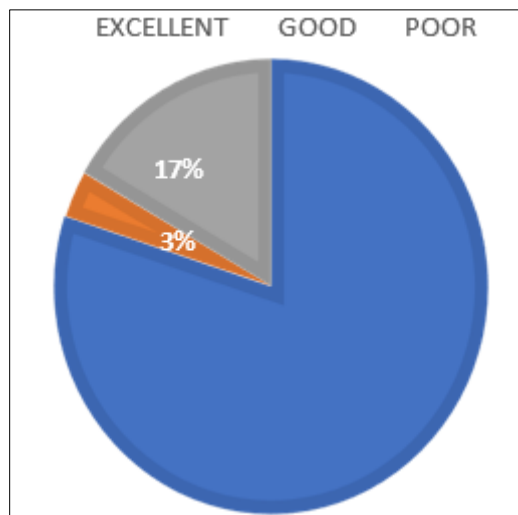
Graph 5: Complication

Overall results

24 cases (80%) had excellent results, 1 case (3.3%) had good result and 5 patients had poor result (16.6%). (Table12 and Graph 11).

Table 10: Distribution of functional outcome among study subjects

		Frequency	Percentage
Functional outcome	Excellent	24	80
	Good	1	3.3
	Poor	5	16.6



Graph 6: No. of cases

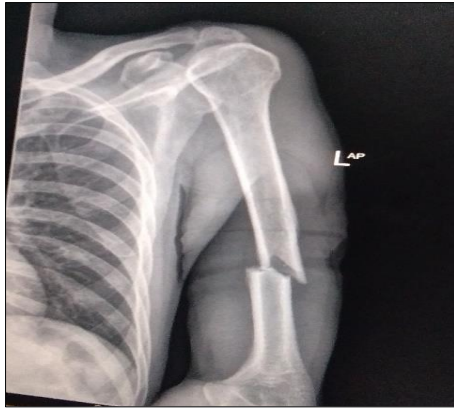


Fig 7: Pre op X ray AP view



Fig 8: Pre op x ray Lateral view



Fig 9: Post op x-ray (3 months)

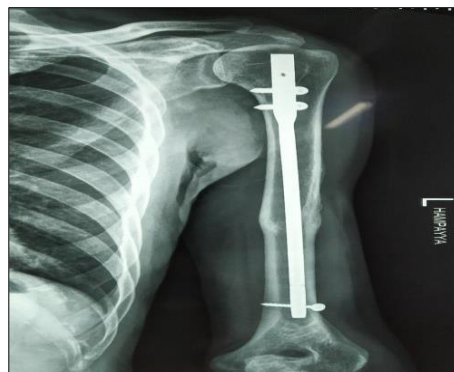


Fig 10: Post op x ray union (6 months)

Post-operative range of movements



Fig 11: Shoulder abduction



Fig 12: Internal rotation



Fig 13: External rotation

Discussion

Conservative management is successful in achieving more than 90% of union [7] and is still preferred for isolated low energy humeral shaft fractures [17]. It is also used as initial treatment for displaced spiral and oblique humeral fractures [7]. In transverse and short oblique fractures, the contact area of the fracture fragments are very small and fracture instability is relatively high, thus leading to a high number of delayed and non-united fractures.

Another major disadvantage of conservative treatment is the stiffness of the adjacent joints especially shoulder, requiring prolonged rehabilitation. Operative stabilization is known to improve the healing, fracture alignment and functional result in patients with high energy humeral shaft fractures [8].

Plate osteosynthesis is an accepted surgical option ^[18]. The main disadvantage of plate osteosynthesis is that they need large tissue dissection with extensive soft tissue stripping¹⁹. With its inherent complications. It also requires the mobilization of the radial nerve both during insertion and removal ^[16], with high rate of secondary radial nerve palsies. Plate osteosynthesis is of limited use in patients with osteoporosis, where a strong bone-implant interface is difficult to achieve.

In external fixation, there is lack of comfort to the patient and makes nursing care more difficult. Schanz screws may perforate muscle bellies of the deltoid and triceps muscles and hinder the free movements of the shoulder and elbow joint ^[19].

Flexible intramedullary nails with the techniques of Rush ^[20], Ender and Hacketh ^[21] can be inserted proximally or distally. Rush pins and Ender's nails internally splint the fractured humeral shaft and secure the axial alignment. These are associated with problems like rotatory instability, nail migration, non-union and poor joint function ^[8]. Their routine use is not recommended ^[19].

Locked intramedullary nails used in our series were of medium diameter and introduced with reaming. These nails allow load sharing between the implant and the fractured bone. They infrequently require bone grafting ^[17]. They avoid extensive soft tissue dissection required for plating thus leading to increased rates of union. Ante grade interlocked nail has now become the implant of choice for humeral shaft fractures with surgical indications ^[7]. In this study 30 cases of humeral shaft fractures were treated by antegrade, interlocking intramedullary nailing to determine clinical outcome and complications of nailing.

1. Age distribution

Diaphyseal fractures of the Humerus are commonly seen in young adults. The average age in our series was 42.1 years with the maximum number of patients in 3rd, 4th and 5th decades. These finding were similar to the observation of Lin and Hou ^[22], Bassi *et al.* ^[23]

Table 11: Age Distribution in Various Studies

Study	Age group range (years)	Average Age (years)
Ingman and Waters ^[24]	16-90	53
Crates and Whittle ^[17]	13-75	32
Rommens <i>et al.</i> ^[19]	16-90	55.1
Lin and Hou ^[22]	20-82	42.6
Bassi <i>et al.</i> ^[23]	20-75	43
Present Study	18-69	42.1

2. Sex distribution

There was male predominance in this series which was also observed in other studies. Our study showed similarity to the observation of Lin and Hou ^[22], Bassi *et al.* ^[23], Crates and Whittle ^[17].

Table 12: Sex Distribution in various studies

Study	No. Patients in Study	M:F Ratio	Percentage of males
Ingman and Waters ^[24]	41	21:20	51.2%
Crates and Whittle ^[17]	71	43:28	60.5%
Rommens <i>et al.</i> ^[19]	190	100:90	52.6%
Lin and Hou ^[22]	47	28:19	59.5%
Bassi <i>et al.</i> ^[23]	15	10:5	66.7%

Present Study	30	19:11	63%
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3. Fracture union

28 (93.33%) patients had sound union in less than 6 months, 1 (3.33%) patient had delayed union and required bone marrow injection to augment union and union was achieved at the end of 7th month and there was one case (3.33%) of non-union seen, which was managed with open reduction and internal fixation with plating.

While in other series of intramedullary interlocking nail done by Rommen *et al.* (1995) ^[16], Rodriguez *et al.* (1995) ^[25] and Shyamasunder Bhat N (2005) ^[26] non-union was seen more commonly (7 Cases) than delayed union (2 Cases) out of 140 cases.

Table 13: Comparison of union rate obtained in various studies in literature

Study	Total Number of Cases	Operative procedure	Delayed union	Non Union	Overall union
Bell M J <i>et al.</i> ^[27]	34	AO plating	---	1 (3%)	33 (97%)
Grient R V, Tomasin J and Ward E F 28	36	DCP plating	5 (14.6%)	1 (3%)	35 (97%)
Rodriguez ^[25]	20	Intramedullary nailing		--	19 (95%)
Rommen <i>et al.</i> ^[16]	39	Retrograde Intramedullary nailing		1	78 (94%)
Syamasunder Bhat 26	37	Intramedullary nailing	1	3	31(91.89%)
Present study	30	Intramedullary nailing	1 (3.3%)	1 (3.3%)	28 (93.33%)

Overall result

We had 25 (83.3%) patients with excellent or good result out of 30 patients in our series. Overall results obtained by various authors using intramedullary interlocking nailing have reported the results comparable with this present series.

Table 14: Comparison of results obtained in various other studies in literature

Study	Total no of patients in study	Method of treatment	Excellent/Moderate result
Rodriguez ^[25]	20	Intramedullary nailing	95%
McCormack R G <i>et al.</i> ^[29]	44	Intramedullary nailing	95.7%
Syamasunder Bhat ^[26]	37	Intramedullary nailing	92%
Rommen <i>et al.</i> ^[16]	39	Retrograde Intramedullary nailing	95%
Bell M J <i>et al.</i> ^[27]	34	AO plating	91.2%
Present study	30	Intramedullary nailing	83.3%

Conclusion

Based on our study and results, we conclude that all closed humerus diaphyseal fracture extending between 2cm from the surgical neck to 3cm proximal to the olecranon fossa can be treated with closed intramedullary nailing. It is an outstanding method of treating comminuted and unstable humeral diaphyseal fractures. Excellent results were seen in patients with associated injuries when humeral diaphyseal fractures were fixed with intramedullary interlocking nail as shown in the reduction in operative time and early rehabilitation. Bone healing occurs without much problem, as soft tissue and periosteal dissection is minimal with nailing & closed nailing does not disturb the fracture hematoma, it decreases the time required for callus formation. Complications like delayed union can be treated with bone marrow injection at fracture site to augment fracture union. Certain

technical aspects like burying the proximal end of the nail at the entry portal and selecting proper length of the nail is essential in avoiding impingement and to gain better shoulder function. Hence, we conclude that closed interlocking nailing by ante-grade technique is a safe and reliable method for treating humerus diaphyseal fractures.

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