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Clinical and radiographic outcomes after antegrade intramedullary nail fixation of humeral fractures

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ABSTRACT

INTRODUCTION: Humerus fractures are frequent, accounting for about 3-4% of all fractures in adults. Treatment for fractures of the diaphyseal and proximal meta-epiphyseal regions remains controversial: there is no unanimity in the scientific community about the superiority of surgical treatment over non-surgical treatment and which is the best between possible surgical treatments. Among the choices for surgical treatment the most commonly used implants are the locking-compression plate and the intramedullary nailing. The purpose of this study was to perform a clinical and radiographic follow-up in patients who underwent surgical procedures for reduction and osteosynthesis of proximal or diaphyseal humeral fractures by means of antegrade intramedullary nailing with a straight-shaped nail.

PATIENTS AND METHODS: A clinical and radiographic follow-up was performed in 56 patients who underwent surgical procedures for reduction and osteosynthesis of proximal or diaphyseal humeral fractures by means of antegrade intramedullary nailing using Synthes MultiLoc® system. Clinical data were collected using subjective quality of life assessment forms (SF12-v2), quality of life related to specific disabilities assessment forms (Quick-DASH, ASES score, WORC) and objective functional assessment forms (Constant-Murley score). The radiographic Follow-Up was performed at 30, 90 and 180 days from the date of the surgery.

RESULTS: Almost all patients were able to return to a satisfactory quality of life, comparable with the one before the traumatic episode. The functional results were assessed as excellent or good with almost complete recovery of the range of motion and moderate recovery of strength. The residual pain encountered was moderate or zero. The average QuickDASH score was 17.7 ± 4.3 (range 9.1 - 27.3). The average ASES score was 73.8 ± 8.1 (range 58.3 - 88.3). The average WORC score was 543.3 ± 100 [74% \pm 4.8%] (range 310 - 740). The mean Constant-Murley score was 69.6 ± 4.6 (range 61 - 84). All patients had a fair or good consolidation of the fracture on radiographic examinations. The calculated RUST score was 4.2 ± 0.4 (range 4-5) 30 days after surgery, 6.1 ± 0.9 (range 4- 8) 90 days after surgery and 9.8 ± 1.5 (range 7-12) to 180 days after surgery. No major complications were found.

CONCLUSIONS: Treatment of the diaphyseal and proximal meta-epiphyseal humeral fractures with antegrade intramedullary nail provides excellent subjective and objective clinical results and good radiographic results. However, clinical studies with larger number of patients and longer follow-up are necessary.

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INTRODUCTION

Humerus fractures are frequent, accounting for about 3-4% of all fractures in adults. They present a dual etiopathogenesis: in young individuals they are usually caused by high-energy trauma, while

in the elderly due to lower bone quality they are often caused by low-energy trauma. About 75% of these fractures involve patients over 60 years of age, in fact they occupy the third place among the most common fractures in the elderly, the second place after distal radius fractures if we consider only the upper limb.[1]

Treatment for fractures of the proximal meta-epiphyseal and diaphyseal regions remains controversial: there is no unanimity in the scientific community about the absolute superiority of surgical treatment over non-surgical treatment [2] and which is the best among the possible surgical treatments. Some authors estimate

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that 15% to 64% of proximal humerus fractures are displaced and need surgical treatment.[3] The conservative treatment of these fractures can in fact result in stiffness of the gleno-humeral joint, post-traumatic arthrosis, lack of consolidation. The surgical treatment modalities for treating these fractures are multiple, including percutaneous osteosynthesis, joint replacement, plate and screws osteosynthesis, intramedullary nailing. However, no single technique has demonstrated evidence-based superiority in the treatment of proximal humerus fractures. [4] Intramedullary nail osteosynthesis prevents further damage to the vascularization of the fragments. On the other hand, anterograde intramedullary nailing is correlated with a higher incidence rate of residual pain, limitation of movement and subacromial impingement. The causes are probably correlated with the incision of the rotator cuff for implant fixation. The results analyzed by Kurup et al did not demonstrate differences in the functional capacity of the operated limb patients after six months of treatment using the American shoulder and elbow index (ASES), regardless of the implant used. [5] According to Schmidutz et al the evaluation and interpretation of shoulder and upper limb lesions is controversial and subjective and should be considered beyond the clinical examination. [6] Subjective variables such as emotional aspects, habits, sports of each patient must be considered and interpreted differently.

The purpose of this study was to perform a clinical and radiographic follow-up in 56 patients who underwent surgical procedures for reduction and osteosynthesis of proximal or diaphyseal humeral fractures by means of anterograde intramedullary nailing with a straight-shaped nail (Synthes MultiLoc® system).

MATERIALS AND METHODS

A retrospective review of the patients' register of the Orthopedic and Traumatology Complex Operative Unit of the Agostino Gemelli Polyclinic (Rome, Italy) was performed, selecting all who underwent surgery for reduction and osteosynthesis with an anterograde intramedullary straight nail (MultiLoc® Synthes system) in the period from January 2016 to July 2018. Inclusion criteria were: adult patients (over 18 years), both male and female, with a simple or complex fracture in the proximal or diaphyseal area of the humerus (1.1-A, 1.1-B, 1.2-A, 1.2-B1.2-C according to AO classification), subjected to osteosynthesis with an anterograde intramedullary straight-shaped nail at least 6 months before and not subjected to other forms of treatment (surgical or not) before arrival in the hospital, which have not reported previous pathologies or other surgery to the shoulder.

Exclusion criteria: patients under the age of 18, patients suspected of pathological fractures or infections, evidence of neurological or vascular lesions in the initial diagnosis of the fracture or association of severe abdominal, thoracic or cranial traumas.

Clinical data were collected using subjective quality of life assessment forms (SF12-v2), quality of life related to specific disabilities assessment forms (Quick-DASH, ASES score, WORC) and objective functional assessment forms (Constant-Murley score). Radiographic follow-up was carried out by follow up visits at 30, 90 and 180 days after the surgery. Antero-posterior and lateral projections were performed. For each of them the modified RUST score was used to assess the state of consolidation of the fracture. [Tab. 1] [7,8]

We also included basic information such as age, sex, time elapsed since the last surgery, dominance. The incidence of infections and implant removal for any reason were also recorded. Fig. 1.

All patients were operated by the same team of orthopedic surgeons, belonging to the Complex Operative Unit of Orthopedics and Traumatology of the Policlinico A. Gemelli (Rome, Italy). Fig. 2.

Tab. 1

Individual cortex score based on radiographic findings. These scores are added to calculate the RUST

Score per cortex	Callus	Fracture line
1	Absent	Visible
2	Present	Visible
3	Present	Invisible

Tab. 2

Anagraphic data

Mean age	59,84 ys
Sex	19 M/37F
Laterality	28 R/28L

SURGICAL TECHNIQUE

The patient is placed in semi-sitting position (beach chair). The image intensifier is positioned posterior to the patient's head. Before setting up the operating field it is evaluated, with appropriate maneuvers, the possibility of a close reduction of the fracture. If the close reduction fails it's necessary to resort to open reduction. Once the reduction is achieved, the Synthes MultiLoc® Humeral Nailing System device is used for definitive osteosynthesis. It is a straight-shaped intramedullary nail developed to have a humeral apex entry point. The choice of the length of the device is based on the anatomical position of the fracture identified during the preoperative radiographic examination and on the intraoperative assessments of the stability of the osteosynthesis. Short stems are indicated for fixations of fractures involving the proximal third of the humerus. Long stems are indicated for diaphyseal fractures, taking into account the space for the placement of at least one distal locking screw. Once the osteosynthesis is completed, the rotator cuff is then closed with sutures using a non-resorbable suture. Fig. 3.

POSTOPERATIVE TREATMENT

In the first 4 weeks after surgery, patients have to wear a shoulder brace, encouraging the active mobilization of the hand, wrist and elbow, pendular movements of the arm. 4 weeks after surgery, the first radiographic check is performed: if there's an initial callous formation, the brace is progressively removed and the patient begins to perform passive and active-assisted physiotherapy for the recovery of the range of motion, simultaneously with magnetotherapy. Fig. 4.

At the next clinical and radiographic check, 3 months after surgery, if the recovery of range of motion, pain symptoms and radiographic progress of the repair process are satisfactory, the patient begins active physiotherapy for muscle strengthening.

RESULTS

Of 108 patients who underwent surgery in the time interval considered, 56 met the inclusion criteria. The 56 patients (19 men and 37 women) had a mean age of 59 ± 19 years (range 18 - 97) and a mean follow-up duration of 18 ± 9 months (range 6 - 35). The operated side was the right in 28 cases and the left in 28 cases. 38 of the 56 patients declared to be right-handed, the remaining 18 being left-handed, so that in 32 cases the affected side was the dominant, in the remaining 24 the opposite side. [Tab. 2].

No cases of wound infection or post-operative infections have been reported.

In almost all patients the return to a satisfactory quality of life was found, comparable with the one preceding the traumatic episode. [Tab. 3]



Fig. 1. The first x-ray was performed at the time of the access of the emergency department.



Fig. 2. 30 days after surgery. The callus is absent and the fracture line is still visible in all cortices. RUST score is 4



Fig. 3. 90 days after surgery. An initial callus formation is visible. Fracture line is still visible. RUST score is 5.

Tab. 3

SF-12 results

	Physical functioning	Role Physical	Bodily pain	General health	Vitality	Social functioning	Role emotional	Mental health
MEAN	67,5	59,5	62,5	57,4	49	62	71	63

The functional results were assessed as excellent or good with almost complete recovery of active and passive range of motion. A moderate recovery of strength was recorded. The residual pain encountered was moderate or zero.

The average QuickDASH score was 17.7 ± 4.3 (range 9.1 - 27.3). The average ASES score was 73.8 ± 8.1 (range 58.3 - 88.3). The

average WORC score was 543.3 ± 100 [$74\% \pm 4.8\%$] (range 310 - 740). The mean Constant-Murley score was 69.6 ± 4.6 (range 61 - 84). [Tab. 4]

A fair or good consolidation of the fracture on radiographic examinations was found in all patients. The calculated RUST score was 4.2 ± 0.4 (range 4 - 5) at 30 days after surgery, 6.1 ± 0.9 (range

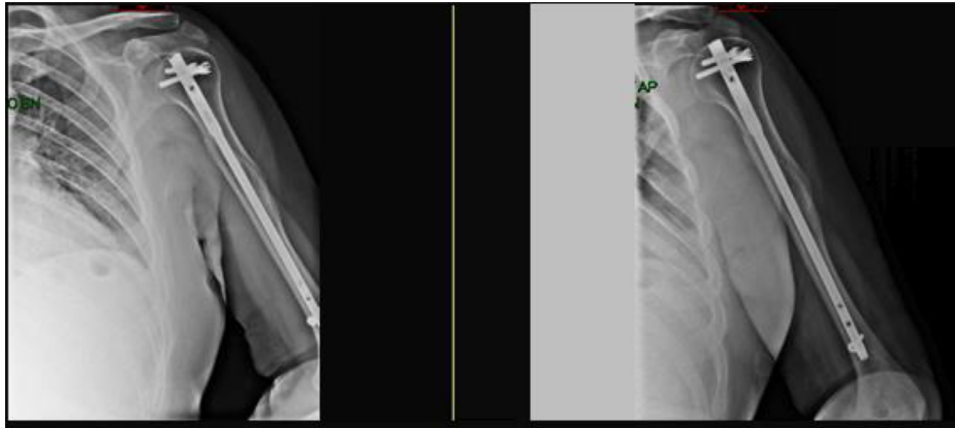


Fig. 4. 180 days after surgery. Callus is present. Fracture line is still visible on two cortices. RUST score is 10.

Tab. 4
Functional Scores

	Quick-DASH	ASES	WORC	Constant-Murley
Mean	17,73	73,80	543,3	69,58
St Dev	4,30	8,15	100,07	4,57
Median	18,2	75	520	69,5
Min	9,1	58,3	310	61
Max	27,3	88,3	740	84

Tab. 5
Radiographic Scores

	30 DAYS	90 DAYS	180 DAYS
Mean	4,21	6,14	9,78
St Dev	0,41	0,92	1,47
Median	4	6	10
Min	4	4	7
Max	5	8	12

4 - 8) at 90 days after surgery and 9.8 ± 1.5 (range 7 - 12) at 180 days after surgery. [Tab. 5]

In no case nail dynamization or implant removal was needed.

DISCUSSION

The most important result that emerges from this study is that the intramedullary humeral nailing with a straight nail shows good clinical and radiographic outcomes at 18 months of follow up. No patient underwent surgery for implant removal due to a nail impingement and/or infection.

The design of the humeral nails has had important innovations in the last 40 years and now its indication has extended diaphyseal, proximal and tuberositary fractures. [1]

Medial access to the head of the humerus and the use of a straight nail could also decrease the incidence of postoperative cuff tendinopathy and allow better alignment of the fracture avoiding malalignment. With a more medial access compared to the anatomical nail, in fact, the straight nail passes through the muscular component of the supraspinatus which has a greater potential for healing than the rotator cuff. [1]

A recent cadaveric study by Schwarz investigated the risk of tendon injury in the different entry points of the right humerus nail. The different entry points were three: in line with the humeral diaphysis, 5 mm medial to the anatomical neck, therefore a more lateral access and a medial access, i.e. to the center of the humeral head. The results on 40 humeri showed that the risk of damage to the supraspinatus and CLB was low in the standard

position with an entry point in line with the axis of the humeral shaft and lower in a more lateral position. A medial entry point leads to a statistically significant risk of iatrogenic tendon injury. While no statistically significant association between humeral head size and tendon injury rate has been demonstrated.[9]

Lopez et al. performed a randomized clinical trial between a straight and anatomical nail. In a population of 54 patients with 2 or 3-part fractures, 26 were treated with a straight nail, 26 with a curvilinear nail. The mean follow-up was at 14 months. The results demonstrate that the Constant Score was better in the straight nail, although not statistically significant. The reoperation rate was 42% in the curvilinear nail, 11.5% in the straight nail. The symptoms related to rotator cuff tendinopathy were far less in the right nail than in the anatomical one (34.6% vs 73%), with significant statistics ($p < 0.001$) of the data. [10]

Nolan et al in the study of the anatomical nail, had reported 94% incidence of healing, although with 50% loss of post-operative reduction (due to the non-optimal design for osteoporotic bone and the access point which did not allow the optimal reduction).[11]

A recent literature review shows that, in a total population of 448 patients, treatment with intramedullary nail of 2 or 3-part fractures is satisfactory. The functional outcomes stood at 84.3 for the ASES score, 72.8 for the Constant-Murley score. Analyzing the range of motion, mean forward flexion was 137.3° , mean abduction 138.4° , mean external rotation 43.1° . [12]

As regard to four-fragments fractures, plate fixation has superior results. [13]

In another recent study of 22 patients with a 12-month follow-up, the mean Constant-Murley score was 75.5 and ASES score 81.7. The average ROM was 144.3° in forward flexion, 141.3° in abduction, 58° in external rotation and 62° in internal rotation. [14]

In the present study the strength in forward flexion and abduction at 90° of the arm of both the affected and the contralateral side was evaluated. The Constant-Murley score was very good with a mean result of 69.6, similar to the results in the literature where Hessmann et al confirm the good results of the straight nail with a Constant-Murley score of 66.1.[15]

Although treatment with intramedullary nail gives similar long-term functional results to conservative treatment or treatment with plate, it allows shorter immobilization times and therefore early mobilization. Comparing with plate fixation this treatment can decrease immobilization times and in addition has the advantage of decreasing surgical blood loss and the incidence of wound infections.

The present study has some limitations. The most notable limitations are the variability of the population studied and the ab-

sence of a control group. Secondly, the small number of cases, a short follow-up and the number of surgeons included.

The strength of this study is the use of multiple objective and subjective clinical-functional scores and radiographic scores.

CONCLUSIONS

Intramedullary nailing with a straight nail of the humerus shows good clinical and radiographic outcomes at 18 months of follow up.

Declaration of Competing Interests

None.

References

- [1] Dilisio MF, Nowinski RJ, Hatzidakis AM, Fehringer EV. Intramedullary nailing of the proximal humerus: evolution, technique, and results. *J Shoulder Elbow Surg* 2016;25:e130–8. doi:10.1016/j.jse.2015.11.016.
- [2] Sarmiento A, Kinman PB, Galvin EG, Schmitt RH, Phillips JG. Functional bracing of fractures of the shaft of the humerus. *J Bone Joint Surg Am* 1977;59:596–601.
- [3] Aaron D, Shatsky J, Paredes JCS, Jiang C, Parsons BO, Flatow EL. Proximal humeral fractures: internal fixation. *Instr Course Lect* 2013;62:143–54.
- [4] Konrad G, Audigé L, Lambert S, Hertel R, Südkamp NP. Similar outcomes for nail versus plate fixation of three-part proximal humeral fractures. *Clin Orthop* 2012;470:602–9. doi:10.1007/s11999-011-2056-y.
- [5] Kurup H, Hossain M, Andrew JG. Dynamic compression plating versus locked intramedullary nailing for humeral shaft fractures in adults. *Cochrane Database Syst Rev* 2011 CD005959. doi:10.1002/14651858.CD005959.pub2.
- [6] Schmidutz F, Beirer M, Braunstein V, Bogner V, Wiedemann E, Biberthaler P. The Munich Shoulder Questionnaire (MSQ): development and validation of an effective patient-reported tool for outcome measurement and patient safety in shoulder surgery. *Patient Saf Surg* 2012;6:9. doi:10.1186/1754-9493-6-9.
- [7] Leow JM, Clement ND, Tawonsawatruk T, Simpson CJ, Simpson AHRW. The radiographic union scale in tibial (RUST) fractures. *Bone Jt Res* 2016;5:116–21. doi:10.1302/2046-3758.54.2000628.
- [8] Cazzato G, Saccomanno MF, Noia G, Masci G, Peruzzi M, Marinangeli M. Intramedullary nailing of tibial shaft fractures in the semi-extended position using a suprapatellar approach: A retrospective case series. *Injury* 2018;49:S61–4 Suppl 3. doi:10.1016/j.injury.2018.10.003.
- [9] Schwarz AM, Hohenberger GM, Euler S, Weiglein AH, Riedl R, Kuchling S. Straight proximal humeral nailing: Risk of iatrogenic tendon injuries with respect to different entry points in anatomical specimens. *Injury* 2018;49:1750–7. doi:10.1016/j.injury.2018.07.007.
- [10] Lopiz Y, Garcia-Coiradas J, Garcia-Fernandez C, Marco F. Proximal humerus nailing: a randomized clinical trial between curvilinear and straight nails. *J Shoulder Elbow Surg* 2014;23:369–76. doi:10.1016/j.jse.2013.08.023.
- [11] Nolan BM, Kippe MA, Wiater JM, Nowinski GP. Surgical treatment of displaced proximal humerus fractures with a short intramedullary nail. *J Shoulder Elbow Surg* 2011;20:1241–7. doi:10.1016/j.jse.2010.12.010.
- [12] Wong J, Newman JM, Gruson KI. Outcomes of intramedullary nailing for acute proximal humerus fractures: a systematic review. *J Orthop Traumatol* 2016;17:113–22. doi:10.1007/s10195-015-0384-5.
- [13] Gracitelli MEC, Malavolta EA, Assunção JH, Ferreira Neto AA, Silva JS, Hernandez AJ. Locking intramedullary nails versus locking plates for the treatment of proximal humerus fractures. *Expert Rev Med Devices* 2017;14:733–9. doi:10.1080/17434440.2017.1364624.
- [14] Hao TD, Huat AWT. Surgical technique and early outcomes of intramedullary nailing of displaced proximal humeral fractures in an Asian population using a contemporary straight nail design. *J Orthop Surg* 2017;25:230949901771393. doi:10.1177/2309499017713934.
- [15] Hessmann MH, Nijs S, Mittlmeier T, Kloub M, Segers MJM, Winkelbach V. Internal fixation of fractures of the proximal humerus with the MultiLoc nail. *Oper Orthop Traumatol* 2012;24:418–31. doi:10.1007/s00064-011-0085-z.