Endosteal Strut Allograft Augmentation in the Osteosynthesis of Proximal Humerus Fractures

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ABSTRACT

Introduction: Proximal humeral fractures (PHF) are common, particularly in the elderly. Locking plate fixation continues to provide unpredictable outcomes. Medial hinge support plays a significant role in stability. We aim to evaluate the outcomes of plate fixation with endosteal strut allograft augmentation in PHFs. **Materials and Methods:** We evaluated the clinical and radiological outcomes of 12 patients with PHF who were treated with plate fixation and strut allograft augmentation. The strut allograft was introduced into the humeral shaft to add support to the medial hinge. We compared the final follow-up radiographs to those taken immediately after surgery. We defined a loss of reduction if the change in Humeral Head Height or the Neck-Shaft Angle measured over 3 mm or 5°, respectively. The clinical evaluation included range of motion, Constant-Murley (CM) score, Subjective Shoulder Value (SSV), Visual Analog Scale (VAS), and return to daily activities. **Results:** Twelve patients completed follow-up. The patients' average age was 62.8. Ten patients healed without loss of reduction. Average CM and SSV scores were 82.1 and 80%, respectively, and average VAS was 1.9. Anterior elevation averaged 138.3°, external rotation 49.5°, and internal rotation at L3 level. The mean differences in HHH and NSA were 2.3 mm and 4.92°, respectively. We recorded no complications associated to the procedure. **Conclusion:** Locking plate fixation with endosteal strut allograft augmentation is a reliable technique for the treatment of PHF. It provides support to the humeral neck and maintains reduction in fractures with disruption of the medial hinge.

Key words: Proximal humerus; surgical neck fracture; strut allograft; augmentation; locking plate; neck-shaft angle; humeral head height.

Level of Evidence: IV

Aumento con injerto estructural endomedular en la osteosíntesis de fracturas de húmero proximal

RESUMEN

Introducción: Las fracturas de húmero proximal son frecuentes, particularmente en la población mayor. Los resultados de la fijación con placa bloqueada siguen siendo impredecibles. El soporte de la columna medial jugaría un rol significativo. Nuestro propósito fue evaluar los resultados de la osteosíntesis de húmero proximal con aloinjerto óseo estructural. **Materiales y Métodos:** Se evaluaron los resultados clínico-radiológicos en 12 pacientes con fractura de húmero proximal tratados con placa bloqueada e injerto estructural endostal. Se definió como pérdida de reducción a un cambio del ángulo cervicodiafisario >5° o en la altura de la cabeza humeral >3 mm. La evaluación clínica incluyó rango de movilidad, puntaje de Constant-Murley, valor subjetivo del hombro, escala analógica visual para dolor y retorno a la actividad habitual. **Resultados:** Doce pacientes completaron el seguimiento (edad promedio 62.8 años). Diez mantuvieron la reducción. El puntaje promedio de Constant-Murley fue de 82,1; el del valor subjetivo del hombro, del 80%, y el de la escala analógica visual, de 1,9. La elevación anterior fue de 138,3°; la rotación externa, de 49,5°, y la rotación interna a nivel de la vértebra de L3. La diferencia de la altura de la cabeza humeral y el ángulo cervicodiafisario fue de 2,3 mm y 4,92°. No hubo complicaciones. **Conclusiones:** La osteosíntesis con placa bloqueada y aumento con injerto estructural endomedular es una técnica fiable para tratar fracturas de cuello quirúrgico del húmero. Proporciona soporte al cuello humeral y mantiene la reducción en la fractura de húmero proximal con rotura de la bisagra medial.

Palabras clave: Húmero proximal; fractura de cuello quirúrgico; aloinjerto estructural; aumento; placa bloqueada; ángulo cervicodiafisario; altura de la cabeza humeral.

Nivel de Evidencia: IV

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INTRODUCTION

Proximal humerus fractures (PHF) in the elderly are the most frequent after fractures of the distal radius and femoral neck, with an incidence of 105 per 100,000 patients per year. They are partly due to the deterioration of bone quality due to osteopenia and osteoporosis.[1] The incidence of PHF is continuously growing; in the United States, a 13% annual increase in cases was reported over the last three decades.[2]-

Many of these fractures are treated conservatively.[1,2] Treatment is selected according to the type of fracture and factors related to the patient, such as age, comorbidities, and functional status.[1] Osteosynthesis in displaced PHFs can be technically challenging and have unpredictable outcomes.[3,4] Locking plates have the theoretical advantage of providing greater stability, tolerating a greater load until system failure.[5] However, several studies revealed high rates of complications, among which the intra-articular screw perforation and varus collapse of the fracture stand out, particularly in patients with osteoporosis or comminution of the medial cortical bone.[6-10] In these scenarios, the use of an endosteal strut allograft (ESA) has been described, which, associated with the locking plate, provides greater structural support to the system and reduces the aforementioned complications.[11,12]

The purpose of this study was to evaluate the clinical and radiographic results of the treatment of PHFs by open reduction and internal fixation with locking plate and augmentation with ESA. We believe that the publication of the results obtained with this technique can help consolidate this treatment as a reliable alternative and contribute to improving surgical outcomes in patients with complex PHF.

MATERIALS AND METHODS

In this retrospective study, we evaluated patients who had a PHF and were treated with locking plate fixation plus ESA. We searched for patients with PHF operated on by the upper limb team between 2017 and 2020 in our center's database, and the cases treated with this technique were isolated. The inclusion criteria were: patients >18 years of age with displaced fractures of the surgical neck of the proximal humerus corresponding to grade III and IV of the Resch classification, with insufficiency of the medial hinge or a mean cortical thickness of the humerus (MCT) <6 mm, treated with ESA and locking plate; a minimum follow-up of 12 months or at least six months in those with signs of consolidation. The exclusion criteria were: open or pathological fractures; dislocation-fractures; fractures corresponding to grades I, II, and V of the Resch classification;[3] associated neurovascular injuries; and previous surgery on the affected shoulder.

The indications for receiving this treatment were: surgical neck fractures with comminution or insufficiency of the medial hinge and patients with indirect signs of osteoporosis using the modified Tingart MCT measurement method, with values <6 mm (Figures 1 and 2).[13]

Surgical technique

All surgeries were performed by the same surgical team, at the same Center. Before antibiotic induction, patients were placed on a radiolucent table in a beach chair position, with interscalene block and sedation. A deltopectoral approach was performed in all cases. 2-0 non-absorbable sutures were placed in the rotator cuff tendons for traction and manipulation of the proximal fragment. 2mm Kirschner pins were used to assist with reduction if necessary (Figures 1 and 2).

Figure 1. Anteroposterior right shoulder and axial scapula radiographs of a 78-year-old patient with a surgical neck fracture with medial hinge displacement and a mean cortical thickness of the humerus of 4.3 mm, which correlates with osteoporosis.

Figure 2. Anteroposterior left shoulder and axial scapula radiographs of a 22-year-old patient with a surgical neck fracture with severe metaphyseal involvement and a mean cortical thickness of the humerus of 4.3 mm, which correlates with osteoporosis.

The previously carved cadaveric structural graft was introduced into the intramedullary cavity, entering through the fracture line and placed in a medial position to support the medial column and the humeral head (Figures 3 and 4).

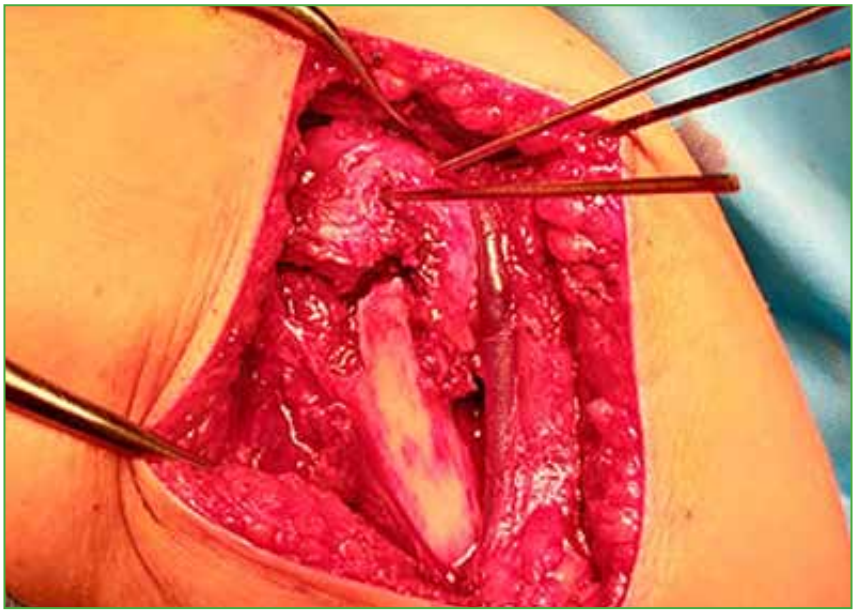

Figure 3. Intraoperative image of the same patient. The fracture line is observed at the level of the surgical neck. The surgeon assists in the reduction of the humeral head using Kirschner pins.

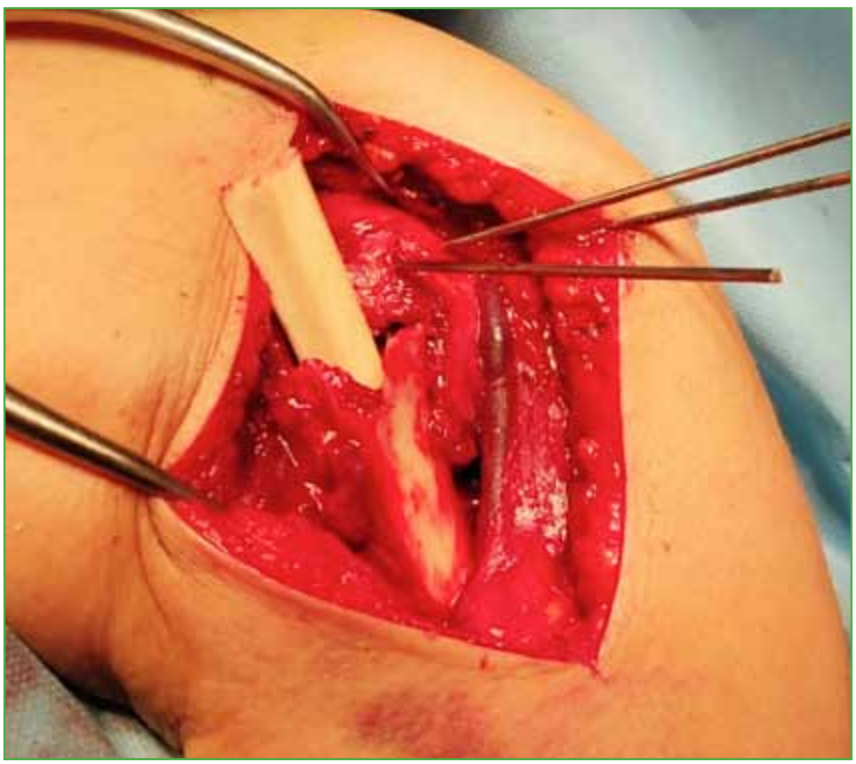

Figure 4. Intraoperative image. Presentation of the endosteal strut graft in the intramedullary cavity after reduction of the humeral head.

A structural allograft of the radius was used in 10 cases and of the ulna in two cases, from our Center's bone bank. After visualizing a correct and stable reduction in the image intensifier, an AZ anatomical locking plate for the proximal humerus (South America Implants, Buenos Aires, Argentina) was applied. The plate was fixated with locking cortical screws that crossed the ESA and, whenever possible, at least one screw directed towards the calcar (Figures 5 and 6).

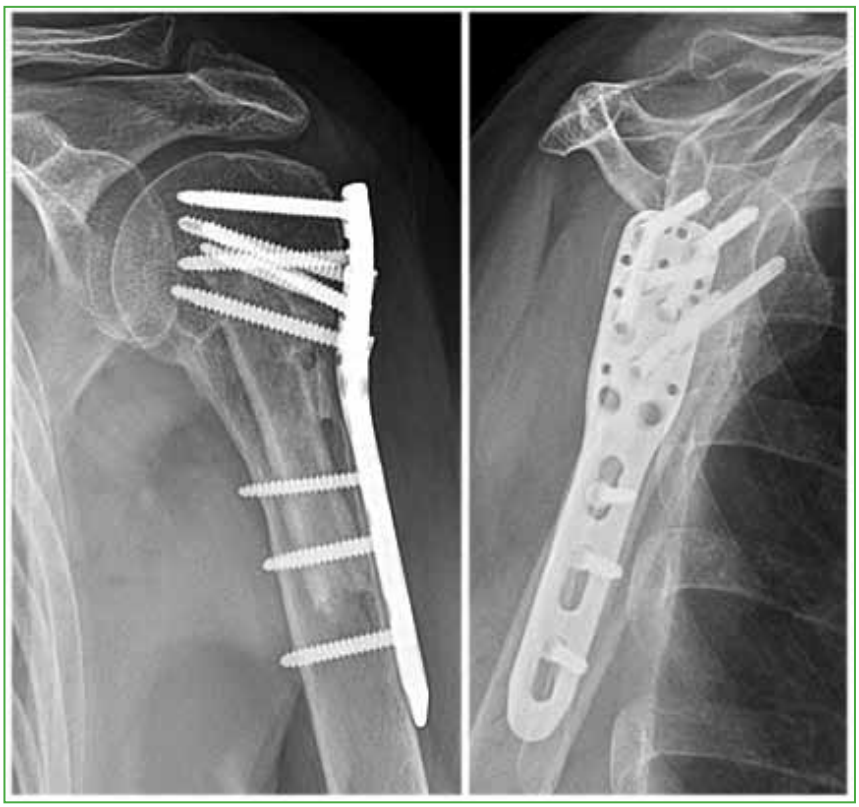

Figure 5. Anteroposterior left shoulder and axial scapula radiographs of the patient in Figure 1 taken in the postoperative period. Fracture consolidation and the presence of the endosteal strut graft are observed.

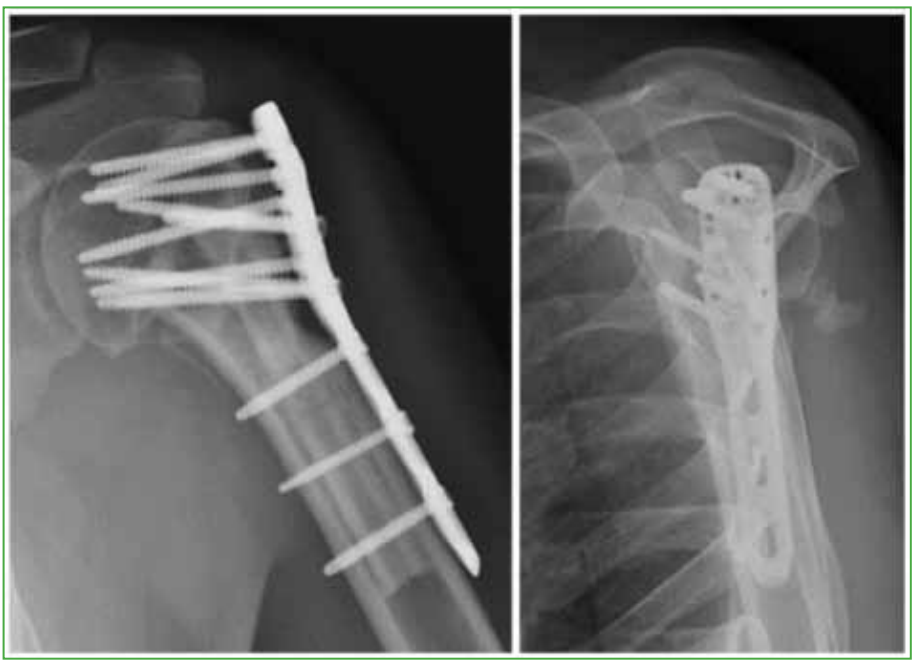

Figure 6. Anteroposterior left shoulder and axial scapula radiographs of the patient in Figure 2 taken in the postoperative period. Signs of fracture consolidation and the presence of endosteal strut graft are observed.

At the end of the surgery, the affected limb was placed in a sling for four weeks and a prophylactic antibiotic was administered in the first 24 hours after surgery. On the first postoperative day, the patients started with pendulum and flexo-extension movements of the elbow. Assisted passive and active range of motion exercises were then indicated at three weeks, and active range of motion exercises at six weeks. Clinical and radiographic controls were performed at 2 and 4 weeks, at 2, 3, 6 and 12 months, and then annually.

The demographic data evaluated were: age, sex, and whether the fracture involved the dominant shoulder. One of the authors (N. N. A.), who was not part of the surgical team, performed the clinical evaluation in the last control. The Constant-Murley score, the subjective value of the shoulder and the visual analog scale for pain were used.[14,15] The range of motion was determined clinically with a goniometer, considering the anterior elevation in the plane of the scapula, the external rotation with the elbow close to the body, and the internal rotation estimated according to the maximum level reached by the thumb. Likewise, clinical complications were recorded: surgical site infections, hematomas, neurovascular injuries, stiffness, and the need for reinterventions. Finally, we recorded whether the patients resumed their usual activities normally.

The radiographic evaluation was carried out by the same evaluator (N. N. A.), with the preoperative images, together with those of the first and last postoperative control, in the anteroposterior Grashey projection. In the preoperative radiographs, the type of fracture was evaluated according to the Resch classification and the MCT measurement was obtained (Figure 7), whose results <6 mm are associated with osteoporosis.

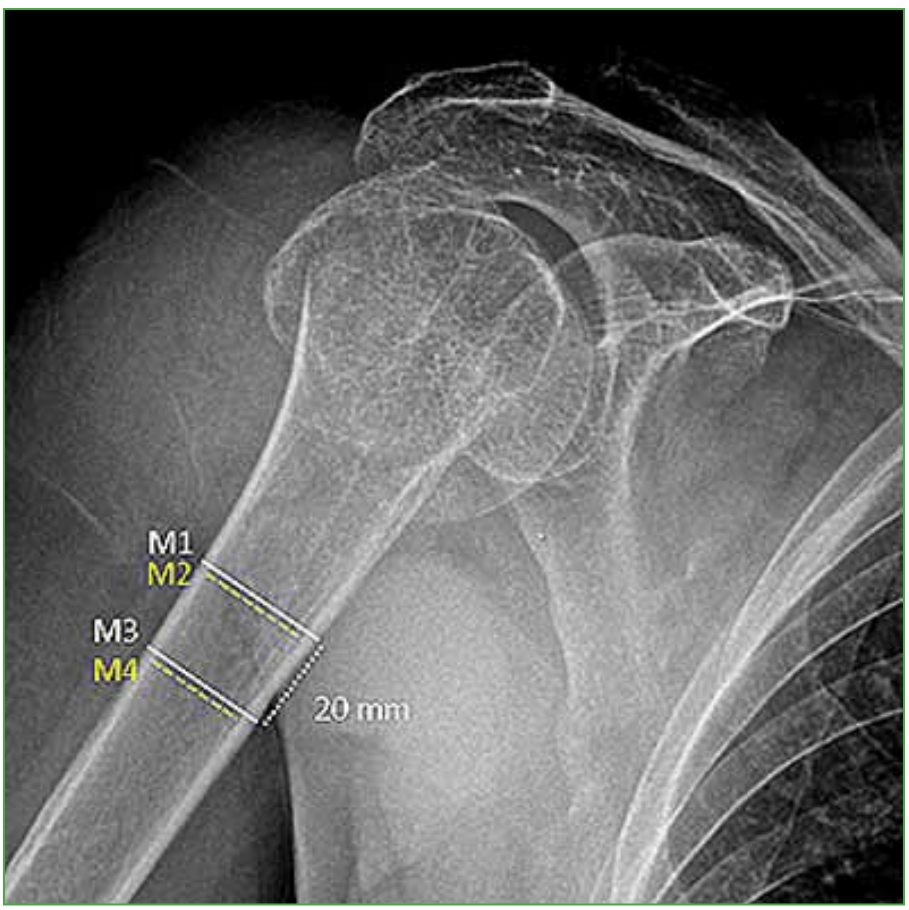

Figure 7. Mean cortical thickness of the humerus proposed by Mather et al.

The measurement consists of the difference between the total thickness of the diaphysis and the thickness of the intramedullary canal, measured at two different levels: one superior, when the diaphysis converges on two parallel cortical lines, and another 2 cm below it.[3,13,16] Postoperative radiographic controls were performed immediately after surgery and at the last visit. Humeral head height (HHH) was measured in relation to the plate, defined by the distance between a line perpendicular to the axis of the plate at the level of its upper edge and another parallel line that passes tangentially to the upper end of the humeral head. The neck-shaft angle (NSA), formed by the diaphyseal axis of the humerus and the axis perpendicular to the anatomical neck of the humerus, was also measured (Figure 8).[7]

A 3-mm change in HHH or a >5° change in the NSA was considered a loss of reduction.[17,18] Finally, the radiographic complications were recorded: fracture collapse, loss of reduction, joint protrusion of the screws, loosening of the osteosynthesis material, avascular bone necrosis of the humeral head, and nonunion.

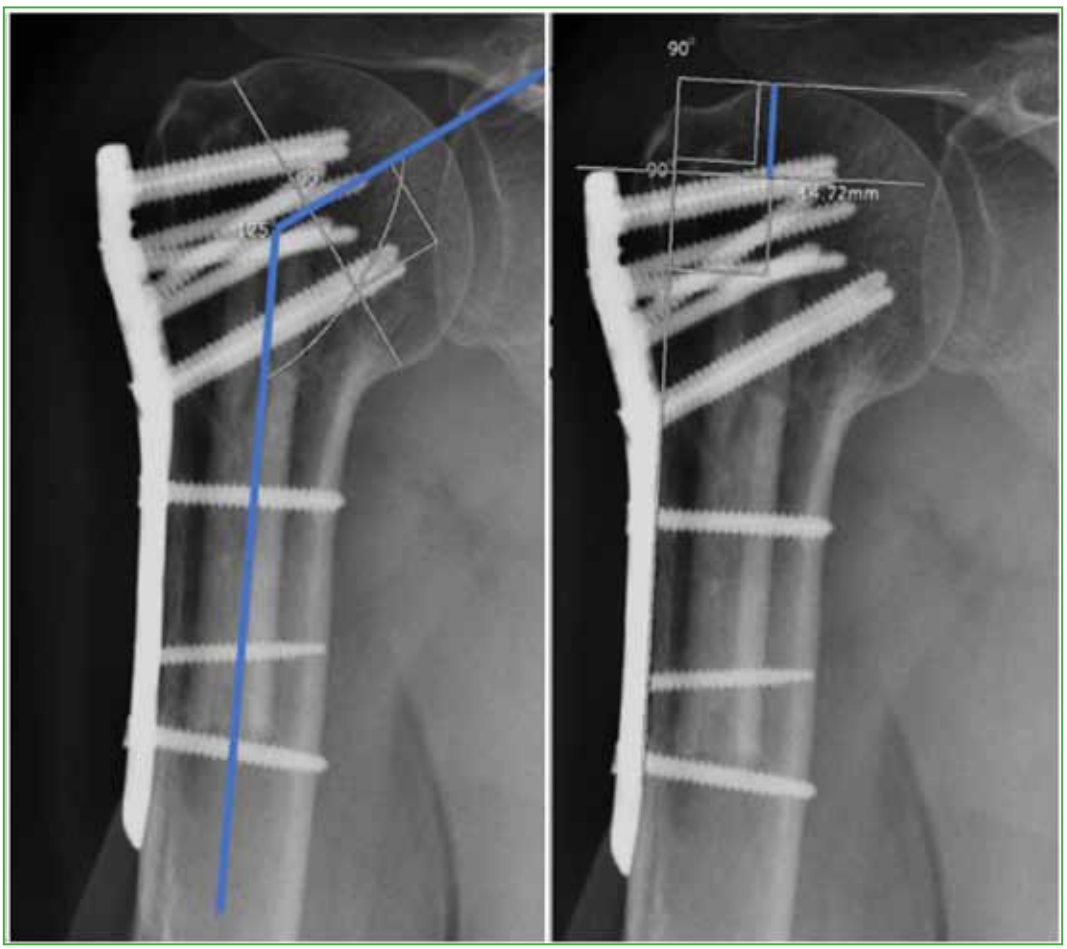

Figure 8. Anteroposterior right shoulder and axial scapula radiographs after osteosynthesis of the right proximal humerus with endosteal strut graft. The measurements, made with the program available at our Center (Synapse, Fujifilm), are shown. In blue, the neck-shaft angle (left) and the humeral head height (right) are highlighted.

RESULTS

During 2017 and 2020, we treated 243 PHFs. Fifteen patients underwent shoulder hemiarthroplasty and 75 reversed shoulder arthroplasty; 24 were treated by intramedullary nail osteosynthesis; 99, with anatomical locking plate; 14, with cannulated screws and 15, with harpoons. Fifteen were operated on with the previously described technique and 12 of them met the criteria and were included in the analysis. Of the three excluded patients, one had not completed follow-up, and the remaining two had undergone surgery for a rotator cuff injury in the affected shoulder. The group consisted of 10 women and two men, with a mean age of 62.8 years (range 22-78). The affected shoulder was dominant in seven cases. The average follow-up was 21.25 months (range 6-48).

Clinical evaluation yielded a mean Constant-Murley score of 82.1 (range 65-94) and a subjective shoulder value of 80% (range 70-95%). The average value of the visual analog scale was 1.9 points (range 1-4). Regarding the range of motion, the values were: anterior elevation 138.3° (range 100-165°), external rotation 49.6° (range 25-80°), and internal rotation corresponding to the L3 level (gluteal area-interscapular area) (Figure 9).

Figure 9. Clinical outcomes in a patient with 40 months of follow-up. Active range of motion in anterior elevation (**A**), abduction (**B**), external rotation (**C**), and internal rotation (**D**) is detailed.

Ten patients resumed their previous activities without difficulty, one reported having difficulties in daily tasks, and another withdrew from work activities due to retirement and had no functional limitations.

Eight of the 12 patients included had grade IV fractures and four had grade III fractures of the Resch classification. Insufficiency of the medial hinge was observed in eight cases (67%), humeral MCT <6 mm in three cases (with preserved medial hinge), and the combination of both factors in one patient. The mean preoperative humeral MCT value was 6.6 mm (range 4.3-7.95 mm).

Anatomical reduction was obtained in 10 patients, with two cases of varus reduction with insufficient correction of the medial hinge due to an error in the surgical technique. 83% of the patients evolved without loss of reduction according to the changes in both the HHH and the NSA. The mean change in HHH between the radiographs at the end of follow-up and those in the immediate postoperative period was 2.3 mm (range 0.4-7.24). The average difference in NSA between both controls was 4.92° (range 1-17°). Two patients presented an inadequate reduction and a HHH change >3 mm (3.4 mm and 7.2 mm). In one of these cases, a NSA change >5° (17°) was also associated (Figure 10). Both patients had an initial varus reduction, with MCT values of 6.15 mm and 6 mm. The fracture had consolidated at the end of follow-up in all patients. No clinical complications were observed and no patient required a second surgery.

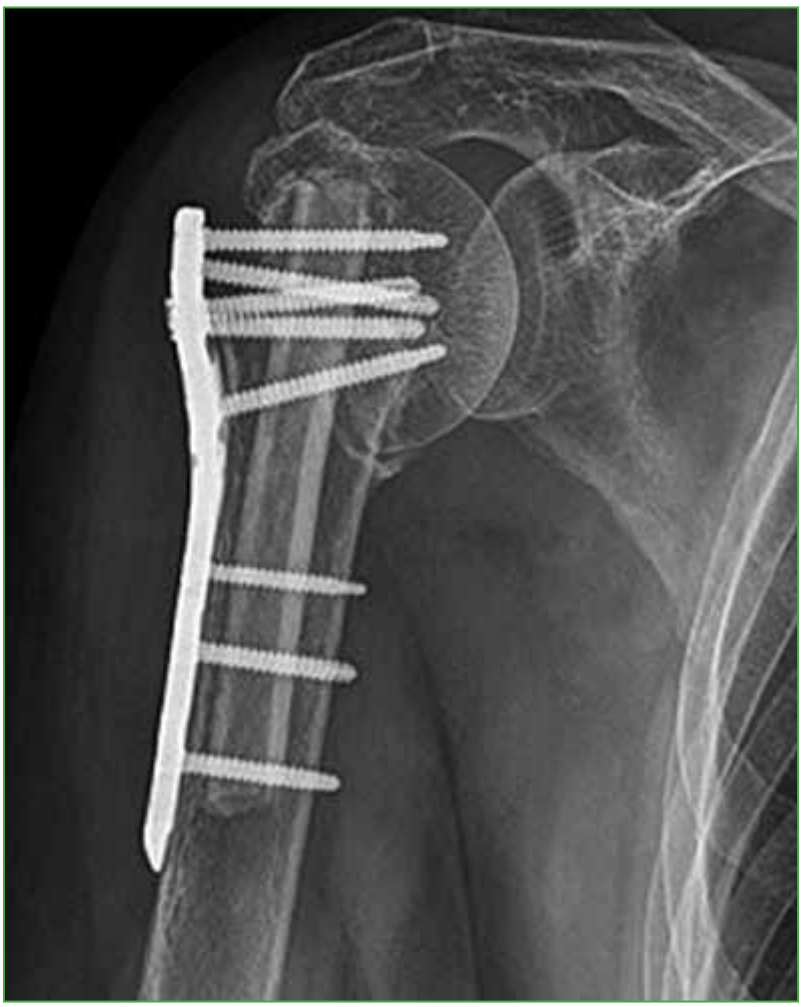

Figure 10. One case of the series with loss of reduction at the end of follow-up. The lack of medialization of the endosteal graft is observed.

DISCUSSION

Locking plate fixation with ESA prevented loss of reduction in 83% of complex surgical neck fractures with medial hinge involvement or osteoporosis. A mean Constant-Murley score of 82.1 was recorded and no second surgeries were performed in our group of patients at 21.25 months of follow-up.

In the radiographic evaluation, two patients presented a loss of humeral head height of 7.2 mm and 3.4 mm, one of them also with varus collapse. Both patients were women, 68 and 71 years old, with MCT values above 6 (6 and 6.15, respectively). Loss of reduction was due to failed reduction in unstable fractures. We attribute these results to an error in the surgical technique. Despite these radiographic failures, the clinical and functional outcomes were acceptable in both patients, with anterior elevation values of 135° and 110°, external rotation of 45° and 25°, and a Constant-Murley score of 76.

Lee et al. obtained outcomes similar to ours in a retrospective series that compared osteosynthesis of the proximal humerus with or without ESA. These authors reported a 7.1º less displaced NSA in the group treated with graft, compared to the group treated with isolated osteosynthesis (3.2º vs. 10.3°) and 2.4 mm less HHH displacement (1.8 vs. 4.2mm). Likewise, they observed a significant clinical improvement in anterior elevation in the group treated with ESA.[19] Cui et al. also reported a significant improvement in functional scores in ESA patients.[20] In both studies, there was a significant decrease in the rate of complications in the group treated with ESA.[19,20] Matassi et al. reported no more than 2 mm of HHH collapse without other complications in 17 patients treated with this technique, a mean Constant-Murley value of 79 points, anterior elevation of 149°, and external rotation of 47°.[21]

In a prospective multicenter study by Brunner et al, the overall complication rate was 35% in PHFs treated with locking plates, with screw perforation being the most common complication (22%).[6] We consider that the support of the medial surgical neck of the humerus is critical for a stable and long-lasting reduction, so in cases with medial cortical insufficiency or poor bone quality, some augmentation method is necessary. In a cadaveric biomechanical study, Hsiao et al. showed that augmentation of the locking plate with ESA doubled the load required to cause system failure.[22] In a retrospective study of 35 patients, Gardner et al. found that the presence of medial support had a significant protective effect on the loss of reduction.[7] Subsequently, Gardner et al. published the first clinical experience with this method and obtained promising results, the PHF consolidated without loss of reduction in the seven patients treated.[23] Neviaser reported low rates of loss of reduction (2.6%), screw penetration (0%), and osteonecrosis (2.6%), as well as favorable clinical outcomes in a series of 38 patients with displaced PHF treated with locking plate fixation and ESA.[24]

The use of structural grafts was also studied specifically in the treatment of surgical neck fractures in osteoporotic patients, regardless of calcar involvement. Avilucea et al. published a retrospective series of 13 patients with fractures treated by plate osteosynthesis and intramedullary structural graft introduced through the humeral head. All patients had bone consolidation at four months.[25]

Our study has limitations. In the first place, those inherent to retrospective studies and a low number of patients, which prevented us from obtaining statistically relevant results. Secondly, the absence of a control group with similar fractures treated with an alternative method did not allow us to make direct comparisons. Therefore, a comparative study between this and other procedures is pending. We consider the findings obtained to be relevant because it is the first publication in the national sphere, of a reproducible technique, which allows obtaining very good outcomes in a complex and challenging setting.

CONCLUSIONS

Anatomical locking plate osteosynthesis with ESA augmentation is a reliable technique for supporting the humeral head and medial column. Our experience with this technique demonstrated that it is a reliable option for the treatment of PHFs with osteoporosis and medial column failure. We understand that the use of ESA can minimize the frequent complications reported with locking plates. We emphasize that failures in the reduction of the medial hinge and the placement of the graft in an incorrect position can predispose to the collapse of the humeral head and to poor outcomes with this treatment.

Conflicts of interest: The authors declare no conflicts of interest.

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