Biological plating for diaphyseal humeral fractures

Mohamed O. Hegazy[a], Gamal A. Hosny[a], Hossam E.A. Elbegawi[a], Hesham A. El-Attar[a], Nagui S.E Elnakkadi[b]

[a]Department of Orthopaedic Surgery, Faculty of Medicine, Benha University, Benha, [b]Department of Orthopedic Surgery, El Nile Health Insurance Hospital, Cairo, Egypt

Correspondence to Nagui S.E. Elnakkadi, MSc, Department of Orthopedic Surgery, El Nile Health Insurance Hospital, Cairo, Egypt
Tel: +20 100 557 3647;
e-mail: drmosolini@ gmail.com

Received: 24 October 2022
Revised: 15 November 2022
Accepted: 19 November 2022
Published: 14 April 2023

The Egyptian Orthopaedic Journal 2023, 57:326–331

Background
Diaphyseal humeral fracture is one of the common injuries in orthopedic surgery. The biological plating technique or minimally invasive plate osteosynthesis (MIPO) is the fixation of the fracture with minimal opening, preserving the soft tissue attachment and blood supply to the bone.
Aim
To evaluate the biological plating technique in the management of diaphyseal humeral fractures by comparing MIPO with open reduction and internal fixation (ORIF) techniques.
Patients and methods
This study is a randomized controlled trial. It was performed on 40 adult patients with a humeral diaphyseal fracture. The patients were randomly divided into two groups: 20 MIPO cases and 20 ORIF controls. We compared the two groups.
Results
MIPO is superior to ORIF, as it has a shorter duration of surgery, shorter incision length, and less blood loss. It may minimize to some extent the duration of fracture healing and the risk of deep infection. MIPO and ORIF have excellent shoulder and elbow functional outcomes.
Conclusion
MIPO offers many advantages over the ORIF, but it has some disadvantages.

Keywords:
biological plating, diaphyseal humeral fractures, minimally invasive plate osteosynthesis, open reduction and internal fixation

Egypt Orthop J 2023, 57:326–331

1110-1148

Introduction

Diaphyseal humeral fracture accounts for 3–5% of all body fractures [1], and with increasing road traffic accidents, it is likely to be more common in the future [2]. Many factors affect the incidence of diaphyseal humeral fractures such as age, sex, and the pathology of the bones. Surgical management has the advantages of early return to function and reducing the complications that may occur from low compliance of the patients. Moreover, Serrano *et al.* [3] stated that surgical management has the advantage to reduce the rate of nonunion that may occur; the reported incidence of nonunion is 33% for nonoperative management, and for surgery, the rates of nonunion range from 0 to 13%.

Biological plating [minimally invasive plate osteosynthesis (MIPO)] preserves the normal biology of bone and soft tissues, as it prevents large surgical approaches, extensive soft tissue stripping, and disruption of periosteal blood supply. Therefore, it helps the physiological process of bone healing carefully and optimally. In addition, it preserves fracture hematoma, allows solid union, and decreases the rate of infection [4]. Biological plating (MIPO) is reported as a satisfactory procedure for the treatment of diaphyseal humeral fractures [5]. A biological plate is inserted after opening an extraperiosteal tunnel alongside the surface of the humerus through proximal and distal windows. Care should be taken to protect the radial nerve, and after verification of the correct positioning of the plate, and the fracture, the proximal and distal screws are inserted.

Aim

The aim was to evaluate the biological plating technique in the management of diaphyseal humeral fractures by comparing MIPO and conventional ORIF techniques.

Patients and methods

This study is a randomized controlled trial. It was performed on 40 adult patients with a humeral diaphyseal fracture. The patients were randomly divided into two groups: the first patient was treated

with the MIPO technique, and the next patient was treated with the ORIF technique correspondingly until we recruited 20 patients treated with the MIPO technique (case group) and 20 patients treated with ORIF technique (control group). The patients were recruited with a convenient sampling selection from June 2018 to January 2022, from the ER of El Nile Health Insurance Hospital (Shobra El-Khema, the great Cairo) and of Benha University Hospital (Benha City). Case sheets and written informed consent were taken from the patients, a Plain radiography was done, and the fracture pattern was classified [6]. The duration of surgery was from skin incision to skin closure. Intraoperative bleeding was estimated by visual estimation [7]. We used in MIPO, narrow locking compression plate (LCP), and in ORIF, broad dynamic compression plate (DCP), narrow DCP, or narrow LCP. The approaches performed in MIPO patients were anterior or anterolateral or transdeltoid lateral approaches, whereas in ORIF, patients underwent anterolateral or posterior approaches. We evaluated bone healing clinically and radiologically on a monthly basis until complete healing was achieved (if complete healing was achieved after 4 months, it was delayed union [8]). Then, functional evaluation was performed by the University of California, Los Angeles (UCLA) shoulder scale [9] and Mayo Elbow Performance Score (MEPS) [10]. Finally, we compared MIPO and ORIF patients regarding the results. The collected data were statistically analyzed using SPSS software (Statistical Package for the Social Sciences, version 28.0.1.1, February 8, 2022).

Inclusion criteria

They were as follows: (a) skeletally mature patients less than 60 years of age, (b) fresh fracture within 2 weeks of injury, (c) bilateral humeral fractures or fractures associated with other injuries of the ipsilateral arm, (d) unsatisfactory closed reduction with conservative treatment, (e) distracted type A diaphyseal humeral fracture, (f) long oblique shaft fracture extending to the proximal humerus with varus angulation, (g) noncompliant patients, (h) obesity or large-breasted patients, and (i) closed diaphyseal humeral fractures.

Exclusion criteria

They were as follows: (a) fracture in skeletally immature patients and patients over 60 years of age (to exclude the influencing factor of osteoporosis, the upper limit of age was defined as 60 years), (b) multiple injured patients, (c) open fractures, (d) concomitant radial nerve palsy (RNP), (e) concomitant vascular injury, (f) pathological fractures, (g) old neglected fractures, (h) revision cases, (i) periprosthetic fractures, (j) concomitant head trauma, (k) diaphyseal humeral fractures with intraarticular extension, and (l) delayed or nonunited fracture requiring open surgery for bone grafting. The study was approved by the institutional ethics committee in the Orthopedic Department of Orthopaedic Surgery, Benha University.

Results

There is an insignificant difference between MIPO patients and ORIF patients regarding the sample and fracture descriptions, as shown in Table 1. The anterior technique was used in 18 MIPO patients, the anterolateral was used in one MIPO patient, and the transdeltoid lateral technique was used in one MIPO patient experiencing proximal diaphyseal humeral fracture with humeral neck fissure. In ORIF patients, the anterolateral technique was used for middle or proximal diaphyseal humeral fractures (11 patients) and the posterior technique was used for middle or distal diaphyseal humeral fractures (nine patients). The plate used in the MIPO technique was narrow LCP

Table 1 Sample and fracture descriptions

Parameters	MIPO group	ORIF group	χ^2 or FE or (*t* test)	*P* value
Age distribution (years) (18–27/28–37/38–47/48–57)	8/4/5/3	7/5/5/3	0.254	0.968
Mean±SD (years)	35.55 ± 13.129	34.5 ± 11.487	0.269	0.789
Age range (years)	18–57	19–57	–	–
Sex distribution (male/female)	12/8	13/7	0.107	0.744
Medical conditions (smoking/DM/none)	6/2/12	7/3/10	0.114/FE/0.404	0.736/1.00/0.525
Humerus fracture classification: A1/A2/A3/B2/B3/C2/C3	3/4/4/6/2/0/1	3/3/5/6/3/0/0	1.842	0.871
Fracture side (dominant/nondominant)	12/8	14/6	0.440	0.507
Humerus shaft fracture location (proximal/middle/distal)	3/12/5	2/13/5	0.377	0.996
Causes of fractures (RTA/FH/Machine)	12/5/3	11/7/2	0.241	0.886
Associated ipsilateral fractures (clavicle/floating elbow/ metacarpal/radius/humeral neck/none)	1/2/2/1/1/13	1/1/2/1/1/14	0.580	0.748
Preoperative period (days) (0–4/5–9/10–14)	10/6/4	11/5/4	0.139	0.93

χ^2, χ^2 test; DM, diabetes mellitus; FE, Fisher's exact test; FH, falling from height; Preoperative period, duration from injury to surgery; MIPO, minimally invasive percutaneous plate osteosynthesis; ORIF, open reduction and internal fixation; RTA, road traffic accident.
P value greater than 0.05, insignificant difference.

Table 2 Operative characteristics and postoperative complications

Parameters	MIPO group	ORIF group	χ^2 or FE or (*t* test)	*P* value
Skin incision length (cm) (10–14/15–19/20–24)	20/0/0	2/16/2	42.048	<0.001*
Mean±SD of intraoperative bleeding (min)	90.8±15.077	293.3±33.293	24.779	<0.001*
Mean±SD of operative duration (min)	108.8±20.214	132.75±20.303	-3.739	<0.001*
Deep infection (*n*.)	Zero	1	FE	1.000
Iatrogenic RNP (*n*.)	2	2	0.000	1.000
Delayed union (*n*.)	3	6	FE	0.451
No postoperative complications (*n*.)	15	11	1.026	0.311

There is one open reduction and internal fixation patient suffers from two postoperative complications (deep infection and delayed union). The two open reduction and internal fixation radial nerve palsy recovered spontaneously, while the two minimally invasive percutaneous plate osteosynthesis radial nerve palsy recovered after another surgical intervention.
χ^2, χ^2 test; FE, Fisher's exact test; MIPO, minimally invasive percutaneous plate osteosynthesis; ORIF, open reduction and internal fixation; RNP, radial nerve palsy.
**P* value less than 0.001, highly significant.

Table 3 Radiological and functional outcomes

Parameters	MIPO group	ORIF group	χ^2 or FE or (*t* test)	*P* value
Union time distribution (weeks) (>8–12/>12–16/>16–20/>20–24/>24–28)	5/12/2/1/0	4/10/4/1/1	2.359	0.670
Malalignment distribution (4° vl/3° vl/5° vr/3 vr/no angulation)	2/2/1/1/14	1/0/1/0/18	5.000	0.287
UCLA score (excellent/good/fair/bad)	7/12/1/0	7/11/2/0	0.383	0.826
Mean UCLA score±SD	33.05±1.959	32.85±2.346	0.293	0.771
ROM of shoulder flexion (angle) (150°/155°/160°/165°/170°)	1/0/5/8/6	1/1/4/9/5	1.648	0.800
Mean±SD of ROM of shoulder flexion (angle) (°)	164.5±5.104	164±5.282	0.304	0.762
Strength of shoulder flexion (good/normal)	1/19	2/18	FE	1.000
MEPS (excellent/good/fair/poor)	15/5/0/0	14/6/0/0	0.125	0.723
Mean (MEPS±SD)	94.25±6.34	93.25±6.544	0.491	0.626
ROM of elbow flexion (angle) (125°/130°/135°/140°)	2/4/10/4	2/5/9/4	0.164	0.882
Mean±SD of ROM of elbow flexion (angle) (°)	134±4.472	133.75±4.552	0.175	0.862

Normal strength (muscle power Grade 5)=movement against gravity and moderate resistance. Good strength (muscle power Grade 4)=movement against gravity and some resistance.
χ^2, χ^2 test; FE, fisher's exact test; MEPS, Mayo Elbow Performance Score; MIPO, minimally invasive percutaneous plate osteosynthesis; ROM, range of motion; UCLA, University of California, Los Angeles; vl, valgus; vr, varus,
P value greater than 0.05, insignificant difference.

with combination holes. LCP was used with six ORIF patients who had comminuted or spiral fractures, broad DCP was used in 10 ORIF patients with stable transverse or short oblique fractures, and narrow DCP was used in four ORIF patients with small humerus that cannot fit the width of the broad DCP (Tables 2 and 3).

Discussion

All the demographic and fracture descriptions of MIPO and ORIF groups are identical, so many factors that might interfere with the validity of our results are excluded.

Operative characteristics

(a) The narrow LCP with combination holes used in the MIPO technique was not completely fitted to the bone surface, so it protects the periosteal blood supply and helps fracture healing. In addition, the conventional holes in this plate have a great value in the reduction of humerus because while tightening the screw, the plate comes in contact with the bone at the sagittal plane. Smith *et al.* [11] stated that the locking holes of the plate allow the application of locked screws that provide the angular stable screw-plate interface. Because of this stable monoblock construct, the pullout strength of locking head screws is significantly higher than that of conventional screws. Because the screws are locked to the plate holes, it is difficult for one screw to pull out or fail unless all adjacent screws fail. (b) In our results, there is significantly shorter skin incision length in MIPO patients than in ORIF patients and (c) significantly lesser intraoperative bleeding in MIPO patients than in ORIF patients, and (d) also it shows the significantly lesser operative duration of MIPO patients than of ORIF patients.

Postoperative complications

There is an insignificant difference between the two groups regarding the postoperative complications. (a) Regarding deep infection, the chance of infection increases when the degree of surgical dissection is increased, as in the ORIF technique. Open surgical techniques lead to extensive intraoperative exposure of bone and soft tissue, which leads to extensive soft tissue stripping and disruption of periosteal blood supply, which in turn increases the chances of infection. Our

insignificant result may be owing to the small number of patients, and also we can prevent this problem by giving the patient suitable antibiotics and by sterilizing the surrounding medium. (b) We had two MIPO and two ORIF patients who experienced iatrogenic RNP. This result agrees with a study by Jiang et al. [12], which reported that iatrogenic RNP occurs in 0–12% of ORIF patients, and with two systematic studies [13,14], where the authors found that the range of iatrogenic RNP that occurs in both MIPO and ORIF patients is from 0 to 13.3%. However, An *et al.* [15] reported that iatrogenic RNP occurs in 31.25% of ORIF patients. In our study, the two MIPO patients with iatrogenic RNP had distal third humeral shaft fractures. The technique used with the first patient is the anterior MIPO approach, and the technique used with the second patient is the anterolateral MIPO approach with radial nerve exploration at the distal window. The risk of radial nerve injury during the anterolateral MIPO approach is real and should not be underestimated, mainly due to its proximity to the plate and the possibility of its interposition during reduction [16]. In a study on distal humeral shaft fracture, the authors stated that the radial nerve is vulnerable in this type of fracture, so they recommend an accessory middle window for direct visualization and isolation of the radial nerve [17]. Regarding the anterior MIPO approach, we must apply two technical tricks. First, the forearm must be positioned in supination. Second, we must avoid screw insertion in the zone at which the radial nerve runs along the spiral groove [18]. (c) Regaridng delayed union fractures, in our study, 15 and 30% of MIPO and ORIF patients, respectively, had delayed union fractures. In a previous study, 20% of MIPO patients had delayed union fracture [19], and in another study, zero of 17 MIPO patients and 1 of 16 ORIF patients had delayed union fracture [15]. However, in other studies, there were no cases of delayed union fracture in both MIPO and ORIF patients [20]. Our ORIF patient with a deep infection received a delayed union fracture. This delayed union may be secondary to the infection or the delayed union, and the infection may be secondary to the extensive iatrogenic devascularization of bone and soft tissues, which can occur in the ORIF technique. (d) Regarding nonunion fractures, in the current study, there was no nonunion in MIPO and ORIF patients. This result agrees with some studies [21–23]. However, in other studies, nonunion occurred in 3.5 and 5% of MIPO and ORIF fractures, respectively [13], and in another study, the rate of nonunion in ORIF fractures was 6–15% [12]. (e) Regaridng malunion in our study, there were no malunion MIPO and ORIF fractures. This result agrees with some other studies [14,15,22,24–27], whereas all of the patients either MIPO or ORIF patients did not experience malunion fractures. (f) Regarding the radiation hazards, we must mention that MIPO patients and their surgeons are exposed to intraoperative radiation, whereas this exposure does not happen with the ORIF technique. However, although the MIPO technique has a radiation hazard, it may reduce perioperative complications as it reduces the operation time, the intraoperative bleeding, and the incision length.

Radiological outcomes

We obtained good results in radiological and functional outcomes in both MIPO and ORIF patients without significant differences between them. (a) Regarding malalignment, after the union of fracture, we found that six MIPO and two ORIF fractures had angulation but they did not exceed 5° (not considered as malunion) and did not affect their functional outcome. In another study, at the end of two years, the authors found 3 and 5° angulation in 10 MIPO fractures (three valgus and seven varus) [28]. In other studies, the authors found on the AP radiographs, 0.8° angulation in 36 MIPO fractures and 0.9° angulation in 32 ORIF fractures, and on the lateral radiographs, 0.6° in the ORIF fractures and 1.5° in the MIPO fractures [25]. (b) The union time of MIPO fractures appears to be lesser than the union time of ORIF fractures but without significant difference. This result agrees with the study by Meinberg et al. [6], whereas there was an insignificant difference between MIPO and ORIF groups regarding the fracture healing time, but in another study [21], the union time in MIPO fractures (14.94 ± 0.99 weeks) was significantly shorter than in ORIF fractures (16.93 ± 1.38 weeks), and in other studies, the mean union time of MIPO fractures was 13.8 weeks [29]. Finally, we conclude that the union time in MIPO fractures was shorter than in ORIF fractures, with a significant difference in some studies and without a significant difference in other studies.

Functional outcomes

Our study found that the MIPO technique gives similar good functional outcomes as the ORIF technique. This result agrees with the results of many previous systematic reviews and meta-analysis studies [13,14,23,30]. (a) In our study, most MIPO and ORIF patients have excellent or good modified UCLA shoulder scores. This result agrees with the previous studies [22,28,29,31,32]. (b) The results of mean UCLA shoulder score of our patients (33.05 ± 1.959 in MIPO patients and 32.85 ± 2.346 in ORIF patients) agree with many other studies [15,22,25,26,29], which showed that the means of UCLA shoulder score in MIPO patients varied from 33.1 to 34.7 and in ORIF patients from 30.9 to 34.38. (c) All our patients (MIPO and ORIF patients) had good active shoulder forward flexion, as they had a range from 150 to 170°. The results of mean range of motion (ROM)

of shoulder active forward flexion in MIPO patients agree with a study by Huri et al. [29], where the mean ROM in MIPO patients was 163.9 ± 5.6°. (d) MIPO and ORIF techniques give good results regarding the strength of shoulder flexion. (e) All our MIPO and ORIF patients (100%) had excellent or good MEPS, which is similar to the study by Hadhoud et al. [22], which reported that all MIPO and ORIF patients had excellent or good MEPS, except 1/15 MIPO patients, who had fair MEPS, and 2/15 ORIF patients, who have fair or bad MEPS, without significant difference between them. In addition, our MIPO result agrees with the study by Hadhoud et al. [28], where the authors found that all MIPO patients had excellent or good MEPS, except 2/31 MIPO patients, who had fair MEPS. In another study [32], 60/70 MIPO patients had excellent or good MEPS. Limitation in elbow flexion can occur secondary to plate malposition, leading to plate impingement against the radial head or coronoid process [33]. (f) The results of mean MEPS in our MIPO (94.25 ± 6.34) and ORIF patients (93.25 ± 6.544) agree with other studies [15,22,25,26,29], where the mean MEPS in MIPO patients varied from 90.3 to 97.6 and in ORIF patients from 87.7 to 98.9. (g) All of the patients (MIPO and ORIF patients) had good active elbow flexion, as they had a range from 125 to 140°. The results of the mean ROM of active elbow flexion in MIPO patients and ORIF patients agree with a previous study [29], where the mean active elbow flexion was 134.6 ± 41.16°. However, our results disagree with Hadhoud et al. [28], where the average elbow ROM in MIPO patients was 116° (range 55–135°). The authors explained the loss of ROM in their cases as secondary to the type of humeral fractures and the delayed union. To allow early ROM recovery with the MIPO technique, the procedure should be performed as soon as possible after the injury. A relatively slower ROM recovery in the elbow than in the shoulder may be due to the splitting of the brachialis muscle during the anterior MIPO technique. If a surgeon tries to avoid splitting the muscle, the RN must be explored and protected (anterolateral MIPO technique) [34].

Conclusion

By comparing the MIPO technique with the ORIF technique in the management of diaphyseal humeral fractures, we found that the MIPO technique gives a similar overall rate of union and functional outcomes to the ORIF technique. It also causes significantly less bleeding, and it requires less operative duration than the ORIF technique. In addition, it may have a lower rate of infection and shorter fracture healing time than the ORIF technique.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1 Sahu RL, Ranjan R, Lal A. Fracture union in closed interlocking nail in humeral shaft fractures. Chin Med J 2015; 128:1428–1432.

2 Verma A, Kushwaha SS, Khan YA, Mohammed F, Shekhar S, Goyal A. Clinical outcome of treatment of diaphyseal fractures of humerus titanium elastic nails in adult age group. J Clin Diagn Res 2017; 11:RC01–RC04.

3 Serrano R, Mir HR, Sagi HC, Horwitz DS, Borade A, Tidwell JE, *et al.* Modern results of functional bracing of humeral shaft fractures: a multicenter retrospective analysis. J Orthop Trauma 2020; 34:206–209.

4 El-Sayed MMH, Hafez K, Gad H, Shams A. The use of biological plating in the treatment of comminuted diaphyseal tibial fracture. Tanta Med J 2014; 42:119–123.

5 Shetty MS, Kumar MA, Sujay KT, Kini AR, Kanthi KG. Minimally invasive plate osteosynthesis for humerus diaphyseal fractures. Indian J Orthop 2011; 45:520–526.

6 Meinberg, EG, Agel JMA, Roberts CS, Karam MD, Kellam JF. Fracture and dislocation classification compendium. J Orthop Trauma 2018; 32(Suppl 1):S1–S10.

7 Algadiem EA, Aleisa AA, Alsubaie HI, Buhlaiqah NR, Algadeeb JN, Alsneini HA. Blood loss estimation using gauze visual analogue. Trauma Mon 2016; 21:e34131.

8 Volpin G, Shtarker H. Management of delayed uni on, non-union and mal-union of long bone fractures. Eur Surg Orthop Traumatol 2014:241–266.

9 Ellman H, Hanker G, Bayer M. Repair of the rotator cuff end-result study of factors influencing reconstruction. J Bone Joint Surg Am 1986; 68:1136–1144.

10 Morrey BF, An KN, Chao EYS. Functional evaluation of the elbow.In: Morrey BF, ed. The elbow and its disorders. 2nd ed. Philadelphia, PA: WB Saunders Co; 1993. 95.

11 Smith WR, Ziran BH, Anglen JO, Stahel PF. Locking plates. tips and tricks. J Bone Joint Surg Am 2007; 89:2298–2307.

12 Jiang R, Luo CF, Zeng BF, Mei GH. Minimally invasive plating for complex humeral shaft fractures. Arch Orthop Trauma Sur 2007; 127:531–535.

13 El-Badrawy MAM. Minimally invasive plate osteosynthesis for humeral shaft fractures: a systematic review [MSc degree]. 2018. Benha, Egypt: Faculty of Medicine, Benha University

14 Fekry MR. Minimally invasive plating osteosynthesis technique versus anterolateral approach for fixation of humeral mid-shaft fractures: systematic review – meta analysis [MSc degree]. 2021. Cairo, Egypt: Faculty of Medicine, Ain Shams University

15 An Z, Zeng B, He X, Chen Q, Hu S. Plating osteosynthesis of mid-distal humeral shaft fractures: minimally invasive versus conventional open reduction technique. Int Orthop 2010; 34:131–135.

16 Livani B, Belangero W, Andrade K, Zuiani G, Pratali R. Is MIPO in humeral shaft fractures really safe? Postoperative ultrasonographic evaluation. Int Orthop 2009; 33:1719–1723.

17 Zogbi DR, Terrivel AM, Mouraria GG, Mongon MLD, Kikuta FK, Zoppi Filho A. Fracture of distal humerus: MIPO technique with visualization of the RN. Acta Ortop Bras 2014; 22:300–303.

18 Apivatthakakul T, Phornphutkul C, Laohapoonrungsee A, Sirirungruangsarn Y. Less invasive plate osteosynthesis in humeral shaft fractures. Oper Orthop Traumatol 2009; 21:602–613.

19 Chincholi S, Ibrahim M. Surgical management of fracture shaft of humerus. Int J Orthod Sci 2016; 2:52–55.

20 Sri SP, Subash Y. Comparison of outcome in MIPO versus ORIF with plate osteosynthesis in the management of fractures of the shaft of humerus. Res J Pharm Technol 2019; 12:3933–3937.

21 Yang J, Liu D, Zhang L, Lu Z, Liu T, Tao 1. C plate treatment of humeral shaft fractures: a new minimally invasive osteosynthesis versus open reduction and internal fixation: a case control study. BMC Surg 2021; 21:349.

22 Hadhoud MM, Darwish AE, Mesriga MMK. Minimally invasive plate osteosynthesis versus open reduction and plate fixation of humeral shaft fractures. Menoufia Med J 2015; 28:154–161

23 Keshav K, Baghel A, Kumar V, Neradi D, Kaustubh K, Mishra P. Is minimally invasive plating osteosynthesis better than conventional open plating for humeral shaft fractures? a systematic review and meta-analysis of comparative studies. Indian J Orthop 2021; 55:284–303.

24 Oh CW, Byun YS, Oh JK, *et al.* Plating of humeral shaft fractures: comparison of standard conventional plating versus minimally invasive plating. Orthop Traumatol Surg Res 2012; 98:54–60.

25 Kim JW, Oh CW, Byun YS, Kim JJ, Park KC. A prospective randomized study of operative treatment for noncomminuted humeral shaft fractures: conventional open plating versus minimal invasive plate osteosynthesis. J Orthop Trauma 2015; 29:189–194.

26 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

27 Wang C, Li J, Li Y, Dai G, Wang M. Is minimally invasive plating osteosynthesis forhumeral shaft fracture advantageous compared with the conventional open technique? J Shoulder Elbow Surg 2015; 24:1781–1788.

28 Hadhoud MM. Results of minimally invasive plate fixation for humerus diaphyseal fractures. Egypt Orthopedic J 2019; 54:61–66.

29 Huri G, Biçer ÖS, Öztürk H, Deveci MA, Tan I. Functional outcomes of minimal invasive percutaneous plate osteosynthesis (MIPPO) in humerus shaft fractures: a clinical study. Acta Orthop Traumatol Turc 2014; 48:406–412.

30 Hu X, Xu S, Lu H, Chen B, Zhou X, He X, *et al.* Minimally invasive plate osteosynthesis vs conventional fixation techniques for surgically treated humeral shaft fractures: a meta-analysis J Orthop Surg Res 2016; 11:59.

31 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; 21:628–633.

32 Saha PK. Comparative analysis of results of minimally invasive percutaneous plate osteosynthesis (MIPPO) and intramedullary nail (IMN) In Humerus Shaft Fracture – a prospective study. Ann Int Med Den Res 2016; 2:24–31.

33 Livani B, Belangero WD. Bridging plate osteosynthesis of humeral shaft fractures. Injury 2004; 35:587–595.

34 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. Orthop Trauma 2010; 24:212–216.