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RESEARCH ARTICLE

Is MIPO as Safe and Effective as Conventional ORIF for Simple Fractures of Humerus Diaphysis?

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ABSTRACT

Objective: This study aimed to compare radiological, functional, and clinical results of minimal invasive plate osteosynthesis (MIPO) and conventional open reduction and internal fixation (ORIF) techniques in simple fractures of humerus diaphysis (AO/OTA 12A2b and AO/OTA 12A3b).

Materials and Methods: We retrospectively evaluated 51 patients who were operated in our clinic for simple fractures of humerus diaphysis (AO/OTA 12A2b and AO/OTA 12A3b) between 2016 and 2021. Group A included patients treated by MIPO while Group B consisted of patients treated by conventional ORIF. Radiological outcomes were determined by fracture union, varus, and valgus malalignment. We evaluated clinical parameters by calculating deep tissue infection, injury to the radial nerve, and implant failure rates. We made the functional assessment by calculating QuickDASH, UCLASS, MEPI, and ROM.

Results: We found no statistically significant differences between the two groups regarding radiological outcomes except that varus angulation was determined to be higher in the MIPO group ($p<0.001$). We followed the obligation of the Helsinki Declaration in our research. The clinical and functional evaluations did not reveal any statistically significant difference between the two surgical techniques.

Conclusion: MIPO technique for simple fractures of humerus diaphysis demonstrated similar radiological, functional, and clinical outcomes to conventional ORIF technique. Thus, we believe that MIPO technique may be as safe and effective as conventional ORIF technique.

Keywords: Bone plates, fracture fixation, fracture healing, humeral fractures*/surgery, humerus, internal, internal/instrumentation*, minimally invasive surgical procedures, treatment outcome

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INTRODUCTION

Various techniques have been defined regarding surgical treatment of humeral shaft fractures. At present, conventional plate osteosynthesis is one of the most common treatment methods. The application of conventional dynamic compression plates with lateral approach is proven to be safe and effective. Open reduction and internal fixation (ORIF) provide an anatomical reduction and a rigid fixation by exposure of the fracture site.[1] However, application of the ORIF technique compromises blood supply, tissue integrity, and biological healing and involves the risk of radial nerve injury during exploration.[2–5]

Minimal invasive plate osteosynthesis (MIPO) technique on the other hand provides bridge plating of the fracture site avoiding excessive exposure.[6] It is a necessarily new technique with limited preference among surgeons.[7] MIPO evolved to overcome specific complications related to ORIF of certain humeral fractures. This technique targets achieving a proper alignment by bridge plating the fracture site and it preserves tissue biology better than open osteosynthesis techniques,[6,8] however, achieving rigid stabilization and proper alignment are more challenging with this technique.[7] MIPO has been long preferred for lower-limb fractures with successful outcomes. On the contrary, surgeons have refrained from applying MIPO technique for upper-limb fractures. Complications due to the absence of radial nerve exploration and challenges upon achieving proper alignment have been the main concerns. Consequently, recent

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data provide insufficient information about the outcome MIPO techniques.[9] In addition to this, there is inadequate research comparing MIPO and conventional ORIF.[10]

Regarding our hypothesis, it was assumed that MIPO is as safe and effective as conventional ORIF. Objective of our study was to retrospectively compare functional and radiologic results of patients who had been treated by MIPO and conventional ORIF techniques in our institute.

MATERIALS and METHODS

Permission from the local clinical research ethics committee was obtained (ethics committee number 2018/12/80 and topic number KAEK/2018.12.80). Patient-related information was gathered anonymously from hospital database.

In this retrospective study, patients who underwent surgical treatment for humeral shaft fractures in our orthopedic surgery department between January 2016 and December 2021 were selected from the hospital database. In this study, we defined humeral shaft fractures as fractures between the levels of surgical neck and olecranon fossa of the humerus.[11] Humeral shaft fractures were selected from the hospital database. Among these patients, the ones who received surgical intervention were identified. They were then classified using the AO/OTA classification system. Patients with fractures other than AO/OTA 12A2b and AO/OTA 12A3b were excluded. Operated patients with fractures matching with AO/OTA 12A2b and AO/OTA 12A3b were selected and then classified according to the surgical technique applied.[12,13] Group A (n=21) consisted of the patients who were operated by MIPO technique whereas Group B (n=30) consisted of the patients who were treated by conventional ORIF technique. Patients without proper follow-up, patients with <1-year follow-up, pathological fractures, patients younger than 18 and older than 60 years of age, patients with additional ipsilateral upper extremity fractures, open fractures, patients with pre-operative radial nerve injury, patients in which surgical intervention delayed more than 1 week, and patients who were treated with any other technique other than lateral approach for ORIF or anterior mini-invasive approach for MIPO were excluded.

Data Collection and Evaluation Criteria

Patients' data were acquired from the hospital database and the following parameters were evaluated: Time until surgery, time until union, injury mechanism, age, gender, fracture type, surgical technique, follow-up period, and affected side.

A simpler version of Disabilities of the Arm, Shoulder, and Hand questionnaire (QuickDASH), University of California at Los Angeles Shoulder Score (UCLASS), Mayo Elbow Performance Index (MEPI), and joint range of motion (ROM) calculations were used to determine the functions of the operated upper extremity.[14,15]

Fracture union was determined by examination of anteroposterior and lateral radiographic views. Identification of callus formation on three cortices and absence of pain on the fracture site were defined as successful union.[16] whereas it was defined as a non-union if fracture healing was not achieved in 6-month follow-up. Radiographic calculations were also made to determine varus and valgus malalignment. Any post-operative complications such as deep tissue infection, injury to the radial nerve, failure of the implant, varus-valgus malalignment, and non-union of bone were noted.

Surgical Procedure

Going through the operational notes, it was identified that surgeries were performed under general anesthesia, and pre-operative application of 75 mg/kg cefazolin was the routine antibiotic prophylaxis in every operation. The operations were performed by orthopedic surgeons working in our orthopedic surgery department with at least 5 years of experience. These surgeons had varied residency training background and the surgical technique they preferred differed according to their experience. Osteosynthesis technique with a lateral approach using a single locking compression plate (LCP) requires an incision between lateral condyle distally and anterior edge of the deltoid muscle proximally.[17] Iatrogenic radial nerve injury is the main concern and it should be explored.[18] Open reduction is achieved and absolute stabilization is made by dynamic compression or with a lag screw insertion.[19] On the other hand, osteosynthesis using MIPO technique requires two mini-incisions proximally and distally to achieve closed reduction and a LCP introduction.[20] The plate can be used to assist fracture reduction in this phase.[21] Forearm is held in the supine position and lateral retractors are avoided to protect the vulnerable radial nerve. It is suggested to explore the radial nerve through a mini-incision for patients with pre-operative radial nerve injuries.[22] In this technique, restoring the proper alignment is the main concern. In this study, the same implant was used in both techniques for all patients (4.5 mm LCP, TST, Istanbul, Türkiye) (Figs. 1, 2).

Statistical Analysis

The IBM SPSS Statistics 26 (IBM, Chicago, IL, USA) program was used for statistical analyses. Evaluation of demographic and clinic properties of patients treated with ORIF and MIPO was done by descriptive statistical analyses such as number, percentage, and median. Median values of age, time to sur-

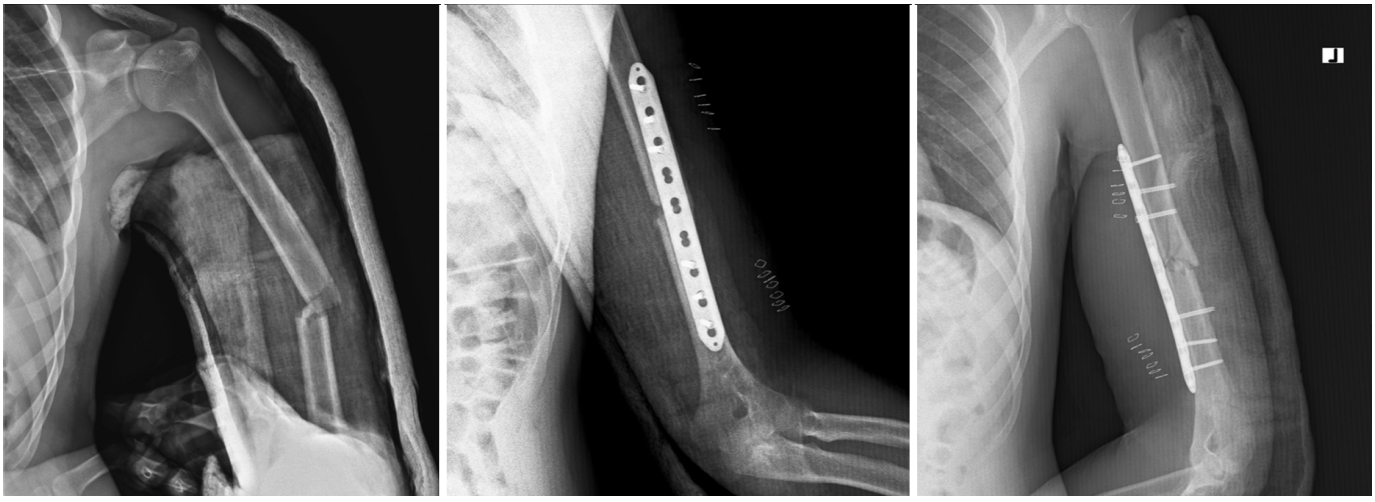

Figure 1. Pre-operative and post-operative radiographic views of minimal invasive plate osteosynthesis

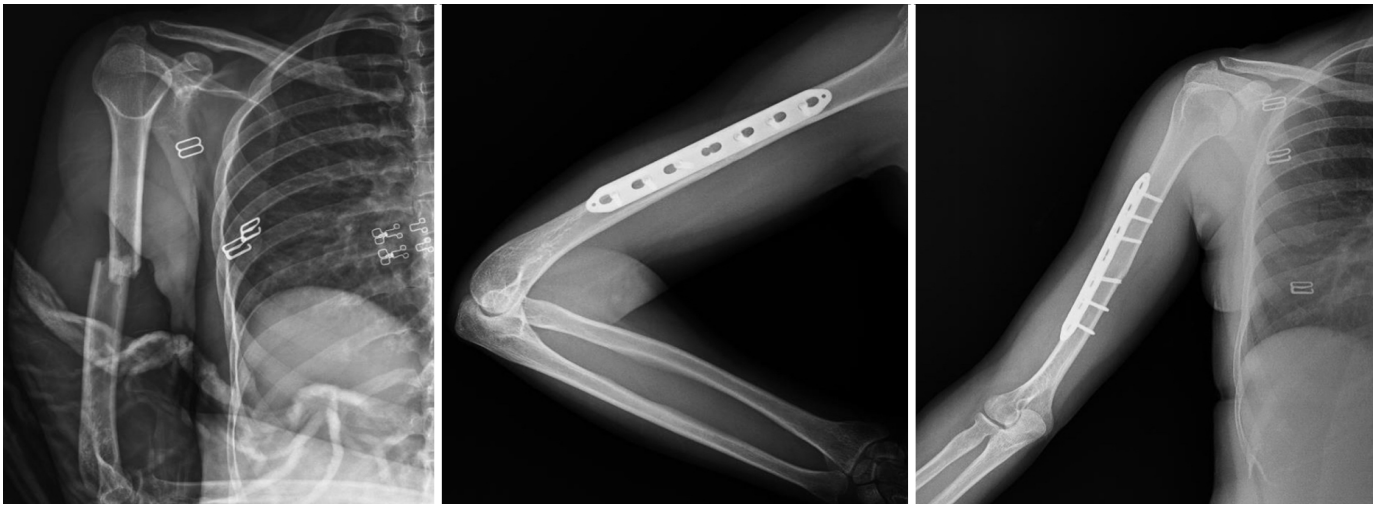

Figure 2. Pre-operative and post-operative radiographic views of conventional open reduction and internal fixation

gery, mean follow-up period, and time to fracture union and median values of varus and valgus angulation, elbow range of motion, UCLA shoulder score, MEPI score, QuickDASH score, and anterior shoulder flexion angle were analyzed using Mann–Whitney U-test. Parameters of gender, injury mechanism, fracture type, affected side, and post-operative radial nerve injury were analyzed utilizing Chi-square test. Effects of parameters such as age, gender, varus angulation degrees, valgus angulation degree, fracture type, affected side and chosen surgical technique on elbow performance, and radial nerve injury risk were evaluated using multivariate binary logistic regression analysis. A $p<0.05$ was considered as statistically significant in all analyses.

RESULTS

Of the evaluated 51 patients, 27 were male and 24 were female. The mean age of the included patients was 41.3 (18–59). Regarding the fracture type according to the AO/OTA classification system, 49% of the patients had AO/OTA 12A2b (n=25) type of fractures whereas 51% of the patients had AO/OTA 12A3b (n=26) type of fractures. Fractures were identified on the left humerus in 28 (54.9%) patients and on the right humerus in 23 (45.1%) patients. Injury mechanism was falling in 60.7% of the patients (n=31), motor vehicle accidents in 27.4% of the patients (n=14), and sports-related trauma in 11.7% of the patients (n=6). Mean follow-up period of the patients included in the study was 39.3 months (12–74). Mean

Table 1. Comparison of demographic and clinic evaluations between ORIF versus MIPO groups

	ORIF				MIPO				
	n	Med.	%	25–75%	n	Med.	%	25–75%	p
Age		45.50		26.00–55.00		45.00		28.00–54.00	0.969[a]
Gender									
Female	14		46.7		10		47.6		0.947[b]
Male	16		53.3		11		52.4		
Injury mechanism									
FALL	19		63.3		12		57.1		0.866[b]
MVA	8		26.7		6		28.6		
SRI	3		10.0		3		14.3		
Fracture type									
AO/OTA 12A2b	14		46.7		11		52.4		0.688[b]
AO/OTA 12A3b	16		53.3		10		47.6		
Affected side									
Left	16		53.3		12		57.1		0.788[b]
Right	14		46.7		9		42.9		
Post-operative radial nerve injury									
No	27		90.0		19		90.5		0.950[b]
Yes	3		10.0		2		9.5		
Time to surgery(days)		2.00		1.00–3.00		2.00		2.00–3.00	0.063[a]
Mean follow-up period (months)		39.00		25.00–53.00		43.00		24.00–52.00	0.759[a]
Time to fracture union (months)		3.00		2.00–5.00		4.00		2.00–5.00	0.475[a]
Varus angulation (degrees)		0.00		0.00–0.00		2.00		0.00–5.00	**<0.001[a]**
Valgus angulation (degrees)		2.00		1.00–3.00		0.00		0.00–3.00	0.129[a]

[a]: Chi-square test; [b]: Mann–Whitney U-test. Med.: Median; ORIF: Open reduction internal fixation; MIPO: Minimally invasive plate osteosynthesis; MVA: Motor vehicle accident; SRI: Sports related injury; AO/OTA: Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association

time to surgery after initial injury was 2,1 days (1–6). Median age values of ORIF group were 45.5 whereas median age values of MIPO group were 45. Median values of age were statistically similar between the two groups (p=0.969). Parameters of gender (p=0.947), injury mechanism (p=0.866), fracture type (p=0.688), affected side (p=0.788), and post-operative radial nerve injury (p=0.950) showed no statistical difference. In addition, parameters of time to surgery (p=0.063), mean follow-up period (p=0.759), time to fracture union (p=0.475), and median values of valgus angulation (p=0.129) did not show any statistical difference. Furthermore, varus angulation median values were statistically higher in the MIPO group compared to the ORIF group (p<0.001) (Table 1).

In addition, during the last follow-up examination, the mean elbow ROM was 132.5° (125–140°) in Group A and 131.9° (125–140°) in Group B. Mean active anterior shoulder flexion angle of the operated upper extremity was 164,3° (160–175°) in Group A and 166.4° (160–170°) in Group B. On the other hand, the mean MEPI was 98 (94–102) in Group A and 97.85 (92–102) in Group B. The mean UCLASS score values were 30.5 for Group A and 30.3 for Group B. In addition, QuickDASH scores were calculated as 22.8 for Group A and 23 for Group B. According to Mann–Whitney U-test; median values of the parameters of elbow range of motion (p=0.655), UCLA shoulder score (p=0.753), MEPI elbow score (p=0.953), and QuickDASH score (p=0.387) did not demonstrate statistical difference. In addition to this, median values of anterior shoulder flexion angle were identified as statistically different (p=0.016) between the two groups, despite the fact that median values were equal (Table 2).

Functional evaluations were made according to cut-off values of specific parameters and only elbow range of motion was found to be low among some of the cases. 4 patients treated with ORIF (13.3%) and 2 patients treated with MIPO

Table 2. Comparison of anterior shoulder flexion angle, elbow range of motion, UCLA, MEPI, and QuickDASH scores between ORIF and MIPO groups

	ORIF		MIPO		
	Med.	25–75%	Med.	25-75%	p
Anterior shoulder flexion angle	165.00	165.00–165.00	165.00	165.00–170.00	**0.016**
Elbow range of motion	132.50	130.00–135.00	130.00	130.00–135.00	0.655
UCLA shoulder score	31.00	29.00–32.00	31.00	29.00–32.00	0.753
MEPI elbow score	98.00	96.00–100.00	98.00	96.00–100.00	0.953
QuickDASH score	22.70	22.50–23.40	22.90	22.50–23.40	0.387

Mann–Whitney U-test. UCLA: University of California Los Angeles; MEPI: Mayo elbow performance index; QuickDASH: Quick disabilities of the arm, shoulder, and hand; ORIF: Open reduction internal fixation; MIPO: Minimally invasive plate osteosynthesis; Med.: Median,

(9.5%) demonstrated inadequate elbow range of motion performances. However, these results were statistically similar among the two groups (p=0.678) (Table 3).

Concerning the radiological results; all patients had their fractures healed with less than 10° of angular deformity. Coronal plane angular deformities had an average value of 2.2° (range, 4° of valgus to 1°of varus) in Group B whereas the mean value was 0.4° (7° of valgus to 7° of varus) in Group A. According to multivariate binary logistic regression analysis, effects of parameters of age, gender, varus angulation degrees, valgus angulation degree, fracture type, and affected side were evaluated. The chosen surgical method did not have a statistically significant effect on diminishing elbow performance (odds ration=1.175, p=0.716, CI: 0.136–18.305) (Table 4).

In addition, the incidence of radial nerve injury after the operation was 14.2% (n=3) in Group A and 9.5% (n=2) in Group B. All 5 cases of radial nerve palsies recovered spontaneously with mean onset time 6 months (range 5–7 months) without a need for surgical exploration. The mean fracture union time was 3.5 months in ORIF group and 3.8 months in MIPO group.

There were no cases of non-union, pseudoarthrosis, implant failure, or deep tissue infections among both groups. Multivariate binary logistic regression analysis was applied to evaluate the effects of parameters of age, gender, fracture type, and affected side on post-operative radial nerve injury risk. It was identified that the chose surgical method did not have a statistically significant effect on radial nerve injury incidence (Odds ratio=0.923, p=0.936, CI: 0.133–6.388) (Table 5).

Table 3. Functional status of the evaluated patients in the study

	ORIF		MIPO		
	n	%	n	%	p
Anterior shoulder flexion angle					
≥120	30	100.00	21	100.00	–
<120	0	0.0	0	0.0	
Elbow range of motion					
≥130	26	86.7	19	90.5	678
<130	4	13.3	2	9.5	
UCLA shoulder score					
≥27	30	100.00	21	100.00	
<27	0	0.0	0	0.0	
MEPI elbow score					
≥90	30	100.00	21	100.00	
<90	0	0.0	0	0.0	

Chi-square test. ORIF: Open reduction internal fixation; MIPO: Minimally invasive plate osteosynthesis

DISCUSSION

In our study, we found several outcomes. First, there was no significant difference between the results of the MIPO group and the conventional ORIF group. Second, evaluations of radiologic results of the two groups were similar. Finally, the difference regarding complications among both of the groups was statistically not significant.

Using the MIPO technique, excellent patient results with full range of elbow and shoulder were reported by Kobayashi et al.[23] A large case series of MIPO was published by Lopez-Arévalo et al.[24] and they concluded that MIPO was associated with no shoulder pain and full-strength recovery of shoulder and elbow movements. Livani and Belangero[25] also reported that shoulder and elbow ROM was normal among the patients who were operated using MIPO technique. In our study, both groups demonstrated excellent results in regard of all functional tests. Our results were coherent with previous research data.[26]

Table 4. Evaluation of parameters associated with risk of diminished elbow performance

	B	SE	Wald	df	p	OR	95% CI	
							LL	UL
Age	84	52	2.545	1	111	1.087	981	1.205
Gender (female)	−9	1.121	0	1	993	991	110	8.916
Varus angulation degrees	−546	592	852	1	356	579	181	1.848
Valgus angulation degrees	−363	371	958	1	328	696	337	1.439
Fracture type (AO/OTA 12A2b)	155	1.011	23	1	878	1.167	161	8.470
Affected side (L)	−337	978	119	1	731	714	105	4.856
Surgical technique (MIPO)	455	1.251	132	1	716	1.575	136	18.305

Nagelkerke R^2=0.19; X^2=5.36; p=0.616. SE: Standard error; df: Degrees of freedom; OR: Odds ratio; CI: Confidence interval; LL: Lower limit; UL: pper limit; AO/OTA: Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association; MIPO: Minimally invasive plate osteosynthesis

Table 5. Evaluation of the association between post-operative risk factors and radial nerve injury

	B	SE	Wald	df	p	OR	95% CI	
							LL	UL
Age	20	36	318	1	573	1.021	951	1.096
Gender (female)	−1.426	1.213	1.383	1	240	240	22	2.587
Fracture type (AO/OTA 12A2b)	146	1.052	19	1	890	1.157	147	9.103
Affected side (Left)	−476	1.034	212	1	645	621	82	4.718
Surgical technique (MIPO)	−80	987	7	1	936	923	133	6.388

Nagelkerke R^2=0.19; X^2=5.36; p=0.616. SE: Standard error; df: Degrees of freedom; OR: Odds ratio; CI: Confidence interval; LL: Lower limit; UL: pper limit; AO/OTA: Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association; MIPO: Minimally invasive plate osteosynthesis

The main concern of MIPO technique is consequent malalignment.[27,28] Wang et al.[29] assessed rotational malalignment post-operatively using CT scans and they found out that MIPO was associated with increased incidence of rotational malalignment. In our study, no malalignment of clinical concern was observed during physical examinations in neither of the groups, thus a radiological evaluation was not found necessary.

Regarding MIPO, lower rates of non-union, infection rates, and radial nerve palsies have been reported in literature.[30,31] Non-union rates suggested by the current literature change between the values 4.7% and 11.8%.[32,33] In a study, the mean time until union was found to be significantly shorter among absolute stability group compared to relative stability group. On the contrary, rates between 0% and 7.9% of non-unions are portrayed with the MIPO technique.[27,34] Interestingly, we found out that union rates are similar between conventional ORIF group and MIPO group.

According to a study, ORIF technique puts the radial nerve in danger during the exposure of the fracture.[2] According to a study by Hu et al.,[35] MIPO was associated with higher rates of union and decreased rates of iatrogenic radial nerve injury. In our study, we excluded patients with compromised radial nerve functions pre-operatively. Interestingly, in contrast with the present data, we observed two iatrogenic radial nerve injuries among the MIPO group whereas three cases were seen among the conventional ORIF group. All iatrogenic nerve palsy patients eventually recovered during follow-ups without the need for additional surgery.

Therefore, this study demonstrated that the application of MIPO technique was as effective and safe as conventional ORIF with similar functional and radiologic results. This technique has evolving and growing to be one of the preferred alternatives to conventional ORIF technique, as it is less invasive. Therefore, the clinical importance of this study lies here. If the number of studies similar to this one increase, surgeons will be more confident to apply the MIPO technique for treating humeral shaft fractures.

This study yet had a few limitations. Due to its retrospective construct, a lot of patients who met the eligibility criteria had to be excluded due to a lack of adequate and

reliable data. This consequently reduced our patient number. However, the literature does not provide large study groups for MIPO technique neither.[32,36] This suggests that more research with larger groups of patients should be assessed. On the other hand, valuable parameters such as intraoperative bleeding, mean surgical time, and intraoperative radiation exposure could not be evaluated due to the retrospective nature of the study. Ethical approvals for constructing prospective studies have been challenging since. By constructing prospective randomized studies, these important parameters can also be evaluated in the future. In addition to this, the number of operating surgeons was relatively large compared to other randomized-controlled studies. This can also be attributed to the retrospective construct of our study, which was handled in a state hospital where surgical operations were done by different surgeons with diverse backgrounds.

CONCLUSION

It has been demonstrated by this study that high rates of union can be achieved using both conventional ORIF techniques and the MIPO technique. Both techniques may provide decent functional results for the specific type of humeral shaft fractures that had been set as a criterion for this study. Results of our study demonstrated satisfactory fracture healing and post-operative functional results for AO/OTA type 12A2b and AO/OTA type 12A3b fractures, thus indicating that MIPO technique may be as safe and effective as conventional ORIF technique in this manner.

Disclosures

Ethics Committee Approval: The study was approved by the University of Health Sciences Kanuni Sultan Süleyman Training and Research Hospital Ethics Committee (No: 2018/12/80, Date: 24/05/2019).

Informed Consent: Written informed consent was obtained from all patients.

Peer-review: Externally peer reviewed.

Authorship Contributions: Concept: G.Ç., A.Ş.; Design: C.E., G.Ç.; Supervision: C.E., A.Ş.; Funding: C.E., A.Ş.; Materials: O.Ç., Y.E.; Data Collection or Processing: O.Ç., Y.E.; Analysis or Interpretation: O.Ç., G.Ç.; Literature Search: Y.E., O.Ç.; Writing: O.Ç., G.Ç., Y.E.; Critical review: C.E.

Conflict of Interest: No conflict of interest was declared by the authors.

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