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Treatment of the Fractures of the Humeral Surgical Neck: MIROS versus Intramedullary Nailing. A Retrospective Study

Michelangelo Palco MD [1], Gabriele Giuca MD [2,*], Domenico Fenga MD [2], Ilaria Sanzarello MD [2], Matteo Nanni MD [2] and Danilo Leonetti MD [2]

[1] Department of Orthopaedic and Trauma Surgery, Casa di Cura Caminiti, Villa San Giovanni (RC), Italy.
[2] Section of Orthopaedics and Traumatology, Department of Biomedical Sciences and Morphological and Functional Images, University of Messina, 98122 Messina (ME) Italy. Research performed at A.O.U Policlinico G. Martino - Messina (Me) Italy, University of Messina (ME).
* Correspondence: author: Gabriele Giuca, MD. Section of Orthopaedics and Traumatology, Department of Biomedical Sciences and Morphological and Functional Images, University of Messina, 98122 Messina, Italy. (E-mail: gabgiuca@unime.it).

Abstract: The aim of this retrospective study was to compare the clinical outcomes of treating isolated surgical neck fractures of the humerus using either the intramedullary nail or the MIROS (Minimally Invasive Reduction and Osteosynthesis System®) system. The study included 42 patients who underwent surgical treatment at the Polyclinic from January 2014 to June 2020. The results indicated that both treatments were effective; however, the MIROS system exhibited a higher complication rate. Intramedullary nailing was more reliable, thus recommended as the primary treatment method. This study underscores the importance of selecting the appropriate fixation technique to minimize complications and enhance patient outcomes.

Level of evidence: IV

Keywords: proximal humerus fractures; MIROS system; intramedullary nailing; orthopedics; retrospective study

1. Introduction

Fractures of the proximal epiphysis of the humerus are particularly common in elderly women and their frequency increases with age, making them a significant concern in geriatric orthopedics [1–3]. These fractures typically result from low-energy falls and are challenging to treat due to the complex anatomy and osteoporotic nature of the bone in older patients [4]. While most minimally displaced fractures can be treated conservatively with satisfactory outcomes, surgical intervention becomes necessary for unstable or non-reducible fractures [4–6].

Several surgical techniques are available, including plates and screws for open reduction and internal fixation (ORIF), minimal fixation, intramedullary nailing, external fixation, and prosthetic replacement [7–17]. The choice of treatment depends on factors such as the type of fracture, patient age and functional requirements, general and local conditions, and bone quality [10].

This study aims to compare the clinical outcomes of two fixation systems: the MIROS (Minimally Invasive Reduction and Osteosynthesis System®) and intramedullary nailing. The MIROS system is designed to treat elderly patients with comorbidities such as cardiac or cardiovascular diseases with minimal invasiveness [18]. It offers benefits like reduced surgical times, minimal invasiveness, and reduced anesthetic impact, but it also has a higher rate of complications, including infections and the migration of K-wires [19].

On the other hand, intramedullary nailing is more invasive but provides better stability of the fracture fragments and has a lower complication rate [20]. Although intramedullary nailing involves

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a bloodless treatment process, it still ensures satisfactory clinical results even if an anatomically perfect reduction is not achieved [21].

A recent review highlighted that intramedullary nailing offers advantages over ORIF in terms of intraoperative bleeding, surgical time, and incidence of complications such as implant failure and osteonecrosis [22]. Our study aims to provide evidence-based recommendations for the treatment of proximal humerus fractures by comparing the outcomes of these two methods.

2. Methods

It was performed in a level IV retrospective cohort study of 85 patients, aged 21 to 82 years, with a fracture of the proximal humerus epiphysis treated surgically at the A.O.U Policlinico G. Martino - Messina (Me) Italy, University of Messina (ME), between 01/01/2014 and 01/06/2020.

After the evaluation of medical records, 43 patients who had one or more of the following criteria were excluded from the study:

- Open fractures;
- Fractures not classified as fractures of the surgical neck of the humerus;
- Previous humerus fractures;
- Peripheral neuropathies;
- ORIF synthesis;
- Prosthetic replacement (covering or total with reverse shoulder prosthesis);
- Lack of follow-up;
- Death;

42 patients were included in the study, of which 18 were treated with the MIROS system (group A) and 24 with intramedullary nailing (group B) (Table 1).

Two different orthopedic surgeons, not initially involved in the treatment re-evaluated the medical records (M.P. – G.G.), the reports of the outpatient visits and the pre and post-operative radiographic examinations for each patient. The clinical evaluation at each check-up visit (15 days after surgery, 1 month, 3 months, 6 months, 1 year) included the assessment of pain through the VAS scale; any possible signs of complications were evaluated. The functional evaluation was performed using the DASH centesimal scale in which the result 0 indicates the absence of dysfunction and the result 100 indicates severe restrictions. Radiological evaluations were performed on a real anteroposterior and lateral x-ray of the shoulder. The average follow up was 43 months, the minimum of 21, the maximum of 65.

All data stored was collected and statistically reviewed using version 21 of SPSS software (SPSS Inc., Chicago, IL). The average values and standard deviations were calculated for all continuous variables. The Student's T Test for independent samples was used to evaluate the difference between the parameters detected in the 2 groups. Values of $P < 0.05$ were considered statistically significant.

3. Results

The 18 patients treated with the MIROS system removed the external fixation device after an average time of 35 ± 6 days.

The mean age at the time of the fracture was different between the two groups (73 ± 8 SD in group A vs 54 ± 21 SD in group B) as well as the gender distribution (66.7% of F in group A vs 37, 5% in group B). In group A, 34% of patients were involved of the dominant limb, 76% in group B (Table 1).

Table 1. Patients included in the study.

	Group A	*Group B*
Gender F/M	12/6	9/15
Age	73,17 ± 7,85	54,38 ± 20,79
Fractured Dominant Limb	34%	76%

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All fractures treated with intramedullary nail were assessed to be radiologically and clinically healed at 3-month follow-up; a patient treated with the MIROS system needed to be re-operated with intramedullary nailing due to system failure. This patient recovered without further complications at the third month follow-up. Fractures treated with the MIROS system were considered radiologically healed 3 months after surgery.

In Group A (MIROS), a total of 22.2% of patients developed complications. These included two cases of superficial infection (11.1%), one case of humeral head avascular necrosis (5.5%), and one case of synthesis failure due to K-wire migration (5.5%), which necessitated reoperation with intramedullary nailing. The infections were managed successfully with antibiotic therapy and did not require further surgical intervention. The patient with humeral head avascular necrosis eventually underwent prosthetic replacement 24 months postoperatively. This complication rate is consistent with the literature, where minimally invasive systems like MIROS have been reported to have higher infection rates due to the percutaneous nature of the procedure [19]. In Group B (intramedullary nailing), only 8.8% of patients developed complications, limited to superficial infections at the surgical site, also treated with antibiotics. These were treated with antibiotics, and no further surgical intervention was required. The lower complication rate in this group aligns with findings from previous studies, which suggest that intramedullary nailing offers better fragment stability and lower risk of infection compared to percutaneous techniques. The infections were revealed at follow-up 15 days after surgery; both were considered superficial and eligible for antibiotic treatment. The patient who developed head necrosis underwent a prosthetic replacement surgery 24 months after the first surgery, while the patient who failed to synthesize with MIROS was re-operated 20 days after the first surgery with intramedullary nailing. The mean DASH score was similar between the two groups (47.8 ± 21 in Group A vs. 49 ± 11 in Group B). However, Group A reported significantly lower perceived pain compared to Group B, with mean VAS scores of 45 ± 25.7 vs. 58.1 ± 12.5 (P = 0.035). This suggests that despite higher complication rates, percutaneous fixation with the MIROS system might offer better postoperative comfort in terms of perceived pain, likely due to the less invasive nature of the treatment. The results are summarized in the table (Table 2). The mean follow-up was 43 months, ranging from 21 to 65 months. All patients in Group B demonstrated radiological and clinical healing within 3 months, whereas one patient in Group A required a second operation due to MIROS system failure but subsequently achieved complete healing. The use of the MIROS system was associated with a higher rate of synthesis failure and infections compared to intramedullary nailing, consistent with other research indicating that minimally invasive systems may carry greater risks of complications compared to more stable and established methods like intramedullary nailing.

Table 2. Caption.

	Group A	*Group B*	*P-Value*
Medium FU	51M	37M	
DASH	47,78 ± 21,04	49,06 ± 10,95	0,799
VAS	45 ± 25,72	58,12 ± 12,49	0,035

4. Discussion

Proximal humerus fractures are prevalent and, in many cases, can be managed conservatively with satisfactory clinical outcomes [4,5]. However, certain factors such as fragment displacement, fracture instability or comminution, and the functional demands of the patient necessitate surgical intervention. In younger patients, ORIF (Open Reduction and Internal Fixation) typically yields optimal results due to the ability to achieve anatomical reduction and the superior bone quality. Conversely, osteoporosis in elderly patients necessitates alternative techniques such as external fixation, minimal fixation, or the use of MIROS or intramedullary nailing to achieve satisfactory clinical outcomes [10].

A critical factor in deciding the treatment for proximal humerus fractures is the fracture location and the number of fragments involved. The MIROS system is designed to treat elderly patients with

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comorbidities, such as cardiac or cardiovascular diseases, with minimal invasiveness, albeit at the cost of not achieving anatomical reduction, which is often unattainable with percutaneous fixation [18]. Intramedullary nailing, while more invasive than MIROS, also aims for minimal invasiveness and has been shown to provide satisfactory clinical results even if perfect anatomical reduction is not achieved [23–25].

The advantages of percutaneous fixation with MIROS include reduced surgical time, minimal invasiveness, and lower anesthetic risk, along with reduced costs. However, disadvantages include complications such as infections, K-wire migration, and non-anatomical reductions [19]. Conversely, intramedullary nailing offers greater fragment stability and is recommended as a primary treatment method due to its lower complication rate [22,26–28]. Our analysis of clinical outcomes indicates that, in terms of functionality, the two fixation systems do not show statistically significant differences (DASH score 47.8 ± 21 SD in group A vs. 49 ± 11 SD in group B). However, pain perception is significantly better in group A treated with the MIROS system (45 ± 25.7 SD vs. 58.1 ± 12.5 SD in group B). Notably, group A exhibited a higher incidence of complications, consistent with existing literature. The results of this study confirm that while the MIROS system can be effective under certain clinical conditions, it presents a higher complication rate compared to intramedullary nailing.

In our study, the infection rate was higher in the group treated with the MIROS system compared to the group treated with intramedullary nailing. We observed superficial infections in 22.2% of patients in the MIROS group and in 8.8% of the intramedullary nailing group. These findings align with existing literature that indicates a higher risk of infections in percutaneous treatments compared to more stable techniques like intramedullary nailing. For instance, studies such as that by Chen et al. [19] have reported similar incidences of infections in percutaneous treatments of proximal humerus fractures. K-wire migration was a specific complication in the MIROS group, with one case of synthesis failure requiring reoperation with intramedullary nailing. This phenomenon is well-documented in the literature, highlighting that the limited stability offered by K-wires can lead to complications, including migration. Resch et al. [24] noted that wire migration is a major cause of failure in percutaneous treatments, especially in osteoporotic bone. One case of avascular necrosis of the humeral head was observed in the MIROS group, necessitating prosthetic replacement. Literature supports that avascular necrosis is a rare but significant complication in patients treated with minimally invasive techniques. According to an article by Ogiwara et al. [21], avascular necrosis can occur due to compromised blood supply during surgical manipulation, especially in elderly patients with osteoporotic bones, indicating that minimally invasive techniques may carry a higher risk of disrupting the vascular supply to the humeral head. Our findings, which show a higher complication rate in the MIROS group compared to the intramedullary nailing group, are consistent with existing literature. Previous studies have highlighted that while the MIROS system may offer better postoperative comfort in terms of perceived pain, it carries a higher risk of complications, as reported by Wang et al. [29] in their analysis of risks associated with less stable fixation techniques.

Specifically, the infection rate and synthesis failure with the MIROS system align with previous studies, emphasizing the need for careful surgical technique selection based not only on patient characteristics but also on the associated risks of different techniques [30]. Although rare, avascular necrosis represents a significant complication requiring careful preoperative evaluation, particularly in patients with risk factors for reduced vascularization [29]. The results suggest that while the MIROS system may be considered for patients with significant comorbidities who require a less invasive procedure, intramedullary nailing should be preferred in most cases due to its greater reliability and lower complication rate. This is particularly important in younger patients or those with a longer life expectancy, where long-term complications could have a greater impact on quality of life [29]. One of the main limitations of this study is the small sample size, which may limit the generalizability of the results. Additionally, the retrospective nature of the study may introduce selection bias and limit the ability to fully control for confounding variables. Future studies should aim to include a larger sample size and a prospective follow-up to confirm these results and improve the evidence base for choosing between MIROS and intramedullary nailing [29]. The non-homogeneity of the sample in terms of age and follow-up duration, along with the retrospective

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nature of the study, are limitations that must be acknowledged. Further randomized studies with more standardized controls are necessary to obtain more scientifically robust results. Following a review of clinical outcomes, our institution has decided to abandon the MIROS technique in favor of the more reliable intramedullary nailing and/or ORIF with plates and screws due to the higher incidence of complications.

5. Conclusions

This study demonstrates that while the MIROS system may have a role in treating patients with severe comorbidities, it does not surpass the effectiveness of intramedullary nailing for surgical neck fractures of the humerus. The notably higher complication rates associated with MIROS underscore that intramedullary nailing should be the first choice for most patients, offering superior reliability and a lower risk profile. Although MIROS may reduce postoperative pain, its elevated risk of complications renders it a less favorable option. Surgeons must weigh the risks and benefits meticulously, reserving MIROS for cases where patient comorbidities necessitate a less invasive approach.

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Ethics Statement: This study was conducted in accordance with the ethical standards of the institutional and national research committees and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

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Conflict of Interest: None

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