Section: Orthopedics

JAMP

Original Research Article

CLINICO RADIOLOGICAL OUTCOME OF ANTERIOR BRIDGE PLATING IN MID HUMERAL SHAFT FRACTURES TREATED BY MIPO TECHNIQUE

N. Sunil Kumar[1], S. Gowdaman[2], Reddy Mohan[3], Mubarak R.M[4]

[1]Associate Professor, Department of Orthopedics, Sri Venkateshwaraa Medical College Hospital & Research Centre, Chennai, India
[2]Senior Resident, Department of Orthopedics, Sri Venkateshwaraa Medical College Hospital & Research Centre, Chennai, India
[3]Assistant Professor, Department of Orthopedics, Sri Venkateshwaraa Medical College Hospital & Research Centre, Chennai, India
[4]Associate Professor, Department of Radiodiagnosis, Sri Lalithambigai Medical College and Hospital, Tamilnadu, India

Received : *15/02/2025*
Received in revised form : *12/04/2025*
Accepted : *27/04/2025*

Keywords:
Humeral shaft fracture, anterior bridge plating, complications, functional outcomes, radiographs.

Corresponding Author:
Dr. Mubarak R.M.,
Email: mubarakbasha91@gmail.com

DOI: 10.47009/jamp.2025.7.2.241

Source of Support: Nil,
Conflict of Interest: None declared

Int J Acad Med Pharm
2025; 7 (2); 1197-1202

Abstract

Background: Humeral shaft fractures account for 1–2% of all fractures and 14% of all humerus fractures. The treatment options include functional bracing, plating, intramedullary nailing, and external fixation. Minimally invasive plate osteosynthesis (MIPO) offers benefits such as early weight-bearing, minimal blood loss, and high union rates. This study evaluated the use of anterior bridge plating for mid-shaft humeral fractures. **Materials and Methods:** This hospital-based observational study included 20 patients and was conducted at Assam Medical College & Hospital, Dibrugarh, for over one year. The patients underwent clinical, radiological, and laboratory evaluations. Surgery was performed via an anterolateral approach using the brachialis-splitting technique. Postoperatively, rehabilitation included early mobilization and regular follow-up. Outcomes were assessed using the OTA classification, radiographs, Constant-Murley Shoulder Score, and Mayo Elbow Performance Score. **Result:** The mean age of patients was 36.00 ± 8.92 years, with males comprising 70%. Road traffic accidents (75%) are the leading cause of injury. The mean injury-to-surgery interval was 5.00 ± 1.38 days, and the average surgery duration was 68.35 ± 6.43 minutes. Type B fractures (75%) were the most common. Functional outcomes improved over time, with the Constant-Murley and MEPS scores showing significant enhancement at 6 months (p=0.0373, p=0.0009). Infection and delayed union occurred in 5% of the cases, while no cases of non-union or nerve palsy were observed. **Conclusion:** Our study concluded that the MIPO technique is effective, with a high union rate, excellent outcomes, and fewer complications. Despite the technical challenges, it promotes faster healing and is a valuable alternative to experience and proper surgical assistance.

INTRODUCTION

A humeral shaft fracture is a break in the middle of the upper arm bone, the humerus. The overall occurrence of humeral shaft fractures is approximately 1-2% of all fractures in the human body and fractures involving the humerus are approximately 14%.[1] The most common closed diaphyseal humeral fractures are radial nerve injuries, accounting for approximately 10% to 12% of all closed humeral shaft fractures.[2] The management of diaphyseal humeral fractures through nonoperative means can be achieved by various techniques, including the abduction cast or splint, velpeau bandage, sling and body bandage, coaptation splint or u-slab, hanging arm cast, and functional bracing.[3] Orthopaedic practitioners widely use functional bracing to manage acute diaphyseal humeral fractures.

Indications for surgical intervention include reduction and stabilisation of diaphyseal humeral fractures. These include misplaced diaphyseal fractures that after conservative management, open fractures, transverse fractures, and comminuted fractures along with radial nerve palsy or pseudoarthrosis, segmental fractures, pathological fractures, bilateral fractures, floating elbow injuries, cases of polytrauma, neurological deficits following penetrating trauma, associated vascular injuries, and fractures that extend into the joint are also considered indications for operative treatment.[4] In the past two decades, surgeons paid attention to complex details of secondary characteristics of fracture patterns.

The application of plates in the management of fractures allows surgeons to realign and alleviate articular and periarticular fragments. Although plating presents significant technical challenges, the outcomes can be reliable. Shoulder or elbow stiffness is rare unless there is an extension of the fracture planes in the periarticular or intra-articular regions. Plating is one of the most effective methods for managing corrected malunion cases after osteotomy and continues to be the preferred treatment for humeral non-union.[5] One alternative approach for the management of humeral fractures is the use of intramedullary nailing. Modern designs include nails with reduced diameters, greater flexibility, various locking mechanisms, and enabling fracture compression. Humeral nails may be inserted through an antegrade or retrograde technique, by a reamed or unreamed insertion method.[6]

External fixation is infrequently used to manage humeral shaft fractures and is primarily limited to the early treatment of cases with extensive soft tissue injury, bone loss, gross contamination, vascular loss, or infection.[7] Minimally invasive methods can be used to plate a multi-fragmentary humeral shaft fracture and are usually performed with a pair of incisions, one distal and one proximal. Minimally invasive plate osteosynthesis (MIPO) techniques present certain challenges; they provide the advantage of reducing soft tissue injury, but not without associated risks.[8]

Among surgical fixations, open plating is associated with certain complications such as non-union, infection, postoperative transient radial nerve palsy, and implant failure. Nailing has disadvantages such as shoulder impingement, non-union, proximal migration of the nail, damage to the rotator cuff, malrotation, varus deformity, and ex-fix has disadvantages such as pin tract infection and refracture after ex-fix re-removal, non-union, and malunion.[9,10] Recent techniques such as MIPO have gained importance because they provide sufficient stability to allow early upper extremity weight-bearing, small incision, minimal blood loss, high union rate, minimal periosteal damage, rapid return of function, and regaining of excellent range of movement at the shoulder and elbow.

Aim

This study aimed to analyse the outcomes of anterior bridge plating in midshaft humeral fractures by using a minimally invasive approach.

MATERIALS AND METHODS

This hospital-based observational study included 20 patients in the Department of Orthopaedics, Assam Medical College and Hospital, Dibrugarh, for one year. The Institutional Ethics Committee approved the study before initiation, and informed consent was obtained from all patients.

Inclusion Criteria

The study included patients aged 18–60 years with a closed unilateral humeral diaphysis fracture and an intact neurovascular status, and patients with type 1 open fractures and fresh fractures sustained within three weeks of injury.

Exclusion Criteria

Patients aged < 18 or > 60 years with associated neurovascular injuries, individuals with type 2 or type 3 open fractures, patients with pathological fractures or fractures older than three weeks, patients with ipsilateral shoulder and elbow injuries or ipsilateral long bone fractures, and those who refused to undergo surgery were excluded.

Methods: All patients underwent clinical examination at the casualty department, were carefully examined, and analgesics were administered to relieve pain. In cases of open fractures, appropriate antibiotic prophylaxis and tetanus toxoid with immunoglobulins were administered. Vital signs were closely monitored, and distal neurovascular status was assessed to rule out radial nerve and vascular injuries. The affected arm was immobilized using a U-slab or bracing. Once the patient stabilized, radiological and laboratory investigations were performed.

Radiological investigations included radiographs of the arm, shoulder, and elbow (standard anteroposterior and lateral views) and an X-ray (chest posterior-anterior view). Fractures were classified according to the OTA classification. Preoperative routine blood tests included haemoglobin percentage, TLC, DLC, Platelet count, ESR, PT-INR, RBS, Serum Urea, Serum Creatinine, LFTs, and viral markers including ICTC, Anti-HCV, and HBsAg. An ECG was conducted to assess anaesthetic fitness. Anaesthesia was administered according to the anaesthesiologist’s choice.

The surgery was performed using the anterolateral approach with a brachialis splitting technique in a supine position, with the arm abducted to 70° of the forearms in full supination and the elbow flexed on the side table. An image intensifier was positioned on the same side as the affected arm. A 3 cm incision was created in the region between the proximal biceps and medial edge of the deltoid muscle, situated approximately 6 cm distal to the anterior aspect of the acromion process. A separate incision measuring 3 cm was created distally along the lateral edge of the biceps, approximately 5 cm above the flexion crease. The musculocutaneous nerve was located and retracted towards the medial side, while the brachialis muscle was longitudinally incised to protect the radial nerve. A subbrachialis extra-periosteal tunnel was established by employing a periosteal elevator as a tunnelling instrument, from distal to proximal, or vice versa.

Care was taken to pass the instrument anteromedially to prevent radial nerve injury. A 4.5 mm dynamic compression plate or locking compression plate was passed through the tunnel and its length was determined using C-arm guidance. Fracture reduction

ISSN (O): 2687-5365; ISSN (P): 2753-6556

was achieved using manual traction to restore the length and correct the varus/valgus angulation and rotation. The plate was temporarily fixed with 2.0 mm K-wires, and the rotational deformity was minimized using the cortical step and diameter difference signs. Final fixation was achieved using locking screws, ensuring a minimum of two screws in both the proximal and distal fragments. Reduction alignment was confirmed using intraoperative fluoroscopy before fixation was completed.

Postoperative management involved immobilization of all patients with an arm sling. Pendular exercises with elbow range of motion (ROM) were initiated 48 h after surgery. Once pain was reduced, active-assisted ROM exercises for both the shoulder and elbow were initiated. Wound evaluations were performed on the 3rd, 6th, and 9th days following the operation, with suture removal scheduled on the 11th day. Fracture union was assessed by the absence of pain and tenderness at the fracture site, as well as the presence of bridging callus in at least three of the four cortices observed on radiographic images. Patients underwent clinical and radiological follow-up at 6 weeks, 3 months, and 6 months post-surgery, with annual evaluations continuing until complete healing of the fracture was confirmed.

At the time of admission, fractures were classified using the OTA classification and the nature of the injury was documented. Postoperative radiographs were analysed to evaluate humeral alignment, including the degree of angulation (anteroposterior, varus/valgus, and rotational deformities), fracture reduction, and radiological evidence of union at the fracture site. Functional outcomes were assessed using the Mayo Elbow Performance Score (MEPS), and Constant-Murley Shoulder Score, and radiological outcomes were evaluated based on the degree of angulation at the fracture site and evidence of union.

Statistical analysis: Data are presented as mean, standard deviation, frequency, and percentage. Continuous variables were compared using an independent-sample t-test. Categorical variables were compared using Pearson's chi-square test. Significance was defined as P values less than 0.05 using a two-tailed test. Data analysis was performed using IBM-SPSS version 21.0 (IBM-SPSS Corp., Armonk, NY, USA).

RESULTS

The age distribution showed equal numbers of patients aged 18–30 years (35%) and 31–40 years (35%), whereas fewer patients were in the 41–50 years (20%) and 51–60 years (10%) age groups. Males (70%) were more prevalent than females (30%). Regarding the dominant side, the right side was dominant in 55% of cases, whereas 45% had left-side dominance.

Regarding the mode of injury, RTA was the most common cause (75%), significantly higher than falls (25%), with no cases of physical assault. The injury-to-surgery interval was higher between 4 and 7 days (85%), only 15% underwent surgery within 1–3 days, and no cases exceeded 7 days. Surgery duration was mostly between 61 and 70 min (60%) and 71–80 min (35%), whereas only 5% of cases had a duration of 51–60 min, with none lasting between 41- and 50-min. Hospital stays were mostly between 1 and 7 days (95%), with only 5% remaining for 8–14 days, and no patients stayed beyond 14 days [Table 1].

Table 1: Demographic and clinical characteristics of patients.

		N (%)
Age (in years)	18–30	7(35%)
	31–40	7(35%)
	41–50	4(20%)
	51–60	2(10%)
Gender	Male	14(70%)
	Female	6(30%)
Dominant side	Right	11(55%)
	Left	9(45%)
Mode of injury	Fall	5(25%)
	RTA	15(75%)
	Physical assault	0
Injury to surgery Interval (in days)	1-3	3(15%)
	4-7	17(85%)
	>7	0
Surgery duration (minutes)	41-50	0
	51-60	1(5%)
	61-70	12(60%)
	71-80	7(35%)
Hospital stays (in days)	1-7	19(95%)
	8-14	1(5%)
	>14	0

The mean age of patients was 36.00 ± 8.92 years, and the interval between injury and surgery averaged 5.00 ± 1.38 days. The mean duration of surgery was 68.35 ± 6.43 minutes, while the average blood loss was 87.50 ± 8.66 ml. Hospital stays had a mean duration of 5.55 ± 1.36 days, and the mean duration of union was recorded as 12.85 ± 1.39 weeks.

Regarding functional outcomes, the Constant-Murley Score showed progressive improvement, with a mean score of 89.45 ± 6.13 at 6 weeks, increasing to 92.35 ± 5.08 at 3 months, and further to 93.25 ± 4.95 at 6 months. Similarly, the MEPS score followed an improving trend, with a mean of 94.50 ± 3.59 at 6 weeks, rising to 97.00 ± 3.40 at 3 months, and reaching 98.25 ± 2.94 at 6 months [Table 2].

Table 2: Clinical and functional outcomes of study patients

			Mean±SD
Age (in years)			36.00±8.92
Injury to surgery Interval (in days)			5.00±1.38
Duration of surgery (minutes)			68.35±6.43
Blood loss (ml)			87.50±8.66
Hospital stays (in days)			5.55±1.36
Time of union (weeks)			12.85±1.39
Functional outcome	Constant-Murley score	At 6 weeks	89.45±6.13
		At 3 months	92.35±5.08
		At 6 months	93.25±4.95
	MEPS score	At 6 weeks	94.50±3.59
		At 3 months	97.00±3.40
		At 6 months	98.25±2.94

Regarding fracture types, Type B fractures were the most common, with 12B2 (40%) being the predominant subtype, followed by 12B1 (25%) and 12B3 (10%). Type C fractures accounted for 25% of the cases, with 12C1 (15%) and 12C3 (10%), whereas Type A fractures were not observed.

Regarding radiological valgus/varus angulation, the majority of cases (90%) exhibited 0–5-degree varus angulation, whereas only 5% had >5-degree varus angulation. No valgus angulation was recorded, and 5% of the cases showed anteroposterior angulation. Among the complications, infection and delayed union were observed in 5% of cases, whereas radial nerve palsy and non-union were not reported in any patient [Table 3].

Table 3: Fracture classification, radiological angulation, and complications

			N (%)
Fracture type	Type A	12A1	0
		12A2	0
		12A3	0
	Type B	12B1	5(25%)
		12B2	8(40%)
		12B3	2(10%)
	Type C	12C1	3(15%)
		12C2	0
		12C3	2(10%)
Radiological valgus/Varus angulation	0–5-degree varus		18(90%)
	>5-degree varus		1(5%)
	Valgus		0
	Anteroposterior angulation		1(5%)
Complications	Radial nerve palsy		0
	Infection		1(5%)
	Delayed union		1(5%)
	Non-union		0

At 6 weeks, 80% of patients achieved an excellent outcome, whereas 20% had a good outcome. None of the cases were classified as fair or poor. At three months, the proportion of excellent outcomes increased to 85%, with only 15% in the good category. No cases were classified as fair or poor, showing no significant difference compared with the 6-week outcome (p=0.1115). At 6 months, the distribution remained similar, with 85% of patients achieving excellent outcomes and 15% achieving good outcomes, showing a significant difference compared to the 6-week outcome (p=0.0373) [Table 4].

Table 4: Functional outcome by Constant-Murley score

	Functional outcome (CMS)				**P value**
	Excellent	**Good**	**Fair**	**Poor**	
	86–100	**71–85**	**56–70**	**<56**	
At 6 weeks	16(80%)	4(20%	0	0	-
At 3 months	17(85%)	3(15%)	0	0	0.1115
At 6 months	17(85%)	3(15%)	0	0	0.0373

At 6 weeks, all patients (100%) achieved excellent outcomes, with no cases classified as good, fair, or poor. At 3 months, the outcomes remained unchanged, with 100% of patients showing an excellent outcome, showing significant improvement compared to the 6-week outcome (p=0.0296). At 6 months, all patients continued to achieve excellent outcomes, with no changes in classification, showing a significant difference compared with the 6-week outcome (p=0.0009) [Table 5].

Table 5: Functional outcome by MEPS score

	Functional outcome (MEPS score)				P value
	Excellent	Good	Fair	Poor	
	≥90	75–89	56–70	<56	
At 6 weeks	20(100%)	0	0	0	-
At 3 months	20(100%)	0	0	0	0.0296
At 6 months	20(100%)	0	0	0	0.0009

DISCUSSION

In our study, the demographic analysis showed a mean age of 36 years, similar to the findings of Livani et al. (40.52 years), Sharma et al. (34.3 years) and Mehraj et al (24.3 years), which also reported a peak incidence in the third decade due to high-energy trauma.[11-13] The male predominance (2.33:1) observed in our study is similar to the findings of Sharma et al. (2.66:1) and Kumar et al. (2.35:1) showing the higher exposure of males to outdoor activities and trauma.[12,14] The right side was more commonly affected (55%), similar to studies by Sharma et al. and Mahajan et al., showing right side predominance.12,15 Road traffic accidents were the leading cause (75%), similar to studies by Sharma et al. (91%) and Mahajan et al. (52.1%) reporting high-energy trauma as the primary mechanism of injury.[12,15]

In our study, fracture classification showed 85% OTA Type B fractures, similar to the study by Livani et al. (47%).[11] The mean time interval between injury and surgery was 5 days, similar to studies by Zhiquan et al. (6.15 days), supporting early intervention's role in better outcomes.[16] Radiological outcomes revealed that 55% of cases had no varus/valgus angulation, with minor malalignment resolving over time. A study by Zhiquan et al. reported similar remodelling patterns.[16] Compared to ORIF and IMN, studies by Oh et al. found that average angular deformities of varus-valgus were 2.2◦ in the MIPO and 0.8° in the ORPO group, the lateral radiographs, showing average angular deformities as 0.6° in the MIPO group and 0.5° in the ORPO group.[9] Esmailiejah et al. in their study found that the incidence of varus deformity more than 5° was higher in MIPO than ORIF, showing that MIPO maintains better alignment and lower malalignment rates.[17]

In our study, surgical time averaged 68.35 minutes, shorter than ORIF and IMN procedures, similar to studies by Garnavos et al., who reported that the treatment of Intramedullary Nailing for humerus shaft fracture found that mean operative time was 105 minutes (range, 50–140 minutes).6 The intraoperative blood loss was lower (87.50 ml) than that of ORIF (320 ml), similar to findings by Hadhoud et al. found that mean intraoperative blood loss was 92 ml (range 70–120 ml) and 366 ml (range 300–450 ml) in the MIPO group and ORIF group, respectively, which is highly significant, showing the benefits of minimal soft tissue disruption in MIPO.[18] with a mean hospital stay of 5.55 days and shorter than ORIF, supported by Chao et al., in their study found that the mean hospital stay in dynamic compression plate is 8.1 days, ender nail is 5.8 days and interlocking intramedullary nail (ILN) is 7.5 days.[19]

In our study, the mean union time was 12.85 weeks, with a 95% union rate, similar to that in the study by Sharma et al. (100%).[12] Compared to IMN and ORIF, MIPO demonstrated faster union, as observed in study by Oh et al. compared between standard conventional plating versus minimally invasive plating for humerus shaft fracture found that 90.5% of MIPO patients and 87% of ORIF patients achieved union. Average union times for the MIPO and ORPO groups were 17.3 and 16.7 weeks.[9]

Functional assessment using the Mayo Elbow Performance Score (MEPS) showed an excellent grade in 100% of cases, similar to studies by Zhiquan et al. (100%).[16] The study by Oh et al. found that the mean Mayo elbow score was 97.7 for the MIPO group and 97 for the ORIF group at the end of the follow-up.[9] Constant-Murley scores also showed superior shoulder function, with an average of 93.25, similar to the study by Apivatthakakul et al. (85.8) and Kumar et al., in their study found that a shoulder score of 66.66% of the Plating group and 60 of the interlocking group showed excellent result good result shown by 26.66% of plating and 33.33% of nailing group.[14,20]

In our study, there were fewer complications, with only one case each of superficial infection and delayed union. These results are similar to ORIF and IMN studies by Esmailiejah et al., who found that ORIF group patients had a higher infection 2(6%), non-union 3 (9%) and Iatrogenic radial injury 4 (12%) than compared with MIPO group infection 0% non- union 1 (3%) and Iatrogenic radial injury 1 (3%).[17]

CONCLUSION

Our study concluded that the MIPO technique is effective, has a high union rate, and has excellent functional and radiological outcomes. It is based on relative stability, which promotes faster healing, facilitates bone callus formation, and reduces the risk of infection and non-union. Moreover, we observed that MIPO had a shorter surgical duration, less intraoperative blood loss, and a lower complication rate, including radial nerve palsy and delayed union. However, MIPO is technically challenging, and with experience and good surgical assistance, is a useful alternative to other fixation methods.

REFERENCES

1. Brinker MR, O'Connor DP. The incidence of fractures and dislocations referred for orthopaedic services in a capitated population. J Bone Joint Surg Am 2004; 86:290–7. https://pubmed.ncbi.nlm.nih.gov/14960673/.
2. Tytherleigh-Strong G, Walls N, McQueen MM. The epidemiology of humeral shaft fractures. J Bone Joint Surg Br 1998;80-B:249–53. https://doi.org/10.1302/0301-620x.80b2.0800249.
3. Papasoulis E, Drosos GI, Ververidis AN, Verettas D-A. Functional bracing of humeral shaft fractures. A review of clinical studies. Injury 2010;41: e21-27. https://doi.org/10.1016/j.injury.2009.05.004.
4. Hosseini Khameneh SM, Abbasian M, Abrishamkarzadeh H, Bagheri S, Abdollahimajd F, Safdari F, et al. Humeral shaft fracture: a randomized controlled trial of nonoperative versus operative management (plate fixation). Orthop Res Rev 2019; 11:141–7. https://doi.org/10.2147/ORR.S212998.
5. Lotzien S, Hoberg C, Rausch V, Rosteius T, Schildhauer TA, Gessmann J. Open reduction and internal fixation of humeral midshaft fractures: anterior versus posterior plate fixation. BMC Musculoskelet Disord 2019; 20:527. https://doi.org/10.1186/s12891-019-2888-2.
6. Garnavos C, Lasanianos N. Intramedullary nailing of combined/extended fractures of the humeral head and shaft. J Orthop Trauma 2010; 24:199–206. https://doi.org/10.1097/BOT.0b013e3181b2b74d.
7. Clement H, Pichler W, Tesch NP, Heidari N, Grechenig W. Anatomical basis of the risk of radial nerve injury related to the technique of external fixation applied to the distal humerus. Surg Radiol Anat 2010; 32:221–4. https://doi.org/10.1007/s00276-009-0568-x.
8. Shetty MS, Kumar MA, Sujay K, Kini AR, Kanthi KG. Minimally invasive plate osteosynthesis for humerus diaphyseal fractures. Indian J Orthop 2011; 45:520–6. https://doi.org/10.4103/0019-5413.87123.
9. Oh C-W, Byun Y-S, Oh J-K, Kim J-J, Jeon I-H, Lee J-H, et al. Plating of humeral shaft fractures: comparison of standard conventional plating versus minimally invasive plating. Orthop Traumatol Surg Res 2012; 98:54–60. https://doi.org/10.1016/j.otsr.2011.09.016.
10. Chaudhary P, Karn NK, Shrestha BP, Khanal GP, Kalawar RPS. Treatment of fracture of shaft of humerus in adults by intramedullary interlocking nail fixation. Health Renaiss 2017; 13:153–9. https://doi.org/10.3126/hren.v13i2.17565.
11. Livani B, Belangero W, Andrade K, Zuiani G, Pratali R. Is MIPO in humeral shaft fractures really safe? Postoperative ultrasonographic evaluation. Int Orthop 2009; 33:1719–23. https://doi.org/10.1007/s00264-008-0616-x.
12. Sharma J, Jain A, Jain PG, Upadhyaya P. Anterior bridge plating with mini-incision MIPO technique for humerus diaphyseal fractures. Ind J Orthop Surg 2015; 1:171. https://doi.org/10.5958/2395-1362.2015.00022.5.
13. Mehraj M, Shah I, Mohd J, Rasool S. Early results of bridge plating of humerus diaphyseal fractures by MIPO technique. Ortop Traumatol Rehabil 2019; 21:117–21. https://doi.org/10.5604/01.3001.0013.1915.
14. Kumar R, Singh P, Chaudhary LJ, Singh S. Humeral shaft fracture management, a prospective study; nailing or plating. J Clin Orthop Trauma 2012; 3:37–42. https://doi.org/10.1016/j.jcot.2012.04.003.
15. Mahajan AS, Kim YG, Kim JH, D'sa P, Lakhani A, Ok HS. Is anterior bridge plating for mid-shaft humeral fractures a suitable option for patients predominantly involved in overhead activities? A functional outcome study in athletes and manual laborers. Clin Orthop Surg 2016; 8:358–66. https://doi.org/10.4055/cios.2016.8.4.358.
16. Zhiquan A, Bingfang Z, Yeming W, Chi Z, Peiyan H. Minimally invasive plating osteosynthesis (MIPO) of middle and distal third humeral shaft fractures. J Orthop Trauma 2007; 21:628–33. https://doi.org/10.1097/bot.0b013e31815928c2.
17. Esmailiejah AA, Abbasian MR, Safdari F, Ashoori K. Treatment of humeral shaft fractures: Minimally invasive plate osteosynthesis versus open reduction and internal fixation. Trauma Mon 2015;20: e26271. https://doi.org/10.5812/traumamon.26271v2.
18. Hadhoud M, Darwish A, Mesriga MK. Minimally invasive plate osteosynthesis versus open reduction and plate fixation of humeral shaft fractures. Menoufia Med J 2015; 28:154. https://doi.org/10.4103/1110-2098.155974.
19. Chao T-C, Chou W-Y, Chung J-C, Hsu C-J. Humeral shaft fractures treated by dynamic compression plates, Ender nails and interlocking nails. Int Orthop 2005; 29:88–91. https://doi.org/10.1007/s00264-004-0620-8.
20. 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; 36:530–8. https://doi.org/10.1016/j.injury.2004.05.036.