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Comparative Analysis of Results of Minimally Invasive Percutaneous Plate Osteosynthesis (MIPPO) and Intramedullary Nail (IMN) In Humerus Shaft Fracture – A Prospective Study.

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ABSTRACT

Background: Treatment of humeral shaft fractures continues to evolve as advances are made in both non-operative and operative management. The encouraging results that have been reported with recent advances in internal fixation techniques and instrumentation. The controversy still exist between plating and intramedullary nailing. MIPO (Minimal invasive plate osteosynthesis) has emerged as a new alternative mode or treatment. In this study, we compare the result of MIPO and intramedullary nailing. **Methods:** This was an institution based, prospective longitudinal and comparative study. Patients of age of 20 to 60 years (skeletally mature) which required operative intervention in this study. Pathological fractures, segmental fractures, neurovascular injury were excluded. Patients were followed for at least one year. **Results:** 130 patients were included in this study. Intramedullary nailing was done in 60 patients and MIPO plating done in 70 pts. Demographically, there was no difference between the groups. No statistical difference was found regarding union and complication. There was significant statistical difference of UCLA shoulder score between the groups. But no difference in Mayo elbow performance score. Discussion: This study shows that the MIPPO technique is safe, convenient and effective, since there was a minimal soft tissue injury and no major complications. It does not disturb the fracture hematoma like open plating and thus help in fracture union. There is no injury to the rotator cuff or supraspinatus tendon like intramedullary nailing in MIPO plating. **Conclusion:** MIPO is a modality which results in a relatively stable fracture construct while preserving a biologic environment that facilitates rapid bone healing without disturbing rotator cuff.

Keywords: Humerus fracture, MIPO, Intramedullary nail.

INTRODUCTION

The humerus shaft fracture is the second most common fracture of the upper extremity and account for roughly 3% to 5% of all fractures. The predominant causes of humerus shaft fractures include low energy trauma such as fall from a standing height in older population, while in the younger population it is caused by high energy trauma resulting from motor vehicle accidents, fall from greater heights, sports injuries or industrial accidents.(1) About 40-60% of humeral fractures occur in the mid shaft while 30-40% occurs in the proximal and 10-20% occurs in the distal humerus.

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Among these fractures, simple fractures account for two thirds while more complex fractures involving spiral or multiple fragments account for the rest of all humeral fractures.[1, 2]

Treatment options for humeral fractures vary according to the type of fracture, age group, bone density, soft tissue status and associated complications. Several modalities are available for the management of humeral shaft fracture. However, fundamental management principles have remained consistent throughout the time.[3] Non-operative management continues as the mainstay for treatment of the majority of these injuries, with acceptable healing occurs in more than 90% of patients. Surgical intervention is indicated in special circumstances including (1) failure of closed reduction, (2) intra-articular extension of fractures, (3) neurovascular compromises, (4) associated ipsilateral forearm and elbow fractures, (5) segmental fractures, (6) pathological fractures, (7) open fractures in polytraumatised patients, (8) bilateral humeral shaft fractures, (9) periprosthetic fractures and (10) transverse or short oblique fractures.[4] These fractures can be surgically treated by either using a dynamic compression plate or intramedullary nail.[5-9]

Although controversy exists over which is the better technique, most authors believe that open reduction and internal fixation with a dynamic compression plate is a more reliable method. The advantages include anatomical reduction of fractures and less interference to elbow and shoulder function.[5, 6, 8, 10, 11, 12] The major disadvantages of this technique, however, are extensive soft tissue stripping and disruption of periosteal blood supply, which increase the risk of nonunion and iatrogenic radial nerve palsy and large skin incision.[13-15] The advantages of intramedullary nail are no disruption of fracture haematoma (biological fixation), less disruption of blood supply, cosmetically better due to small incision. The major disadvantages are shoulder and elbow pain, difficulty in distal locking, injury to radial nerve and distraction of fracture site.

Despite the numerous surgical techniques, plate fixation remains the gold standard for fixation of humeral shaft fractures. It has been reported that humeral shaft fractures can also be successfully treated with minimally invasive percutaneous plate osteosynthesis (MIPPO).[16-20] This technique has advantages of less soft tissue dissection, no disruption of fracture haematoma, cosmetically better and avoids the need to expose the radial nerve like intramedullary fixation.[17] But unlike intramedullary nail, there is no chance of interference of shoulder and elbow function. These advantages appear to indicate that MIPPO is superior to conventional intramedullary nail osteosynthesis. However, there is no large series that reports advantages and disadvantages of MIPPO compared to conventional IMN osteosynthesis technique. Hence the present study has been designed to assess the efficiency and to healing rate of recent displaced fracture shaft of humerus using MIPPO technique in comparison to intramedullary nail.

The aim of the proposed clinical study is to establish the safety of MIPPO technique and also to evaluate the clinical, radiological, and functional outcomes in the treatment of recent humeral shaft fractures. We hypothesize that MIPPO is a safe procedure which allows for prompt and adequate fracture healing and an easy return to near normal function for recent humeral shaft fracture in comparison with open reduction-internal fixation using a plate and intramedullary fixation using nail and thus bone union is promoted and complications such as nonunion are decreased.

MATERIALS AND METHODS

This was an institution based, prospective longitudinal and comparative study. The study was conducted in our institution after getting ethical permission. All the patients were counseled about the advantages, disadvantages, and complications of the procedure. After getting written consent from patients, we performed both procedures. The study period from December 2013 to March 2016 (27 months duration). One hundred and thirty patients were treated with either interlocking nailing or plating procedures. A randomization attempt was made by allocating each patient to either of the groups depending on the criteria of odd or even hospital number.

The inclusion criteria of our study were humeral shaft fractures which required operative intervention and patients of age of 20 to 60 years (skeletally mature). The exclusion criteria were: pathological fractures, segmental fractures, neurovascular injury, fractures within 4cm of proximal and distal end of humerus (shaft of humerus), and patients who were lost to follow-up or at early stages of follow-up at the time of completion of the study (minimum follow up of 12 months required). All fractures were classified according to the AO classification. Of the 67 patients treated by interlocking nail, three were at early stage follow-up and four were lost to follow-up at completion of the study. Of the 78 patients treated by plating, six were in early follow-up and two lost to follow-up. After applying the inclusion and exclusion criteria, we included 60 patients of interlocking nailing and 70 patients of plating for final analysis in the study.

In case of MIPPO plating, the proximal window is 4cm in length and it is made at the interval between the proximal part of biceps brachialis muscle medially and deltoid muscle laterally. Distally, a 4cm incision is made along the lateral border of biceps muscle approximately 1cm proximal to the elbow flexion crease. The lateral quarter of the brachialis muscle is then split longitudinally to expose the anterior cortex of the distal humerus. A sub muscular extra periosteal tunnel is prepared between the brachialis muscle and the underlying periosteum with a narrow periosteal elevator or cobbs elevator inserted first from proximal incision distally and then from distal incision proximally. Through this tunnel noncontoured long narrow 4.5mm dynamic compression plate (DCP, 10 to 12 holes) or locking compression plate is inserted from proximal incision, passing over the fracture site and down to the distal incision. The apposition and the alignment of the fragments are checked with C-arm, and significant valgus or varus if any, was corrected by manual manipulation. As long as a straight plate has been fixed exactly on the anterior border of the humerus, there will be no significant rotation or angulation. When the length of the humerus is approximately restored and both the ends of the plate are in the correct positions mentioned above, the proximal and distal portions of the plate are then fixed to the proximal and distal main fragments, respectively with screws at least six cortical purchases on both sides [Figure 1, 2, 3].

Figure 1: Shows plate insertion.

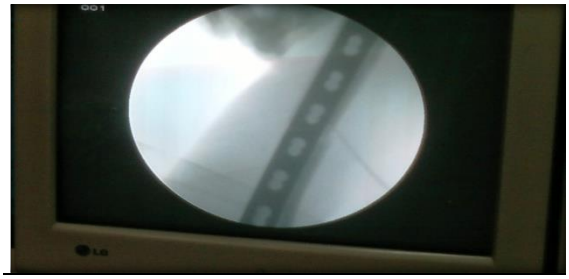

Figure 2: Shows lateral angular correction using hammer undar C-arm.

Figure 3: Shows incision after 48 hours.

In case of intramedullary nailing guide pin was inserted through the opening made in the supraspinatus tendon using image intensification. Proximal end of the humerus was reamed by using a cannulated awl over the guide pin. The nail was inserted advanced in the proximal shaft fragment by using gentle rotatory movements. The nail tip was used as a reduction aid. After passing the fracture site, the nail was inserted up to coronoid fossa by adjusting humeral shaft alignment, rotation, and length under image intensification in two different planes. The proximal locking was done by zig. The distal locking was done by free hand technique [Figure 4].

Figure 4: Intramedullary Nail.

All patients were advised on immediate postoperative shoulder and elbow exercises and radiographs were taken at regular intervals during follow-up. UCLA shoulder score and Mayo elbow performance score were used to compare the final postoperative results of interlocking nailing and plating procedures at one year follow-up.

RESULTS

At the end of the study, we had 70 patients in the Plate group and 60 in the IMN group for comparison. In the Plate group, we had 61 male and 9 female patients, whereas there were 53 male and 7 female patients in the IMN group. The mean age was years 45.1±7.58 (range 18-65 years) in the Plate group and 47.5±5.8 years (range 18-62 years) in the IMN group. The trauma surgery delay was 12.84 ± 5.90 days (range 3-27 days) in the Plate group and 13.79 ± 5.90 days (range 4-27 days) in the IMN group. In the Plate group 38 patients had AO type A 25 pts. had type B and 7 had AO type C fractures, whereas it was 39 type A, and 17 type B and 4 type C in the IMN group. There was no significant difference between the two groups with respect to age (P = 0.92), sex (P = 0.41) and trauma to surgery delay (P = 0.5). The mean follow-up period was 25.12 ± 3.28 months (range 18-30 months) for the plate group and 24.60 ± 2.42 months (range 18-30 months) for the IMN group [Table 1].

Operative indications were failure of non-operative treatment, polytrauma patients, radial nerve palsy, open fractures, floating elbow and fractures with vascular injury. More than half of the patients in our study needed operative intervention due to failure of acceptable fracture reduction and alignment by closed methods [Table 2].

Union was obtained within six months in 71.4% of MIPO and 69.38% of IMN group. Delayed union was noted in 21.4% in MIPPO and 20.4% in IMN group and non-union was found in 7.2% in MIPPO pts and 10.2% in IMN group. Patients with delayed union were followed for at least another six months

after which the possibility of secondary treatment was considered. There was no significant difference in union rates between the MIPPO and the IMN group [Table 3]. In the MIPPO group, non-union after one year was noted in five cases. Reoperation on these five patients was successfully performed with open reduction and internal fixation with anterolateral plating and combined with bone grafting. In the IMN group six patients presented non-union after one year. Two showed loosening of distal locking screws and one migration of the nail. All of these underwent revision with open reduction and internal fixation with posterior plating and bone grafting. A third patient denied any further surgery. He had been given bone marrow injection. In the two patients who had non-union after IMN without loosening of screws or hardware migration, open exchange nailing done with bone grafting.

Table 1: Demographic Parameters.

Parameters	MIPO plating (70)	Intramedullary nail (60)	P value
Gender: male/female	61/9	53/7	0.46
Age (years): mean (range)	45.1±7.58	47.5±5.8	<0.05
Side: right/left	32/38	28/32	0.95
Mechanism of injury Simple fall at home Traffic accident	13 57	16 44	0.39
AO fracture classification **TypeA: simple (non-comminuted) fractures**	38	39	0.85
A1: Spiral fractures	13	17	
A2 : Oblique fractures	8	9	
A3 :Transverse fractures	17	13	
Type B :Fractures with butterfly fragment	25	17	0.82
B1: Spiral fractures	8	4	
B2: Bending wedge fracture	12	11	
B3 : Wedgefractures with more than one fragment	5	2	
Type C : Comminuted fractures	7	4	0.79
C1 : Double spiral fractures	5	2	
C2 : Segmental fractures	1	1	
C3 : Complex fractures	1	1	
Mean follow up period	25.12 ± 3.28	24.60 ± 2.42	<0.05

Table 2: Different indications for fracture fixation.

Indications	Number of patients	Percentage
Humeral fractures with multiple injuries	30	23.07%
Fractures with unacceptable reduction	70	53.84%
Secondary displacement of fracture reduction with non-operative treatment (before 6 weeks)	22	16.92%
Humeral with ipsilateral forearm fractures	8	6.17%

Table 3: Comparison of union.

Parameters	MIPO		IMN		p value
	n	%	n	%	
Union	50	71.4%	42	69.38	<0.05
Delayed union	15	21.4%	12	20.42	<0.05
Non union	5	7.2%	6	10.2	<0.05

By observing UCLA score for shoulder function, thirty-nine out of 60 patients of the interlocking nail group had good to excellent results while 65 out of 70 patients of the plating group had similar results at the final follow-up for the study. This difference was found to be statistically significant on Students t test ($p<0.05$) [Tables 4]. But in case of Mayo elbow performance score, we found sixty patients of MIPPO group and 54 of intramedullary group had excellent to good results. There was no statistically difference of elbow performance between the groups [Table 5].

Table 4: Comparison of results of UCLA Shoulder score.

Result	MIPO		IMN		p value
	n	%	n	%	<0.05
Excellent & Good	65	92.85	39	65	
Fair & Poor	5	7.15	21	35	

Table 5: Comparison of results of Mayo Elbow Performance score.

Result	MIPO		IMN		p value
	n	%	n	%	
Excellent	25	35.72	30	50.00	<.005
Good	35	50.00	24	40.00	
Fair	8	11.43	5	8.33	
Poor	2	2.85	1	1.67	

Preoperative radial nerve palsy was seen in four cases (11.11%) in our series. All cases of preoperative radial nerve palsy recovered completely following stabilization, indicating a neuropraxia type of injury. There were 6 cases of postoperative radial nerve palsy: four in the MIPO group and two in the IMN group. Secondary exploration of the nerve was done in one patient in each group. In both the cases,

nerve was found trapped in between the fracture. In all cases complete recovery occurred.

Three iatrogenic fractures occurred, all in the IMN group: both at the distal tip of an antegrade nail in the distal humerus. All were treated with posterior surface plating.

There were significantly more patients with restrictive pain and/or functional hindrance in the Shoulder IMN group. After antegrade nailing, 7 of 60 patients (11.66%) reported shoulder complaints related with impingement; one patient developed a frozen shoulder. Elbow stiffness noted in three cases in MIPO and one case in IMN group.

Problems with osteosynthesis material occurred as often in the MIPO group (10%) as in the IMN group (11.66%) [Table-6]. One plate breakage, four bended plate were seen in follow-up, as well as screw breakage in four cases. Following bending or breakage of the plate, a new plate fixation was done, ending up in union with an excellent functional outcome. In the IMN group migration of the nail was noted six cases, in each case with impingement in the shoulder. Breakage of the distal locking screws was seen four cases the IMN group.

Table 6: Comparison of complications.

Parameters	MIPO		IMN		P value
Postoperative complication	13	18.57%	12	20%	<.005
Radial nerve palsy	4		2		
Iatrogenic fracture	0		3		
Pain/functional restriction					
Elbow	3	4.2%	1	1.7%	
Shoulder	5	7.1%	21	35%	
Hardware failure	7	10%	7	11.66%	
Breakage implant	1		0		
Bending implant	4		2		
Migration/ breakage screws	4		6		
Infection	3		5		

Table 7: Indication for reoperation.

Parameters	MIPO		IMN		p VALUE
Total	11	15.71%	10	16.67%	<.005
Non union	5		6		
revision for radial nerve palsy	1		1		
Hardware failure	7		7		

Five patients in IMN group and three patients in MIPO group had wound infection. All infections were superficial with coagulase negative staphylococci and were treated with antibiotics.

Overall, no significant difference was in seen in the IMN group and MIPO group .A reoperation was necessary in 15.71% of the MIPO patients and 16.67% of the IMN patients. There was no significant difference between the groups [Table 7].

DISCUSSION

Treatment of humerus shaft fracture has evolved from the conservative cast and brace [21, 22] to internal fixation with plate and screws and intramedullary nailing. Each of these techniques has its own complications.[23-26] and there is no significant data that shows the superiority of one over the other. Zhiquan 2010 reported that plate osteosynthesis has been the treatment of choice for humeral shaft fracture when operative treatment is needed. However, complications such as healing problems, infections and iatrogenic radial nerve palsy have been reported.[16,17] MIPPO has shown promising results recently in the treatment of humerus shaft fracture [16,17,27,19] and also an emerging procedure for the treatment of humeral shaft fracture Zhiquan Apivatthakakul T 2005 reported the advantages of MIPPO regarding less surgical trauma to neurovascular structure and soft tissue with anterior plate insertion through tunnel.[16,17] The periosteal circulation around the fracture fragments is minimally disrupted and thus bone union is promoted and complications such as nonunion are decreased.

Many authors have reported satisfactory results by applying the MIPPO technique in the treatment of humeral shaft fracture.[16, 18, 19, 28-30] In the past 10 years, these principles have been widely used in the treatment of long bone fractures, with good results.(19, 16, 18 28, 29, 30, 31) However, there is no large series of data that reports advantages and disadvantages of MIPPO compared with conventional plating osteosynthesis and intramedullary nailing technique.[17] Therefore, A possibility exists that MIPPO can be used for the treatment of recent fracture shaft of humerus. The aim of this study is to determine the radiological and functional outcome along with effectiveness of simple and economical MIPPO technique.

130 patients who sustained humeral shaft fractures included in our clinical study with maintaining inclusion and exclusion criteria were treated with the MIPPO and IMN technique. In our study 71.4% of MIPPO plating were united with a mean healing of 13.75 weeks (range 10 to 18 weeks) and 69.38% of IMN group were united with a mean healing time 14.15 weeks (range 10 to 21 weeks) which is better than that reported by Zhiquan and Sang-Jin shin 21.25 weeks and 18.4 weeks respectively in case of open reduction and internal fixation.[32, 33]

An added advantage with MIPPO is that it is devoid of the entry-point problems of intramedullary nailing such as rotator cuff impingement.[24, 34] In our study, we have found excellent to good result in 92.85% patients of MIPPO group in comparison to 65% in IMN group according to UCLA scoring system.

Statistically, this difference is significant. But there is no difference in Mayo elbow performance score. Ajmol et al. reported that thirty-three humeral nailings were carried out using the Russell-Taylor nail and gave an overall union rate of 70%. Eighteen patients (56%) experienced pain in the shoulder or at the fracture site. Thirteen patients (41%) had poor shoulder function. Only 17 (51%) of the patients were satisfied with the outcome. Fourteen patients (42%) needed further surgery. (24) The literature regarding management of humeral shaft fractures with locked humeral nailing has been inconsistent at best and has raised concerns based on the various complications noted. One of the chief issues after both antegrade and retrograde techniques has been the insertion site morbidity created at the nail entry site. In the previous literature, the incidence of shoulder dysfunction has been reported to range from 6% to as high as a 100 %.[33-35]

In the reviewed literature, there were no reports of non-union after MIPPO technique. But in our study five cases of nonunion was (7.2%) found in MIPPO and six cases (10.2%) in IMN procedure. The difference is statistically non-significant. The rate of nonunion after intramedullary humeral fixation has ranged between 5% and 29% in the literature, with many of the higher incidences having been noted in several studies.[34] In case open reduction and internal fixation technique, interferes with the local vascularity and fracture hematoma leads to osteonecrosis beneath the implant, which can cause delay union or non-union (the reported rate of nonunion being 5.8%.[36] The primary bone healing without callus formation is not very strong and there exists a real risk for refracture after removal of the implant in the open technique.[37, 38]

However, in our series, four cases of MIPPO plating and two cases of IMN had radial nerve palsy. Exploration of nerve was done for one case in both group where nerve was found trapped in between fracture fragment. On other cases the reason for radial nerve palsy may be due to over traction. In open reduction and internal fixation, carefully exposer and protection of the radial nerve require during the entire procedure. Despite the stress on meticulous radial nerve protection, the incidence of iatrogenic radial nerve palsies following this procedure is reported to be from 5.1% (36) to 17.6% (13) in different series in the literature. The occurrence of iatrogenic radial nerve palsy in case of open reduction and internal fixation, 31.3%,[17] was significantly higher than in our study 3.03%. In case of MIPPO, the brachialis muscle covers the humerus anteriorly and protects the radial nerve from injury when a plate is inserted submuscularly through two small incisions on the anterior side of the arm away from fracture site, supporting our findings of less radial nerve palsies with the technique used in our study.

In our study, we had one case of infection in 3 and 5 cases of MIPPO and IMN procedure respectively. Delayed union was found in 15 and 12 cases in MIPPO and IMN group respectively. Zhiquan et al. reported 6.3% delay union in case of open reduction and internal fixation.[17]

Taken together these results with previous findings suggest that recent fracture shaft of humerus could be effectively treated with the MIPPO technique, with advantages of shorter fracture union time and lower incidence of iatrogenic radial nerve palsies. Thus, our case series shows that optimum arm function is achieved at an early date following MIPPO of humerus shaft fractures. MIPPO is also associated with less operative scars and better cosmesis. This contributes to the high patient satisfaction with this novel treatment.

At the end of this study, we emphasize the advantages of this technique regarding safety and convenient, without requiring special tools and demanding implants or excessive radiographic control. The plate stability allows a fast rehabilitation with superior functional results comparing with the conservative techniques (open reduction and internal fixation, intramedullary nailing). MIPPO for humeral shaft fractures provided satisfactory clinical and radiological outcomes considering high union rate and minor complications and it is safe and effective surgical treatment method and an alternative option to open techniques and intramedullary nailing. The results obtained with this technique are encouraging. Within 6 months, 96% of the patients returned to their normal activities.

Advantages of applying the MIPPO technique are as follows: 1. it is suitable for the treatment of humeral shaft fractures. 2. There is rare risk of axillary nerve injury. 3. The radial nerve is not at risk as long as the forearm is kept in supination during the procedure 4. No screws are inserted into that part of the humeral shaft where the radial nerve runs along the spiral groove.

CONCLUSION

This work presents the MIPPO technique applied in the treatment of recent humeral shaft fractures. The results obtained in this study have shown that the MIPPO technique is safe, convenient and effective, since there was minimal soft tissue injury, nor major complications. From this prospective comparative study, we concluded that humeral shaft fractures could be effectively treated with the MIPPO technique, with advantages of shorter fracture union time and lower incidence of iatrogenic radial nerve palsies rather than the conventional open reduction and internal fixation technique and intramedullary nailing.

MIPPO is a modality which results in a relatively stable fracture construct while preserving a biologic

environment that facilitates rapid bone healing. While MIPPO is most applicable to the fractures of long bones, particularly, humerus shaft fractures. The reported outcomes of MIPPO procedures have been favourable, with rapid stabilisation of the fracture site by bridging callus, progressing to complete union. This technique has gained rapid acceptance for fracture shaft of humerus.

REFERENCES

1. Ekholm R, Tidermark J, Törnkvist H, Adami J, Ponzer S. Outcome after closed functional treatment of humeral shaft fractures. J Orthop Trauma. 2006 Oct; 20(9):591-6.
2. Tytherleigh-Strong G1, Walls N, McQueen MM. The epidemiology of humeral shaft fractures. J Bone Joint Surg Br. 1998 Mar; 80(2):249-53.
3. Brorson S. Management of fractures of the humerus in Ancient Egypt, Greece, and Rome: an historical review. ClinOrthopRelat Res 2009; 467:1907-14. doi:10.1007/s11999-008-0612-x
4. Schemitsch EH, Bhandari M. Fractures of the humeral shaft. In: Browner BD, Jupiter JB, Levine AM, Trafton PG (ed) Skeletal trauma: basic science, management, and reconstruction, 3rd edn. WB Saunders Company, 2003. pp 1487–1488.
5. Niall DM, O'Mahony J, McElwain JP. Plating of humeral shaft fractures—has the pendulum swung back? Injury. 2004; 35(6):580–586.
6. Changulani M, Jain UK, Keswani T. Comparison of the use of the humerus intramedullary nail and dynamic compression plate for the management of diaphyseal fractures of the humerus.Arandomised controlled study. IntOrthop. 2007; 31(3):391–395.
7. Fernandez FF, Matschke S, Hulsenbeck A et al. Five years' clinical experience with the unreamed humeral nail in the treatment of humeral shaft fractures. Injury. 2004;35(3):264–271.
8. Petsatodes G, Karataglis D, Papadopoulos P et al.Antegrade interlocking nailing of humeral shaft fractures. J OrthopSci. 2004; 9(3):247–252.
9. Pogliacomi F, Devecchi A, Costantino C, Vaienti E. Functional long-term outcome of the shoulder after antegrade intramedullary nailing in humeral diaphyseal fractures. ChirOrganiMov. 2008; 92(1):11–16
10. Fernandez FF, Matschke S, Hulsenbeck A et al. Five years' clinical experience with the unreamed humeral nail in the treatment of humeral shaft fractures. Injury. 2004;35(3):264–271.
11. Pogliacomi F, Devecchi A, Costantino C, Vaienti E. Functional long-term outcome of the shoulder after antegrade intramedullary nailing in humeral diaphyseal fractures. ChirOrganiMov. 2008; 92(1):11–16
12. Bhandari M, Devereaux PJ, McKee MD et al. Compression plating versus intramedullary nailing of humeral shaft fractures—a meta-analysis. ActaOrthop. 2006;77(2):279–284.
13. Lim KE, Yap CK, Ong SC et al. Plate osteosynthesis of the humerus shaft fracture and its association with radial nerve injury—a retrospective study in Melaka General Hospital. Med J Malaysia. 2001;56(Suppl C):8–12.
14. Paris H, Tropiano P, ClouetD'orval B et al. Fractures of the shaft of the humerus: systematic plate fixation. Anatomic and functional results in 156 cases and a review of the literature. Rev ChirOrthopReparatriceAppar Mot. 2000; 86(4):346–359.
15. Jawa A, McCarty P, Doornberg J et al. Extra-articular distal-third diaphyseal fractures of the humerus. A comparison of functional bracing and plate fixation. J Bone Joint Surg Am. 2006; 88(11):2343–2347.
16. Apivatthakakul T, Arpornchayanon O, Bavornratanavech S. Minimally invasive plate osteosynthesis (MIPO) of the humeral shaft fracture. Is it possible? A cadaveric study and preliminary report. Injury. 2005; 36(4):530–538.
17. Zhiquan An, BingfangZeng, Xiaojian He, Qi Chen, Shundong Hu Plating osteosynthesis of mid-distal humeral shaft fractures: minimally invasive versus conventional open reduction technique, International Orthopaedics (SICOT) 2010; 34:131–135.
18. Ziran BH, Belangero W, Livani B, Pesantez R. Percutaneous plating of the humerus with locked plating: Technique and case report. J Trauma Inj Infect Crit Care 2007;63:205-10.
19. Livani B, Belangero W, Andrade K, Zuiani G, Pratali R. Is MIPO in humeral shaft fractures really safe? Postoperative ultrasonographic evaluation. IntOrthop. 2009;33:1719-23..
20. Ji F, Tong D, Tang H et al. Minimally invasive percutaneous plate osteosynthesis (MIPPO) technique applied in the treatment of humeral shaft distal fractures through a lateral approach. IntOrthop. 2008; doi:10.1007/s00264–008–0522–2.
21. Camden P, Nade S. Fracture bracing of the humerus. Injury. 1992;23:245-8.
22. Hunter J. Collected works. In: Palmer JF, editor. $4 Vol. London: Longman Rees;1837.
23. Chao TC, Chou WY, Chung JC, Hsu CJ. Humeral shaft fractures treated by dynamic compression plates, Ender nails and interlocking nails. IntOrthop. 2005;29:88-91.
24. Ajmal M, O'Sullivan M, McCabe J, Curtin W. Antegrade locked intramedullary nailing in humeral shaft fractures. Injury. 2001;32:692-4.
25. Petsatodes G, Karataglis D, Papadopoulos P, Christoforides J, Gigis J, Pournaras J. Antegrade interlocking nailing of humeral shaft fractures. J OrthopSci 2004; 9: 247-52.
26. Santori FS, Santori N. The Exp Nail for the treatment of diaphyseal humeral fractures. J Bone Joint Surg Br. 2002;84 (Supp 3):280.
27. Ziran BH, Belangero W, Livani B, Pesantez R. Percutaneous plating of the humerus with locked plating: Technique and case report. J Trauma Inj Infect Crit Care. 2007;63:205-10.
28. Ziran BH, Belangero W, Livani B, Pesantez R. Percutaneous plating of the humerus with locked plating: Technique and case report. J Trauma Inj Infect Crit Care. 2007;63:205-10.
29. Concha JM, Sandoval A, Streubel PN. Minimally invasive plate osteosynthesis for humeral shaft fractures: are results reproducible? IntOrthop. 2010;34(8):1297-305.
30. Kobayashi M, Watanabe Y, Matsushita T. Early full range of shoulder and elbow motion is possible after minimally invasive plate osteosynthesis for humeral shaft fractures. J Orthop Trauma. 2010;24 (4):212-6.
31. Kobayashi M, Watanabe Y, Matsushita T. Early full range of shoulder and elbow motion is possible after minimally invasive plate osteosynthesis for humeral shaft fractures. J Orthop Trauma. 2010;24 (4):212-6.
32. Fernandez DellOca AA. The principle of helical implants: Unusual ideas worth considering. Injury. 2002;Suppl 33: A1-27.
33. Dabezies EJ, Banta CJ 2nd, Murphy CP, d'Ambrosia RD. Plate fixation of the humeral shaft for acute fractures, with and without radial nerve injuries. J Orthop Trauma. 1992;6:10-3.
34. Reimer B. Humeral shaft fractures- intramedullary nailing. In: Wiss D, editor. Master techniques in orthopaedic surgery. Philadelphia: Lippincott-Raven; 1998. p. 81-94.
35. Robinson CM, Bell KM, Court-Brown CM, McQueen MM. Locked nailing of humeral shaft fractures. Experience in Edinburgh over a two-year period. J Bone Joint Surg Br. 1992;74:558-62.
36. Paris H, Tropiano P, ClouetD'orval B et al. Fractures of the shaft of the humerus: systematic plate fixation. Anatomic and functional results in 156 cases and a review of the literature. Rev ChirOrthopReparatriceAppar. 2000; Mot 86(4):346–359
37. Breederveld RS, Patka P, Van Mourik JC. Refractures of the femoral shaft. Neth J Surg. 1985;37:114.

38. Broos PL, Sermon A. From unstable internal fixation to biological osteosynthesis a historical overview of operative fracture treatment. Acta Chir Belg. 2004;104:396-400.

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