

Minimally Invasive Plate Osteosynthesis for Humeral Shaft Fractures: a Systematic Review

Mohamed Sarhan^a, Mohamed Hegazy^b, Mohamed G^b. Montaser, Adel El-Hammady^b

Abstract:

Background: Fractures of the humeral shaft comprise 1% to 3% of all fractures. Incidence rates increase during the third and seventh decades. **Aim:** systematic review of minimally invasive plate osteosynthesis for humeral shaft fractures in comparison to other methods of operative treatment. **Methods:** conducted according to the methods described in the Cochrane Handbook and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines statement. A search of three electronic medical databases was performed: Google Scholar, PubMed, and the Cochrane Central Register of Controlled Trials to identify relevant trials until August 2017. **Results:** 198 patients had MIPO technique resulting in 7 non-united fractures representing 3.5 %, 102 patients had IMN resulting in 9 non-united fractures representing 8.8% and 80 patients had ORPF resulting in 4 non-united fractures representing 5 %. Iatrogenic radial nerve palsy incidence with the MIPO technique was 3.5%. It was 8.7 %, 4.9% with ORPF and IMN respectively. The incidence of post-operative infection was 2 % in MIPO technique while it was 3.8 % and 6.9 % in ORPF and IMN respectively. No significant difference between MIPO technique and ORPF in the functional outcome of the shoulder. MIPO technique had a better shoulder functional outcome than IMN. **Conclusion:** Humeral shaft fractures could be effectively treated with the MIPO technique due to shorter fracture union time and lower incidence of nonunion, iatrogenic radial nerve palsies, iatrogenic fractures and infections rather than the conventional ORPF technique and IMN, with less operative scars and better cosmesis.

Key words: Humeral shaft fractures; minimally invasive plate; osteosynthesis

^a Orthopedic Surgery
Department, Ahmed Maher
Teaching Hospital, Egypt.

^b Orthopedic Surgery
Department, Faculty of
Medicine Benha University,
Egypt.

Corresponding to:
Dr. Mohamed Sarhan.
Orthopedic Surgery Department,
Ahmed Maher Teaching Hospital,
Egypt.
Email: mhmd.badrawy@gmail.com

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Introduction

The humeral diaphyseal fracture involves the segment of bone between the inferior limit of the insertion of Pectoralis major and the upper limit of the insertion of the muscles at the medial and lateral epicondyles. They represent 3% of all the fractures ⁽¹⁾.

Fractures of the humerus account for approximately 5-7% of all fractures. The relative incidence of proximal, diaphyseal and distal humeral fractures are 40, 20 and 40% respectively. Fractures of the humerus usually result from falls or direct trauma. The management of diaphyseal humeral fractures has also been a lively topic of debate ⁽²⁾.

Radial nerve palsy is presented initially in 10–20% of the fractured patients and typically manifests itself as paresthesia or paralysis of wrist dorsiflexion, finger extension at the metacarpophalangeal joints, thumb extension and abduction and hypoesthesia of the dorsal side of the first inter-digital corner. Radial nerve involvement must be pointed out to the patient and/or family and recorded in the observations. It plays an important role in the treatment choice and follow-up. The fracture is typically located in the middle third or at the junction of the middle and distal third and is highly displaced. This is determined more on the basis of the energy of the trauma than based on the radiographs, because the fracture can be realigned during transport or when the radiographs are performed. The neurological status cannot be determined in an unconscious patient ⁽³⁾.

While closed humeral midshaft fractures can be managed non-operatively with reported union rates as high as 94%, the operative management of these fractures has become popular over the last two decades. Non-operatively treated transverse and short oblique midshaft fractures have been associated with delayed union in reference works ⁽²⁾.

Absolute indications for surgical fixation of humeral shaft fractures include fractures

with neurovascular injury, open fractures, fractures with concomitant ipsilateral forearm fractures (floating elbow), and patients with multiple injuries or polytrauma, progressive radial nerve deficits, pathological fractures and failed non-operative management. Relative indications include obese patients who do not tolerate brace and cast. Following conservative or surgical treatment of humerus shaft fractures, 8–13 % nonunion rate has been reported ⁽⁴⁾.

Non-operative management is the treatment of choice in most humeral shaft fractures, and satisfactory outcomes are typically achieved. When operative treatment is indicated, plating and intramedullary nailing are the two main treatment modalities of choice ⁽⁵⁾.

External fixation combines some of the advantages of conservative management (closed reduction, preserving fracture hematoma) and of internal fixation (stability), with a lower incidence of complications ⁽¹⁾.

Traditionally, plating of humeral shaft fractures has been favored, but nailing has become increasingly popular. This is due to improvement in nail design and the development of devices that allow proximal and distal locking, thereby improving axial and rotational stability of the fracture. Intramedullary devices also have the potential advantage over plating of load sharing biomechanical properties, minimally invasive insertion techniques and preservation of the periosteal blood supply ⁽⁵⁾.

MIPO has recently gained popularity in the treatment of long bone fractures, particularly in the lower extremity. Since the feasibility of MIPO for humeral shaft fractures through cadaveric studies had been certified, numerous clinical practice articles have been published ⁽⁶⁾. No difference in the union rate or in radial nerve safety between the ORIF and MIPO groups ⁽⁷⁾.

MIPO offers advantages in terms of the reduced incidence of iatrogenic radial

nerve palsies and accelerated fracture union suggesting that with reduced soft tissue stripping and enhanced vascular supply preservation, the MIPO technique potentially accelerates the union process if compared with conventional plating techniques^(7,8).

The results of the meta-analysis comparing MIPO of humeral shaft fractures with the standard techniques of open reduction and plating or nailing suggest that clinical outcomes in the MIPO group are superior to the 2 conventional techniques. MIPO plating resulted in a significantly lower overall complication rate, which is most apparent when comparing the incidence of postoperative nerve injury between the 2 groups. Infection and nonunion rates were also lower in the MIPO groups⁽⁹⁾.

Aim of the work

The aim of this study is to introduce a systematic review on minimally invasive plate osteosynthesis for humeral shaft fractures showing its indications, advantages, complications and discussing its results in comparison to other methods of operative treatment.

Materials and Methods

Search Strategy and Eligibility:

The research was conducted according to the methods described in the *Cochrane Handbook*⁽¹⁰⁾. The results are reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines statement⁽¹¹⁾.

We performed a comprehensive search of three electronic medical databases: Google Scholar, PubMed, and the Cochrane Central Register of Controlled Trials to identify relevant trials until August 2017.

The study was conducted in Orthopedic Surgery department in faculty of medicine in Benha University in 2018 after being approved by local ethical committee with number: MS.12.3.2018.

Selection Criteria:

❖ Inclusion Criteria:

- Randomized controlled trials.

- Studies published in English language only.
- Skeletally mature population with humeral shaft fractures.
- Trials comparing surgical procedures in treatment of humeral shaft fractures "Minimally invasive plate osteosynthesis" versus either "intramedullary nailing" or "open reduction and internal fixation with plate and screws".

❖ Exclusion criteria:

- Non-randomized controlled trials.
- Studies done on animals and cadavers.
- Trials that enrolled children with humeral shaft fractures.
- Trials that enrolled adults with pathological, periprosthetic or Gustilo–Anderson grade III open humeral shaft fractures.
- Studies published in languages other than English.
- Patients with non-united humeral shaft fractures following conservative or operative treatment.
- Trials comparing surgical procedures other than MIPO or comparing MIPO versus conservative treatment.

Study selection and data extraction:

Four independent reviewers first screened the study titles and abstracts for eligibility. The full text of the trials potentially meeting the eligibility criteria were reviewed to decide the final inclusion. Then, investigators independently extracted information, including the lead author, publication year, randomization methods, participant number, patient characteristics (number, age and gender), follow-up time, loss to follow up, all outcome measures (functional outcome of the shoulder and elbow) and complications. Discrepancies were resolved by consensus after discussion between the four reviewers.

Literature search:

Using the search strategy, 320 articles were addressed. Screening the abstracts and titles resulted in 64 articles for reading. Of these, 6 met our inclusion criteria for this systemic review.

Results

1. Studies description:

Table (1): Studies description.

Reference	Year	Study design	Procedures compared	Country	Study duration	study center	Follow up Time (months)
(12)	2013	Randomized controlled trial	MIPOVsIMN	China	34 months	Single center	14.5
(13)	2014	Randomized controlled trial	MIPOVsIMN	Brazil	54 months	Single center	12
(14)	2015	Randomized controlled trial	MIPOVsORPF	Korea	21 months	Five centers	15
(15)	2015	Randomized controlled trial	MIPOVsORPF	Iran	37 months	Single center	N/A
(16)	2015	Randomized controlled trial	MIPOVsORPF	Egypt	25 months	Single center	6-10
(17)	2016	Randomized controlled trial	MIPOVsIMN	India	27 months	Single center	12

2. Population Description:

- The six papers included in this study contained a total of 380 patients who completed follow up.
- Out of these 380 patients; 198 patients were treated by minimally invasive plate osteosynthesis, 102 patients were treated by intramedullary nailing and 80 patients were treated by open reduction and plate fixation representing 52.1 %, 26.8 % and 21.1% respectively.
- Out of the 380 patients; 196, 128 and 56 patients were classified as type A, B

- All studies are randomized controlled trials.
- Three studies comparing MIPO and IMN, other three comparing MIPO and ORPF
- The studies were done in Brazil, China, Korea, Iran, India and Egypt. A study in each country.

and C humeral shaft fractures respectively according to AO/OTA classification. Thus, type A humeral shaft fractures represent 51.6 % of all included patients who completed follow up. While type B and type C fractures represent 33.7 % and 14.7 % respectively.

Gender of patients:

Out of the 380 patients; 276 patients were male patients representing 72.6% and 104 patients were females representing 27.4%.

Table (2): Population description.

Reference	Number of patients		Mean (Years)	Gender	AO classification (A/B/C,no.)			Dominate side involved		
	Total	Completed follow up			A	B	C			
(12)	56	47	MIPO	24	38.8	15:9	9	9	6	N/A
			IMN	23	37.6	16:7	8	12	3	N/A
(13)	40	40	MIPO	21	44.8	12:9	12	7	2	16
			IMN	19	38.4	14:5	9	4	6	8
(14)	72	68	MIPO	36	40.6	19:17	19	17	0	N/A
			ORPF	32	44.4	18:14	21	11	0	N/A
(15)	68	65	MIPO	32	33.4	24:8	10	9	13	N/A
			ORPF	33	34.6	24:9	12	10	11	N/A
(16)	30	30	MIPO	15	39.7	9:6	9	3	3	9
			ORPF	15	36.1	11:4	10	4	1	7
(17)	145	130	MIPO	70	45.1	61:9	38	25	7	32
			IMN	60	47.5	53:7	39	17	4	28

3. Radiological outcome:

- Regarding to this table; 198 patients were operated using MIPO technique resulting in a total of 7 non-united fractures representing 3.5 %, 102 patients were operated by intramedullary nailing resulting in a total of 9 non-united fractures representing 8.8% and 80 patients were operated by open reduction and internal

fixation using plate and screws resulting in a total of 4 non-united fractures representing 5 %.

- According to the results illustrating mean time needed to union of the fractures; 15.6, 15.5 and 17.9 weeks were needed to union of fractures operated by MIPO, IMN and open reduction and plate fixation respectively.

Table (3): Radiological outcome.

Reference	Number of patients	United fractures (no.)	Malunited fractures (no.)	Nonunited fractures (no.)	Mean time of union (Weeks)
(12)	MIPO	24	23	1	17.1
	IMN	23	21	1	16.8
(13)	MIPO	21	21	0	N/A
	IMN	19	18	0	N/A
(14)	MIPO	36	36	0	14.6
	ORPF	32	32	0	15.8
(15)	MIPO	32	31	0	17.1
	ORPF	33	30	3	21.4
(16)	MIPO	15	15	0	15.3
	ORPF	15	14	0	16.5
(17)	MIPO	70	65	5	13.75
	IMN	60	54	6	14.15

4. Functional outcome of the shoulder

• University of California, Los Angeles (UCLA) Shoulder Score

The UCLA Shoulder Score was first published in 1981 to assess shoulder function in patients undergoing total shoulder arthroplasty^(18,19). It assesses five domains: pain, function, forward flexion, forward flexion strength, and overall satisfaction. A potential score of 35 is possible, with higher scores indicating a better outcome⁽²⁰⁾.

The functional outcome of the shoulder was graded according to the UCLA system as excellent (34 to 35 points), good (28 to 33 points), fair (21 to 27 points), or poor (0 to 20 points)⁽²²⁾.

The mean UCLA scores for the MIPO group was 31.4 points and that for the IMN group was 31.2 points⁽¹³⁾.

The mean UCLA scores for the MIPO group was 33.1 points and that for the ORPF group was 33.9 points⁽¹⁴⁾.

The mean UCLA scores for the MIPO group was 33.1 points and that for the ORPF group was 32.8 points⁽¹⁵⁾.

The mean UCLA scores for the MIPO group was 32.2 points and that for ORPF group was 30.9 points. In the MIPO group five cases showed excellent results, nine cases showed good results, one patient had a fair result, and no patient had a poor result. In the ORPF group, there were five excellent cases, eight good cases, one fair case, and one poor case⁽¹⁶⁾.

Sixty-five out of 70 patients (92.85 %) of the MIPO group had good to excellent results according to the UCLA score and five patients (7.15 %) had fair to poor results, while 39 out of 60 patients(65 %) of the IMN group had good to excellent results and 21 patients(35 %) had fair to poor results⁽¹⁷⁾.

The American Shoulder and Elbow Surgeons (ASES) scoring system not the UCLA score was used in one of the studies

to assess the shoulder's functional outcome postoperatively. A potential total score of this scoring system is 100 points, with highest scores indicating highest function.

In the MIPO group, the mean ASES scores was 98.2 points. In the IMN group, the mean ASES scores was 93.5 points⁽¹²⁾.

Table (4): Evaluation of UCLA score⁽²¹⁾.

Evaluation system	Points
	Total Pain 50
• Present all the time and unbearable, strong medication frequently	1
• Present all the time but bearable, strong medication occasionally	2
• None or little at rest, present during light activities, salicylates frequently	4
• Present during heavy or activities only, salicylates occasionally	6
• Occasional or slight	8
• None	10
	Function 10
• Unable to use limb	1
• Only light activities possible	2
• Able to do house- work or most activities of daily living	4
• Most housework, shopping and driving possible, able to do hair	6
• Slight restriction only, able to work above shoulder level	8
• Normal activities	10
	Active Forward flexion 5
• 150 degrees or more	5
• 120-150 degrees	4
• 90-120 degrees	3
• 45-90 degrees	2
• 30-45 degrees	1
• Less than 30 degrees	0
	Strength of Forward flexion 5
• Grade 5 (normal)	5
• Grade 4 (good)	4
• Grade 3 (fair)	3
• Grade 2 (poor)	2
• Grade 1 (muscle contraction)	1
• Grade 0 (nothing)	0
	Satisfaction of the patient 5
• Satisfied and better	5
• Not satisfied and worse	0

5. Functional outcome of the elbow

• Mayo elbow performance index (MEPI):

Morrey and Adams developed the Mayo elbow performance index in 1992 to evaluate outcomes after total elbow arthroplasty. It consists of physician assessment of pain, arc of elbow motion, and stability, and a patient rating of daily

function. Pain is weighted highest of the four variables (45%). Pain also has the highest influence (66%) on variability of the score. The scale ranges from 0 to 100, with a higher score indicating a better outcome. The raw score is assigned a categorical rank of poor (0 to 59), fair (60 to 74), good (75 to 89), and excellent (90 to 100)⁽²³⁾. The score is more likely to

correlate to other elbow measures if raw scores are reported rather than categorical rank. It has been validated for general

elbow disorders. Its construct validity is good for patient-rated variables and excellent for physician-rated variables⁽²⁴⁾.

Table (5): Mayo elbow performance index score.⁽²⁵⁾

Function	Points	Definition	Points
Pain	45	None	45
		Mild	30
		Moderate	15
		Severe	0
Motion	20	Arc > 100 degrees	20
		Arc 50-100 degrees	15
		Arc <50 degrees	5
Stability	10	Stable	10
		Moderate instability	5
		Gross instability	0
Function	25	Comb hair	5
		Feed	5
		Hygiene	5
		Wear shirt	5
		Wear shoes	5

The mean MEPI scores for the MIPO group was 97.6 points and that for the IMN group was 94.1 points⁽¹²⁾.

The Broberg and Morrey elbow scale was used in one of the studies to assess the elbow's functional outcome postoperatively. This scale ranges from 0 to 100, with a higher score indicating a better outcome. In the MIPO group, the mean Broberg and Morrey scores was 94.8 points. In the IMN group, the mean Broberg and Morrey scores was 94.1 points⁽¹³⁾.

The mean MEPI scores for the MIPO group was 96.4 points and that for the ORPF group was 98.9 points⁽¹⁴⁾.

The mean MEPI scores for the MIPO group was (96.6 points) and that for the ORPF group was 96.9 points⁽¹⁵⁾.

The mean MEPI scores for the MIPO group was 90.3 points and that for the ORPF group was 87.7 points⁽¹⁶⁾.

Sixty out of 70 patients (85.7 %) of the MIPO group had good to excellent results according to the MEPI and ten patients (14.3 %) had fair to poor results, while 54 out of 60 patients(90 %) of the IMN

group had good to excellent results and 6 patients(10 %) had fair to poor results⁽¹⁷⁾.

6. Complications:

- Regarding to iatrogenic radial nerve injury; 7 patients out of 198 in the MIPO had postoperative radial nerve injury (3.5 %), 5 patients out of 102 in the IMN group suffered from postoperative radial nerve injury (4.9 %) and 7 patients out of 80 in the ORPF had postoperative radial nerve injury (8.7 %).
- Regarding infection, 4, 7, 3 patients out of 198, 102, 80 patients in the MIPO, IMN and ORPF groups had postoperative infection representing 2 %, 6.9 % and 3.8 % respectively.
- Regarding to this table; 198 patients were operated using MIPO technique resulting in a total of 7 non-united fractures representing 3.5 %, 102 patients were operated by intramedullary nailing resulting in a total of 9 non-united fractures representing 8.8% and 80 patients were operated by open reduction and internal fixation using plate and screws resulting in a total of 4 non-united fractures representing 5 %.

- Three patients out of 60 patients operated by IMN had iatrogenic fractures representing (5 %), while no patients

suffered from that complication in the MIPO group.

Table (6): Complications.

Reference	(12)	(13)	(14)	(15)	(16)	(17)							
	MIPO	IMN	MIPO	IMN	MIPO	ORPF	MIPO	ORPF	MIPO	ORPF	MIPO	IMN	
No. of patients in the study	24	23	21	19	36	32	32	33	15	15	70	60	
Iatrogenic radial nerve injury	1	3	0	0	0	1	1	4	1	2	4	2	
Infection	0	0	1	2	0	0	0	2	0	1	3	5	
Iatrogenic fracture	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	3	
Nonunion	1	2	0	1	0	0	1	3	0	1	5	6	

Discussion

Humeral minimally invasive plate osteosynthesis (MIPO) is a promising surgical technique that uses a minimally invasive approach, allowing plate fixation without disturbing the fracture site. It is proposed as an alternative to either IMN or ORIF, providing fracture stabilization while theoretically minimizing the risk of the major complications associated sometimes with surgical management of humeral shaft fractures, including nonunion, iatrogenic radial nerve palsy, infection and shoulder dysfunction⁽²⁶⁾.

The aim of this study we compared the MIPO technique in the treatment of humeral shaft fractures with the open reduction and internal fixation with plate and screws, and intramedullary nailing in the terms of radiological outcome, functional outcome of the shoulder and elbow, and common complications as infection, iatrogenic radial nerve injury, and iatrogenic fracture.

The usage of MIPO technique in the treatment of humeral shaft fractures resulted in 191 united fractures representing 96.5 % of all fractures treated by MIPO, while union occurred in 91.2 % and 95 % of the fractures treated by IMN and ORIF respectively. According to the

results illustrating mean time needed to union of the fractures; 15.6 weeks needed to union fractures operated by MIPO technique, 15.5 and 17.9 weeks needed to union fractures operated by IMN and open reduction and plate fixation respectively. These results showed that MIPO technique is superior to IMN regarding the rate of fracture union while there is no significant difference between MIPO and ORIF in the rate of the fracture union. Also, they showed that there is no significant difference between MIPO and IMN regarding the time needed to fracture union while the two techniques are superior to open reduction and internal fixation by plate and screws in this aspect. (12-17)

The functional outcome of the shoulder was evaluated by University of California, Los Angeles (UCLA) score in all studies except one that evaluated the functional outcome by the American shoulder and elbow surgeons (ASES) score and both scores are reliable methods for evaluation. (12-17)

Comparing the MIPO technique to ORPF; the mean UCLA scores for the MIPO group was 33.1 points and that for the ORPF group was 32.8 points⁽¹⁵⁾, the mean UCLA scores for the MIPO group was 32.2 points and that for ORPF group was 30.9 points⁽¹⁶⁾, and the mean UCLA scores for the MIPO group was 33.1 points and

that for the ORPF group was 33.9 points⁽¹⁴⁾. These results proved that there is no significant difference between MIPO technique and ORPF if they are compared at the functional outcome of the shoulder.

Comparing MIPO technique to IMN; the mean UCLA scores for the MIPO group was 31.4 points and that for the IMN group was 31.2 points⁽¹³⁾. 92.85 % of patients of the MIPO group had good to excellent results according to the UCLA score, while 65 % of the IMN group had good to excellent results⁽¹⁷⁾. The mean ASES scores were 98.2 and 93.5 points in the MIPO and IMN groups respectively⁽¹²⁾. These results showed that the MIPO technique had the privilege of having a better shoulder functional outcomes if compared to the IMN.

The functional outcome of the elbow joint is evaluated by the Mayo elbow performance index (MEPI) in all the papers included in this study except one paper which used the Broberg and Morrey elbow scale for evaluation after surgical intervention by MIPO technique, IMN and open reduction and internal fixation with plate and screws⁽¹²⁻¹⁷⁾.

The mean MEPI scores were 96.4 and 98.9 points, 96.6 and 96.9 points, and 90.3 and 87.7 points for the MIPO and ORPF groups respectively⁽¹⁴⁻¹⁶⁾. The mean MEPI scores were 97.6 and 94.1 points for the MIPO and IMN groups respectively⁽¹²⁾. 85.7 % of the MIPO group had good to excellent results according to the MEPI, while 90 % of the IMN group had good to excellent results⁽¹⁷⁾. According to the used the Broberg and Morrey elbow scale, the mean scores were 94.8 and 94.1 points in the MIPO and IMN groups respectively⁽¹³⁾. The results have shown that MIPO technique has no significant difference on the functional outcome of the elbow if it is compared to open reduction and internal fixation technique or intramedullary nailing in the treatment of humeral shaft fractures.

The higher incidence of fracture union with MIPO technique, faster union time

and better functional outcomes of the shoulder if compared to open reduction and internal fixation with plate and screws or intramedullary nailing helped the patient in a faster return to his work and normal daily life postoperatively. Also, this helped to decrease the incidence of reoperations saving more cost and another complications⁽¹²⁻¹⁷⁾.

Discussing the complications resulting from the surgical treatment of the humeral shaft fractures; these complications can be summed up into iatrogenic radial nerve palsy, infection, iatrogenic fractures and nonunion. To admit the privilege of any surgical technique on the other, the incidence of these complications must be considered and compared.

In one of the included studies, three patients out of 60 patients operated by IMN had iatrogenic fractures (5 %), while none had that complication in the MIPO group. MIPO technique decreased the incidence of iatrogenic intraoperative fractures giving MIPO technique an advantage on intramedullary nailing⁽¹⁷⁾.

In this study, 3.5 % of the patients operated using MIPO technique had non united fractures, while 8.8% and 5 % of the patients operated by IMN and ORIF using plate and screws had non united fractures respectively. By analyzing these results, it's obvious that MIPO technique has an advantage on IMN and ORPF in decreasing the incidence of nonunion especially if it's compared to IMN⁽¹²⁻¹⁷⁾.

Iatrogenic radial nerve palsy is noticed to have the lowest incidence with the MIPO technique. On the other hand, its incidence with ORPF reached about triple that happened with the MIPO technique as it reached 8.7 % with ORPF, while it was just 3.5% with MIPO technique, giving another clue about the advantage of MIPO technique on open reduction and plate fixation with plate and screws. Also, the incidence was about 4.9% in patients treated with IMN, giving MIPO a little advantage on IMN in this aspect. Regarding postoperative infection, we

found that incidence is much higher in ORPF and IMN if compared to MIPO technique. The incidence was 2 % in MIPO technique while it was 3.8 % and 6.9 % in ORPF and IMN respectively. This gave us another noticeable advantage of the MIPO technique in the treatment of humeral shaft fractures on the other two techniques. ⁽¹²⁻¹⁷⁾

Conclusion:

This work presents the MIPO technique applied in the treatment of recent humeral shaft fractures. The results obtained in this study have shown that the MIPO technique is safe, convenient and effective, since there was minimal soft tissue injury, nor major complications.

MIPO technique has shown no significant difference in the functional outcomes of the shoulder and elbow when it was compared to ORIF technique, but it has shown it is superior to the IMN especially in the functional outcomes of the shoulder joint.

From this study, we concluded that humeral shaft fractures could be effectively treated with the MIPO technique due to the advantages of shorter fracture union time and lower incidence of fracture nonunion, iatrogenic radial nerve palsies, iatrogenic fractures and infections rather than the conventional open reduction and internal fixation technique and intramedullary nailing.

Recommendations:

Taken together these results suggesting that recent fracture shaft of humerus could be effectively treated with the MIPO technique due to significant advantages and minor complications if compared to ORIF and IMN, with the less operative scars and better cosmesis. This contributes to the high patient satisfaction with this novel treatment.

List of Abbreviations:

MIPO: Minimally Invasive Plate Osteosynthesis

ORPF: Open Reduction and Plate Fixation

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses

IMN: Intramedullary Nailing

ORIF: Open Reduction and Internal Fixation

UCLA: University of California, Los Angeles Shoulder Score

ASES: American Shoulder and Elbow Surgeons

MEPI: Mayo elbow performance index score

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