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Trauma in Argentina

Dr. Fernando Bidolegui
AATO 2021 President

The year was 1992, when Dr. Guillermo Vásquez Ferro, interested in advancing the trauma specialty in the world, asked Dr. Carlos Sancineto to attend the annual meeting of the *Orthopedic Trauma Association* (OTA) the following year. This is how the *Asociación Argentina del Trauma Ortopédico - AATO* (Argentine Association of Orthopedic Trauma) was founded on March 21, 1994, in the house of Vicente López 1878; its first president was Dr. Salomón Schachter.

More than 28 years have passed and there is no doubt that both Trauma and AATO have grown steadily to the present day. This is the result of the growing interest and demand in our country (and in the rest of the world) for physician-surgeons specializing in Trauma.

It is worth noting that trauma (defined as physical damage resulting from exposure of the human body to different energy levels), especially due to traffic accidents, represents the leading cause of death in our country in people under 40 years of age, and third overall.

The constant development of courses (biannual: basic and advanced; refresher courses; conferences specialized in different topics; etc.) and conferences by our association has been a fundamental advance in the training of doctors specialized in trauma throughout the country. Renowned national guests who are part of our association have participated in these events, as well as prominent international speakers, who further enrich these meetings.

Another important aspect of the growth of the AATO was the creation of its Interior Committee, made up of surgeons from different regions of our country. This has enabled us to interact and learn from each other in a federal way, allowing us to know and learn from different situations, which strengthens us as professionals, but above all, as people.

Our annual meetings have been a turning point for the development of knowledge and camaraderie. The last two years have certainly been different, but we have been able, through our ties, to continue our goal of educating and disseminating good trauma management globally.

The educational work carried out during all these years has earned it recognition by international entities, among which the OTA stands out, where our association has actively participated in its last annual conferences, and was a guest nation in 2019. And it is one of the associations that are part of and actively participate in the IOTA (*International Orthopedic Trauma Association*), which, without a doubt, gives prestige to our work.

Participating in this issue of our mother association's journal makes us proud, but also encourages us to move forward in the development and improvement of the specialty.

I want to thank all our fellows, the board of directors, colleagues, friends, and the administrative staff of the AATO, the *Asociación Argentina de Ortopedia y Traumatología*, and its Journal for their selfless help in achieving this important goal for all of us.

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Case Presentation

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Resolution on page 299.

A 15-year-old adolescent who suffered a traffic accident. The patient denied having lost consciousness and reported severe pain in the neck, with functional impairment as well as dysesthesia in the lower limbs. He was admitted in a spine table with cervical immobilization with a collar.

The radiographs included in the management protocol for traumatized patients were requested, in which the anteroposterior and lateral radiographs of the cervical spine stood out.

FINDINGS AND INTERPRETATION OF IMAGING STUDIES

In the radiographs of the cervical spine (Figure 1), a bilateral facet dislocation was visualized in the lateral projection, as well as loss of continuity of the three lines (anterior, posterior, and spinolaminar) at C5-C6 with overlapping of the facets of C5 on C6 (circle). There were no visible fractures.

The patient was hospitalized to continue with the studies and to undergo a more exhaustive neurological evaluation.

The imaging study was completed with a computed tomography and magnetic resonance imaging of the cervical spine.

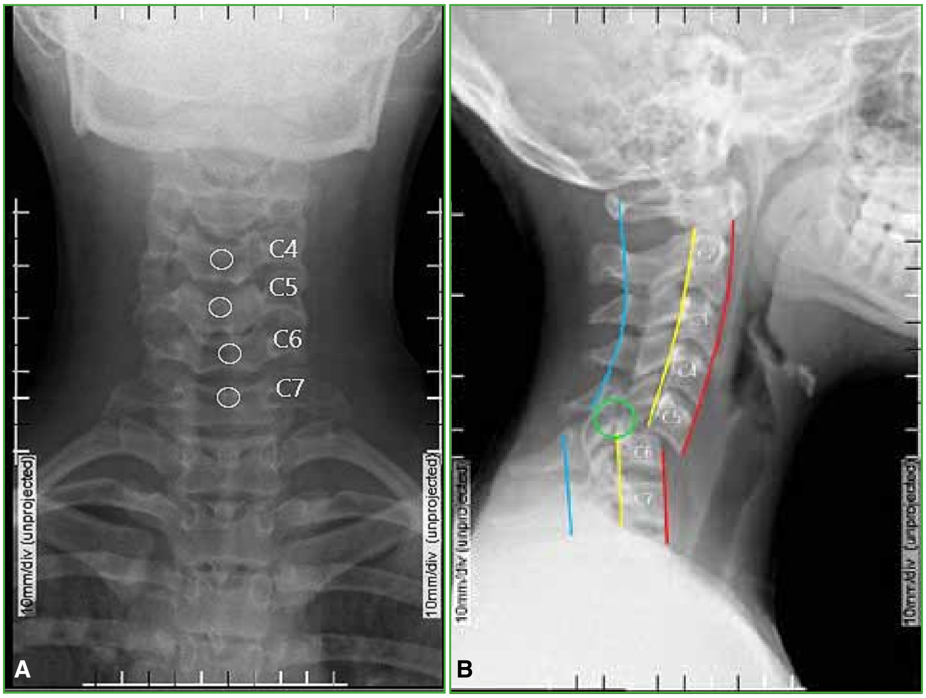

Figure 1. Cervical spine radiographs. **A.** Anteroposterior. Loss of continuity of the three lines (anterior, posterior, and spinolaminar) at C5-C6 with overlapping of the facets of C5 on C6 (circle). **B.** Lateral. Bilateral facet dislocation. Enlargement of the space between the C5-C6 spinous processes with loss of normal alignment. No evidence of fracture lines. No visible fractures.

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Cerclage Wiring in Subtrochanteric Hip Fractures. Analysis of Benefits and Complications

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ABSTRACT

Background: The aim of this retrospective study was to assess whether open reduction with cerclage wire affected the union and/or complication rate in subtrochanteric hip fractures treated with cephalomedullary nails. **Materials and Methods:** We analyzed all patients who had undergone surgery in our center between January 2010 and December 2017. We comparatively analyzed those treated with (Group A) and without (Group B) cerclage wire in terms of fracture type, hospital stay, surgical time, blood transfusions, malalignment, union, and complications (infection rates, non-union, and reoperations). **Results:** Fifty-eight patients were included. Group A consisted of 20 patients and Group B of 38. The most frequent type of fracture was 3A (*p* 0.0004). The mean hospital stay was similar (9 vs 10.6 days *p* 0.81), the surgical time and transfusions were higher in group A (*p*<0.0001 and *p* 0.58 respectively). The union rate was similar (90 vs 92.1%;*p* 0.09, respectively). Malalignment was only observed in group B (5 - 13.5%; *p* 0.01). The complication (15 vs 18.4%) and reoperation (15 vs 15.8%) rates were similar (p 0.99). **Conclusions:** The use of cerclage wire in subtrochanteric hip fractures treated with cephalomedullary nails generated a significant increase in surgical time and a lower rate of malalignment. It allowed a lower rate of re-operation, although it was not significant.

Key words: Subtrochanteric fracture; cerclage wire; union; nonunion; infection; malalignment.
Level of Evidence: III

Cerclaje con alambre en fracturas subtrocantéricas de cadera. Análisis de beneficios y complicaciones

RESUMEN

Introducción: El objetivo de este estudio retrospectivo fue evaluar si la reducción abierta con cerclaje de alambre afectó la consolidación, la tasa de complicaciones y de reoperaciones en pacientes con fracturas subtrocantéricas de cadera, tratadas con clavos cefalomedulares. **Materiales y Métodos:** Se evaluó a todos los pacientes operados consecutivamente entre enero de 2010 y diciembre de 2017. Se comparó a los tratados con cerclaje (Grupo A) o sin cerclaje (Grupo B) de alambre en términos de tipo de fractura, estancia hospitalaria, tiempo quirúrgico, necesidad de transfusiones, calidad de la reducción, consolidación y complicaciones (infección, seudoartrosis, reoperaciones). **Resultados:** Se incluyó a 58 pacientes. El grupo A estaba conformado por 20 pacientes y el grupo B, por 38. El tipo de fractura más frecuente fue 3A (p = 0,0004). La estancia hospitalaria fue similar (9.0 vs. 10.6 días; p = 0,81), el tiempo quirúrgico y la necesidad de transfusiones fue mayor en el grupo A (p <0,0001 y p = 0,58, respectivamente). La tasa de consolidación fue similar en ambos grupos (90 vs. 92,1%, respectivamente; p = 0,09). Los desejes se observaron solo en el grupo tratado sin lazadas (5-13,5%; p = 0,01). Las tasas de complicaciones (15 vs. 18,4%) y de reoperaciones (15 vs. 15,8%) fueron similares (p = 0,99). **Conclusiones:** El uso de lazadas de alambre en fracturas subtrocantéricas de cadera tratadas con clavos cefalomedulares generó un aumento significativo del tiempo quirúrgico, y disminuyó significativamente la incidencia de desejes. La incidencia de reoperaciones fue menor, aunque no significativamente.

Palabras clave: Fractura subtrocantérica; lazada de alambre; consolidación; seudoartrosis; infección; desejes.
Nivel de Evidencia: III

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INTRODUCTION

Subtrochanteric fractures represent between 4% and 19% of fractures of the proximal femur.[1,2] The muscular insertions of this anatomical region cause these fractures to present with deformities in flexion, external rotation, and abduction.

The compression and tension forces of the proximal femur require an adequate osteosynthesis that provides relative stability in search of consolidation. The treatment of choice is locking cephalomedullary nailing, which achieves a reported healing rate of up to 95%.[2-4]

The use of a traction table and, on some occasions, of elements such as levers, pins, reduction forceps, facilitates the adequate alignment of these fractures.[4-8] However, in certain fracture patterns, manipulation and closed reduction do not achieve correct alignment, and require the opening of the focus and the use of cerclage wire in 7-40% of cases, according to the literature.[2-6]

Due to the loss of the fracture hematoma and the theoretical damage to the periosteal vascularization, some authors try to avoid its use.[9-11] Perren[9] maintains that biological fixation is the ideal treatment for these fractures and that the periosteal vascularization should not be affected with open reductions or cerclage wire.

The objective of this retrospective study was to evaluate whether open reduction with cerclage wire affected union rates, complications, and reoperations in patients with subtrochanteric hip fractures treated with cephalomedullary nails.

MATERIALS AND METHODS

Between January 2010 and December 2017, 75 consecutive subtrochanteric hip fractures were treated at our center. The identification of the patients was carried out through a search in the database of our service, where each operated patient is systematically registered and the information on their evolution is collected prospectively. This study was conducted after approval by the Institutional Review and Ethics Committee of our institution.

The inclusion criteria were: patients >18 years old, subtrochanteric fracture, treatment with cephalomedullary nail, use or not of cerclage wire, minimum follow-up of 12 months.

The exclusion criteria were: fractures caused by tumor processes, fractures related to the use of bisphosphonates, and those derived from another center with some type of previous treatment.

All patients underwent surgery in the same center, by the same surgical team, on a traction table under fluoroscopy. Initially, closed reduction of the fracture was always attempted. When it was not possible, the focus was opened with careful management of soft tissues and then the fracture was directly reduced and cerclage wire was placed (Figure 1). 1.5 mm diameter wires were always used.

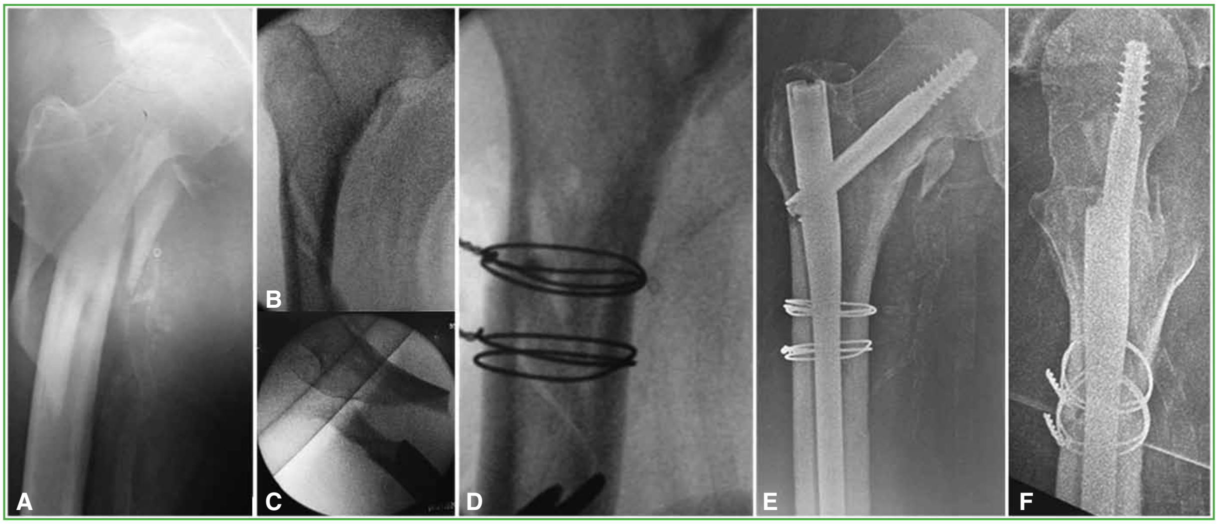

Figure 1. A. Anteroposterior radiograph of the right proximal femur. A 3A subtrochanteric fracture is observed. Intraoperative radioscopy. **B.** Anteroposterior view showing acceptable alignment. **C.** With the same reduction of image A, but in the lateral view, where a significant misalignment is observed. **D.** Reduction with cerclage wire. **E and F.** Anteroposterior and lateral radiographs of the right proximal femur in the postoperative control, where consolidation can be observed.

Postoperative rehabilitation consisted of progressive weight bearing with a walker or Canadian crutches from the second day after the operation. Clinical-radiological controls were performed at 3 and 6 weeks, and at 3, 6, and 12 months depending on the evolution of each case.

The variables analyzed were sex, age, mechanism of injury (high or low energy), type of fracture according to the Seinsheimer classification,[12] surgical time, quality of reduction, tip-apex distance, days of hospitalization, need for blood transfusions, rate and time of consolidation, any type of complication and reoperation.

On the immediate postoperative radiograph, the quality of the reduction and the tip-apex distance were assessed. The quality of the reduction was evaluated by determining the cervico-diaphyseal angle of the operated femur and the contralateral femur, evaluating the existence of angulations in both anteroposterior and lateral radiographs. Reduction was considered good when this measurement presented a comparative misalignment with the non-operated limb $<10^{\circ}$ in the anteroposterior and lateral projections; acceptable when the misalignment was observed in one of the two projections; and poor when it was observed in both projections. A rotational misalignment of $\geq 4^{\circ}$ was considered poor reduction.

The tip-apex distance was measured using the method described by Baumgaertner, and a value of ≤25mm was considered correct.[13]

Through the analysis of the successive radiographic controls, the rate and time of consolidation, and the development of any type of complication were evaluated.

In the clinical-radiographic evaluation, the fracture was considered to be consolidated if there was no pain on weight-bearing and the bone callus was observed in three of the four cortices, in the two projections (anteroposterior and lateral of the femur).

Pseudarthrosis was defined as the absence of consolidation nine months after surgery, with no progress in healing in the last three months.

For the objective analysis of function, the Harris hip score recorded at the last office follow-up was used.[14]

The results were generally evaluated for each variable and then comparatively analyzed by dividing the patients into two groups: group A, with cerclage wire, and group B, without cerclage wire.

Statistical analysis

The categorical variables were summarized with frequency and percentages. To analyze the association between the categorical variables, the chi-square or Fisher test was used when the assumptions were not verified. Continuous variables were summarized as mean and standard deviation when there were no atypical values and as median and range or interquartile range when it was more appropriate according to their distribution; they were compared between groups with the Wilcoxon test. The analysis was performed with the R program and the conclusions were drawn with a significant p value <0.05.

RESULTS

Seventeen of the 75 patients analyzed were excluded: nine because they had been treated at another Center at the time of referral, three for fractures associated with bisphosphonates, three for fractures secondary to tumor processes, and two for not complying with the minimum follow-up.

The series consisted of 58 patients with 58 subtrochanteric fractures, 35 (60.3%) were women. The mean age was 68.34 ± 22.06 years. The mechanism of injury was low energy in 39 (67.2%) cases and high energy in 19 (32.8%).

According to the Seinsheimer classification, the most frequent fracture pattern was subtype 3A (36%), followed by subtype 2B (22%), type 5 (16%), type 4 (9%), subtype 3B (7%), subtype 2C (7%), 2A (3%).

In 38 (65.5%) patients, the fracture reduction was closed and, in 20 (34.5%), open; wiring was used in all cases: one loop in eight patients and two loops in 12 patients. The fracture subtype in which wiring was used the most was 3A (52.38%, $p = 0.004$).

The implants used were: 28 PFN® (Depuy Synthes, WA Ind, USA), 16 Galileo TNS® (AOS, TO CA, USA), nine Gamma II® (Stryker, WA Ind, USA), five ITST® (Zimmer, WA Ind, USA).

The comparative characteristics regarding sex, age, and type of fracture of each group are detailed in Table 1.

Table 1. Preoperative characteristics of each group

	Group A (with cerclage wire) (n = 20)	Group B (no cerclage wire) (n = 38)	p
Female sex (%)	70	55.3	0.41
Age	75.3 ± 17.3	64.7 ± 23.5	0.07
Type of fracture (n %)			
2A	1 - 5	1 - 2.6	0.90
2B	2 - 10	11 - 28.9	0.18
2C	0	4 - 10.5	0.28
3A	11 - 55	10 - 26.3	0.004
3B	3 - 15	1 - 2.6	0.11
4	1- 5	4 - 10.5	0.65
5	2 - 10	7 - 18.4	0.47

The surgical time was 69.19 ± 8.34 min, the transfusion rate was 43.1%, and the median hospital stay in the series was 9 days (range 6-50).

The group treated with cerclage wire required fewer hospital days, more surgical time (Figure 2), and more postoperative red blood cell transfusions than the group treated without cerclage wire (Table 2).

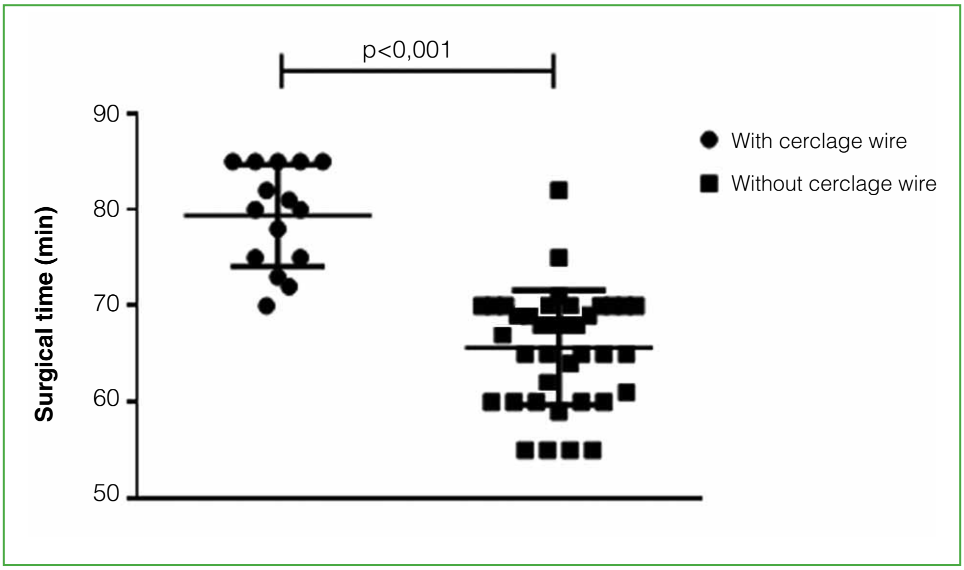

Figure 2. Distribution and significant difference regarding surgical time between groups.

Table 2. Comparative results between the groups with cerclage wire and without cerclage wire.

	Group A (with cerclage wire) (n = 20)	Group B (no cerclage wire) (n = 38)	p
Hospital stay (days) (median IQR)	9 (3-18)	10 (3-22)	0.81
Surgical time (min) (mean SD)	75.2 ± 9.05	66.03 ± 5.94	<0.0001
Transfusions (n %)	10 - 50	15 – 39,8	0.58
Reduction (n %) Good Acceptable Fair	 20 -100 0 0	 33 - 86.8 3 - 7.8 2 - 5.3	 0.46
TAD (mm) (mean SD)	14.8 ± 4	15.8 ± 3.6	0.23
Misalignment (n %)	---	5 – 13.5	0.01
Consolidation (n %)	18 - 90	35 – 92.1	0.9
Consolidation time (weeks)	15.1	15.2	0.21
HHS (mean SD)	89.8 ± 2.05	87.9 ± 3.75	0.11

IQR = interquartile range, SD = standard deviation, HHS = Hip Harris Score, TAD = tip-apex distance.

Radiographic results

The reduction was classified as good in 53 (91.4%) cases, acceptable in three (5.2%), and regular in two (3.4%) (Figure 3).

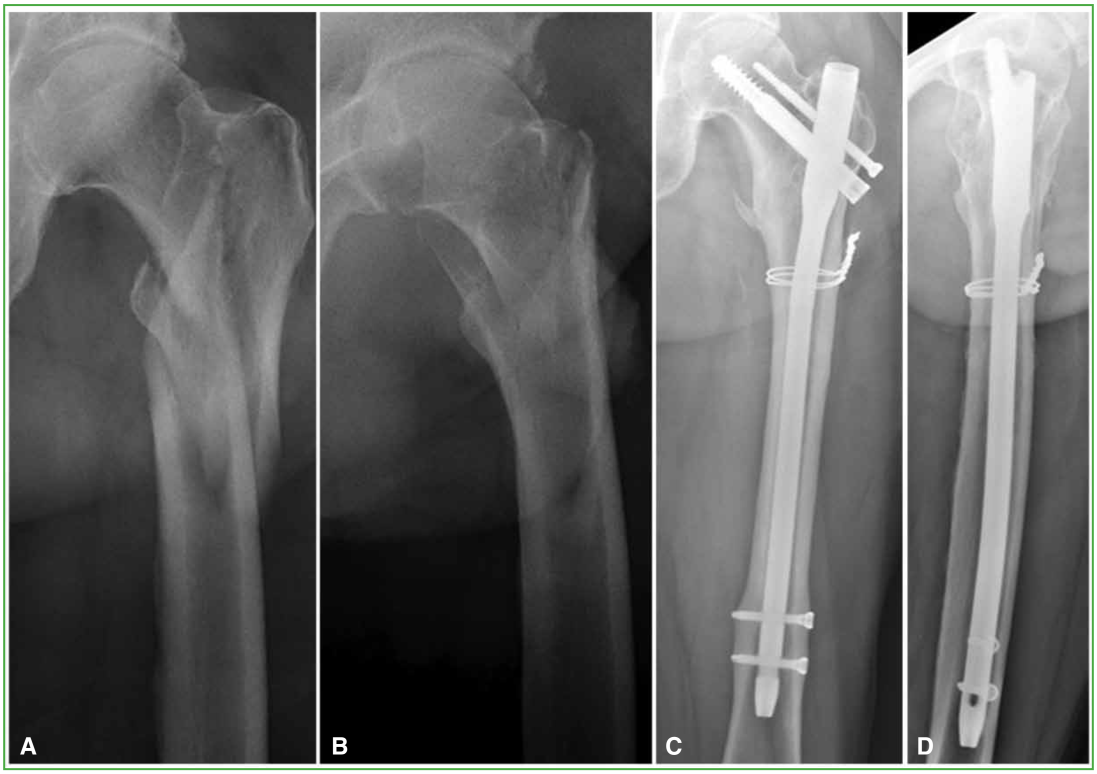

Figure 3. A and B. Preoperative anteroposterior and lateral radiographs of the left proximal femur showing a type 5 subtrochanteric fracture. **C and D.** Postoperative anteroposterior and lateral radiographs of the left proximal femur, in one of the fractures where cerclage wire was used. Good alignment and consolidation are observed in both projections.

Five (8.6%) patients, all from the group treated without wire, presented misalignment: one only in the anteroposterior view (12°); one in the anteroposterior and lateral views (12º and 10º, respectively); and two only in the lateral view (10°-15°). The remaining presented a rotational defect of 15°. The tip-apex distance of the series was 15.41 ± 3.74 mm.

The consolidation rate was 91.4% (n = 53), at an average of 15.9 weeks (range 8-32) (Table 2). The Harris hip score at the end of follow-up was 88.60 ± 3.47 (range 80-94). The median follow-up was 30 months (interquartile range 15-40).

The comparative results between the groups with and without cerclage wire are detailed in Table 2.

Complications

There were nine (15.5%) complications that required reoperations. Five patients evolved to pseudarthrosis (8.6%). Three of them were infected and were treated by prosthetic revision in two stages, with a favorable evolution. Two (3.4%) presented an aseptic pseudarthrosis, one with nail fracture, which was treated with a nail replacement, and the other with a nail replacement plus bone graft. The fracture consolidated at 22 and 26 weeks, respectively.

One patient suffered an acute infection that required surgical cleaning 20 days after the operation and subsequent antibiotic treatment. Another patient presented an internal rotation defect of 15º in the operated limb, and underwent reoperation at 48 h. Extrusion of the cephalic screw was detected in five patients, two of whom had discomfort on the lateral side of the thigh, and the screws were removed once the fractures had consolidated.

The comparative analysis of the groups showed significant differences in the presence of postoperative misalignment, while there were no significant differences regarding complications and reoperation rates (Table 3).

Table 3. Comparative detail of complications in both groups.

	Group A (with cerclage wire) (n = 20)	Group B (no cerclage wire) (n = 38)	p
Complications (n%)	3 - 15	6 – 18.4	0.99
Aseptic pseudarthrosis (n %)	1 – 5	1 – 2.6	0.99
Infected pseudarthrosis (n%)	1 - 5	2 – 5.7	0.99
Infection (n%)	1 - 5	-	0.34
Rotation defect	-	1 – 2.6	0.78
Cephalic screw removal (n %)	-	2 – 5.3	0.54
Reoperations (n %)	3 - 15	6 – 15.8	0.99

DISCUSSION

Among the main findings of this study, it is highlighted that the use of cerclage wire allowed to improve the quality of the reduction and caused a significantly lower incidence of misalignment, although it was associated with a significant increase in surgical time.

In this series, 60% of the patients who presented misalignment had to be re-operated, which highlights the importance of the reduction. We attribute this significant difference in misalignment to two points in particular. Because the loops allow a correct reduction to be achieved and maintained, they facilitate the placement of the implant at the appropriate entry point, favoring its correct positioning.[15,16]

Finsen[17] noted that, in addition to facilitating fracture reduction, cerclage wire increases the overall stability and strength of the construct, minimizing the possibility of implant fatigue. Muller et al.[18] reported similar results in their biomechanical study where they described that the use of wire loops significantly decreased the osteosynthesis failure rate.

We understand that adequate reduction is a fundamental factor for the good evolution of this type of fracture. Starr et al.[19] reported reductions with varus displacement in up to 18% of their series (2-3.4% of cases in our series). Shukla et al.[20] pointed out that this type of misalignment increases the chances of pseudarthrosis, implant fatigue, and hospitalization.

In this series, wire loops were used whenever the focus was opened. In this regard, Kennedy et al.[21] published that the opening of the fracture site without the use of wire loops causes up to 15% of reoperations due to misalignment. According to our understanding and coinciding with Afsari et al.,[4] this is generated because, by reducing the fracture with the opening of the focus on the traction table and placing the implant, on certain occasions, after releasing the traction, it is possible that the reduction is lost, at least partially.

The fracture subtype in which we used the most loops was 3A of the Seinsheimer classification. Usually, after reduction on the traction table, this fracture pattern may appear aligned when checking in the anteroposterior projection but, when evaluating the lateral projection, there may be an important misalignment (Figure 1). This displacement is not always possible to reduce with external manipulation, levers, or even with the nail itself, and requires the opening of the focus and reduction with wire loops.

In agreement with Robinet et al.,[5] and Malik et al.,[22] the use of loops in this series generated an increase in surgical time and postoperative transfusions, although the latter were not significant.

Consolidation rates were comparable to those of Trikha et al.[15] (92%) and lower than those of Kennedy et al.[21] (94.2%). Meanwhile, the need for a new procedure was higher than the 3.84% described by Robinet et al.[5] and lower than the 23% and 21% reported by Krappinger et al.,[23] and Barbosa de Toledo and Pires,[2] respectively.

Those who defend the biological fixation of the fracture and avoid the use of wire loops are based on its theoretical negative effect on the vascularization of the fracture that predisposes to consolidation problems.[24] Different histopathological studies of the femoral periosteum that describe the concept that its arteries supply nutrients longitudinally to large segments have been rejected. In this regard, Pazzaglia et al.[25] reported that, in reality, this vascularization is distributed circumferentially in the periosteum with multiple musculoperiosteal vessels that nourish it, and an average of 26 vessels per mm2 stand out, so the adverse effect of one or two loops does not significantly affect the vascularization of the fracture.

In recent years, the percutaneous placement of wire loops has gained popularity and has achieved excellent outcomes, although this requires specific instruments, which are not always available.[4,5,8] In this study, the wire loops were placed in the traditional way, with careful and meticulous handling of soft tissues, without causing a significant increase in complications, with outcomes similar to those reported with percutaneous placement.[5,8]

The limitations of this study are those of a retrospective study with a low number of patients, which limited the depth of the statistical analysis. On the other hand, the low number of reported complications may have generated a lack of statistical significance in some of the variables analyzed, causing a type 2 error. Although there was an unequal number of patients in each group, the similar distribution of their preoperative characteristics allowed for an adequate comparative analysis. The strengths are the appropriate follow-up and the fact that treatments were carried out in the same center, by the same surgical team, with identical surgical technique and pre- and postoperative evaluations.

CONCLUSIONS

The use of cerclage wire in the treatment of subtrochanteric fractures with cephalomedullary nails allowed to obtain a better quality reduction and a significantly lower incidence of displacement, with a longer surgical time. Its use was more frequent in subtype 3A fractures. Its use did not significantly affect the rates of consolidation, complications, or reoperations, at least in this series. Properly designed studies with a higher level of evidence and a higher number of patients are needed to determine the external validity of our results.

Conflict of interests: The authors declare no conflicts of interest.

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Floating Hip: Comparative Analysis of Outcomes and Associated Injuries

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ABSTRACT

Objective: We aim to describe the lengths of hospitalization, surgery, and rehabilitation of a series of patients with floating hip. As a secondary objective, to compare the outcomes obtained in terms of return to work in patients who had suffered fractures of the pelvis or acetabulum without an associated femoral fracture. **Materials and Methods:** Descriptive, retrospective, and multicenter study of patients with high-energy trauma to the pelvis and acetabulum divided into two study populations according to the presence of associated ipsilateral femur fracture (floating hip) for comparison, during the period January 2014 – March 2019. **Results:** 102 patients with pelvis and/or acetabulum trauma were included, grouped into 2 populations according to the presence of a floating hip (Floating hip: 23 patients; Pelvis/acetabulum: 79 patients). The median days of hospitalization [floating hip: median=15.5 (range=4-193); pelvis/acetabulum: 7 (3-31); p = 0.0001] and the number of surgeries per patient [FH: median = 5 (range = 3-8); pelvis/acetabulum: 2 (1-4); p = 0.0001] were higher in patients with floating hip. Additionally, temporary work disability was higher (p = 0.00012), with no significant differences in the rate of job retraining (p = 0.11). **Conclusion:** Floating hip significantly increased the length of hospitalization, necessary surgical procedures, and recovery times according to temporary work disability in patients with trauma to the pelvis and/or acetabulum.

Keywords: Floating hip; associated injuries; high energy trauma; pelvis; acetabulum.
Level of Evidence: III

Cadera flotante: análisis comparativo de resultados y lesiones asociadas

RESUMEN

Objetivo: Describir los tiempos de internación, cirugía y rehabilitación de una serie de pacientes con cadera flotante. El objetivo secundario fue comparar los resultados obtenidos en función de la reinserción laboral con los de pacientes que sufrieron fracturas de pelvis o acetábulo sin fractura femoral asociada. **Materiales y Métodos:** Estudio descriptivo, retrospectivo y multicéntrico de pacientes con trauma de pelvis y acetábulo de alta energía, divididos en dos grupos de estudio según la presencia de fractura de fémur asociada homolateral (cadera flotante) para su comparación, durante el período comprendido entre enero de 2014 y marzo de 2019. **Resultados:** Se incluyó a 102 pacientes con trauma de pelvis o acetábulo agrupados en 2 poblaciones según la presencia de cadera flotante (cadera flotante 23; pelvis/acetábulo 79). Las medianas de días de internación [cadera flotante 15,5 (rango 4-193); pelvis/acetábulo 7 (rango 3-31); p = 0,0001] y de la cantidad de cirugías por paciente [cadera flotante 5 (rango 3-8); pelvis/acetábulo 2 (rango 1-4); p = 0,0001] fueron mayores en los pacientes con cadera flotante. Además, la incapacidad laboral temporaria fue más alta (p = 0,00012), sin diferencias significativas en la tasa de recalificación laboral (p = 0,11). **Conclusión:** La asociación de la lesión cadera flotante aumentó significativamente el tiempo de internación, los procedimientos quirúrgicos necesarios y el tiempo de recuperación según la incapacidad laboral temporaria en pacientes con trauma de pelvis o acetábulo.

Palabras clave: Cadera flotante; lesiones asociadas; trauma de alta energía; pelvis, acetábulo.
Nivel de Evidencia: III

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INTRODUCTION

The term "floating" associated with a joint indicates a skeletal disruption above and below it, which may be intra-articular or extra-articular. This term was introduced by Blake and McBryde in 1975 to describe the floating knee.[1] In our case, we refer to a rare situation in which a fracture of the femur is involved with a fracture of the pelvis or ipsilateral acetabulum and that will require specific and sequential surgical treatment (Figures 1 and 2).[2]

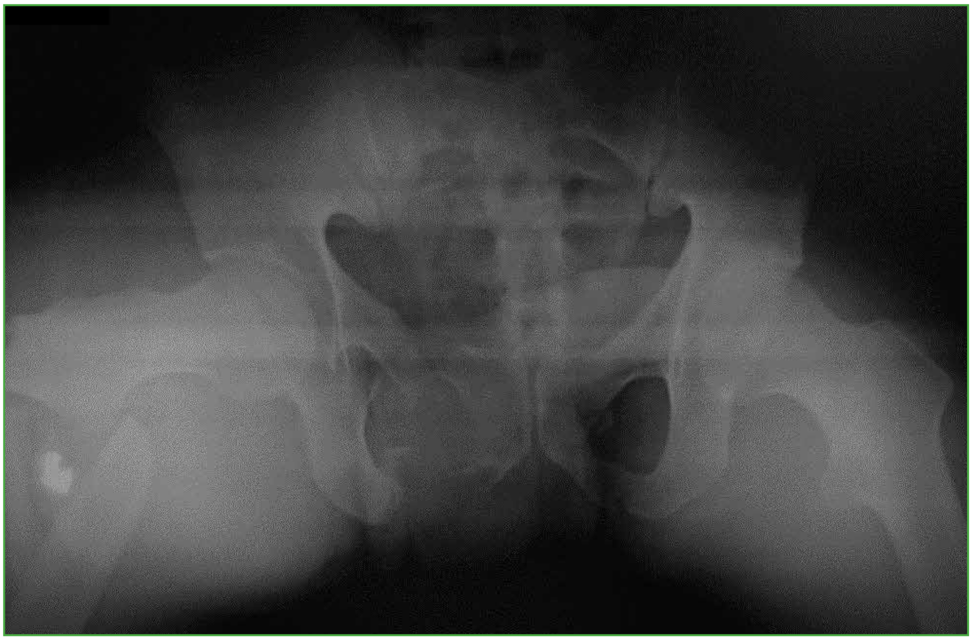

Figure 1. Anteroposterior pelvic radiograph. A pelvic fracture associated with an ipsilateral femur fracture (floating hip) is observed.

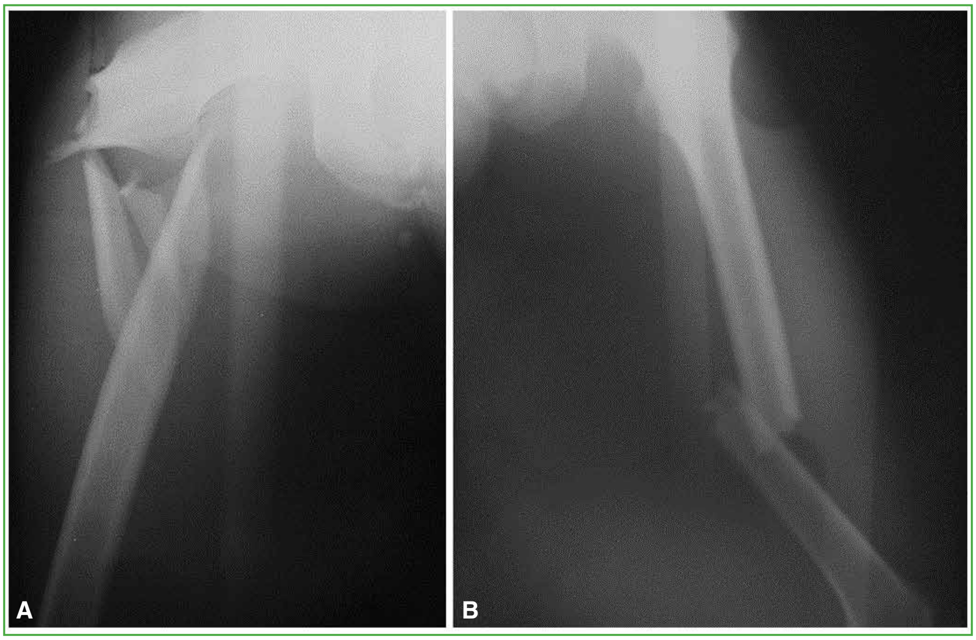

Figure 2. Anteroposterior femur radiographs with evidence of fractures (**A.** proximal, **B.** diaphyseal) in patients with floating hip.

Mechanisms of injury include high-energy accidents, and it is common for patients to sustain other associated injuries, such as fractures of other segments, soft tissue injury, traumatic brain injury, or thoracoabdominal injuries. In 1992, Liebergall classified them into three types: A, B, and C Type A floating hips (FH) are those that involve a fracture of the femur with one of the acetabulum that requires surgical treatment. Type B includes a fracture of the pelvis with another of the ipsilateral femur and type C represents a fracture of the femur together with one of the pelvis and ipsilateral acetabulum.[2] In 2002, in a series of 20 patients, Liebergall et al. explained that the mechanisms that generate these injuries are, for the most part, lateral compression, causing a fracture of the proximal femur and acetabulum, or are eventually related to the impact of the knee with the dashboard in motor vehicle accidents, with the consequent acetabular fracture-dislocation and femoral shaft fracture.[3]

The treatment of this group of patients takes place in a polytrauma setting and requires a multidisciplinary team. It poses multiple difficulties, from the initial resuscitation to the definitive resolution of the associated injuries. Various publications evidenced the need for more complex centers due to the therapeutic resources needed to treat this condition.[4,5] Although there is no management protocol for patients with FH, it is agreed that initial external stabilization is effective for resuscitation in patients who require it, since it reduces bleeding and respiratory complications, and facilitates nursing care.[6,7] Likewise, the sooner definitive osteosynthesis is performed and the patient can be mobilized, the better the functional outcomes.[8,9]

The main objective of this study was to describe the hospitalization, surgery, and rehabilitation times of a series of patients with FH. The secondary objective was to compare the outcomes obtained based on return to work with those of patients who suffered fractures of the pelvis or acetabulum without an associated femoral fracture.

MATERIALS AND METHODS

A descriptive, retrospective and multicenter study of patients with pelvic and acetabular trauma was carried out during the period between January 2014 and March 2019.

The inclusion criteria were: actively working patients, aged 18 to 65, who, at the time of admission, had a pelvic ring fracture or acetabular fracture, with a minimum follow-up of one year, between January 2014 and March 2019.

Patients with ipsilateral tibial fractures were excluded, as well as those who were initially treated at another hospital for a subsequent referral to our institution.

Patients were divided into two groups for comparison based on the presence of an associated ipsilateral femur fracture, i.e., FH patients: a) group 1 (FH); b) group 2: isolated fractures of the pelvis/acetabulum.

The data obtained from the archive of medical records and images were recorded on the following study variables: age, sex, Judet classification for acetabular fractures,[10] Tile classification for pelvic fractures,[11] and AO classification for femur fractures, number and topography of associated injuries, total surgical time, blood loss in trauma surgical procedures, temporary incapacity for work, hospitalization time in days, number of trauma surgical procedures per patient (skeletal and soft tissue), and need for job retraining.

All were evaluated following the ATLS (Advanced Trauma Life Support) protocol for the primary review of polytraumatized patients (ABCDE). When the case required it, hemodynamic stabilization and orthopedic damage control were performed[12] according to clinical parameters, initial analysis results, Injury Severity Score, and type of injury (unstable pelvic fractures with hemodynamic compromise).

Statistical analysis

Categorical variables were expressed as numbers and percentages, and were analyzed using the chi-square method or Fisher's test. The interval variables were described with the mean and median, according to their distribution and measure of dispersion, standard deviation (SD), and range. For the comparison of continuous variables, Student's t and Mann-Whitney-Wilcoxon U tests were used according to the expressed distribution. A p value <0.05 was considered statistically significant. For the analysis, the SPSS Statics 25 program was used.

RESULTS

A total of 102 patients with trauma to the pelvis or acetabulum were included, divided into two groups according to the presence of FH (FH: 23 patients, pelvis/acetabulum: 79 patients). Table 1 summarizes the global description of the sample.

Table 1. Sample Description

Variables	Results
Group, n (%) Floating Hip Pelvis or acetabulum	 23 (22.5) 79 (77.5)
Age Mean (SD) Median (range)	 38 (12) 39 (27-49)
Sex, n (%) Female Male	 23 (22.5) 79 (77.5)
Job retraining Yes No Suggested	 18 (17.6) 35 (34.3) 49 (48)
Number of procedures Mean (SD) Median (range)	 3 (1) 2 (2-3)
Days of hospitalization Mean (SD) Median (range)	 13 (23) 8 (5-10)

SD = standard deviation.

Regarding the patients in group 1 (FC), 60.9% (n = 14) were men and 39.1% were women (n = 9), with a mean age of 30 years (SD = 10). The mechanism of injury was motorcycle-car collision (78.2%, n = 18), car-car collision (13%, n = 3), and fall from own height (8.8%, n = 2). 60.8% of the patients (n = 14) had a Liebergall type A classification; 30.45% (n = 7), type B; and 8.7% (n = 2) type C. The mean follow-up time was 4.6 years (range 1.2-5).

After primary review and initial resuscitation according to the ATLS protocol with temporary stabilization of the fracture using external supports in patients, osteosynthesis was scheduled (Figures 3-5).

The femur fracture had been treated with intramedullary nails in 95.7% (n = 22) (Figure 6) and with plate and screws only in 4.3% (n = 1). The median number of hospitalization days for this population was 8 (range 5-10). The median duration of the procedures was 247 min (range 120-480) and the median estimated blood loss during the operation was 500 ml (range 300-900).

The median number of trauma procedures performed per patient was 5 (range 4-5). The median time until complete resolution of FH was 12 days (range 2-54), mainly delayed by the clinical-hemodynamic status of the patient. At the time of discharge, 17 (73.9%) patients had no pain and two (8.8%) had an injury to the external popliteal sciatic nerve, which remitted completely in both cases, six and eight months after surgery. 56.5% (n = 13) suffered associated injuries (Table 2).

In relation to group 2 (n = 79), 82.3% (n = 65) were men and 17.7% (n = 14), women. The average age was 41 years (SD 12). In this population, 77.2% (n = 61) had pelvic fractures: 25 Tile A, 28 Tile B, and 8 Tile C. The rest (22.8%, n = 18) had acetabular fractures, which, classified according to Judet, included: 4 type A, 3 type B, 5 type C, and 6 type D.

Figure 3. Patient with floating hip on the operating table before proceeding to damage control.

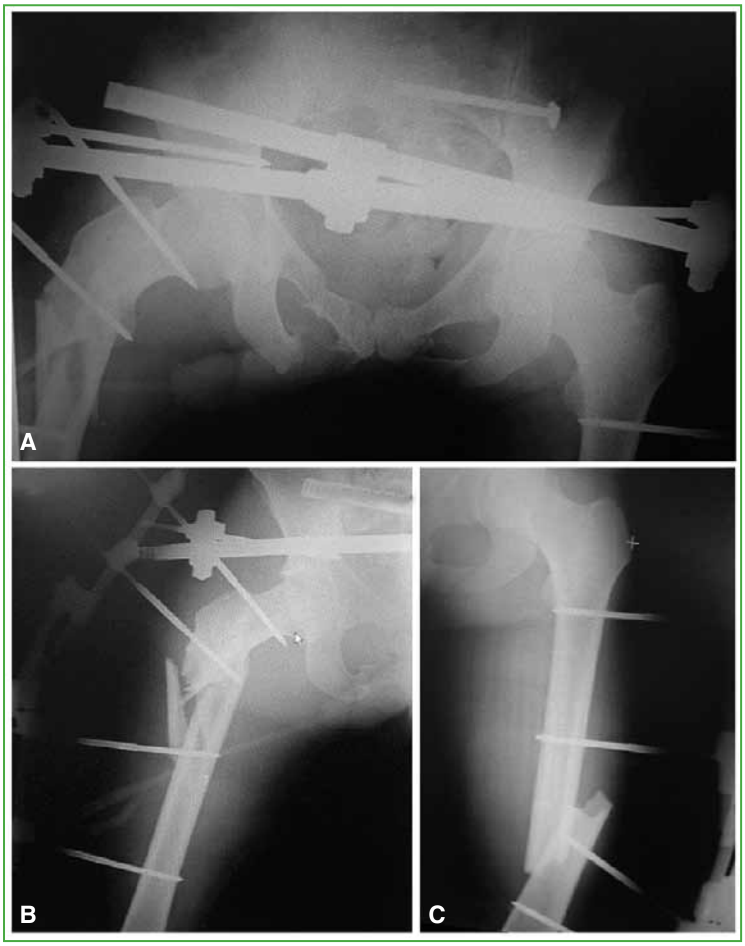

Figure 4. Anteroposterior radiographs of the pelvis and both femurs after damage control surgery. **A.** Placement of external tutors and posterior pelvic fixation. **B and C.** External fixation of femur.

Figure 5. Patient with floating hip after stabilization with external fixators.

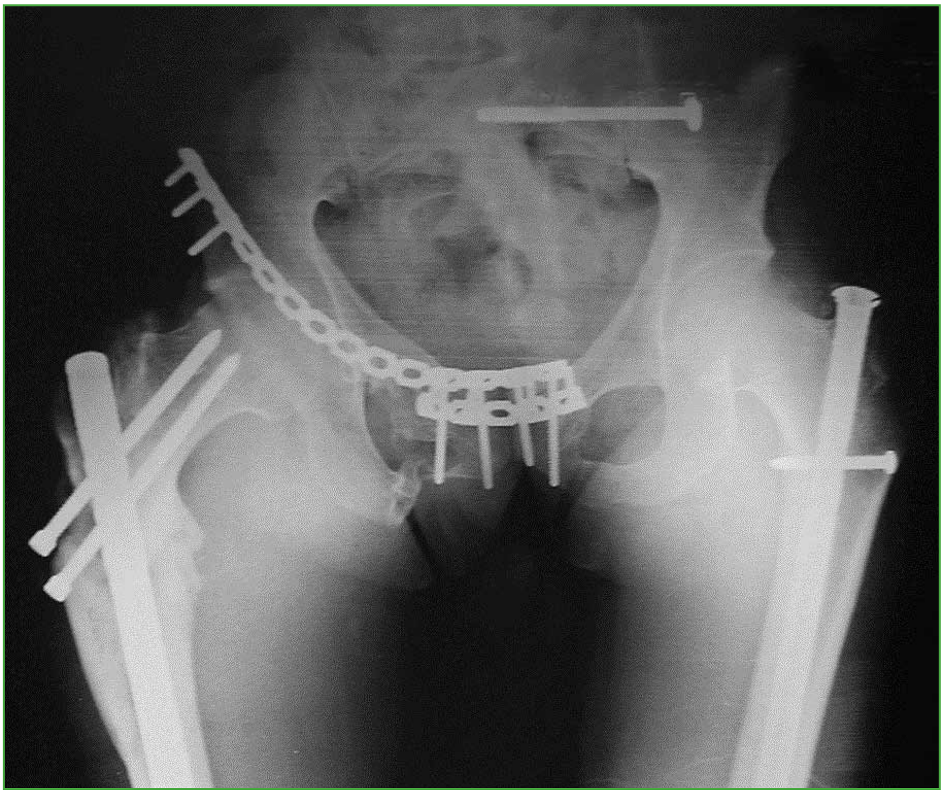

Figure 6. Pelvic radiograph including proximal femur. Postoperative control of a patient with floating hip and osteosynthesis of the pelvis and bilateral femur.

Table 2. Characteristics of the floating hip group.

Patient	Age	Sex	Pelvis (Tile) or acetabulum (Judet)	Femur (AO)	Associated injuries
1	25	F	A1	C.	TiF + MI
2	47	M	Judet A	33 A3	TMD + TiF
3	23	F	B1	32 A3	OF
4	22	F	A2/ D Judet	32 A3	PTX + STI + LSF
5	49	M	A1	C.	TPF + AF + PTX
6	25	M	E Judet	33 C3	BCP + PTX + UGI
7	28	F	A1	31 C	No
8	40	M	Judet A	33 B1	No
9	21	M	C3	32 A2	SFAL + AF + RF + mild TBI + EPSNP
10	24	M	B1	32 B3	No
11	37	F	B2	31 B	No
12	40	M	B2	31A3	No
13	19	M	B2	33C3	RF
14	23	M	A2/ D Judet	31A3	No
15	22	M	C1	32A3	HF + moderate TBI + OF + FF
16	26	M	F Judet	31A2	No
17	27	M	C3/ J Judet	32A3	TiF
18	19	M	B1	32B2	PTX
19	31	F	C3	32A3/33C1	BPC + OF + TiF + LSF + SFAL
20	35	F	G Judet	33C2	TPF + EPSNP
21	32	F	B2	32A2/32A2	HF
22	49	M	D Judet	33 A3	No
23	42	M	D Judet	31 A3	No

BPC = bilateral pulmonary contusion, FF = forearm fracture, RF = rib fracture, LSP = lumbar spine fracture, HF = humerus fracture, OF = olecranon fracture, TiF = tibial fracture, TPF = tibial plateau fracture, RF = radius fracture, AF = ankle fracture, SFAL = superficial femoral artery laceration, MI = meniscal injury, STI = soft tissue injury, TMD = tarsometatarsal dislocation, UGI = urogenital injury, PTX = pneumothorax, EPSNP = external popliteal sciatic nerve palsy, TBI = traumatic brain injury.

The surgical treatment of acetabular fractures included open reduction and internal fixation (n = 18) through a Kocher-Langenbeck approach in 50% (n = 9) of cases, an ilioinguinal window approach in 11.1% (n = 2), and, in 38.9% (n = 8), the reduction and osteosynthesis of the fracture were done percutaneously. Patients with pelvic fractures were operated on according to the fracture pattern. 24% percent (n = 6) of patients with Tile A fractures were treated percutaneously. All patients with Tile B fractures were treated with open reduction and internal fixation through a Pfannenstiel approach and the placement of one or two sacroiliac screws according to the Routt-Matta technique.[13] In 25% (n = 2) of those with Tile C fractures, reduction and anterior and posterior osteosynthesis were required, and the other cases were resolved with reduction and anterior osteosynthesis through a Pfannenstiel approach and the placement of percutaneous sacroiliac screws according to the Routh-Matta technique.

Median follow-up time was 4.5 years (range 1.2-5); hospitalization days, 7 (range 5-9); and duration of orthopedic procedures, 132 min (range 90-252). Regarding the number of orthopedic procedures per patient, the median was 2 (range 2-3). A median blood loss of 320 ml (range 250-700) was confirmed.

Comparison of the groups

When both groups were compared, significant differences were found according to age (p <0.0002) (Figure 7). Due to this difference, the sample was paired by age and sex characteristics, so that the groups could be comparable.

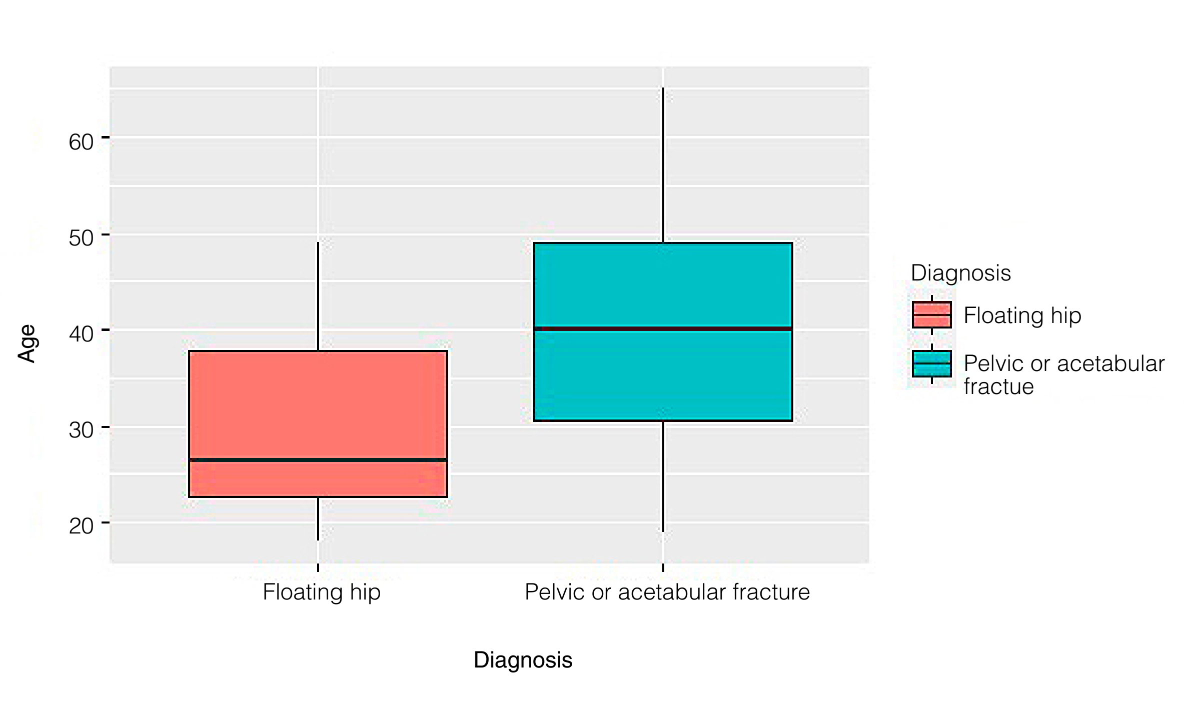

Figure 7. Box plot, age distribution according to floating hip versus pelvis/acetabulum diagnosis. The significant difference in the median age of both populations is observed.

Thus, only a subgroup of 86 patients was included in the comparison, of which 23 were from the FH group and 63 from the pelvis/acetabulum group, with no statistically significant differences between the age (p = 0.054) and gender (p = 0.15) (Figure 8).

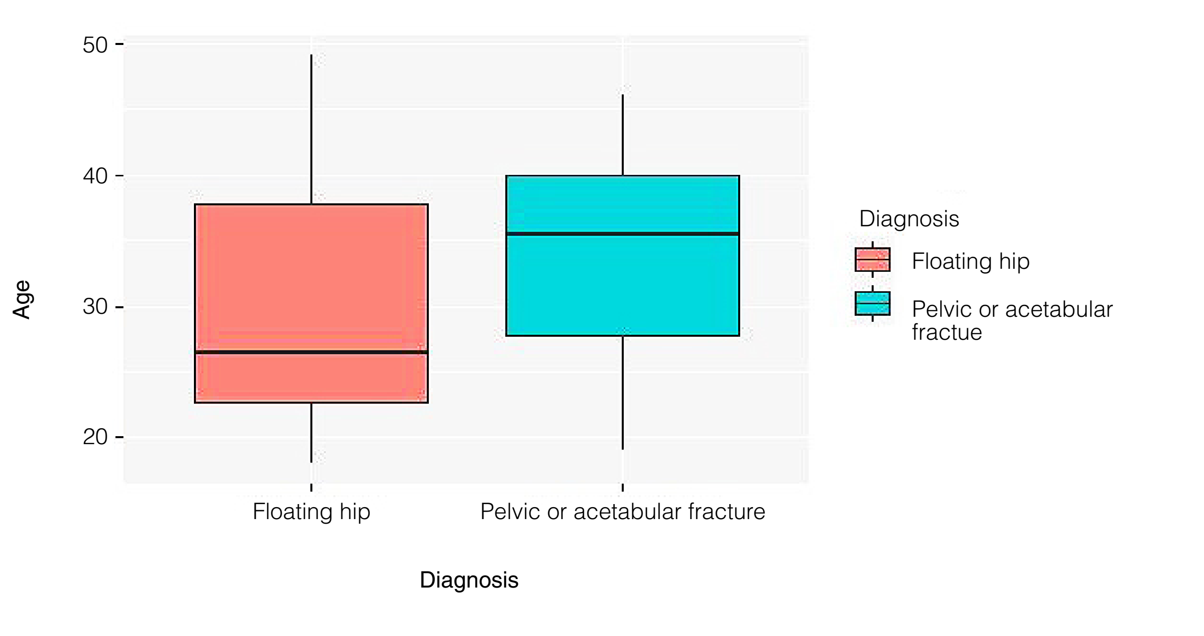

Figure 8. Box plot, distribution of age by floating hip versus pelvis/acetabulum diagnosis after age-sex pairing. No significant differences in the median age of both populations.

In this subgroup of the sample, the median number of surgical procedures per patient was 3 (range 1-8), with a mean of 2.99 (SD 1.5). The median number of hospitalization days was 8 (range 3-193), with a mean of 15.12 days (SD 26.9).

When analyzing these variables in the comparison between patients with FH versus those with fracture of the pelvis/acetabulum, the median days of hospitalization [FH 15.5 (range 4-193); pelvis/acetabulum 7 (range 3-31); p = 0.0001] and the number of surgeries per patient [FH 5 (range 3-8); pelvis/acetabulum 2 (range 1-4); p = 0.0001] were higher in patients with FH, with a statistically significant difference in the distribution of both variables (Figure 9).

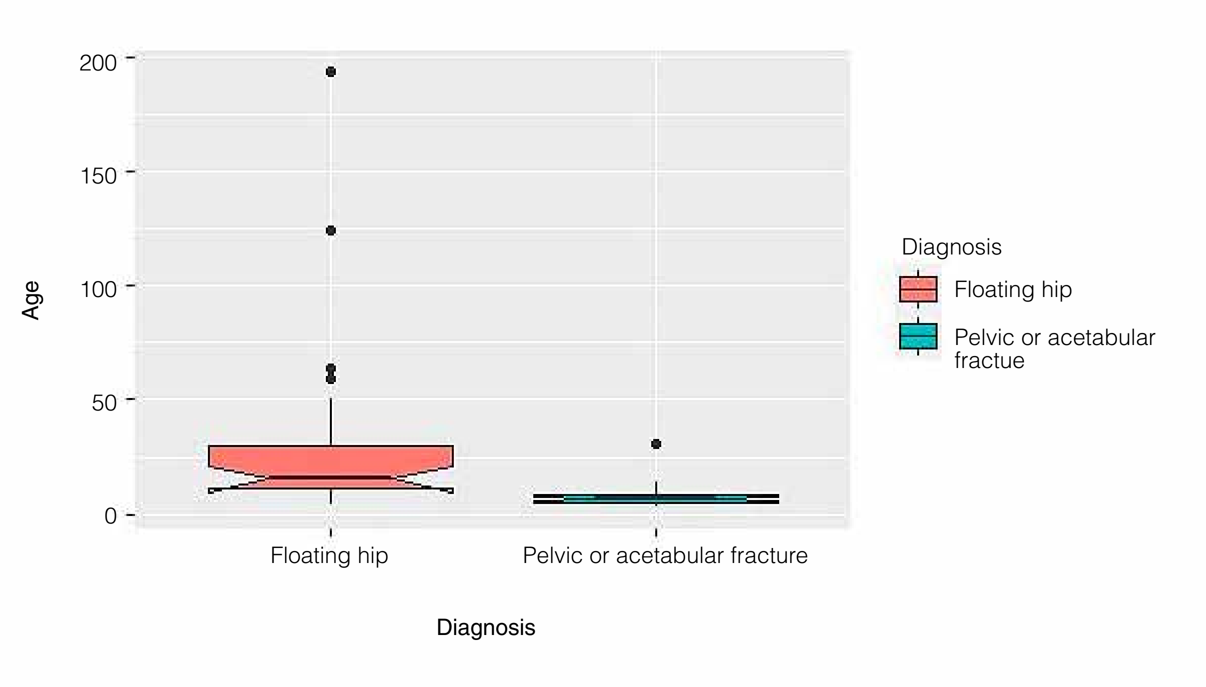

Figure 9. Box plot, distribution of days of hospitalization according to diagnosis. A statistically significant difference is observed with a higher median of hospital days in patients with floating hip.

The differences between the groups regarding temporary incapacity for work were statistically significant ($p = 0.00012$). There were no statistically significant differences in the job retraining rate between the groups based on the FH diagnosis ($p = 0.11$) (Figures 10 and 11).

DISCUSSION

Pelvic and acetabular fractures require a meticulous evaluation and skillful reconstruction to achieve the best possible outcome. The association of a femoral shaft fracture is a devastating injury that has a great impact on the quality of life of the patient. In the 1990s, Liebergall et al.[2] described this type of injury in a series of 17 patients, and Müller et al.[14] also presented 40 patients. In our study, the initial treatment of these patients was hemodynamic stabilization with external fixators, both in the femur and in the pelvis, if required. More than one surgical procedure was necessary to resolve this type of injury and the femur fracture was always the first to be treated. Liebergall et al. had a similar experience with femoral fixation as an initial procedure over fixation of pelvic or acetabular fractures, while Müller et al. fixated the femur first in only 38% of their patients.[2,14] Liebergall et al. reported several interesting correlations regarding the mechanism of injury and the type of acetabular and femoral fractures. Their data showed that car dashboard trauma was associated with proximal femoral injuries and posterior acetabular fractures, while lateral impact was associated with femoral shaft and central acetabular injuries, which would be consistent with the kinematics of transmitted energy.[2] In addition, they observed that midshaft injuries and proximal femoral fractures correlated with posterior and central acetabular fractures.[2]

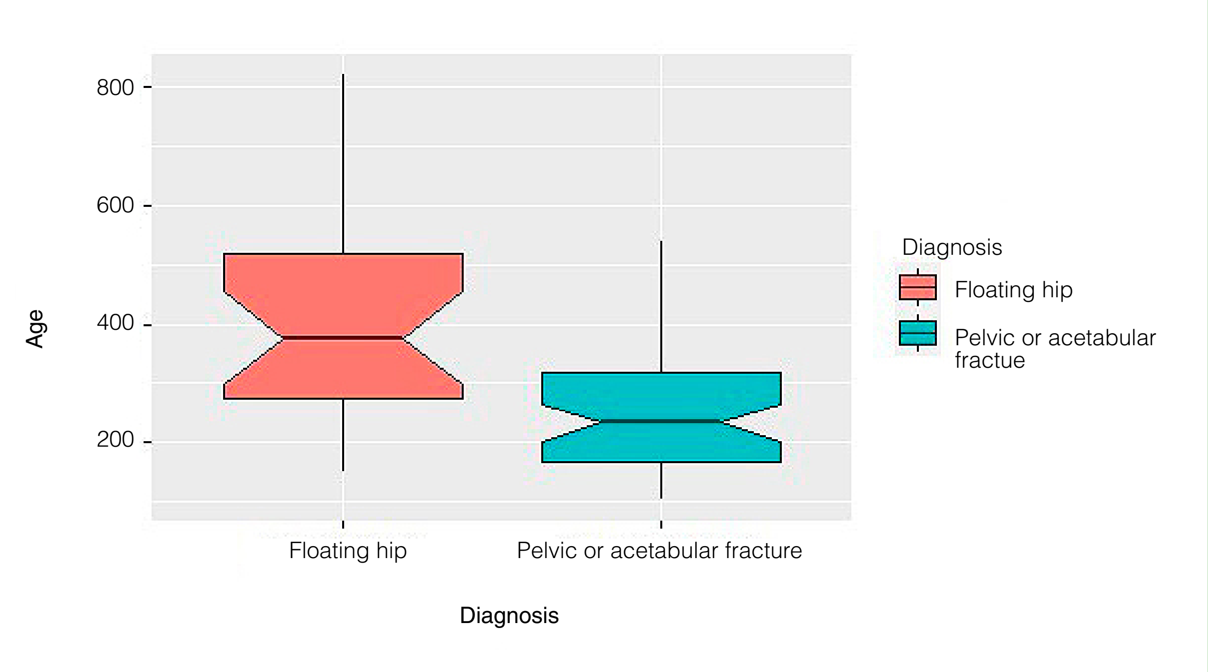

Figure 10. Box plot, distribution of days of temporary incapacity for work by group. Note that the differences were statistically significant.

Figure 11. Stacked bar chart, distribution of job retraining rate according to diagnosis.

Achieving the reduction and stabilization of the femur fracture as the first surgical stage allowed us to carry out a better preparation of the patient and achieve a better position on the operating table at the time of observing, reducing, and stabilizing the fracture of the pelvis or acetabulum According to the literature, the orthopedic surgeon must examine the pathophysiology of the trauma and evaluate the complexity of the injuries of each traumatized patient, considering the urgent need to wait for the definitive surgery to avoid the second inflammatory impact that surgery can produce.[14,15]

The results in patients with FH must be evaluated from several points of view, including the functional, physical, emotional and economic aspects.[16,17] In the FH group, the rate of complications was higher. As previously published, it is worth highlighting the sciatic nerve injuries in two patients.[18,19]

Statistically significant differences were found regarding the length of hospitalization in both groups, which would lead us to think of an eventual possible relationship with the femoral injury when analyzing this variable. Also, non-orthopedic associated injuries that prolong hospital stay should be considered and were not analyzed in the study. We must emphasize that no published articles analyzing this item were found.

When evaluating the number of procedures performed in both groups, a statistically significant difference was found, which was greater in patients with FH. We believe that it is related to the association of other soft tissue and non-orthopedic injuries that could delay skeletal stabilization. Also, this population required more days of hospitalization.

Regarding temporary incapacity for work, the seriousness of FH was statistically demonstrated in terms of the time it took for patients with pelvic and acetabulum trauma to achieve labor reinsertion.

When analyzing the job retraining rate, no statistically significant differences were found. The job retraining rate may be related to each patient's work activity and associated non-orthopedic injuries that were not evaluated in this study. We also did not find any literature concerning this item.

Finally, regarding the blood loss recorded in the FH group during surgery, although its estimation was not the primary objective of our study, it is worth noting the lower blood loss than that reported in the original study by Liebergall et al. in 1992.[2] We believe that this could be due to better resuscitation techniques, the use of systematized protocols in orthopedic damage control surgery, the use of tranexamic acid in trauma surgeries, and the development of percutaneous techniques.

As for the weaknesses and limitations of our study, we can mention that it is a descriptive, retrospective study based on the analysis of medical records and images; thus, the patients could not be evaluated with any satisfaction scale, leading to an eventual bias. However, we consider that it is a significant contribution, because it provides information on an association of high-morbidity injuries, with few international publications and without precedents published in our country and the regio

CONCLUSION

In our series, patients with FH required more surgical procedures and days of hospitalization, and temporary incapacity for work was greater, with the consequent increase in days of rehabilitation, compared to isolated fractures of the pelvis or acetabulum. No differences were found in the job retraining rate.

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

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Treatment of APCII Pelvic Fractures. Variables That Affect the Outcomes

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ABSTRACT

Introduction: Pelvic fractures are frequently associated with high-energy trauma. Mortality varies from 5%-46%. In these patients, the factors related to poor outcomes are still controversial. **Purpose:** To explore if the variables analyzed were related with the long term outcomes of the treatment of an anterior-posterior compression type II pelvic fracture (APCII; AO/OTA: 61B2.3). **Materials and Methods:** 79 cases were analyzed and 23 patients remained for evaluation according to inclusion and exclusion criteria. Pelvic radiographs (anteroposterior, inlet and outlet) and CT-scans were evaluated. The Young & Burgess classification was used to define the fracture pattern and the Majeed Score for clinical outcomes. Variables analyzed: emergency treatment, associated injuries, delay for definitive fixation, method of fixation, quality of immediate postoperative reduction and surgical site infection. **Results:** We did not find any statistical relation between the type of emergency treatment, associated injuries, delay for definitive fixation, method of fixation, and the long-term clinical outcome. Patients who had an immediate postoperative reduction of less than 1 cm and those who did not have a surgical site infection obtained better functional outcomes (statistically significant). **Conclusion:** The quality variables of immediate postoperative reduction and surgical site infection in patients with APCII pelvic fracture had a direct relation with long-term functional and clinical outcomes.

Key words: Pelvic fracture; APCII; Majeed score; variables.
Level of Evidence: IV

Tratamiento de las fracturas de pelvis APCII. Variables que afectan el resultado final

RESUMEN

Introducción: Las fracturas de pelvis se asocian frecuentemente a un trauma de alta energía. La tasa de mortalidad varía del 5% al 46%. El objetivo de este estudio fue explorar si las variables analizadas se asociaron con el resultado final del tratamiento de las fracturas de pelvis APCII (AO/OTA: 61B2.3). **Materiales y Métodos:** Se evaluó a 23 de 79 pacientes luego de aplicarles los criterios de selección. Las fracturas fueron clasificadas, según Young y Burgess, en una radiografía panorámica de pelvis, de entrada y de salida, y tomografía computarizada. Se evaluó el resultado clínico según la escala funcional de Majeed. Las variables evaluadas fueron: tratamiento en la urgencia, lesiones asociadas, días de espera hasta la cirugía, fijación utilizada, reducción posquirúrgica inmediata, infección del sitio quirúrgico. **Resultados:** No se halló una diferencia estadísticamente significativa entre el tipo de tratamiento realizado en la urgencia, las lesiones asociadas, los días de espera hasta la cirugía y el tipo de fijación, con el resultado final a largo plazo. Los pacientes que tuvieron una reducción posoperatoria inmediata <1 cm y los que no sufrieron una infección del sitio quirúrgico obtuvieron mejores resultados funcionales, de manera estadísticamente significativa. **Conclusión:** Las variables calidad de la reducción posquirúrgica inmediata e infección del sitio quirúrgico en pacientes con fractura de pelvis APCII se asocian directamente con los resultados funcional y clínico a largo plazo.

Palabras clave: Fractura de pelvis; APCII; escala de Majeed; variables.
Nivel de Evidencia: IV

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INTRODUCTION

Pelvic fractures affect approximately 20-37 per 100,000 inhabitants per year. They are associated with high-energy trauma, and the main cause is car accidents, although they can also be caused by low-energy trauma.[1] The mortality rate varies from 5% to 46% and is directly related to the type of injury. suffered trauma.[2,3] In addition, this condition generates long periods of hospitalization and recovery.[4]

If pelvic fractures are not treated correctly, they can cause long-term sequelae, such as chronic pain, dysmetria and various functional problems.[5,6] In the event of an injury to the pelvic ring, we must determine the magnitude and decide on the appropriate management of the patient according to the degree of instability.[7,8]

The classification system developed by Young and Burgess[9] is still widely used. Injuries to the pelvic ring can be of different magnitudes and cause a wide range of instabilities that can be life-threatening.[10] In injuries due to an anteroposterior compression mechanism (type II of the Young and Burgess classification), called “open book” (APCII), the pubic symphysis, pelvic floor (including sacrospinous ligament), and anterior sacroiliac ligaments are injured. The posterior ligaments remain intact, so the hemipelvis is defined as partially unstable.[11] According to the AO/OTA classification,[12] this injury is classified as 61B2.3. To unify the nomenclature, in this study, they will be defined as APCII.

The classic treatment of APCII lesions was based solely on anterior fixation. Over time, and with the analysis of the range of rotational instability, the need for supplementary fixation of the posterior ring with sacroiliac screws was recognized.[13-16] A series of controversies regarding variables and definitive treatment have taken place in the literature, some of which we will analyze in this article.[2,3,5-7,11]

The aim of this study was to explore whether emergency treatment, associated injuries, waiting time for definitive surgery, type of fixation used, postoperative reduction, and surgical site infection were associated with final functional outcome in patients who suffered pelvic fractures due to type II anteroposterior compression mechanism of the Young and Burgess classification.

MATERIALS AND METHODS

A retrospective study was carried out in a cohort of patients with anteroposterior type II pelvic compression fractures of the Young and Burgess classification by collecting data from the medical records archive of the Orthopedics and Traumatology Service. All patients signed the corresponding informed consent form and we obtained the approval of the ethics committee of our hospital. We began with a “pelvic fracture” diagnosis and then each particular clinical record was selected according to the inclusion and exclusion criteria.

The inclusion criteria were: 1) age >15 years, 2) type II anteroposterior compression fractures of the pelvis according to the Young and Burgess classification (APCII; AO/OTA: 61B2.3), 3) surgery performed in our site between January 2014 and January 2018, 4) minimum follow-up of one year, and 5) surgeries performed by the same surgeon.

Patients with one or more of the following characteristics were excluded: 1) >75 years old, 2) pathological fracture, 3) fractures with orthopedic treatment, and 4) psychiatric illnesses and sensorium decline that prevented interpretation and compliance with indications.

According to the criteria described, 23 patients were obtained for analysis from a sample of 79 patients with pelvic fractures in our hospital.

Fractures were classified according to the Young and Burgess classification in panoramic (Figure 1), pelvic inlet (Figure 2) and outlet (Figure 3) radiographs, and computed tomography.

Clinical evolution was evaluated with the Majeed scale,[17] which assesses pain, sitting, standing and walking, and sexual intercourse, with a maximum score of 80 that decreases according to severity. The sum of the parameters yields a score and this is evaluated as: excellent (70-80 points), good (55-69 points), fair (45-54 points), and poor (<45 points). The original score also includes work activity, adding 20 more points, reaching a maximum of 100. This variable was not included, because it would generate more confusion in the results, since not all the patients analyzed were working when they had an accident. In addition, work activities varied widely, from field laborers and construction workers to administrative and other jobs without greater physical effort than sitting in front of a computer for less than four hours.

The variables evaluated were: 1) emergency treatment, 2) associated injuries, 3) waiting days until surgery, 4) type of fixation used, 5) quality of immediate postoperative reduction, and 6) surgical site infection.

Figure 1. Panoramic pelvic radiograph.

Figure 2. Pelvic inlet radiograph.

Figure 3. Pelvic outlet radiograph.

Each variable was analyzed per patient, and the result obtained according to the Majeed scale was compared between subgroups.

Emergency treatment was analyzed according to whether it had been a pelvic strap, anterior external fixation, or pelvic packing. The patients were divided into two groups: those treated with a strap and those treated with external fixation or pelvic packing. External fixation is supra-acetabular, unless it is not possible due to soft tissue injuries or another situation.

"Pelvic fracture with associated injuries" was defined as one that presented injuries that could affect the final outcome according to the Majeed score, for example, open or closed fracture of the acetabulum, ankle, calcaneus, or long bones of the lower limbs, severe traumatic brain injury, and ligamentous injuries. In this way, patients were divided into two groups: with or without associated lesions. Injuries that, due to their evolution or severity, did not affect the final outcome, such as upper limb fractures, cutting wounds, spinal fractures without spinal cord involvement, and traumatic brain injury without loss of consciousness were not considered to be associated.

Waiting days until surgery ranged from 1 to 60. Two groups were formed: waiting up to 7 days and waiting 8 days or more for surgery.

The types of fixation analyzed were divided into two groups. The first group included patients operated on with anterior plate fixation using a Pfannenstiel and percutaneous sacroiliac approach. The second group was made up of patients operated solely with anterior plate fixation using a Pfannenstiel approach (without posterior fixation), plus those operated on with anterior external and percutaneous sacroiliac fixation. The division into groups was made in this way to compare the treatment that is currently most accepted and recommended in the literature (anterior plate fixation and posterior percutaneous fixation) with the rest of the treatments. The treatment for each patient was selected together with the other treating services according to their characteristics and their associated diseases and injuries. In addition, the first patients in the series had been treated with anterior fixation only; in the later years of the series, percutaneous posterior fixation was added. Anterior fixation was performed, in all cases, with a 3.5-mm reconstruction plate or DCP plate, depending on availability. Most of the patients were operated on with 3.5 mm reconstruction plates and two with 3.5 mm DCP plates. The sacroiliac screws used were 6.5 mm and 7 mm.

The degree of postoperative reduction was analyzed in the radiographs. According to the criteria of Matta and Tornetta,[18] "excellent" was defined as a reduction with less than 0.4 cm of displacement; "good", when it was between 0.4 and 1 cm; "tolerable", when it was between 1 and 2 cm; and "poor", when it was more than 2 cm. They were divided into two groups for statistical analysis: reduction <1 cm and >1 cm.

Patients who had a surgical site infection were compared with those who did not. A patient was considered to have a surgical site infection if there were signs and symptoms of infection and a microbial rescue was obtained from a tissue sample taken in the operating room. This variable was corroborated with the records of the Infectious Diseases Service of our institution. Patients who suffered a surgical site infection were treated by surgical debridement and intravenous treatment directed by the Infectious Diseases Service.

The analysis was performed with the Stata 14.1 program (StataCorp, Texas, USA). The final outcome of the Majeed numerical scale was compared in two groups formed by each predictive variable using the Mann-Whitney test. Fisher's exact test was used to compare proportions in groups defined by categories of the Majeed scale. A p-value <0.05 was considered statistically significant.

RESULTS

Twenty-three patients diagnosed with APCII pelvic fracture (16 men and 7 women) were analyzed. The median age was 32 years (range 15-70). Median follow-up was 3.2 years (min. 2, max. 6). Associated injuries were documented in nine patients (39.13%). Emergency treatment was pelvic strap in 19 patients (82.61%), external fixator in two (8.69%) (Figure 4) and two (8.69%) were hemodynamically stabilized by pelvic packing. The median wait until definitive surgery was 10 days (range 1-60).

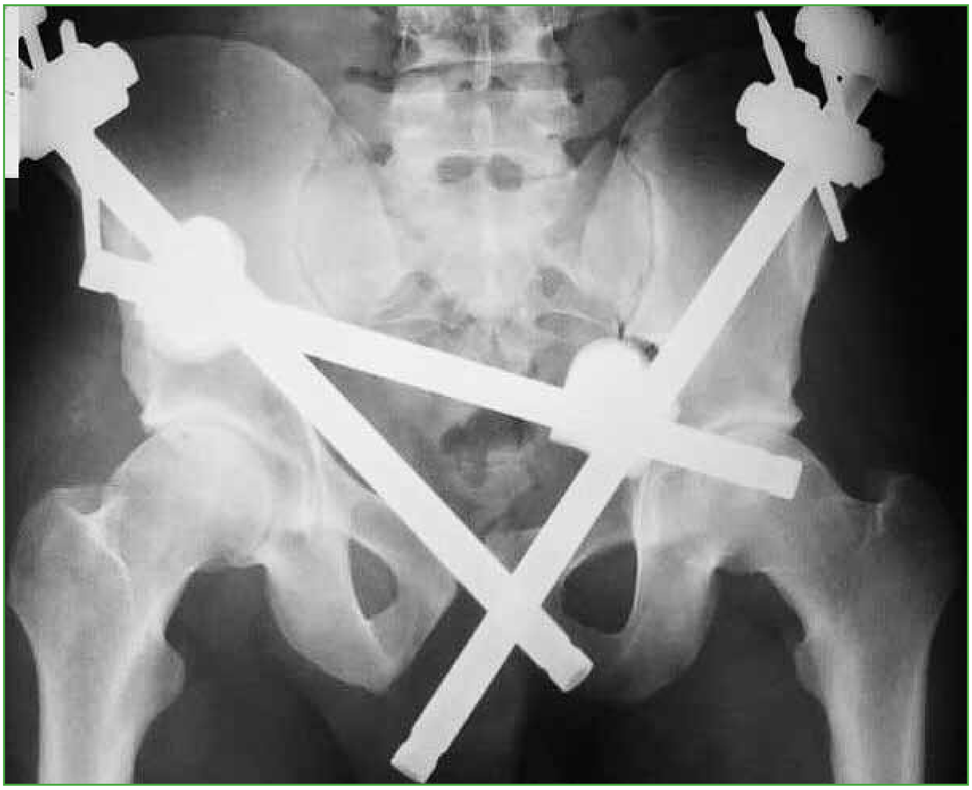

Figure 4. Panoramic radiograph of the pelvis with external fixator.

Five patients (21.73%) underwent anterior fixation only with a Pfannenstiel approach, 13 (56.52%) underwent anterior and percutaneous sacroiliac fixation (Figure 5-7), and five (21.73%) underwent anterior and percutaneous sacroiliac external fixation. Postoperative reduction was <1 cm in 16 patients (69.57%). Five (21.73%) suffered from a surgical site infection.

Figure 5. Panoramic pelvic radiograph. Anterior fixation with plate and posterior with sacroiliac screw.

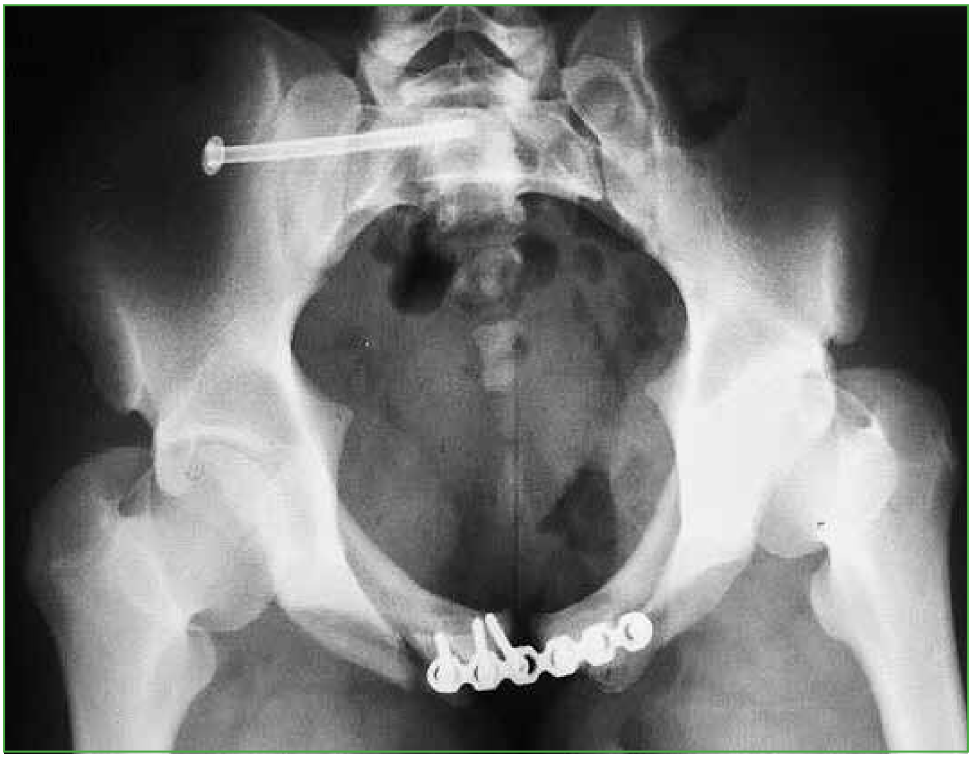

Figure 6. Pelvic inlet radiograph. Anterior fixation with plate and posterior with sacroiliac screw.

Figure 7. Pelvic outlet radiograph. Anterior fixation with plate and posterior with sacroiliac screw.

The median Majeed scale score was 70 (excellent) (range 30-80). Table 1 shows the comparison of medians in different groups. No differences were found between the groups according to associated injuries. The medians of the scale were higher in groups <40 years old, men, emergency treatment with a tutor or packing, time <8 days until definitive surgery, and in the group with the Pfannenstiel approach fixated in the anterior region with a plate and the posterior region with sacroiliac screws, but the differences were not statistically significant. We observed that patients who had an immediate postoperative reduction <1 cm obtained a better functional scale score (median 75 points) compared to those with a reduction >1 cm (median 65 points) and the difference was statistically significant ($p = 0.0310$). We observed that the patients who suffered from infections (5 in total) obtained worse functional outcomes (median 56 points) compared to those who did not (median 75 points) and the difference was statistically significant ($p = 0.0006$).

Table 1. Comparison of medians of the Majeed scale in different groups.

Variables	Number (n)	Median	Range	p*
Age				
≥40 years	8	64.5	52-80	0.1857
<40 years	15	70	30-80	
Sex				
Male	16	72.5	56-80	0.2307
Female	7	65	30-80	
Emergency treatment				
Sheet wrap	19	70	30-80	0.1575
Tutor or packing	4	77.5	70-80	
Associated injuries				
Yes	9	70	56-80	0.8464
No	14	70	30-80	
Waiting time until surgery				
<7 days	8	77.5	69-80	0.0639
≥8 days	15	69	30-80	
Fixation type				
Anterior with plate and posterior percutaneous	13	75	52-80	0.0700
Anterior alone or tutor and posterior percutaneous	10	67	30-80	
Quality of immediate postoperative reduction				
≤1 cm	16	75	56-80	0.0310
>1 cm	7	65	30-80	
Surgical site infection				
Yes	5	56	30-60	0.0006
No	18	75	65-80	

*Mann-Whitney test.

According to the categories of the Majeed scale, eight (34.78%) patients obtained an excellent outcome; six (26.09%), good; five (21.74%), fair; and four (17.39%), poor. Although the results were not statistically significant, the group with a "poor" outcome was older, had a higher frequency of reduction >1 cm, was wrapped with a sheet in the emergency room, and waited more than 8 days for definitive treatment. We observed a statistically significant association of surgical site infection with the Majeed scale (Table 2).

Table 2. Comparison of the characteristics of the sample (n = 23) in groups of results according to the Majeed scale

Variables	Majeed Scale				p*
	Excellent (n = 8)	Good (n =6)	Fair (n = 5)	Poor (n = 4)	
Age <40 years	6	5	3	1	0.333
Male sex	6	5	3	2	0.711
Sheet wrap as an emergency treatment	6	4	5	4	0.481
Associated injuries	3	2	2	2	0.999
Waiting time until definitive treatment ≥8 days	4	3	4	4	0.347
Anterior fixation with plate and posterior percutaneous	6	4	2	1	0.362
Post-surgical reduction >1 cm	1	1	2	3	0.147
Surgical site infection	0	0	1	4	<0.001

The results are presented as number of observations (n).
*Fisher's exact test.

In the five patients with surgical site infection, methicillin-resistant *Staphylococcus aureus* was isolated and, in one of them, also *Klebsiella pneumoniae*. All five underwent surgery after seven days of hospitalization and all were over 40 years old.

DISCUSSION

In this study, different long-term variables were evaluated by comparing them with the functional outcomes according to the Majeed scale in patients with APCII injuries. According to a systematic review of 28 articles carried out by Lefaivre et al.,[19] the Majeed scale was used in more than half of them.

Regarding data collection, most of the patients in all the groups observed did not have sexual disorders or dysfunctions, probably due to incomplete information on these charts. This idea coincides with the findings of Harvey-Kelly et al.,[20] who reported a high rate (28%) of patients who refused to complete the sexual questionnaires. The incidence of sexual dysfunction and dyspareunia reported in the literature varies from 5% to 44%.[11,21]

No statistically significant relationship was found between the initial treatment in the emergency room and the final functional outcome according to the Majeed scale. This may be due to multiple variables not analyzed in our study, such as the hemodynamic status at admission, the available resources, and the experience of the surgeon in charge of emergency treatment.

The relationship between the patients who suffered associated injuries and the final score on the Majeed scale was not statistically significant. In contrast to this, Hessmann et al.[21] stated that functional outcomes after pelvic trauma are often affected by associated injuries and other variables. In our study, four patients also had acetabular fracture; three, fracture of long bones (femur or tibia); two, spinal fracture; four, fracture around the ankle and foot; one, severe traumatic brain injury and a sciatic nerve injury.

The patients who underwent surgery within seven days had better functional outcomes on the Majeed scale, while those who underwent surgery after 7 days had worse outcomes, although without significant differences. Vallier et al.[22] reported a decrease in morbidity and length of hospitalization in patients who received early treatment, but did not assess the long-term functional outcome. In addition to this, it can be noted that five patients in the group that had undergone surgery after seven days of admission suffered a surgical site infection and had poor functional outcomes. This is understandable, since prolonged hospitalization increases the probability of infection by hospital germs and impoverishes the final outcomes.

Previous studies have shown that age, severity of injury, type of fracture, and type of fixation used could influence functional outcomes.[20,23,24] In our study, patients who underwent surgery with anterior plate fixation using the Pfannenstiel approach without sacroiliac fixation, along with patients operated on with anterior external fixation and percutaneous posterior fixation, had worse functional outcomes than those treated with anterior plate fixation and percutaneous sacroiliac fixation. However, no statistically significant results were obtained. In 2011, Sagi et al.[15] proposed a modification to the Young and Burgess classification of "open book" injuries based on dynamic stress examination with fluoroscopy under anesthesia. In this case, APCII lesions were divided into two subgroups: those that required only anterior fixation (APCIIa) and those that required additional posterior fixation (APCIIb). In 2016, Avilucea et al.[16] carried out a comparative study and reported a lower rate of material failure and malunion when anterior fixation was supplemented with posterior percutaneous fixation, when compared to anterior fixation with an isolated plate in APCII pelvic fractures. These authors attribute the poor outcomes to inadequate fixation, and this coincides with our observations, because stable anterior and posterior internal fixation led to better outcomes.

A better functional outcome (median 75 points) was observed in patients who obtained a postoperative reduction <1 cm compared to those who obtained reductions >1 cm, with statistically significant values, coinciding with the statements of Hessmann et al.[21] In their reviews, Lefaivre et al. concluded that the correlation is unknown, since there is a wide variety of measurement methods, and none of them is properly validated.[25] According to our study, the degree of postoperative reduction influences the long-term functional outcome in patients with APCII injuries.

Likewise, it was shown with statistically significant values that patients who suffered a surgical site infection obtained worse functional outcomes compared to those who did not. This may be due to increased hospitalization days, days in intensive care, or prolonged surgical times.

In summary, we found, with statistically significant values (Table 1), that the variables "immediate postoperative reduction quality" and "surgical site infection" affect the final outcome in patients with APCII pelvic fractures. In addition, the medians of the functional scale were higher in groups of patients under 40 years of age, men, emergency treatment with tutor or packing, time <8 days until definitive surgery, and in the group with a Pfannenstiel approach with anterior plate fixation and posterior sacroiliac screw fixation, but the differences were not statistically significant.

The strengths of our study are that it focused on a specific pelvic injury and explored the relationship between clear variables and the final functional outcome. In addition, all the patients in the series were operated on and monitored over time by the same surgeon, with the same follow-up protocol, which gave the sample greater purity. Another point in favor is that we carried out a comparative study for a better statistical evaluation. To our knowledge, there is no research of this type in the national literature.

The weaknesses are the design (retrospective without double blind), the small universe, and the lack of a multivariate statistical analysis.

We believe that our research can be a good starting point for multicenter studies, such as prospective studies with a larger sample, to adapt the classification systems to new knowledge about the mechanism of trauma and the different associated variables, thus predicting long-term functional outcomes.

CONCLUSION

We can affirm that the quality variables of immediate postoperative reduction and infection of the surgical site in patients with anteroposterior compression fracture of the pelvis—type II (APCII) of the Young and Burgess classification—are directly associated with the long-term functional and clinical outcomes.

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

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Comparative Study of Knee Function and Pain Between the Suprapatellar and Medial Parapatellar Approaches After Intramedullary Nailing of a Tibial Fracture

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ABSTRACT

Introduction: Anterior knee pain is the most frequent cause of reoperation after intramedullary nailing of a tibial fracture. In recent years, semi-extension approaches have simplified the surgical technique, but postoperative pain continues to be the most frequent complication. The aim of this study is to compare the medial parapatellar approach (PPM) vs the suprapatellar approach (SP) with respect to knee pain and postoperative function after intramedullary tibial nailing. **Materials and Methods:** We retrospectively formed 2 groups of patients with tibial fractures treated with intramedullary nailing through the PPM (n:33) and SP (n:17) approaches. We evaluated postoperative knee pain with the VAS and Lysholm score; and function with the SF-12. They were clinically evaluated at 1, 3, 6 and 12 months. **Results:** The mean age of the groups was 41.5 years (29-76) for the PPM group and 40.4 years (23-90) for the SP group. Pain and knee function were significantly better in the group of patients operated through the SP approach. **Conclusion:** The suprapatellar approach is associated with less knee pain and better postoperative function after intramedullary nailing of a tibial fracture. However, prospective studies should validate these results.

Key words: Tibia fracture; tibia nailing; semi-extended approach; suprapatellar approach; parapatellar approach.
Level of Evidence: III

Estudio comparativo de la función y el dolor de la rodilla entre el abordaje suprarrotuliano y pararrotuliano medial luego del enclavado endomedular de una fractura de tibia

RESUMEN

Introducción: El dolor anterior de rodilla es la causa más frecuente de reoperaciones luego del enclavado endomedular de una fractura de tibia. En los últimos años, los abordajes en semiextensión han facilitado la técnica quirúrgica; sin embargo, el dolor posoperatorio sigue siendo la complicación más frecuente. El objetivo de este estudio fue comparar el abordaje pararrotuliano medial con el suprarrotuliano en cuanto al dolor de rodilla y la función posoperatoria luego del enclavo endomedular de tibia. **Materiales y Métodos:** Se conformaron retrospectivamente 2 grupos de pacientes con facturas de tibia tratados con clavo endomedular a través del abordaje pararrotuliano medial (n = 33) y suprarrotuliano (n = 17). Se evaluaron el dolor de rodilla posoperatorio con las escalas analógica visual y de Lysholm, y la función con el SF-12, al mes 1, 3, 6 y 12. **Resultados:** La edad promedio era de 41.5 años (rango 29-76) para el grupo con abordaje pararrotuliano y de 40.4 años (rango 23-90) para el otro grupo. Los resultados respecto del dolor y la función de la rodilla fueron significativamente mejores en el grupo operado con el abordaje suprarrotuliano. **Conclusiones:** El abordaje suprarrotuliano se asocia con menor dolor de rodilla y mejor función posoperatoria luego del enclavado endomedular de una fractura de tibia. Sin embargo, estudios prospectivos deberán validar estos resultados.

Palabras clave: Fractura de tibia; clavo de tibia; abordaje en semiextensión; abordaje suprarrotuliano; abordaje pararrotuliano.
Nivel de Evidencia: III

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INTRODUCTION

Tibial fracture is one of the most frequent long bone fractures.[1] Intramedullary nailing is the treatment of choice since, in most cases, it achieves excellent consolidation outcomes with a low rate of complications.[2] However, anterior knee pain is a frequent cause of disability in patients and is responsible for reoperation rates of up to 29.8%.[3] Although the cause of anterior knee pain after tibial intramedullary nailing is multifactorial, the surgical approach has been identified as one of the main causes.[4]

In the last decade, modifications in nail design and the development of different approaches in the semi-extension position have made it possible to extend the indication for intramedullary nailing to all segments, facilitating the surgical technique.[5] However, they have not been able to reduce postoperative knee pain.[6-8]

Initially used for metaphyseal fractures and then for all tibial fractures, we have adopted the semi-extension position technique through the medial parapatellar approach (MPP) for tibial intramedullary nailing. However, due to the most recent advent of the suprapatellar technique (SP), we began to incorporate it within the possibilities of approaches. For this reason, we propose to carry out a comparative study between both techniques to evaluate the functional outcomes and postoperative knee pain. Our hypothesis is that there are no significant differences between both approaches regarding postoperative pain and function of the knee.

MATERIALS AND METHODS

The study was approved by the Ethics Committee of the Institution. We retrospectively evaluated 85 tibial fractures treated with intramedullary nailing at our institution between January 2017 and January 2020. We included skeletally mature patients treated with an MPP or SP approach with a minimum follow-up of one year. In the first period (January 2016-December 2017), all patients underwent an MPP approach, while in the second period (January 2018-June 2020), the choice of the approach was based on the availability of the implant.

We excluded patients with fractures associated with a fracture of the ipsilateral femur (floating knee), pathological fractures, pre-existing knee disease, fractures that progressed to nonunion or developed infection, and those unable to walk.

After incorporation, two groups were formed according to the approach used: MPP (n = 33) and SP (n = 17). We collected data on age, sex, side, type of fracture according to the AO/OTA classification, open vs. closed, and follow-up time.

Anterior knee pain was assessed with the visual analog scale and with the pain section of the Tanger-Lysholm scale.[9] The functional assessment was performed with the SF-12 questionnaire.[10] Knee pain and function records were made in clinical controls at one month, and at 3, 6, and 12 months. All data collected were compared between the two groups.

In the statistical analysis, the chi-square or Fisher test was used for categorical variables, depending on whether they met assumptions. For continuous variables, since the distribution was not normal, the summary measure was the median with its interquartile range and the Wilcoxon or Mann-Whitney tests were used. A p value <0.005 was considered statistically significant.

RESULTS

The mean age was 41.5 years (range 29-76) for the MPP approach group and 40.4 years (range 23-90) for the SP technique group ($p > 0.05$). Four fractures from the MPP approach group and two from the other group were open ($p > 0.05$). However, there were significant differences in the type of fracture between both groups. In the group with the MPP technique, metaphyseal fractures were more frequent (4.1/4.3) (Table 1).

The evaluation of anterior knee pain with the visual analog scale showed a significant difference in favor of the group with the SP approach at one month, and at 3 and 6 months after surgery.

When the Tanger-Lysholm scale was applied to assess knee pain, there were also significant differences in favor of the group with the SP technique at one month, and at 3, 6, and 12 months of follow-up ($p < 0.05$) (Table 2).

The knee function analysis also showed significant differences in favor of patients operated on with the SP approach. However, these differences were only significant in the remote evaluation at 6 and 12 months ($p < 0.05$) (Table 2).

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Table 1. Demographics, side, classification, and percentage of open fractures

	Medial parapatellar approach (n = 33)	Suprapatellar approach (n = 17)	p
Sex (male)	22 (66.67%)	9 (52.94%)	0.344
Age (years)	35 (IQR 33-48)	38 (26-43)	0.310
Side (left)	16 (48.48%)	10 (58.82%)	0.488
OTA/AO Classification			0.016
4.1	0 (0%)	4 (23.53%)	
4.2	15 (45.45%)	7 (41.18%)	
4.3	18 (54.55%)	6 (35.29%)	
Open			NS

NS = not significant. IQR = interquartile range.

Table 2. Postoperative pain and functional outcomes

	Medial parapatellar approach	Suprapatellar approach	p
VAS 1 month	5 (4-6)	2 (2-3)	0.001
VAS 3 months	3 (3-4)	1 (1-2)	0.001
VAS 6 months	2 (2-3)	0 (0-1)	0.001
VAS 12 months	1 (0-1)	0 (0-1)	0.07
Lysholm 1 month	15 (15-20)	20 (20-20)	0.017
Lysholm 3 months	20 (15-20)	20 (20-25)	0.013
Lysholm 6 months	25 (20-25)	25 (25-25)	0.048
Lysholm 12 months	25 (20-25)	25 (25-25)	0.004
SF-12 1 month	70 (65-72)	70 (70-73)	0.1142
SF-12 3 months	72 (70-75)	75 (73-75)	0.0745
SF-12 6 months	75 (72-80)	80 (80-85)	0.0003
SF-12 12 months	78 (75-80)	85 (80-85)	0.0004

VAS = visual analog scale, Lysholm = Tanger-Lysholm scale, SF-12 = SF-12 questionnaire.

DISCUSSION

The analysis of the results of this study has refuted the initial hypothesis, since we have found a significant difference in functional outcomes and postoperative knee pain between the MPP and SP approaches after intramedullary nailing of a tibial fracture.

A first consideration that explains the significant difference in the type of fracture between both groups is that the first cases in this series correspond to patients with metaphyseal fractures in whom we began to use the semi-extension technique exclusively through the MPP approach. In the following years, we extended it to all tibial fractures with an indication for intramedullary nailing, and we incorporated the SP approach.

In different studies, knee pain continues to be reported as the most frequent complication after tibial intramedullary nailing.[3,4] Several factors responsible for postoperative knee pain have been pointed out.[4] Most of them are related to the skin incision,[11,12] tendon injury,[13] nail protrusion,[14] and injury to structures caused by making the entry point.[15,16]

Although, in recent years, the development of approaches in the semi-extended position has introduced some advantages over the infrapatellar technique,[17] the shift of the approach from the patellar tendon area has not been accompanied by a decrease in postoperative knee pain.[6-8] Although both approaches move the incision away from the patellar tendon area, especially the SP, there is no conclusive evidence that this is associated with less postoperative knee pain.[6-8] The intra-articular entry of both approaches poses an associated risk of injuring intraarticular structures that could be responsible for postoperative knee pain. Although the management of the patella with both approaches is different and one could assume that the SP access would cause a chondral injury responsible for postoperative pain, especially over the patellofemoral joint, cadaveric and biomechanical studies have not found a direct relationship between eventual joint damage and knee pain.[15,16]

In a cadaveric study that sought to determine the damage of intra-articular structures between the SP vs parapatellar technique, Zamora et al. reported that intermeniscal ligament injuries occurred in three out of ten specimens in each group. Regarding the risk of chondral damage, they detected a cartilage injury in the patellofemoral joint in three of 10 cases in the SP approach group, while in the parapatellar approach group, a lesion occurred in the lateral aspect of the lateral condyle in one of 10 cases. Consequently, the authors concluded that, despite the fact that the risk of soft tissue injury is the same in both groups, the risk of chondral injury should be considered with the SP technique.[16] In a cadaveric study, Gelbke et al. showed that the pressure received by the cartilage of the patellofemoral joint is significantly higher with the SP technique than with the traditional infrapatellar technique.[18] However, they clarified that the level of pressure generated is below that necessary to produce an irreversible injury to the chondrocyte .

For the evaluation of knee pain, we used scales used in other studies, such as the Tanger-Lysholm scale and the visual analog scale. In the case of the Tanger-Lysholm scale, we decided to use the segment aimed at evaluating only knee pain and thus avoid other responses that might not be directly related to the surgical technique of nail insertion. For the functional evaluation, we used the SF-12 questionnaire because it is a widely used score to evaluate traumatic pathology.

Most studies that evaluated knee function and pain after tibial intramedullary nailing have focused on comparing the SP or parapatellar technique with the traditional infrapatellar hyperflexion technique.[6-8,15-17] Although recently some authors have reported less pain with the SP technique,[17] most have not found significant differences between the different approaches.[6-8] Our study is novel as it compares two of the three approaches described for intramedullary nailing of the tibia in semi-extension; to our knowledge, there are no studies comparing the different approaches available.

We are aware of some limitations of the study that force us to take the results obtained with caution. First of all, this is not a prospective, randomized study; therefore, the first cases of the series correspond to those operated with the MPP technique, so some factors related to the learning curve with the semi-extension position may have influenced the results. Secondly, our study lacks an analysis of knee pain regarding its location. Although anterior knee pain is the most common after tibial intramedullary nailing, there are other locations that were not analyzed and are not included in the scales used and could influence the rate of knee pain reported. Lastly, the number of the series is low considering the frequency of the pathology and, therefore, studies with a larger sample should validate these results.

CONCLUSION

Based on the results of this study, the SP approach is associated with less pain and better knee function than the MPP approach after tibial intramedullary nailing. However, these results must be validated by studies with a larger number of patients and prospective designs.

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

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Suprapatellar vs. Infrapatellar Intramedullary Nailing for the Treatment of Distal and Diaphyseal Tibial Fractures: Comparative Analysis and Surgical Technique

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ABSTRACT

Introduction: Fractures of the medial and distal tibial segment often occur in young patients with high-energy trauma and older patients with low-energy trauma. The objective of this study is to compare the time of surgery, time of use of fluoroscopy, functional outcomes, and postoperative pain in patients treated with the suprapatellar vs. infrapatellar technique for tibial nailing. **Materials and Methods:** We carried out a retrospective study between March 2018 and October 2019. All the data was collected from the electronic clinical record (ECR). We included patients with diaphyseal and distal tibial fractures. The variables analyzed were: fluoroscopy and surgery time, pain evaluation, and functional outcomes of the patients using the Lysholm score. **Results:** 80 patients met all the inclusion criteria. Sociodemographic data were divided into 2 similar groups. The suprapatellar approach was used in 44 patients and the infrapatellar in 36 of them. A statistical difference was obtained in the analysis for the time of surgery, use of fluoroscopy, and pain evaluation in favor of the suprapatellar technique. **Conclusions:** The results of our study showed shorter surgery and fluoroscopy times with the use of the suprapatellar technique compared with the infrapatellar technique. The suprapatellar technique also yielded better pain results in the visual analog scale.

Key words: Suprapatellar approach; infrapatellar approach; tibial fractures; surgical technique.
Level of Evidence: III

Enclavado endomedular suprarrotuliano vs. infrarrotuliano en el tratamiento de fracturas diafisarias y distales de tibia: análisis comparativo y técnica quirúrgica

RESUMEN

Introducción: Las fracturas diafisarias y distales de tibia son lesiones frecuentes en personas jóvenes que sufren un trauma de alta energía y en ancianos por un trauma de baja energía. El objetivo de este estudio fue comparar el tiempo quirúrgico, el uso de radioscopia, la evaluación funcional y el dolor en el tratamiento de fracturas diafisarias y distales de tibia mediante una técnica suprarrotuliana y una infrarrotuliana. **Materiales y Métodos:** Se realizó un estudio retrospectivo entre marzo 2018 y octubre de 2019. La información de los pacientes se obtuvo de la historia clínica electrónica. Se incluyó a pacientes con fracturas diafisarias y distales de tibia. Se estudiaron y compararon los tiempos de radioscopia y de cirugía. El dolor posoperatorio se evaluó mediante la escala analógica visual y la función, con el puntaje de Lysholm. **Resultados:** Ochenta pacientes cumplían con los criterios de inclusión. Sus datos sociodemográficos fueron pareados en dos grupos similares. Treinta y seis pacientes fueron tratados con la técnica infrarrotuliana y 44, con la técnica suprarrotuliana. Se obtuvieron diferencias estadísticamente significativas en el tiempo de cirugía, el tiempo de radioscopia y en el puntaje de la escala analógica visual para dolor al año. **Conclusiones:** Los resultados mostraron un menor tiempo de cirugía y de radioscopia, y mejores resultados en la escala analógica visual para dolor con la técnica suprarrotuliana para el tratamiento de las fracturas mediodiafisarias y distales de tibia.

Palabras clave: Abordaje suprarrotuliano; fractura de tibia; abordaje infrarrotuliano; técnica quirúrgica.
Nivel de Evidencia: III

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INTRODUCTION

Distal and diaphyseal tibial fractures are frequent injuries in young people who suffer high-energy trauma and in the elderly due to low-energy trauma. The most frequent procedure to treat them is intramedullary nailing of the tibia.[1]

The use of the suprapatellar technique for nailing the tibia in proximal segment fractures has been well studied. Fluoroscopy time, postoperative pain, and functional outcomes have been evaluated with this technique and compared with the infrapatellar approach.[1,2]

On the other hand, the publications on the use of the suprapatellar technique to treat fractures of the tibia in diaphyseal and distal segments are scarcer, and report variable results in terms of postoperative pain, functionality, and clinical evolution.[3-5]

The objective of this study was to compare the surgical time, the evolution of pain, the functional evaluation, and the use of radioscopy in the treatment of diaphyseal and distal fractures of the tibia with the suprapatellar and infrapatellar techniques. In addition, we described the surgical technique and presented a literature review.

MATERIALS AND METHODS

A retrospective cohort study was carried out between March 2018 and October 2019. All patients were treated by the same surgical team, at our institution, a level I trauma center.

The selection of the implant and its approach was not randomized. Both placement systems were available as of the aforementioned date and were selected based on the experience of the surgeon.

Patient information was obtained from the electronic health records. Inclusion criteria were: age 18-70 years, skeletal maturity, involvement of the diaphyseal or distal segment of the tibia, open or closed tibial fracture treatable with intramedullary nailing, isolated tibial fractures, and a minimum postoperative follow-up of 12 months. The exclusion criteria were: proximal tibia fractures, pathological fractures, polytraumatized patients, and skeletally immature patients.

Radioscopy time was evaluated in seconds and surgery time in minutes.

Postoperative pain was determined using the visual analog scale. Functional evaluation was performed with the Lysholm score in the postoperative period, at one year of follow-up.

Statistical analysis

The medians and interquartile ranges between quantitative variables were evaluated with a range of 25-75. The Wilcoxon test was applied for quantitative variables.

The chi-square test was used to compare the qualitative and functional variables of the patients. A p value <0.05 was considered statistically significant.

For the statistical analysis, the Stata 13TM program (Stata Corp., College Station, Texas, USA) was used.

SURGICAL TECHNIQUE

The procedure begins with the patient in the supine position, under regional anesthesia, on a radiolucent surgical table. With radioscopy, it is feasible to evaluate the reduction maneuvers before the surgical procedure, which will be useful during the operation.

After the corresponding asepsis and under surgical conditions, the procedure begins with the placement of a cushion under the hamstring, in such a way as to achieve a semi-extension position to facilitate the procedure of entering the joint. It should be noted that the size of the cushion is not uniform and will depend on the dimensions of the limb to be treated (Figure 1).

Surgical access is then carried out through a skin incision of approximately 3 cm in the longitudinal direction and 2 cm above the superior pole of the patella. It is important to make the incision in a single plane that encompasses the skin tissue, the cellular tissue and finally the quadriceps tendon.

After performing the approach, the entry of the protection cannula can be facilitated with the prior introduction of tissue scissors so that, if there is abundant synovial tissue, an adequate path is achieved (Figure 2).

Once the protection cannula, covered with an external layer of silicone, has been inserted, it is fixed to the femur with a pin and its corresponding guide hole in the cannula, to prevent its expulsion.

Figure 1. Limb in semi-extension, with placement of a cushion in the hamstring and suprapatellar system with guide wire in position.

Figure 2. Cannula system, silicone sheath, and wire guide for the suprapatellar approach.

We then proceed with the search for the entry point under radioscopic vision. Manipulating the protection cannula is necessary to allow access to said point (Figure 3).

After achieving the entry point, which will be penetrated by the guide pin, the drill sleeve is removed and the entry point is subsequently created with a drill bit. Said entry hole can be made manually or with a motor, depending on the characteristics of the bone (Figure 4).

Finally, the drilling guide will be placed, taking special care to avoid expulsion of the tissue protection cannula.

Depending on the fracture pattern, the drilling of the medullary canal will continue, as well as the maneuvers to reduce the fracture line(s).

Finally, and after inserting the intramedullary nail with its corresponding locking guide, we proceed with the locking of the nail and the subsequent removal of the instruments. If the surgeon prefers, the nail closure plug can be placed through the tissue protection cannula.

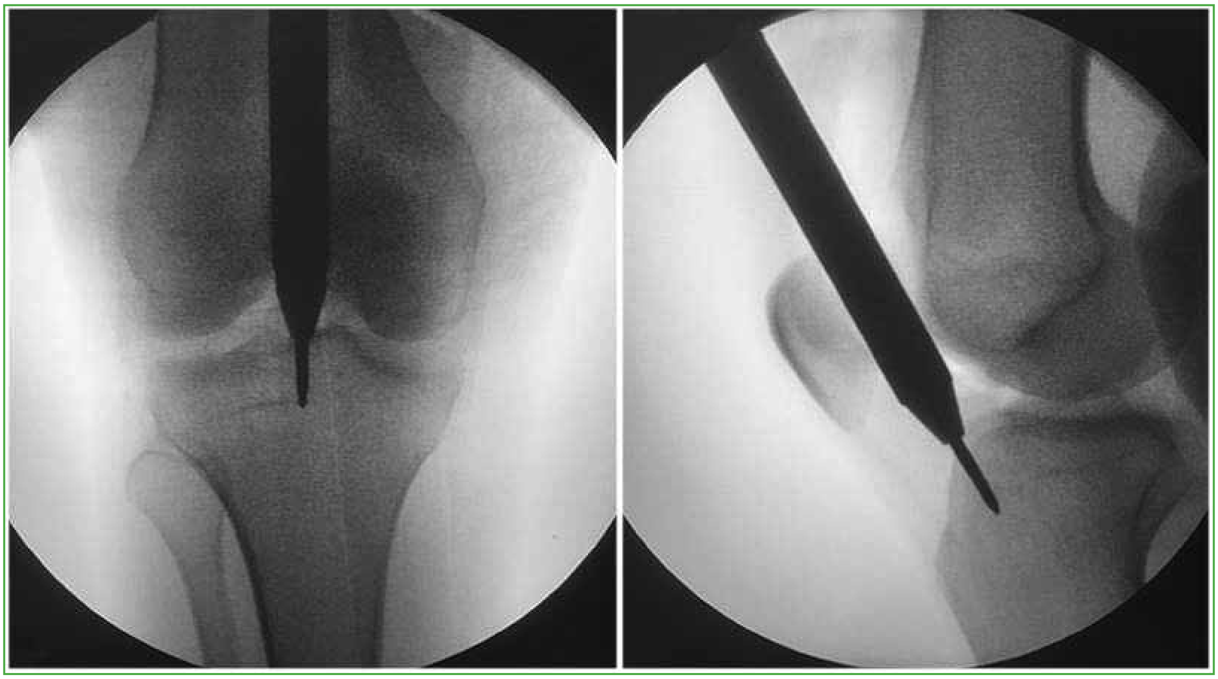

Figure 3. Anteroposterior and lateral fluoroscopic images with the use of the suprapatellar system and placement of the guide wire at the appropriate entry point.

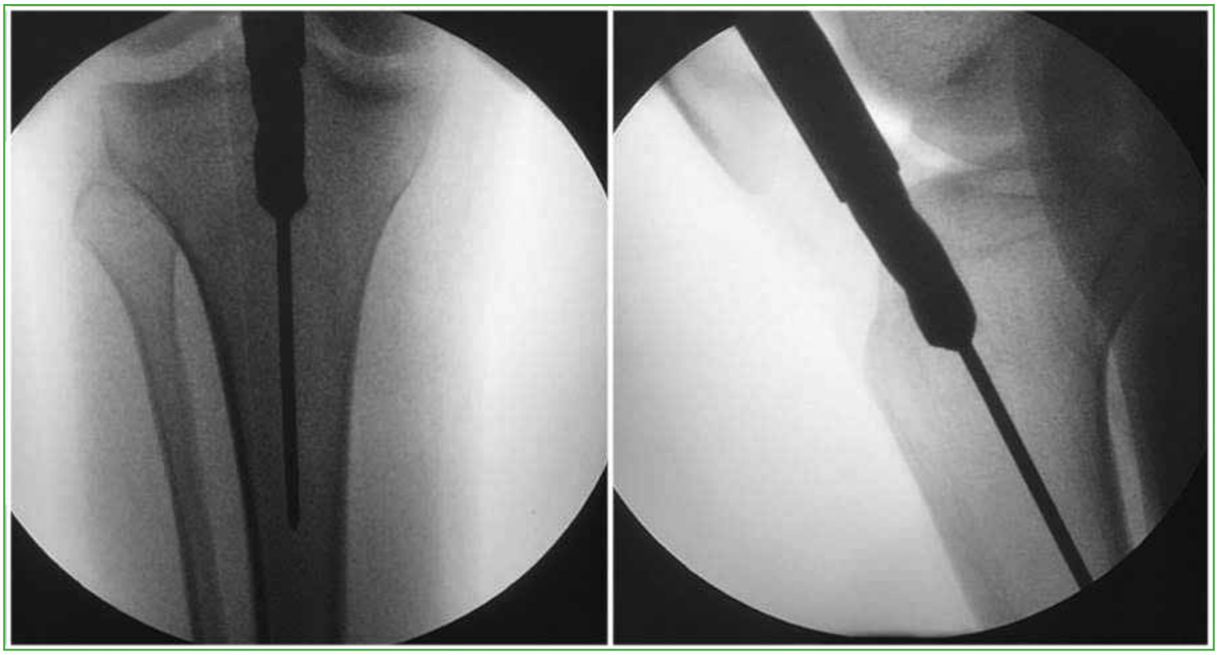

Figure 4. Anteroposterior and lateral fluoroscopic images with the removal of the guide wire sheath and placement of a drill bit to drill the implant entry site.

It is essential to carry out a profuse lavage of the joint in order to remove debris that could have been retained in the joint.

The wound is closed by planes, using a strong suture for the tendinous plane and a smaller suture for the superficial planes.

Finally, skin asepsis and the placement of the appropriate bandage are performed.

RESULTS

Eighty patients met the inclusion criteria. Sociodemographic data were paired in two similar groups. Thirty-six patients were treated with the infrapatellar technique and 44 with the suprapatellar technique. The mean age of the group with the suprapatellar technique was 48 (range 33-64) and that of the other group, 46 (range 32-68). 83% (67 patients) had a midshaft tibial fracture and 17% (13 patients) a distal tibial fracture.

The mean surgery time was 90 min (range 72-107) in patients undergoing the suprapatellar technique (n = 44) and 106 min (range 71-172) in those operated on with the infrapatellar technique (n = 36). . In the corresponding statistical analysis, the difference was significant (p = 0.008).

The fluoroscopy use time was 94.5 s (range 71.5-172.5) for the suprapatellar technique (n = 44) and 204.5 s (range 152.5-262) for the other technique (n = 36), also with a significant difference (p = 0.0001).

Regarding pain assessment at one year of follow-up, the mean visual analog score of patients treated with the suprapatellar technique (n = 44) was 2 (range 1-3), while in the group treated with the infrapatellar technique (n = 36) it was 3 (range 2-5), with a significant difference (p = 0.01).

The Lysholm functional score at one year's follow-up did not show significant differences between both techniques (p = 0.153). Despite this, their absolute values were different, with a mean score of 89 (range 79-96) for the suprapatellar technique (n = 44) and 86.5 (range 77-92) for the infrapatellar technique (n = 36).

DISCUSSION

The results of our study coincide with those of most of the published articles. The shorter fluoroscopy and surgery times with the suprapatellar technique are well documented in the literature.[2,3,6] These results are reflected both in fractures of the proximal tibia, its original indication, as well as in the diaphyseal and distal segments of the tibia.

The functional assessment and the evolution of pain in these patients yielded dissimilar results in the different literature reports.[3-5,7] Some refer that there was no significant difference in knee functionality and range of motion, as reflected in our study. On the other hand, studies such as the one by Cui et al. observed improvements in the range of motion of the knee with the suprapatellar technique compared to the infrapatellar technique.[8] Regarding the evaluation of pain, in our study, the evaluation of the pain one year after surgery revealed significant differences in favor of the infrapatellar technique, as reported largely in the literature. In a large series with a retrospective design and a follow-up of 3.8 years, Isaac et al. reported that they found no difference between both techniques when evaluating postoperative pain.[9]

In all the patients in our cohort, the fracture had consolidated at one year of follow-up, without associated complications. The aforementioned studies did not establish this variable as considerable when determining the selection of the approach, and this was reflected in the absence of said complication among our patients.

The limitations of this study are diverse; the main one is its retrospective cohort design with the disadvantages and biases that this entails compared to a prospective design. In addition, it could be considered that the number of patients evaluated is not one of the largest in the literature; however, having excluded the proximal segment, this value remains considerable and relevant.

CONCLUSION

According to our study, the suprapatellar nailing technique proved to be safe and, in addition, significantly improved surgical and radioscopy times when compared to the infrapatellar technique. Likewise, better outcomes were demonstrated in the visual analog scale for pain.

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Intramedullary Nailing of Tibial Fractures. Is There a Relationship Between the Entry Point and Its Final Alignment?

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ABSTRACT
Introduction: Tibial fractures represent approximately 2% of adult fractures. Today, intramedullary nailing is the procedure of choice to treat diaphyseal fractures of the tibia; however, this technique is not exempt from complications, misalignment in the coronal plane is one of the most frequent and feared by surgeons. The aim of this study was to investigate the relationship between nail entry point and misalignment in the coronal plane after surgery. **Materials and Methods:** We carried out a retrospective, descriptive, observational study between January 2015 and January 2019 of patients with diaphyseal fractures of the tibia, treated with intramedullary nailing. Radiographs were obtained in the immediate postoperative period and then every two months. The eighth-month radiograph, in which clear signs of bone consolidation could be observed, was taken into account to assess tibial alignment. **Results:** When the nail entry point was central, there was only a 0.021 chance (or 2.1%) of any significant misalignment in the immediate postoperative period and after 8 months. In contrast, when it was medial, the chances of a valgus tendency were >0.85 (or 85%) already at the first image, i.e., post-surgery; and when it was lateral, this possibility was modified and deepened according to the time elapsed until the image achieved in the patient. **Conclusion:** A marked and continuous relationship was observed between the entry point of the intramedullary nail and the alignment of the tibia after bone consolidation.
Keywords: Intramedullary nailing; tibia; misalignment.
Level of Evidence: IV

Enclavado endomedular en fracturas de tibia. ¿Existe una relación entre el punto de entrada para la inserción del clavo y su alineación final?

RESUMEN
Introducción: Las fracturas de tibia representan aproximadamente el 2% de las fracturas del adulto. El enclavado endomedular es hoy el procedimiento de elección para tratar fracturas diafisarias de tibia; sin embargo, esta técnica no está exenta de complicaciones, la desalineación en el plano coronal es una de las más frecuentes y temidas por los cirujanos. El objetivo de este estudio fue investigar la relación entre el punto de entrada del clavo y la desalineación en el plano coronal después de la cirugía. **Materiales y Métodos:** Se realizó un estudio retrospectivo, descriptivo, observacional, entre enero de 2015 y enero de 2019, de pacientes con fracturas diafisarias de tibia, tratadas con clavo endomedular. Se obtuvieron radiografías en el posquirúrgico inmediato y luego cada dos meses, se tuvo en cuenta la radiografía del octavo mes, en la que se observaban signos francos de consolidación ósea, para valorar la alineación tibial. **Resultados:** Cuando el punto de entrada del clavo fue central, hubo apenas un 0,021 de posibilidades (o 2,1%) de alguna desalineación significativa en el posquirúrgico inmediato y luego de 8 meses. En cambio, cuando fue medial, las posibilidades de una tendencia al valgo fueron >0,85 (u 85%) ya al tomar la primera imagen, i.e., poscirugía; y cuando fue lateral, esta posibilidad se modifica y profundiza según el tiempo transcurrido hasta la imagen lograda en el paciente. **Conclusión:** Se observó una relación marcada y continua entre el punto de entrada del clavo endomedular y la alineación de la tibia después de la consolidación ósea.
Palabras clave: Enclavado endomedular; tibia; deseje.
Nivel de Evidencia: IV

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INTRODUCTION

Tibial fractures account for approximately 2% of fractures in adults.[1,2] High-energy trauma, traffic accidents, and sports accidents are the most common causes in young adults, and low-energy trauma and falls from their own height are the most common causes in the elderly.

Nowadays, intramedullary nailing is the procedure of choice to treat tibial shaft fractures, because it is a minimally invasive technique that avoids additional soft tissue trauma. Conservative management of these fractures has often resulted in nonunion, rotational deformity, or stiffness of the adjacent joints, so there has been a shift toward surgical management of these fractures in recent times. However, the optimal surgical approach to treat these fractures remains debatable. Options include intramedullary implants, external fixation, plate fixation, or a combination of these techniques. In recent years, closed reduction with minimally invasive plates and locked intramedullary nailing have become widely used therapeutic modalities for fractures of the proximal and distal tibial metaphysis. In numerous studies, a superior outcome was observed after intramedullary nailing. However, this surgical technique is not exempt from complications.[3,4] Misalignment in the coronal plane is one of the most frequent and feared by surgeons.[5,6] Different nail entry points have been studied to avoid this complication and prevent varus or valgus deviation.[7,8]

The objective of this study was to investigate the relationship between the entry point of the nail and the final alignment after surgery in adult patients with tibial shaft fractures that had undergone surgery at our institution.

MATERIALS AND METHODS

We carried out a retrospective, descriptive, observational study, approved by the ethics committee of our institution, which included all patients who had suffered a tibial shaft fracture treated with intramedullary nailing between January 2015 and January 2019. All surgeries had been carried out by orthopedic surgeons trained in orthopedic trauma.

The inclusion criteria were: patients with tibial shaft fractures, with intra-articular extension or without extension, with skeletal maturity, and who had undergone definitive treatment with an intramedullary nail. We included 42 A-B-C fractures according to the OTA/AO classification.

Additional exclusion criteria were patients with preexisting ankle arthrodesis, initial amputation, and follow-up <12 months.

A serial radiographic control was performed in the immediate postoperative period, at 4 weeks, and then at 2, 4, and 8 months after the intervention. A fracture was considered to have consolidated if a minimum of three bony bridges were observed in the anteroposterior and lateral projections. The presence of delayed consolidation was also evaluated, that is, the lack of clear signs of osseous consolidation at 3-6 months after surgery. These images were collected using the Picture Archiving and Communication System (Kodak Carestream PACS, Kodak Company). Normal alignment was determined between 5° varus and 5° valgus.

All patients followed a similar postoperative protocol consisting of early range of motion and weight bearing based on pain tolerance.

Surgical technique

Patient positioning

The patient was placed in the supine position. The knee of the leg to be operated on was flexed at 90-110°, to maintain this angle a carbon fiber triangle was used below the knee. A pillow was placed under the glute of that leg in order to neutralize the external rotation tendency of the limb by tilting the hemipelvis.

Approach

Through a transpatellar approach, the infrapatellar fat pad was released, exposing the anterior edge of the tibial plateau, where the entry point of the nail was located. The entry point was centered on the medullary canal, this was controlled by intraoperative radioscopy.

Fracture reduction

After the approach, we performed a fluoroscopy-guided reduction of the fracture; this can be done by various methods, such as manual traction, distractors, joystick, or by opening the fracture site for direct reduction. In our case, we used manual traction on the tibial axis.

Creation of the medullary canal

Once the entry point of the nail was located, the medullary canal was created using a metal guide which was then advanced through the canal; at this stage, a soft tissue protector was used to minimize soft tissue damage. All these steps were guided by fluoroscopy.

Reaming

We inserted the cannulated flexible drill bit over the guide wire. We reamed sequentially from the smallest to the largest diameters, with 0.5mm increments. The reaming should be 0.5 to 1.5 mm larger than the nail diameter, since the medullary canal is not a perfectly straight structure.

Intramedullary nail placement

After drilling and measuring the length of the implant, the definitive nail was placed. The distal lock was performed first and then the proximal, always guided by fluoroscopy. The stability of the fracture was examined; then, both the main approach and the locks (two proximal and two distal) were closed by planes.

In the immediate postoperative radiograph, the entry point of the intramedullary nail was observed, which was classified as: central, medial, and lateral (Figure 1), taking both tibial spines as radiographic references.

Figure 1. Intramedullary nail entry points. **A.** Center. **B.** Medial. **C.** Lateral.

For this procedure, a straight vertical line was drawn from the midpoint of the tibial spines to the distal end of the tibia, above the tibiotalar joint (Figure 2); then, the deviation of the fracture was observed and it was classified as varus, valgus, or neutral. This assessment was made by drawing a straight line from the tibial spines to the center of the tibial diaphysis and then another straight line from this last point to the distal end of the tibia without taking into account, in this time, the degrees of misalignment.

Radiographic controls were performed every two months to detect if there was a delay in consolidation.

Eight months after surgery and with the fractures already consolidated, the measurement was performed again to assess the alignment of the fracture, in the same way as in the immediate postoperative period. On this occasion, we took into account the degrees of misalignment of the fracture in the coronal plane, classified as: varus, valgus, and neutral (Figures 3-5).

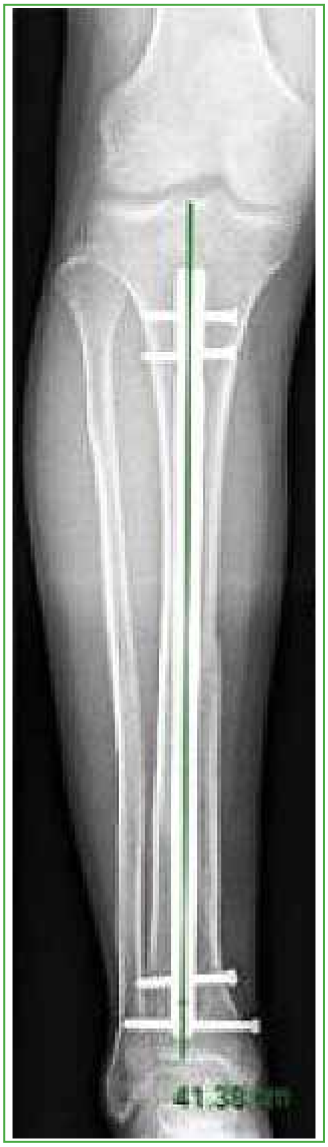

Figure 2. Methodology for measuring the coronal axis of the tibia for the classification of the entry point of the intramedullary nail.

Figure 3. Tibial fracture, post-placement of the intramedullary nail, without deviation in the coronal axis. **A.** 177.74°. **B.** 179.21°.

Figure 4. Varus deviation of the tibia, post-placement of the intramedullary nail, with a lateral entry point. **A.** 174.38°. **B.** 168.54°.

Figure 5. Valgus deviation of the tibia, post-fracture and intramedullary nailing with a medial entry point. **A.** 179.15°. **B.** 173.80°.

RESULTS

The sample consisted of 77 patients (74% men), representing two different age strata (p = 0.0096) with 95% confidence intervals [40.3; 59.6] and [31.9; 41.7] years, for women and men, respectively, this shows that the age representation of the study is concentrated around 37 years. On the other hand, age was not associated with the selection of the entry point of the intramedullary nail (p = 0.832), nor with the assessments of the positions reported by the immediate postoperative images (p = 0.547) and after 8 months (p = 0.868). This aspect is shown in Figure 6.

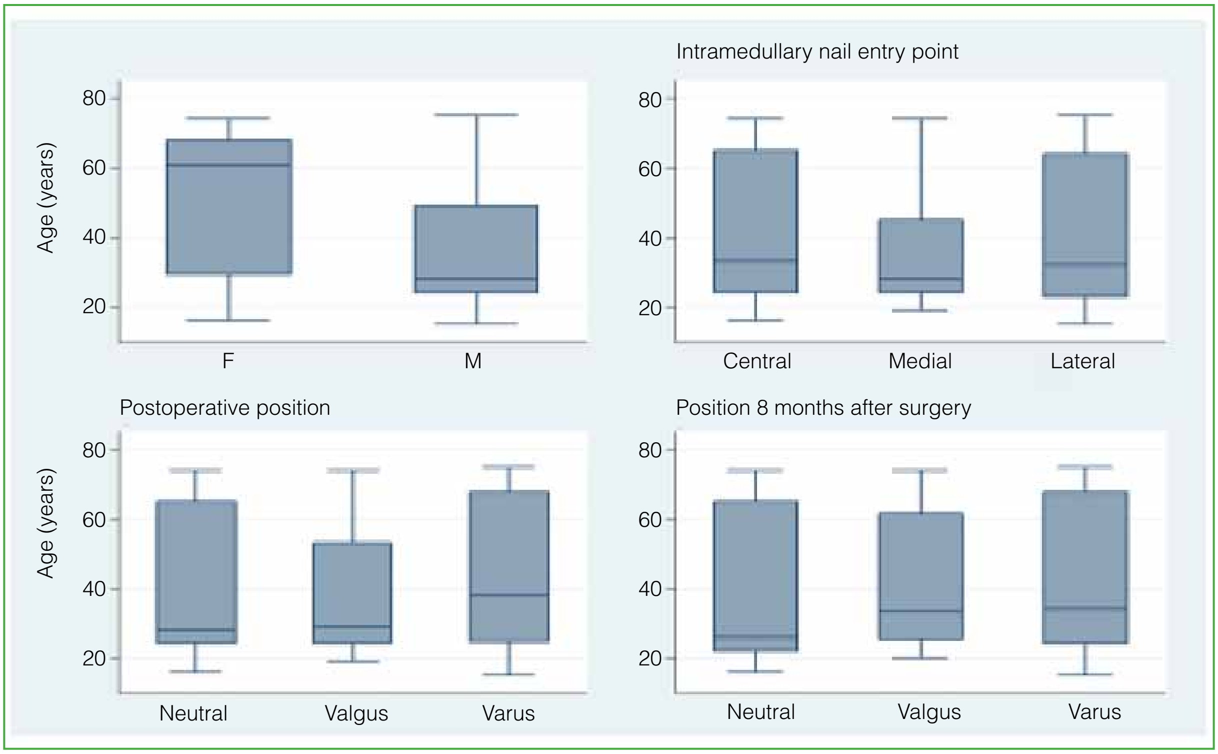

Figure 6. Box-plot for patient age by sex (upper left), entry point (upper right), postoperative nail position (lower left), and postoperative nail position after 8 months (lower right), 2015-2019.

The nail entry point was not randomly selected in the different fracture classifications (p = 0.012, Figure 7, upper right); for example, only 6% of the 54 surgeries for 42 A fractures, and 67% of the 42 B fractures, had a medial entry point.

Considering the entry point of the intramedullary nail (central, medial, or lateral), after surgery, the radiograph indicates that, except for the former (central), the remaining positions suffered significant misalignment (p = 0.002 and p = 0.0011 for medial and lateral, respectively). Indeed, in 87% of patients who received the nail in the central position, it was also central (i.e., neutral) after surgery. In contrast, of those who received the nail in the medial position, only 3.5% remained in the original position, with 93% reporting a misalignment or valgus tendency, while in all patients with lateral entry, misalignment in the coronal plane was observed in the postsurgical radiographs, and 84% of these presented misalignment or varus tendency. This behavior was only attenuated when the fracture classification (AO) was 42C, being homogeneous in the rest (42A and 42B, p = 0.634).

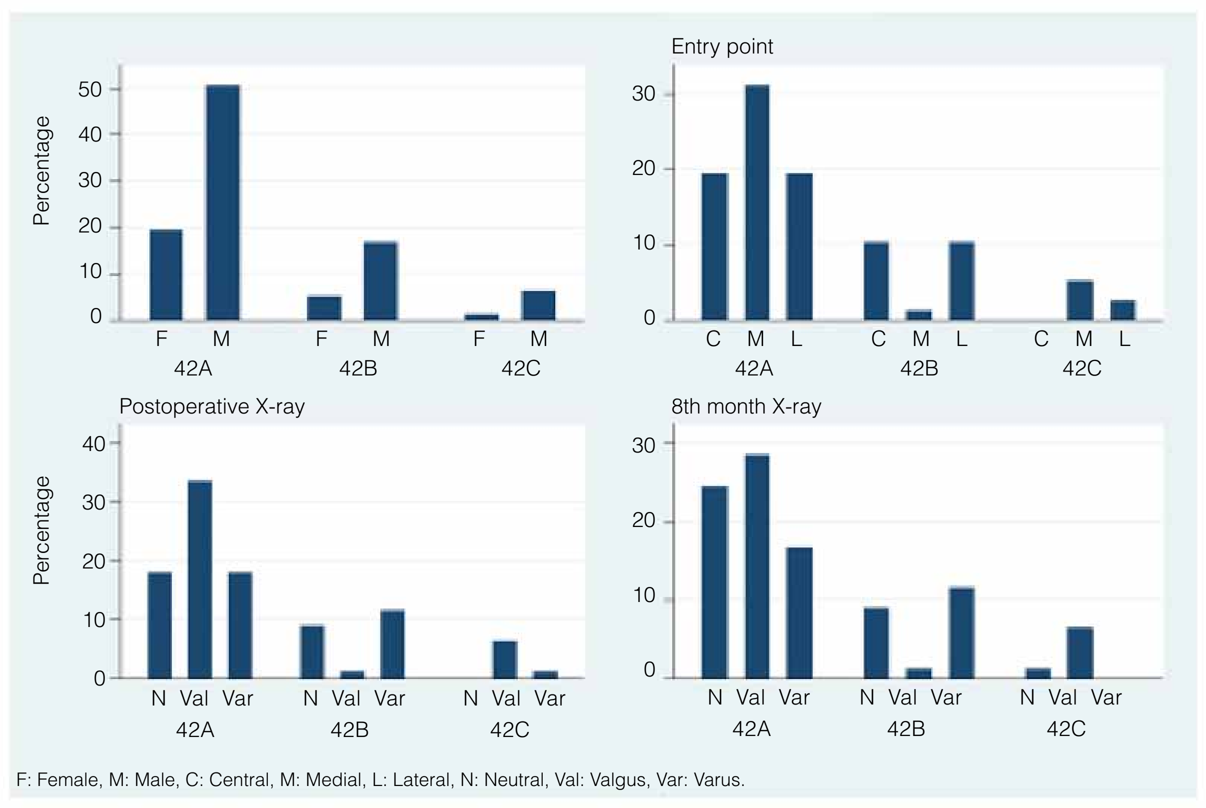

Figure 7. Patient frequency distributions based on fracture classification and gender (upper left), intramedullary nail entry point (upper right), post-surgery alignment assessment (lower left), and after 8 months (lower right), 2015-2019.

Eight months after surgery, the radiographic assessment showed partial agreement (overall adherence 81%) with the one made immediately after surgery; that is, although most central ones remained in that position (87% of patients) and medial ones had a tendency to valgus misalignment (73%), seven patients from the latter group (24%) maintained their original position. Figure 2 globally illustrates this behavior.

Finally, looking at the immediate postoperative radiographs, as well as the eight-month control radiograph, when the nail entry point was central, there was only a 0.021 chance (or 2.1%) of any significant misalignment in the postoperative period and after eight months. In contrast, when the entry point was medial, the chances of presenting a valgus tendency were greater than 0.85 (or 85%) already at the time of taking the first postoperative radiograph. When the entry point of the intramedullary nail was lateral, this chance was modified and deepened according to the time elapsed until the final radiographic image achieved in the patient.

In summary, in a population such as the one who attended our institution in the mentioned period to achieve a satisfactory alignment, the entry point must be central, regardless of the patient's age and the fracture type or classification.

DISCUSSION

Tibial shaft fractures represent around 5-11% of all tibial fractures.[9] The locked intramedullary nail is the accepted primary treatment for this type of fracture,[10-14] and is the treatment of choice in most of the literature reviewed, as well as in our study, because it is a minimally invasive procedure, with less soft tissue damage, and fewer post-surgical complications. Krishan et al.[15] showed a satisfactory angular alignment for tibial shaft fractures treated with intramedullary nailing. In our study, 35% of the patients treated with this method obtained a neutral radiographic alignment eight months after surgery, without misalignment in the coronal plane, this was what the orthopedic surgeons expected when they planned the surgery, while Nork et al.[16] reported an acceptable radiographic alignment, with an angle <5° in any plane, in 92% of metaphyseal tibial fractures treated with intramedullary nailing. Kruppa et al.[17] reported a lower percentage of correct alignment and acceptable coronal plane angulation, within the defined 5° norm, in 76% of intramedullary nail fractures. Fracture malalignment in the coronal plane is a fairly common complication of intramedullary nailing of tibial shaft fractures, as shown by Franke et al.[18] In our study, it was the main postoperative complication, given that 65% of our patients experienced some degree of misalignment, either varus or valgus, although it should be noted that many of these cases were radiographic findings in postoperative controls, without causing symptoms or discomfort in the patients. Kruppa et al.[17] reported that most of the misalignments had a valgus tendency, information that is reflected again in our analysis, since 33.8% of our cases had a valgus misalignment, compared to 31.2 % of varus misalignment. Weninger et al.[19] showed that the degree of frontal plane malalignment depended on the location of the nail entry on the tibial plateau, as well as that lateral nail insertion led to varus malalignment in a significant number of patients. In our study, we agreed with the latter, since we observed a marked relationship between the entry point of the intramedullary nail and its posterior alignment. It was shown that patients with central entry points had less possibility of some misalignment; furthermore, all patients with a lateral entry point developed misalignment in the coronal plane, the most frequent being varus misalignment, as reported by Weninger et al.[19] However, 25% of our cases with a medial entry point and a valgus malalignment on immediate post-surgical radiographs were corrected and we observed an acceptable angle <5° in all planes eight months after implant placement, an important situation that is extremely useful at the time to carry out the procedure and on which there is not much literature.

In an anatomical study, Lembcke et al.[8] found a varus malalignment caused by a lateral and valgus entry point after medial nail insertion. This result was similar to that of our analysis, because we found a direct relationship between a lateral entry point (32.5%) and varus deviation (31.2%), as well as between valgus deviation (33.8%) and a medial entry point (36.4%).

In the already mentioned study by Weninger et al.,[19] it was observed that valgus misalignment decreases if the intramedullary nails have a central entry point, and also that surgeons should take into account that varus angulation decreases if the nails are inserted less laterally. We agree with this information and it is clearly reflected in the development of our study.

We believe it is extremely important to highlight again the results obtained regarding the medial entry point, because several authors, including Tejwani et al.,[20] described that a medial entry point exaggerates the valgus deformity, a situation that occurred throughout our study, but with the variable that 25% of patients with a medial entry point did not develop any misalignment, a fact that should be taken into account by orthopedic surgeons who routinely perform this procedure.

CONCLUSIONS

We can affirm that the entry point of intramedullary nailing is directly and continuously related to the post-surgical alignment of tibial shaft fractures treated with this procedure. We found that the recommended entry point for the intramedullary nail is the central one, due to the fact that it experiences fewer postsurgical deviations in the coronal plane. Regarding the two remaining entry points, it should be noted that 25% of the fractures with a medial entry point did not have any deviation, while all of those with a lateral entry point had some defect in the final alignment.

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Traumatic Injuries to the Hand From the Use of an Angle Grinder. A Problem in Our Field

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ABSTRACT

Introduction: Hand injuries caused by angle grinders are frequent and generally take place among young adults. In developing countries, the domestic and informal work environments are the most frequent places where this could happen. The present study is aimed at describing associated factors to these types of injuries. Lesions were quantified and classified according to the severity and anatomic region of the hand involved. **Methods:** An epidemiologic, retrospective study was performed between 2016 and 2020. The patients' level of education, previous experience using the machine, use of personal protective equipment (PPE), sex, and age were analyzed. To determine the pattern of the injuries, a clinical-anatomical and a detailed and individualized radiological analysis were performed on each patient. The severity was measured using the "Hand Injury Severity Score" (HISS). **Results:** 928 patients were studied (920 men, 8 women, average age of 42 years [range 18-67]). Only 22.4% were wearing PPE at the time of the accident. 776 participants were performing tasks for which the tool was not intended (84.5%). The left hand was the most affected (60%). In 784 patients, the injuries involved their fingers (84.48%); the predominant pattern was the index and middle finger (55%). According to the HISS, 24.1% were minor injuries, 41.3% were moderate, 26% were serious, and 8.6% were severe. **Conclusions:** Injuries caused by an angle grinder can be devastating. We believe that an epidemiological update is likely to increase the need to develop preventive methods to decrease its high incidence.

Keywords: Angle grinder; traumatic injuries; hand; epidemiology.

Level of Evidence: IV

Lesiones traumáticas en la mano por el uso de amoladora. Un problema en nuestro medio

RESUMEN

Introducción: Las lesiones en las manos causadas por amoladora son comunes y generalmente ocurren en adultos jóvenes. En países en desarrollo, el ámbito doméstico y el trabajo informal son los escenarios más frecuentes. El objetivo de este estudio fue describir factores asociados a las lesiones por amoladora, y cuantificar y clasificar las heridas, según la gravedad y la región anatómica de la mano involucrada. **Materiales y Métodos:** Se realizó un estudio epidemiológico, retrospectivo. Entre 2016 y 2020, estudiamos a los pacientes con heridas de mano causadas por amoladora. Se analizaron el nivel educativo, la experiencia con la herramienta, el material cortado, el uso de equipo de protección personal, la edad y el sexo. Para determinar el patrón de las lesiones se realizó un análisis clínico-anatómico y radiológico detallado e individualizado. La gravedad fue evaluada con el *Hand Injury Severity Score*. **Resultados:** Se evaluó a 928 pacientes (920 hombres y 8 mujeres, edad promedio 42 años). Solo el 22,4% usaba equipo de protección personal en el momento del accidente. El 83,5% (776 casos) realizaba tareas inusuales para la que esta herramienta no fue diseñada. La mano más afectada fue la izquierda (62,06%). En 784 pacientes, las heridas involucraban los dedos, el patrón de asociación predominante fue entre el 2do y 3er dedo (54,44%). Las lesiones fueron leves (24,1%), moderadas (41,3%), graves (26%) y mayores (8,6%). **Conclusiones:** Las lesiones por amoladora pueden resultar devastadoras. Una actualización epidemiológica reforzaría la necesidad de desarrollar métodos preventivos con el fin de disminuir su alta incidencia.

Palabras clave: Amoladora; lesiones traumáticas; mano; epidemiología.

Nivel de Evidencia: IV

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INTRODUCTION

Hand injuries caused by angle grinders are common and usually occur in young adults. They are characterized by a highly variable extension and distribution. These injuries have a significant impact on activities of daily living, as well as physical functions, which affect socioeconomic aspects.[1]

In addition to occurring in a work context, they also occur during different activities of daily living. In developing countries, the domestic sphere and informal work are the most frequent scenarios. The underreporting of this type of injury is common due to the high unemployment rate and the deficiencies of the legislation on work safety and health.[2,3]

Dysfunctional tool use, lack of personal protective equipment (PPE), distraction, fatigue, and performing unusual tasks are associated with serious and disabling injuries.[4] A 2003 Australian case report indicated that less than 5% of patients presenting with angle grinder injuries reported using appropriate PPE.[5]

In our region, the angle grinder is associated with one of the highest rates of injury per hour of use.[6]

In 2004, Frank et al. described the injuries to the hand caused by the use of the circular saw, with an interesting analysis from which it can be deduced that the most frequent injuries affect the fingers, in general, at least two of them, with a predominance of the thumb and the index finger. In turn, with the increase in the number of affected fingers, the level of the lesion was closer to the proximal phalanx. In the majority of cases in which a finger was amputated, the adjacent fingers were affected.[7]

We conducted an extensive literature search and were unable to find a study that described, in detail, the spectrum of injuries caused by angle grinder and questions remain about which modifiable risk factors should preventive measures focus on.

The large number of patients admitted to our hospital with injuries caused by this tool and the wide variety of injury patterns we have treated motivated us to undertake this study.

Objective

We set out to describe factors associated with angle grinder injuries, and to quantify and classify the injuries, according to the anatomical region of the hand involved and the severity.

MATERIALS AND METHODS

We conducted a retrospective, descriptive, cross-sectional cohort study. Between 2016 and 2020, we registered all patients admitted to the Emergency Department of our hospital with hand injuries caused by a angle grinder. The inclusion criteria were: acute injuries caused by a angle grinder in a domestic or informal work environment, that had affected the hand(s) and finger(s), understanding the area of the body to be studied as the anatomical region distal to an imaginary line between the eminences of the carpal, pisiform, and scaphoid bones. We excluded patients with wounds caused by another cause or involving another anatomical region, injuries with more than seven days of evolution, workers in a regulated environment under biosafety standards and those with insufficient or no contact data.

All the patients included in the study were in the database of our hospital, and they were contacted and notified about their participation. An informed consent was designed for their registration and a questionnaire was prepared with basic questions from which the following variables to be analyzed emerged: age, sex, educational level, time and place of the incident, background in the use of this tool, material that was being cut, and use of protection elements at the time of the accident. Other variables analyzed were injury patterns and their severity. To determine the type and pattern of the lesions, we performed a detailed and individualized clinical-anatomical and radiological analysis.

The severity of the injuries was evaluated with the Hand Injury Severity Score (HISS) (Tables 1 and 2).[8] This system evaluates damage to the skin and to musculoskeletal and neural structures. We calculated it for each case and grouped the cases as: minor (HISS <20), moderate (HISS 21-50), severe (HISS 51-100) or major (HISS >101) injury.

According to the Argentine Ministry of Production and Labor,[9] the PPE that a worker should use for this type of work is: protective footwear, gloves, helmet, goggles, and protective clothing suitable for cuts. Since the hands are the anatomical region involved in this study, we only considered the use of gloves when referring to PPE in our patients.

Table 1. *Hand Injury Severity Score* (HISS)

Integuments				
Skin loss	Absolute values (hand)	Dorsum	<1 cm^2	5
			>1 cm^2	10
			>5 cm^2	20
		Palm	Dorsum x 2	
	Weight values (digital)	Dorsum	<1 cm^2	2
			>1 cm^2	3
		Finger pulp	<25%	3
			>25%	5
Skin laceration			<1 cm	1
			>1 cm	2
Nail injury				1
Skeletal				
Fractures	Diaphyseal fractures			1
	Comminuted diaphyseal fracture			2
	Distal interphalangeal intra-articular fracture			3
	Intra-articular proximal interphalangeal fracture			5
	Intra-articular metacarpophalangeal joint fracture			4
Dislocations	Open			4
	Closed			2
Ligament injury	Sprain			2
	Tear			3
Motor				
Extensor tendon	Proximal to proximal interphalangeal			1
	Distal to proximal interphalangeal			3
Deep flexor	Zone 1			6
	Zone 2			6
	Zone 3			5
Superficial flexor				2
Neural				
Absolute values	Recurrent branch of the median nerve			30
	Deep ulnar branch			30
Weight values	Digital nerve x 1			3
	Digital nerve x 2			4

Table 2. Individual digital weighting factors

Finger	Weighting factor
Thumb	x 6
Index	x 2
Middle	x 3
Ring	x 3
Pinkie	x 2

RESULTS

Of a total of 1062 patients, 134 could not be contacted and were therefore excluded from the study, 928 met the inclusion criteria: they were 920 men (99.13%) and eight women (0.86%), with a mean age of 42 years (range 18-67).

Most patients reported that they were cutting wood at the time of the accident (84.5%), marking a wide difference with the rest of the materials (metals 12.1% and ceramics 3.4%). Only 22.4% declared using PPE when they suffered the accident, while the rest did not use protection.

With regard to educational level, only 46 patients had university or tertiary education (4.96%), 375 had not completed secondary education (40.41%), and 415 had completed it (44.72%), 91 patients had completed their primary studies (9.81%) and only one was illiterate (0.1%).

In the interview, 25.9% of those surveyed reported having used the angle grinder for the first time, while the rest said they had used it before. When analyzing the time records, it was observed that a large number of accidents (72.4%) occurred during the afternoon (between 12:00 and 8:00 p.m.). The day with the highest incidence in our study was Friday (27.6%) (Figures 1 and 2).

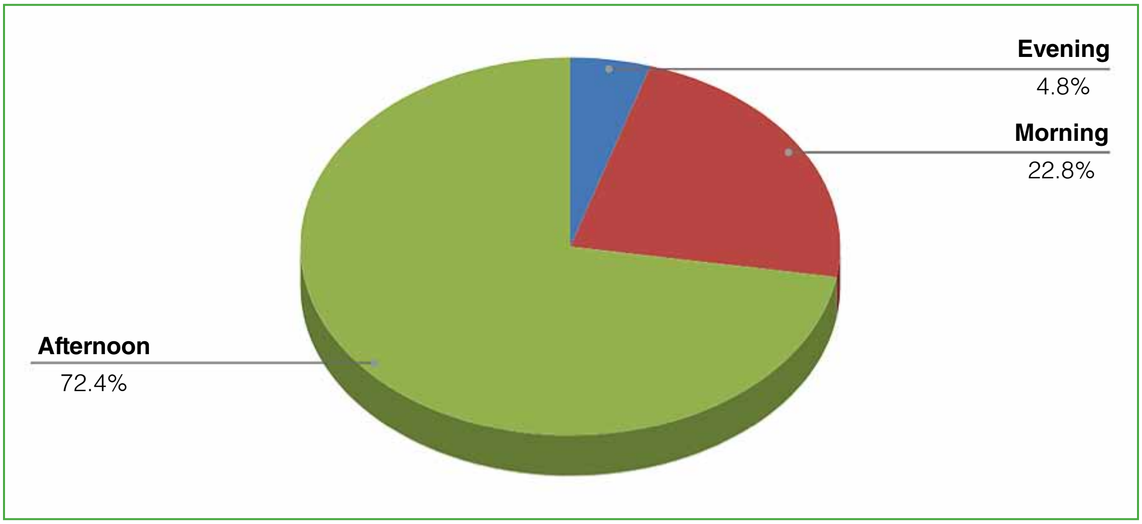

Figure 1. Distribution of traumatic events according to the time of day in which they occurred.

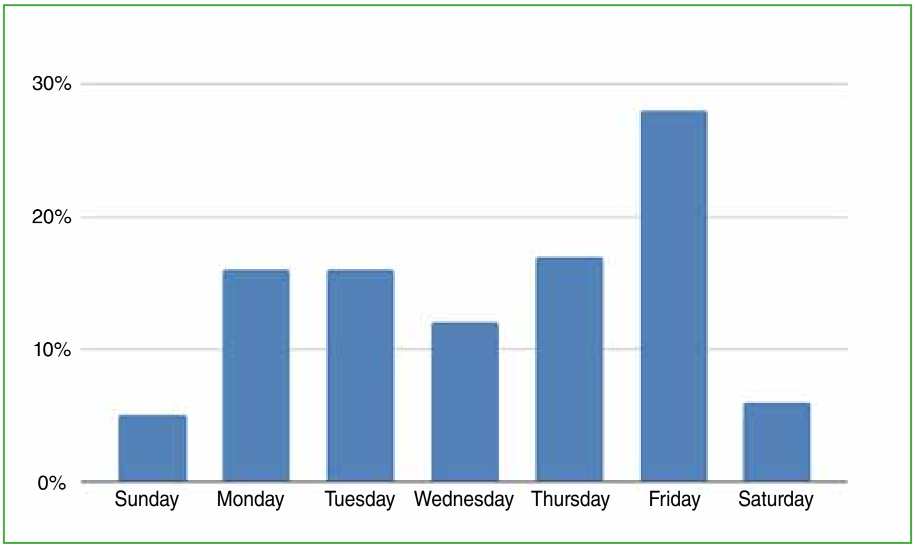

Figure 2. Incidence of injuries according to the day of the week.

36.21% (336 patients) suffered injuries to the right hand, 576 (62.07%) to the left hand, and 16 to both hands (1.72%). 84.48% of the injuries (784) involved the fingers, in 448 of these (48.27%) only one finger was affected, and there was a predominance of the thumb (57.14%), followed by the index (35.7%) (Figure 3).

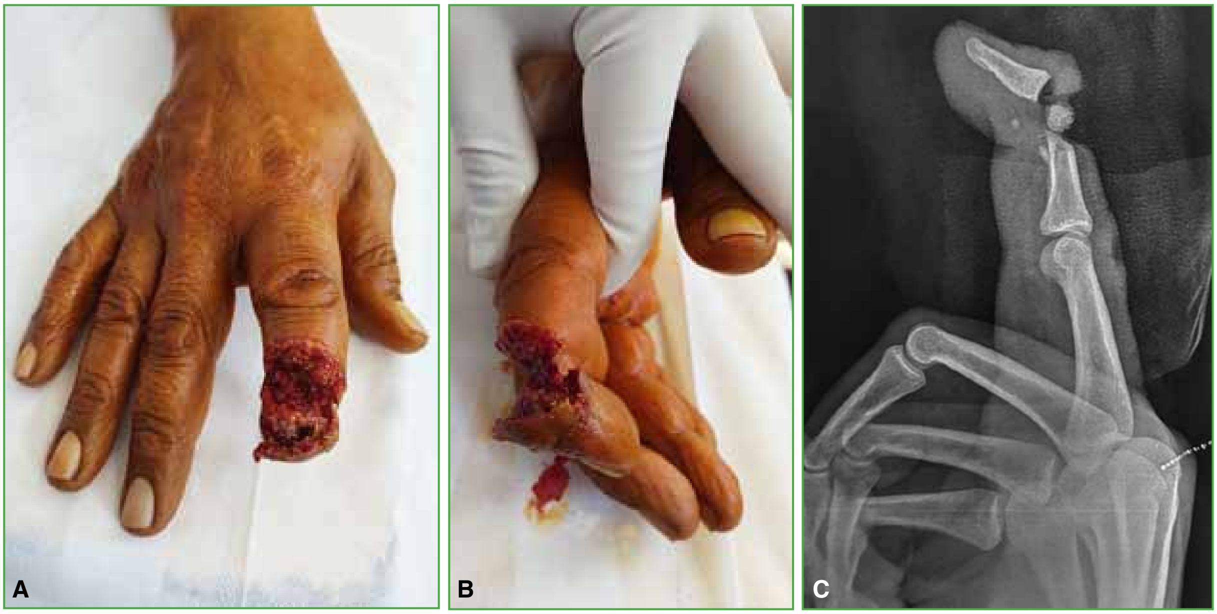

Figure 3. A. Serious injury to the index finger of the right hand, dorsal view. **B.** Serious injury to the index finger of the right hand, lateral view. **C.** Radiograph of the index finger, lateral view. A fracture of the second phalanx is observed.

In 336 cases, there was more than one affected finger (36.2%), the combination of two fingers was the most common (52.38%). 13.8% (128 patients) had four fingers involved during the accident (Figure 4), and only 32 patients (3.45%) suffered injuries to three fingers. There were no cases involving the five fingers. The predominant pattern was the association between the index and middle fingers (54.44%). The rest of the combinations did not show significant differences in the frequency of presentation (Figure 5).

Figure 4. A. Serious hand injury involving four fingers at different levels, dorsal view. **B.** Serious hand injury involving four fingers at different levels, palmar view.

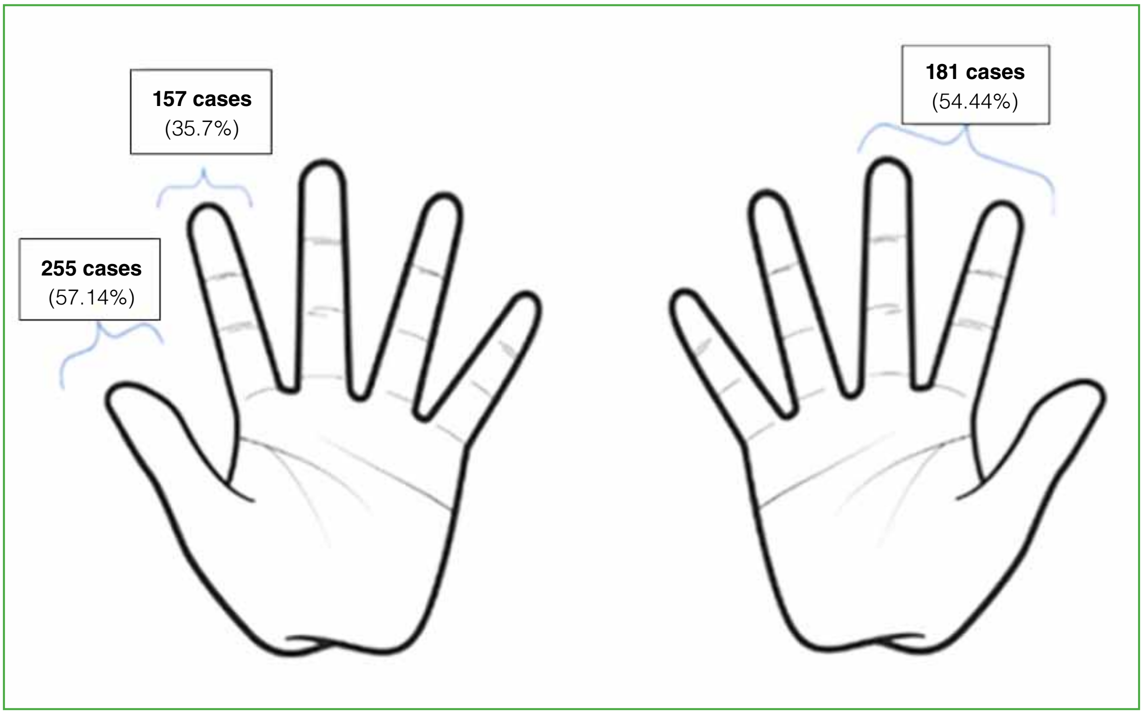

Figure 5. Diagram of injuries.

Traumatic amputations only affected the fingers, and represented 15.51% (144 patients). The middle finger was the most prevalent (41.67%), and the level of amputation was higher in the second phalanx for this finger (60%) (Figure 6).

Figure 6. A. Serious hand injury with compromise of the three central fingers plus amputation of the middle finger at the level of the second phalanx, dorsal view. **B.** Palmar view. **C.** Anteroposterior radiograph of the hand showing the amputation of the middle finger at the level of the second phalanx and the comminuted fracture of the ring finger at the level of the second phalanx.

Of the total number of registered patients, 240 suffered fractures of at least one bone, all of which were considered open. Our findings show that the bone involvement of the index finger and thumb was the most prevalent in order of frequency (Table 3). In the index finger, the involvement of the second phalanx predominated (75.53%) while in the thumb, first phalanx involvement was the most frequent (80.5%). The metacarpal bones were affected in 3.45% of the injured and there were no differences between the frequency of presentation.

Table 3. Total sectorized fractures according to affected finger and phalanx

Finger	1st Phalanx	2nd Phalanx	3rd Phalanx	Total
1°	58	14		72
2°	10	66	15	91
3°	0	29	7	36
4°	8	27	1	36
5°	1	1	5	7
				240

Regarding the severity of the injuries, the HISS score was taken into account when evaluating the involvement of each wound, including tendon injuries (we found 659 injuries: 371 involved extensor tendons and 288, flexor tendons), neurological and vascular involvement (96 and 32 cases, respectively), and whether the injury was to the hand or only to the fingers. We determined that 24.1% were minor injuries; 48.3%, moderate injuries; 19%, serious; and 8.6% severe.

DISCUSSION

Hand injuries are of great importance because it is an anatomical region of exceptional value, due to its use in almost all professions and occupations.[10]

According to our findings, we found some similarities and differences with the literature regarding the pattern of lesions. In accordance with what was described by Frank et al., the most frequently injured hand was the left (62.02%).[7] In turn, when the fingers were involved, in isolation, the most affected was the thumb, followed by the index. We found a difference in the pattern of prevalent injury, in their investigation, the association between the index and middle fingers was the most frequent. However, in our study, the association between the index and middle fingers was the prevalent combination.

Regarding the severity of the injuries, the moderate ones prevailed (48.3%). The serious (19.0%) and severe (8.6%) injuries, together with the moderate ones, far exceed the percentage of minor injuries (24.1%), which allowed us to confirm that the injuries produced by this tool are, for the most part, disabling for the patient.[11]

Temporary and transient factors (including time and time of day) can combine under different conditions to synergistically trigger injury. According to the literature, the highest frequency of injuries occurred during the morning (between 8:00 and 12:00)[12] but, in our study, the most frequent time was during the afternoon (between 12:00 and 20:00).

As described by Chow et al. or Ribak et al., most accidents occurred between Monday and Friday, with a marked decrease on Saturday and Sunday.[13,14]

Regarding PPE, there is controversy among the authors about the efficacy of its use, due to the different mechanisms and types of wounds. For their part, Sorock et al.[15] maintained that the implementation of the use of gloves managed to reduce the relative risk of damage to the hand by up to 60%, and that their use was identified as a significant protection factor. On the contrary, other current authors assert that their use could cause discomfort when handling the tool and be associated with a high risk of injury.[16] Stewart et al.[17] stated that gloves have a protective factor in terms of minor injuries, but they do not prevent more severe injuries. Only 22.4% of our patients reported using PPE at the time of the accident and suffered the most diverse injuries, minor injuries being the least frequent (30.7%).

A angle grinder is a power tool used to cut, reduce size, or polish various items, including stone, concrete, metal, wood, and ceramics, among others. The angle grinder has a disc that rotates between 6,000 and 15,000 times per minute. When used incorrectly, it can cause severe trauma.[6] Using unusual equipment for the task at hand is a transient risk factor.[18] It is important to emphasize that the use of a tool such as a angle grinder on jobs for which it was not intended is one of the most important risk factors that we have found. The most frequent pattern was the use of the angle grinder to cut wood or firewood, and it was the main cause for all kinds of injuries. These occur due to a “kickback” of the disc from the surface, causing the sharp blade to come directly at the user. Additionally, an inexperienced operator may choose the wrong blade for the type of substrate being cut, further increasing the risk of accidents.[19,20] We also note that using the wrong size, worn, or chipped blade increases probability that it will break or jam.[21]

The strengths of our study are the sample size and the detailed record of injury patterns. On the other hand, the weaknesses are its retrospective nature and also the heterogeneity of the variables analyzed.

CONCLUSIONS

In our field, angle grinder injuries are common and can be devastating. In this study, 84.5% of the patients were cutting wood or firewood when they suffered the accident. The easy access to this tool and its various discs, as well as the insistence on the part of users to use it to cut this material, are key factors in the production of injuries.

We believe that an epidemiological update would reinforce the need to develop preventive methods and provide greater training to users in order to reduce its high incidence.

Conflict of interests: The authors declare no conflicts of interest.

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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).

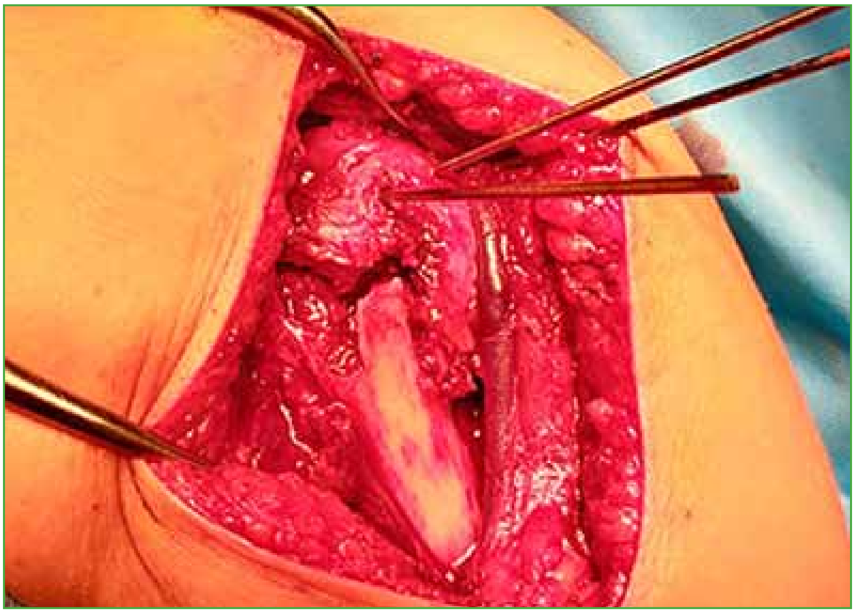

Figure 3. Intraoperative image of the same patient. The fracture line is observed at the level of the surgical neck. The surgeon assists in the reduction of the humeral head using Kirschner pins.

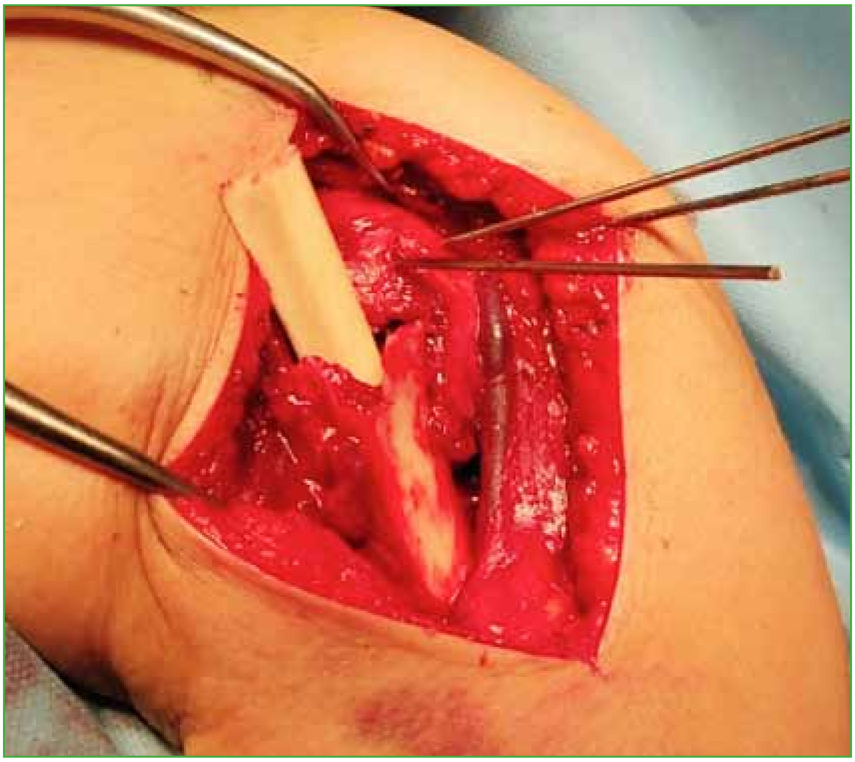

Figure 4. Intraoperative image. Presentation of the endosteal strut graft in the intramedullary cavity after reduction of the humeral head.

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).

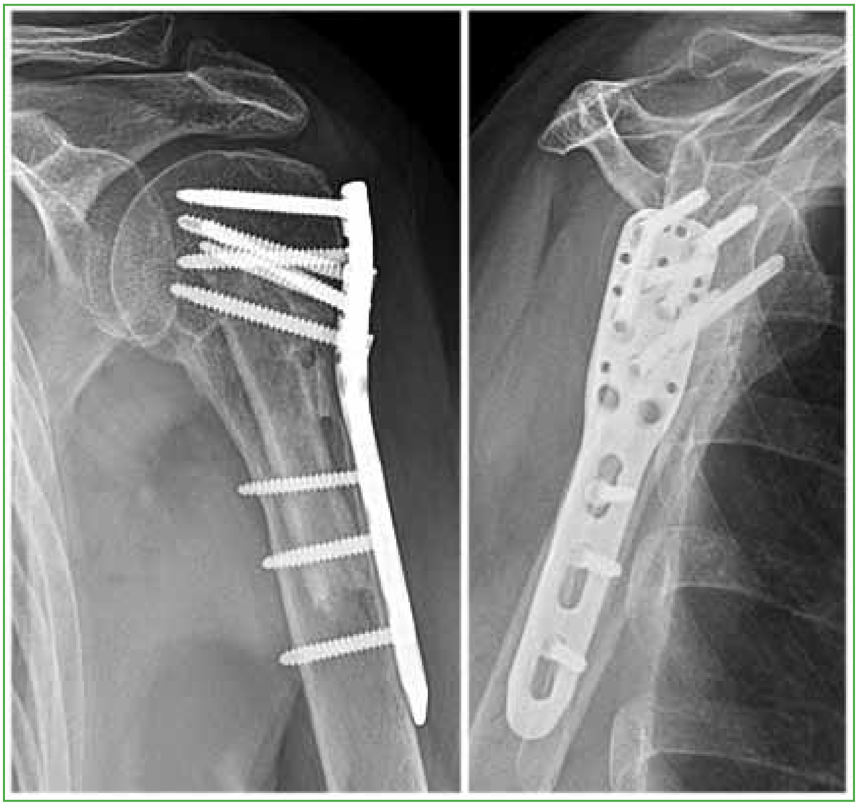

Figure 5. Anteroposterior left shoulder and axial scapula radiographs of the patient in Figure 1 taken in the postoperative period. Fracture consolidation and the presence of the endosteal strut graft are observed.

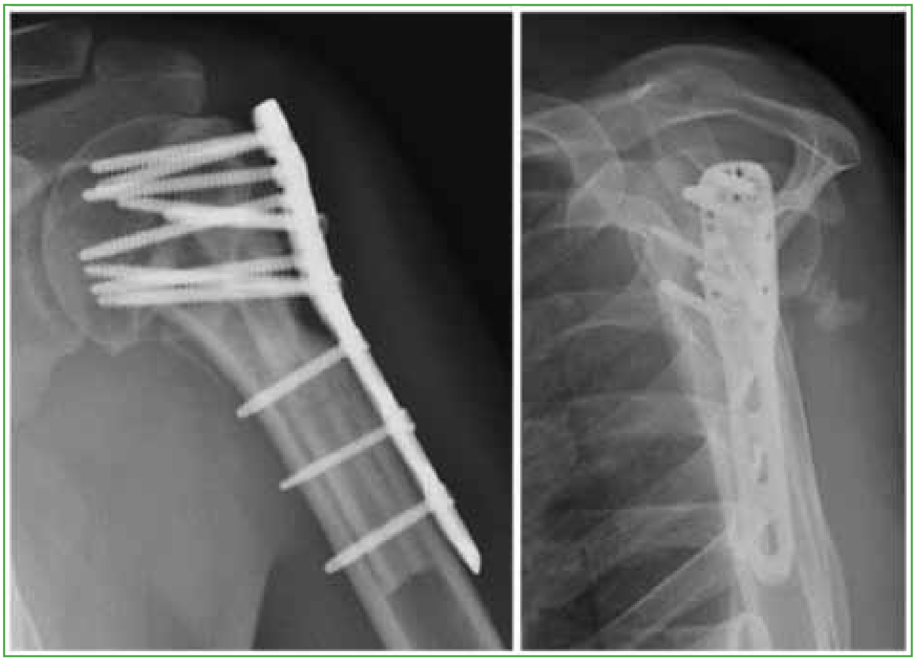

Figure 6. Anteroposterior left shoulder and axial scapula radiographs of the patient in Figure 2 taken in the postoperative period. Signs of fracture consolidation and the presence of endosteal strut graft are observed.

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.

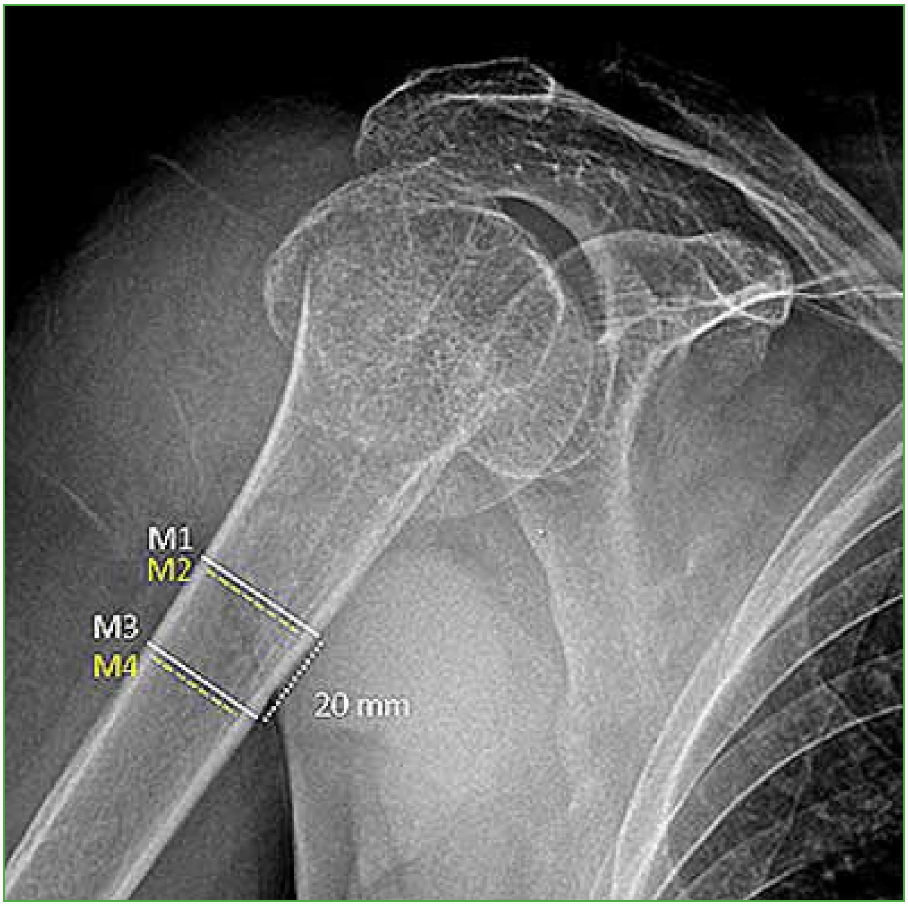

Figure 7. Mean cortical thickness of the humerus proposed by Mather et al.

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.

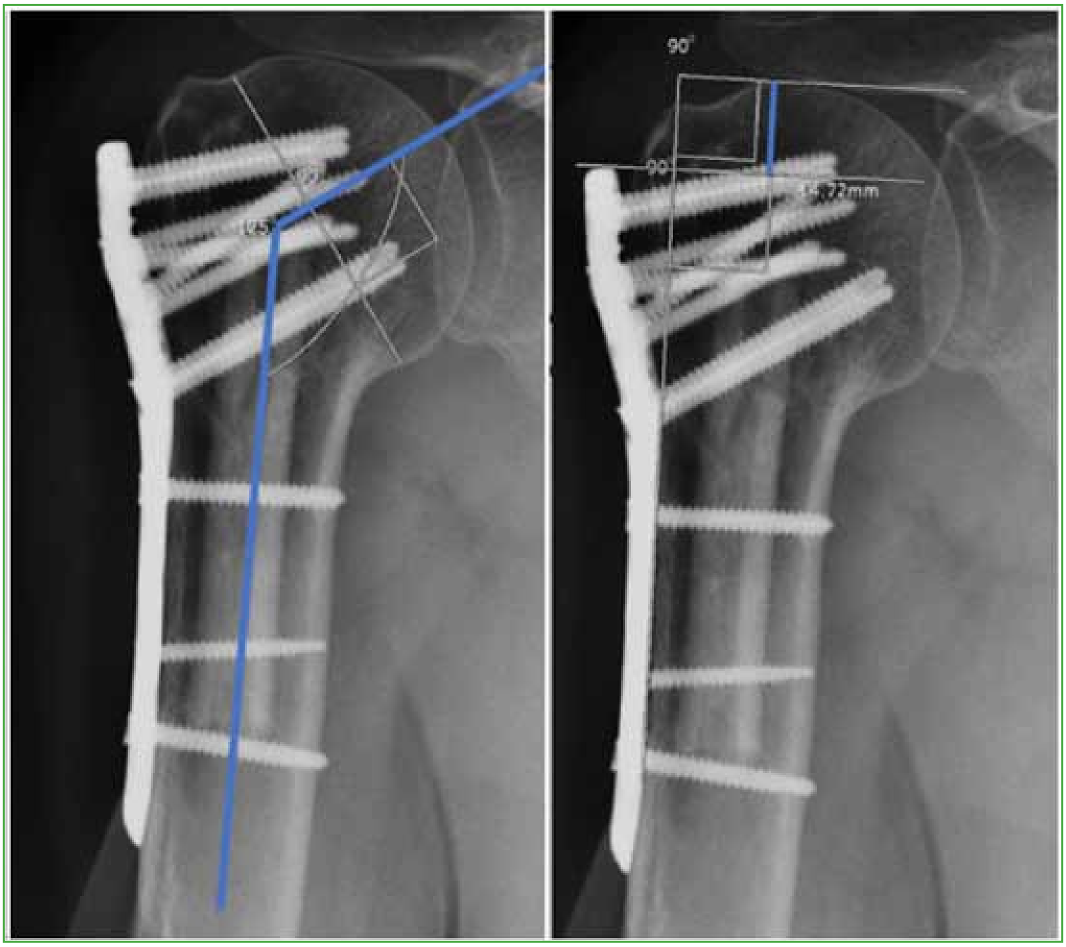

Figure 8. Anteroposterior right shoulder and axial scapula radiographs after osteosynthesis of the right proximal humerus with endosteal strut graft. The measurements, made with the program available at our Center (Synapse, Fujifilm), are shown. In blue, the neck-shaft angle (left) and the humeral head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

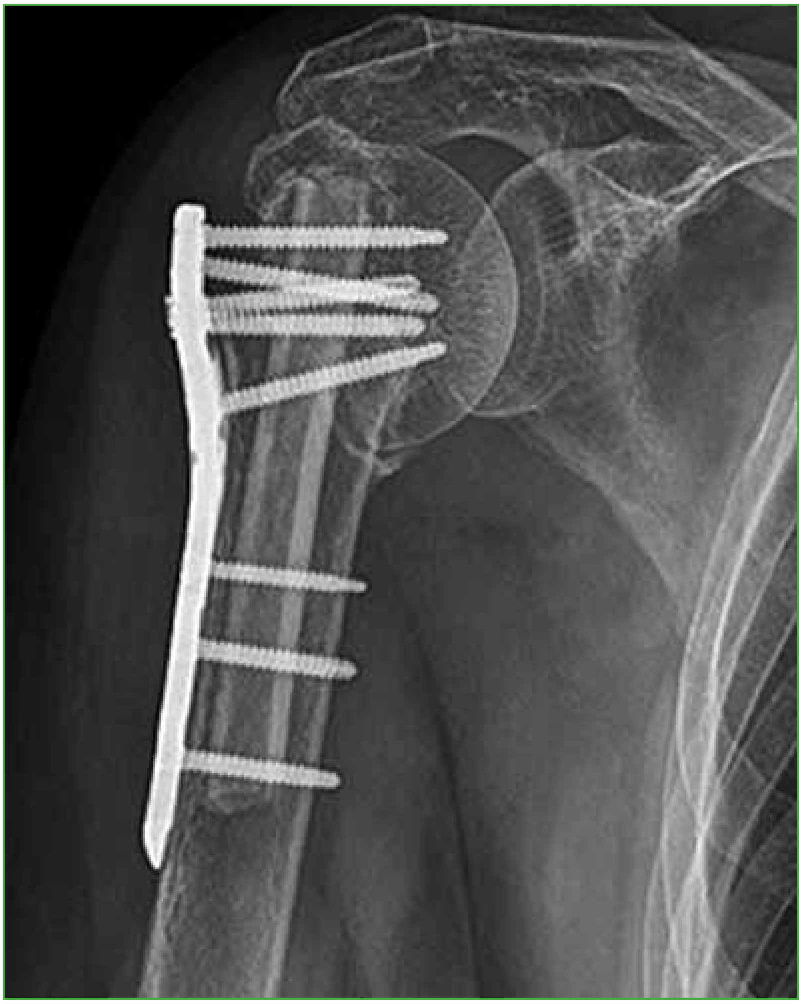

Figure 10. One case of the series with loss of reduction at the end of follow-up. The lack of medialization of the endosteal graft is observed.

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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Segmental Bone Defects: Use of Custom-Designed Trabecular Titanium Implants

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ABSTRACT

Introduction: There is a wide variety of therapeutic options for the reconstruction of segmental bone defects caused by fractures, tumors, or infections, but it continues to be a challenge in orthopedic surgery. **Materials and Methods:** The present work presents six (6) cases of patients with massive bone loss treated by means of what we call a "synergistic combination" of an induced membrane, to provide biological benefits, plus a trabecular titanium scaffold designed for each patient to provide stability and structure. **Results:** Five men and one woman with an average age of 30 years were operated on by this technique. The average follow-up was 24 months. In the immediate postoperative period, the axis, length, and sufficient mechanical stability to initiate partial weight-bearing were reestablished. Full weight-bearing according to the patients' conditions (pain, muscle strength) required an average of 25 to 30 days. **Conclusion:** We propose a rare treatment option in our field with sufficient biomechanical stability to tolerate early weight-bearing, recovering the entire length of the defect in a single stage with excellent functional outcomes, understanding these as an advantage over traditional therapeutic options such as bone transport or the Masquelet technique.

Keywords: Trabecular titanium; scaffold; segmental bone defect.
Level of Evidence: IV

Defectos óseos segmentarios: uso de implantes de titanio trabecular diseñados a medida

RESUMEN

Introducción: Se dispone de una amplia variedad de opciones terapéuticas para la reconstrucción de defectos óseos segmentarios causados por fracturas, tumores o infecciones, pero aún es un desafío en la cirugía ortopédica. **Materiales y Métodos:** Se presentan seis casos de pacientes con pérdida ósea masiva tratados mediante lo que denominamos "combinación sinérgica" de una membrana inducida para aportar beneficios biológicos, más un andamiaje (*scaffold*) de titanio trabecular desarrollado especialmente, según cada paciente, para el aporte de estabilidad y estructura. **Resultados:** Cinco hombres y una mujer (edad promedio 30 años) fueron operados con esta técnica. El seguimiento promedio fue de 24 meses. En el posoperatorio inmediato, se logró el restablecimiento del eje, la longitud y la estabilidad mecánica suficiente para iniciar la carga parcial. La carga total, según las condiciones del paciente (dolor, fuerza muscular), demandó un promedio de 25 a 30 días. **Conclusiones:** Proponemos una opción de tratamiento poco frecuente en nuestro medio que brinda estabilidad biomecánica suficiente para tolerar la carga precoz recuperando la longitud total del defecto en un solo acto, con excelentes resultados funcionales, entendiendo estas como ventajas frente a las opciones terapéuticas de uso tradicional, como transporte o técnica de Masquelet.

Palabras clave: Titanio trabecular; andamiaje; defecto óseo segmentario.
Nivel de Evidencia: IV

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INTRODUCTION

In our daily practice, it is increasingly common to see patients suffering from serious injuries with extensive bone defects that require long treatments with multiple reconstructive surgeries and a high incidence of complications. There is a wide variety of therapeutic options for the reconstruction of segmental bone defects caused by fractures, tumors, or infections, but they remain a challenge in orthopedic surgery. Among the most widely used treatments in our field are bone grafting (whether autologous or heterologous),[1,2] vascularized grafts, bone transport,[3] the induced membrane technique,[4-9] and the growing use of calcium sulfate and phosphate bone substitutes (hydroxyapatite matrix), stem cells, and biological stimulators, such as growth factors, especially morphogenetic protein (BMP 2 and 7).

The advent of new materials and technologies based on tomographic reconstructions and three-dimensional printing allows us to develop 'customized' interlayer trabecular titanium implants[10-13] for each patient.

The biocompatibility of titanium and its intrinsic characteristics of osteoinduction, conduction, and integration,[12] as well as its mechanical[11] and infection[14,15] resistance, allow its safe implantation in previously infected patients, achieving full length recovery of the defect, early weight-bearing, and excellent functional outcomes.

The skeletal reconstruction principle we report is based on the "synergistic combination" concept proposed by our team. It involves the use of an induced membrane with its well-known biological benefits, generated under Masquelet's precepts, plus the implantation of a custom-made trabecular titanium scaffold to provide stability and structure.

In this article, we report the first description of this novel technique and present a series of cases with segmental bone defects of traumatic and infectious etiology in which the scaffolding technique was applied on trabecular titanium molds made with three-dimensional technology. We propose the following hypothesis: open fractures with segmental bone loss treated by this technique have a faster clinical-functional evolution than those treated by other methods, and patients resume their previous activities in less time.

MATERIALS AND METHODS

We carried out a retrospective and observational case series study. The series comprised six cases of patients with open fractures with massive lower limb bone loss between 2016 and 2019. Four were defects of the femoral shaft, one of the distal tibia, and one of the tibial midshaft. All patients were operated using what we call "synergistic combination". Each implant was developed in a particular way for each type of defect, taking the healthy limb as a reference. To do this, it is necessary to perform 1-mm thin-slice tomography scans in the three planes of the healthy and affected limb. By superimposing images of both bones, using a specific program, the length and diameter of the defect to be corrected are calculated. The RAOMED company was in charge of printing the final design developed jointly by our team in trabecular titanium.

We carried out a clinical evaluation before and after surgery, and requested radiographs and a CT scan. All patients were operated on with the same technique described by our team. According to the classification of long bone defects proposed by Solomin and Slongo, the fractures were grade C.

The inclusion criteria were: patients with a mature skeleton, segmental bone defects >4 cm, a history of bacterial infection confirmed by bacterial culture and with a specific treatment, open fractures.

The exclusion criteria were: patients with active bacterial infection, bone defects secondary to tumor.

CASE DESCRIPTION

Case 1

A 54-year-old woman with a Gustilo 3B open fracture of the left distal tibia and massive bone loss as a result of a traffic accident (Figure 1).

Initially, she was treated with debridement and an external fixator. She underwent serial debridement (3 times in total), placement of a cement spacer with antibiotics (vancomycin-imipenem) (Figure 2) and a vacuum aspiration system.

Figure 1. Gustilo 3B open fracture in the distal third of the left leg, extensive soft tissue injury.

Figure 2. Anteroposterior leg radiograph after antibiotic spacer placement and external fixation.

The culture of a bone sample was positive for *Enterococcus faecalis* and the patient received antibiotic treatment with ampicillin. After 22 days, the wound had improved, the antibiotic spacer was replaced, and a new bone puncture, definitive soft tissue coverage, and fibular osteosynthesis were performed. A positive culture for *Acinetobacter* was obtained from said surgery, so intravenous imipenem was indicated, which was later changed to meropenem to comply with a 90-day antibiotic treatment plan at home. After 45 days, the patient was readmitted due to a surgical site infection. She underwent a new cleaning, spacer replacement, Schanz repositioning, and sample collection for culture, the result of which was positive for *Staphylococcus aureus*. We administered outpatient treatment with cephalexin due to the good evolution of soft tissues. Once treatment with meropenem ended, a puncture was performed and the culture was positive for cephalexin-resistant *S. aureus*, so trimethoprim/sulfamethoxazole plus rifampin were indicated. After 90 days, six samples were taken for culture, all of which were negative. After 10 months, the patient underwent reconstructive surgery with the placement of a trabecular titanium implant.

Implant development

We developed cutting guides to regularize the fracture edges and determine the length of the resection, and designed a trabecular titanium implant for the placement of interfragmentary compression screws both proximally and distally. At the implant-bone interface, spikes were also used to interdigitate the bone-implant surface to increase contact surface and stability. An oval hole design was chosen to accommodate screws from an anterolateral LCP regional tibial plate (Depuy, Synthes) (Figure 3) placed to neutralize and avoid loss of reduction and eventual displacement of the implant (Figure 4).

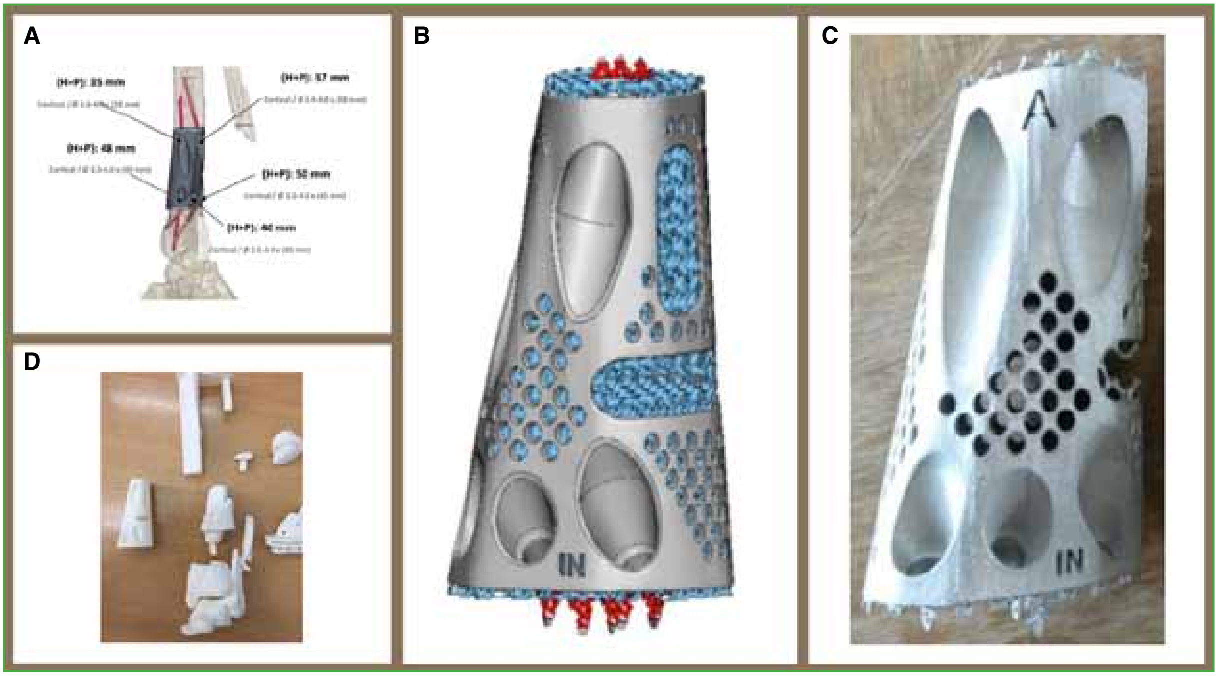

Figure 3. A. Scaffolding development: cutting guides and a trabecular titanium implant designed for the placement of interfragmentary compression screws were created. **B and C.** Final design of the virtual and real scaffolding. **D.** Scale polypropylene biomodelling of the bone defect and scaffolding for preoperative planning.

Figure 4. Anteroposterior and lateral radiographs of the left leg two years after surgery.

Case 2

A 40-year-old man with an open fracture of the left tibia, an open fracture of the right patella, and a mid-shaft fracture of the right radius, with bone loss in the tibia, as a result of a traffic accident. The initial treatment consisted of debridement and resection of the third devitalized and contaminated fragment plus placement of an external fixator (Figure 5). The patient was hospitalized in the Intensive Care Unit for a splenic hematoma. At 48 h, he was evaluated again and *Streptococcus viridans* was isolated, so ampicillin was prescribed for 45 days.

Two weeks later, osteosynthesis of the right forearm and antibiotic nailing of the left tibia were performed. At the end of antibiotic treatment, a needle biopsy was performed, all samples were negative, and skeletal reconstruction was performed (Figure 6).

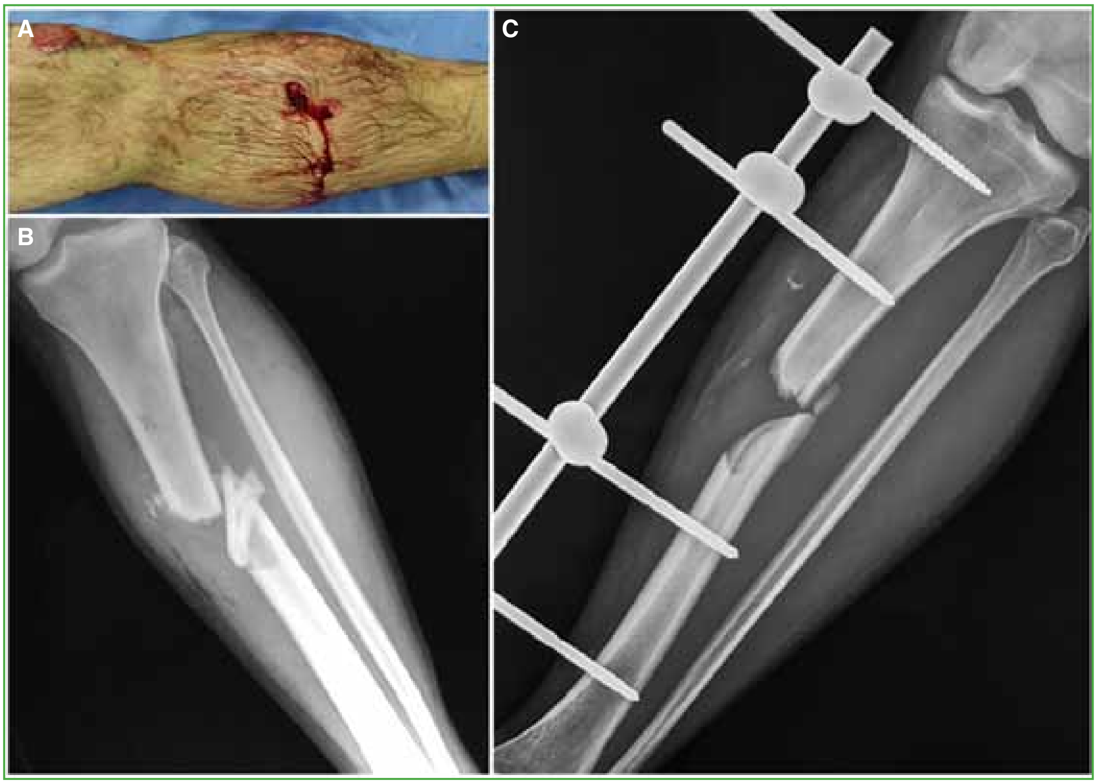

Figure 5. A. Gustilo 2 open fracture, soft tissue injury. **B.** Anteroposterior radiograph of the leg. The fracture line with segmental bone loss at the distal diaphyseal level of the left tibia is observed. **C.** Anteroposterior radiograph of the left leg after the first debridement and external fixation.

Figure 6. Anteroposterior and lateral radiographs of the left leg, two years after surgery.

Implant development

Cutting guides were developed to regularize the fracture edges. We chose stabilization with an intramedullary nail and designed a channel to house it; in this case, we added tabs at both ends to place fixation screws and prevent rotation and improve the stability of the scaffolding (Figure 7). We chose a smooth external surface to reduce soft tissue abrasion and avoid adherence of the ankle extensor tendons due to the particular anatomy of this region, and the implant was placed under the subcutaneous and submuscular tissue.

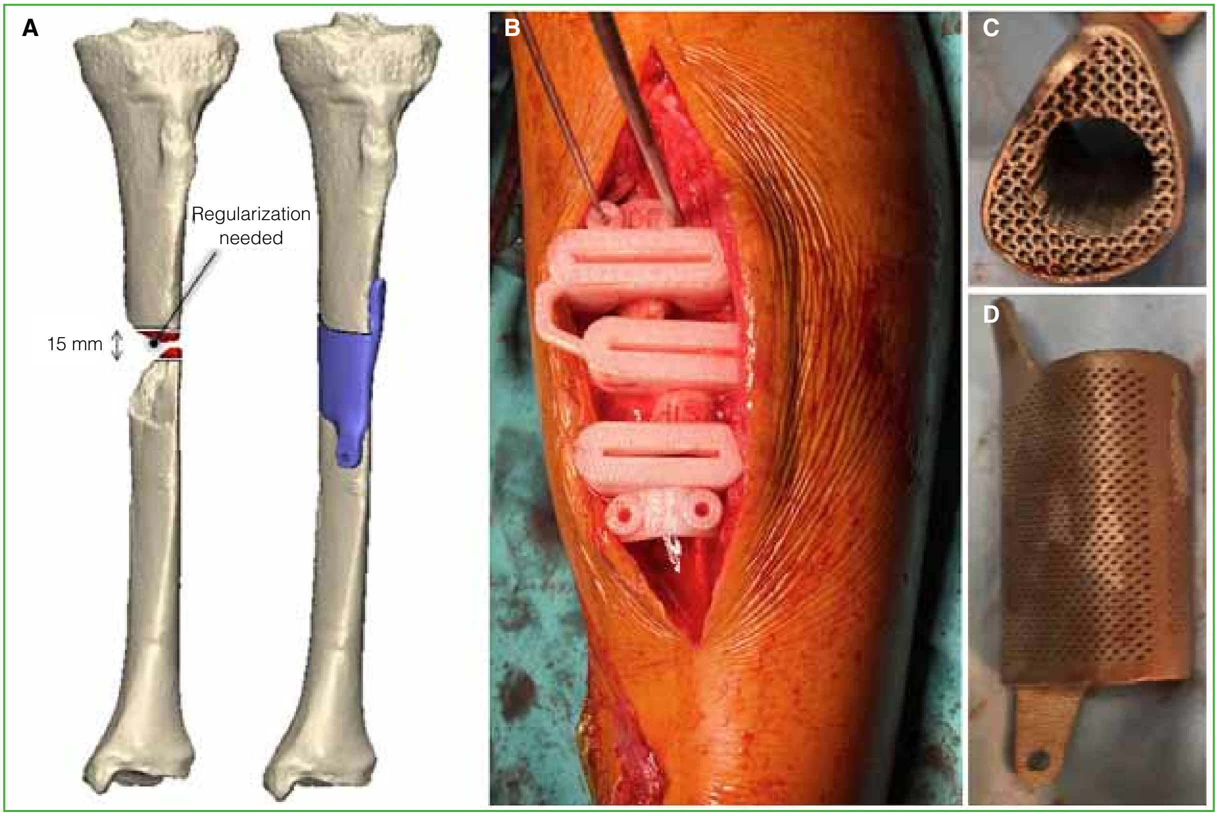

Figure 7. A. Bone regularizations necessary for the development of the scaffolding. **B.** Intraoperative image with cutting guides. **C.** Trabecular titanium implant with channel for intramedullary nail placement. **D.** Tabs were added at both ends to place fixation screws and prevent rotation.

Case 3

A 19-year-old man was referred from the province of Misiones due to a surgical site infection after osteosynthesis of the left femur with one month of evolution. He was treated empirically with cephalexin. Upon admission, he had a phlogotic wound with purulent secretion on the distal femur osteosynthesis plus a comminuted patella fracture without surgical treatment. He underwent debridement and the local placement of antibiotic beads. The samples taken were positive for extended-spectrum beta-lactamase-producing *Klebsiella*. Ten days after admission, the patient underwent a scheduled surgery to remove the beads and the osteosynthesis plate, we performed an oncological-type massive bone resection and placed the LFN nail and cement spacer with gentamicin (Figure 8). Due to the poor evolution of the wound, it was necessary to carry out four more cleanings, and to replace the nail and the cement spacer with antibiotics.

Figure 8. A. Radiograph of the left femur taken immediately after the first surgical stage (performed in another institution). **B.** Wound with spontaneous purulent discharge from a fistula. **C.** Radiograph of the left femur after the first debridement with exeresis of the devitalized fragments and placement of antibiotic beads. **D.** Oncological bone resection, placement of antibiotic spacer/beads, and stabilization with an intramedullary nail.

After the sixth debridement since admission, the wound began to improve. Antibiotic treatment was completed and puncture samples were taken, which were negative. Skeletal reconstruction was carried out, with good clinical-functional evolution.

Implant development

We developed a truncated cone interlayer segment with a larger diameter at both ends for better implant-bone coaptation (Figure 9). We chose stabilization with an intramedullary nail and designed a channel to house it. Given its length (13.5 cm), it was necessary to place a graft, so we decided to use a rough surface for embedding cancellous bone.

Figure 9. A and B. Final design of the scaffold. C and D. Anteroposterior and lateral radiographs of the complete femur two years after surgery. Bone formation encircling of the scaffold is observed.

Case 4

A 21-year-old man with a open femoral shaft fracture exposed on the posterior aspect of the thigh was referred four days after suffering a car accident. As background, drug addiction stood out. Initially, a mechanical-surgical debridement was performed with the placement of a tutor and reassessment at 48 h. Seven days later, intramedullary nailing was performed. Three days later, he was discharged with no complications (Figure 10).

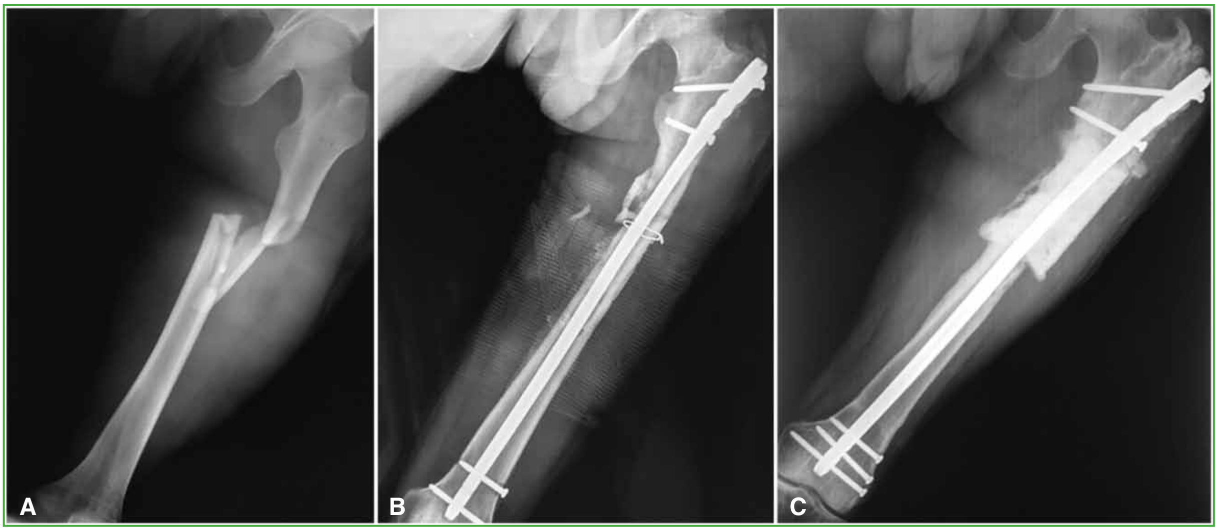

Figure 10. A. Anteroposterior radiographs of the left femur upon admission. **B.** Anteroposterior radiograph of the left femur after intramedullary nailing with cerclage wire. **C.** Postoperative anteroposterior radiograph of the left femur. The antibiotic spacer/beads and intramedullary nailing can be seen.

Three months after surgery, the patient presented with a purulent discharge and a fistula that coincided with the initial exposure site on the posterior thigh. Debridement with bacteriological isolation of methicillin-resistant *S. aureus* was performed twice, and targeted antibiotic treatment was indicated. Given the poor evolution, it was decided to remove the material and place a new nail with antibiotic coating. The patient escaped from the hospital and was readmitted a few days later due to discharge from the wound. A new debridement was carried out with *Staphylococcus haemolyticus* isolation. Psychological treatment was indicated. Due to the possibility of oral antibiotic treatment, he was discharged with regular check-ups in an outpatient clinic. At the third month, he reported that he had abandoned the antibiotic treatment without medical indication and that he had not attended physiotherapy sessions, he had stiffness in the ipsilateral knee. The patient did not comply with the traumatological and infectious guidelines and did not appear for subsequent controls. A year after the accident, he was admitted again with a thigh abscess under tension. Rarefaction of the fracture focus was observed on the radiograph. Debridement with positive isolation of methicillin-sensitive *S. aureus* was performed twice. Due to the poor evolution, we chose a radical approach which consisted of removal of the implant, resection of bad-looking bone fragments, and placement of a cement spacer with antibiotics. Given the good response, he was discharged to finish antibiotic treatment on an outpatient basis. A CT scan was requested for the preparation of the custom scaffolding.

Once the antibiotic treatment was finished, a puncture biopsy was performed, which was negative. Reconstructive surgery was performed (Figure 11).

Figure 11. Anteroposterior and lateral radiograph of the complete left femur, nine months after surgery. Bone formation encircling of the scaffolding is observed.

Implant development

We developed a conical interlayer titanium segment with a larger proximal diameter to allow the development of an internal oval-shaped canal, in order to facilitate the entry of the intramedullary nail without secondary displacement of the scaffold. To achieve greater coaptation of the bone segments, two divergent channels were designed in the direction of the lesser trochanter to place 3.5 mm cortical screws in compression. At the level of the medial aspect, we made a slot that extended connecting the proximal and distal segments, intended for the placement of bone graft in order to achieve an internal column of bone. Due to its length (11 cm), it required the placement of a graft, so it was decided to use a rough surface for embedding cancellous bone (Figure 12).

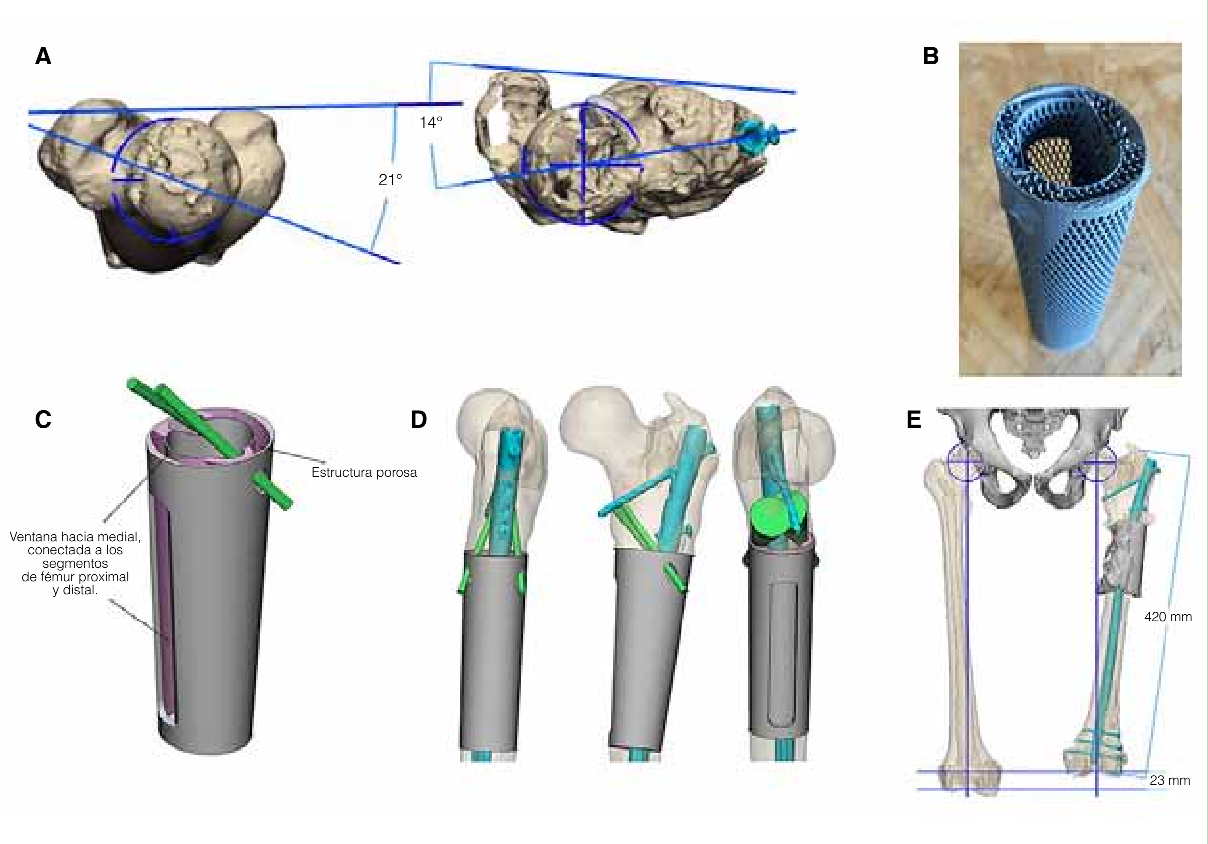

Figure 12. A. Comparative image with the healthy femur to carry out the design of the scaffolding taking into account the correction of axes, length, and rotation. B. Scaffold development. C. Development of an internal oval-shaped channel in order to facilitate the entry of the intramedullary nail. D. On the medial aspect, a slot that extends connecting the proximal and distal segments is created for bone graft placement. E. Final design of the scaffold to be implanted.

Case 5

A 22-year-old man was referred to our hospital with a plaster cast 5 weeks after a car accident. He had an open femoral shaft fracture, exposed on the anterior side with a segmental defect of approximately 10 cm, a comminuted fracture of the ipsilateral patella (Figure 13), and injury to the brachial plexus.

Upon admission, the open fracture wound was reviewed and it was decided to place skeletal traction for five days due to the marked shortening of the limb.

Figure 13. Anteroposterior and lateral radiographs of the femur. The fracture line with segmental bone loss of approximately 11cm is observed.

Before definitive surgery, an intramedullary nail was placed to equalize limb length together with a vancomycin-gentamicin cement spacer; oral antibiotic treatment was administered (Figure 14). Four months later, the spacer was replaced and samples were taken, which were negative. At two weeks, reconstructive surgery was performed (Figure 15).

Figure 14. **A.** Postoperative radiograph of the entire right femur. Intramedullary nailing with length recovery without focus opening. **B.** Anteroposterior radiograph of the entire right femur after the second surgery to place a cement spacer for Masquelet membrane formation.

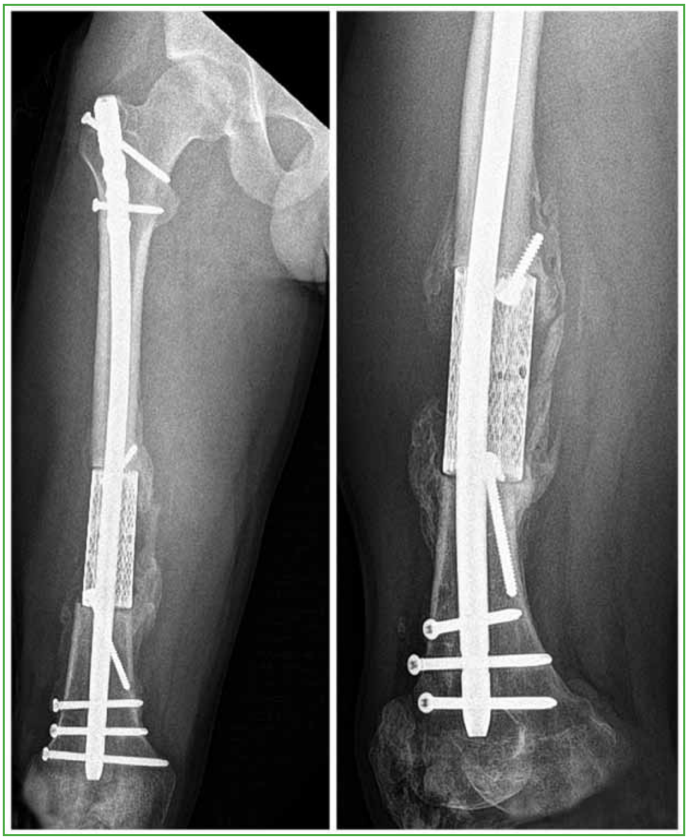

Figure 15. Anteroposterior and oblique radiographs of the entire right femur, two years after surgery. Bone formation encircling the scaffold is observed.

Implant development

We developed cutting guides. It was a cylindrical interlayer titanium segment with the same diameter as the patient's femoral diaphysis. Cutting guides were designed to regularize the fracture edges. We decided to perform stabilization with an intramedullary nail; therefore, a channel was designed to house it. In order to achieve greater coaptation to the bone segments, it was designed with a 45° channel, both proximal and distal, for the placement of 4.5 mm cortical screws in compression. Due to its length (12.5 cm), it required grafting, so it was decided to use a rough surface for embedding cancellous bone (Figure 16).

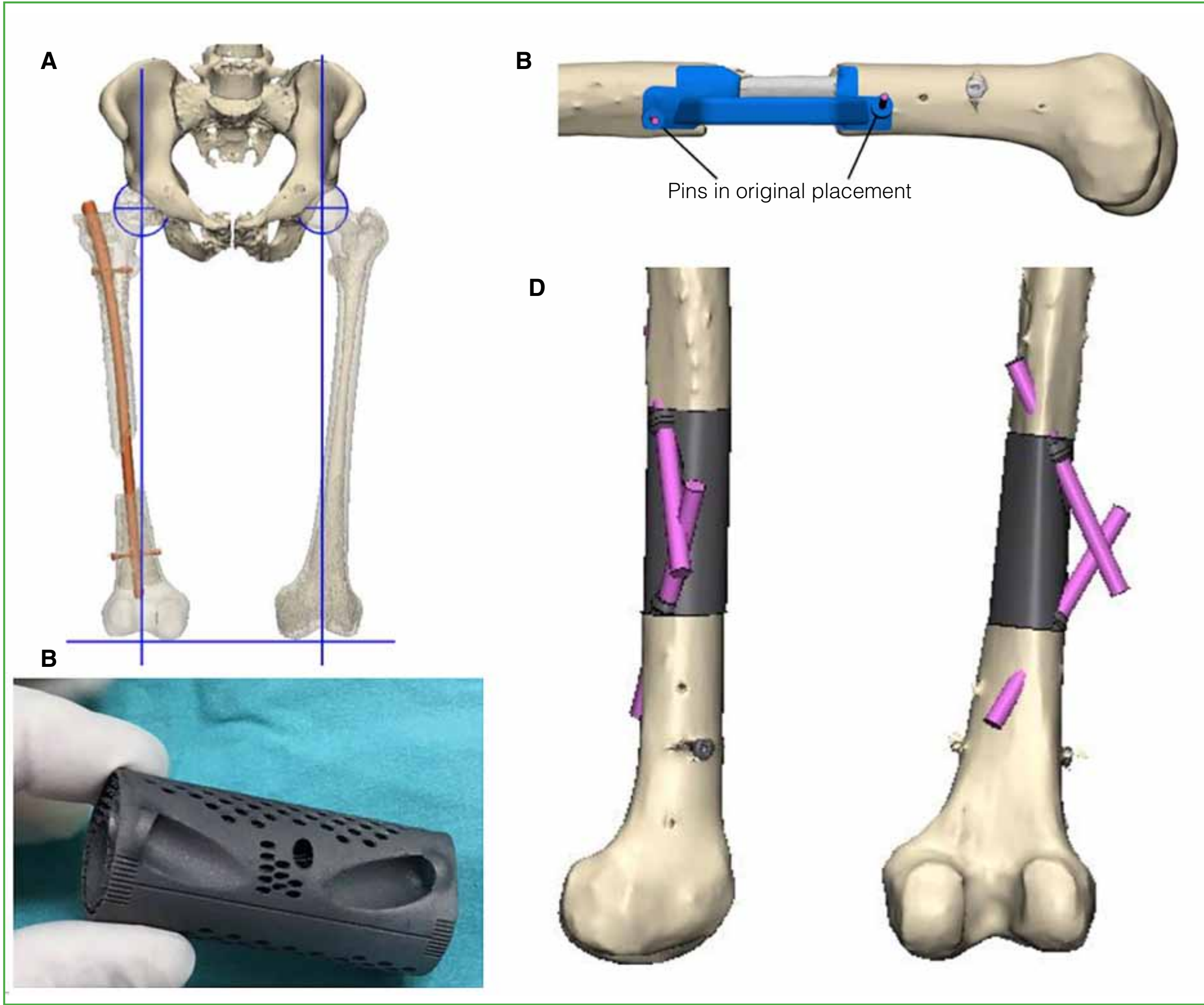

Figure 16. A. Comparative image with the healthy femur to carry out the scaffold design. B. Scaffold development. C. To achieve greater coaptation to the bone segments, it was designed with a 45° channel, both proximal and distal, for the placement of 4.5 mm cortical screws in compression. D. Final design of the scaffold to be implanted.

Case 6

A 24-year-old man was referred to our hospital 24 hours after a car accident. He had a multifragmentary open femoral shaft fracture, a fracture of the scapula, a fracture of the left 5th metatarsal, and multiple excoriations. Upon admission, mechanical-surgical debridement and external fixation were performed. After 10 days, intramedullary nailing of the femur and osteosynthesis of the 5th metatarsal were performed. He was discharged on the third day after surgery. After 10 days, he consulted again fo secretion from the wound and mechanical-surgical debridement was performed again. It was decided to remove the devitalized bone fragments and place antibiotic beads. The patient began empirical treatment with vancomycin, meropenem, and rifampicin. At 48 h, debridement was carried out again and the beads were replaced. Methicillin-resistant *S. aureus* was isolated from culture and, based on the antibiogram, the treatment switched to cephalothin plus rifampin. Given the poor evolution, we proceeded to remove the nail and all the bone fragments, and place a spacer with cement and antibiotics, which eradicated the infection and provided clinical improvement. After 20 days, he was discharged to complete 90 days of outpatient antibiotic treatment. The interlayer scaffolding design began. Once the antibiotic treatment was finished, a puncture was performed with a negative result and skeletal reconstruction was carried out after 10 days.

Implant development

We developed cutting guides. It was a cylindrical interlayer titanium segment with the same diameter as the patient's femoral diaphysis. We chose stabilization with an intramedullary nail; therefore, a channel was designed to house it. In order to achieve greater coaptation to the bone segments, it was designed with a 45° channel, both proximal and distal, for the placement of 4.5 mm compression cortical screws. Due to its length (13.5 cm), graft placement was required, so it was decided to use a rough surface for embedding cancellous bone (Figure 17).

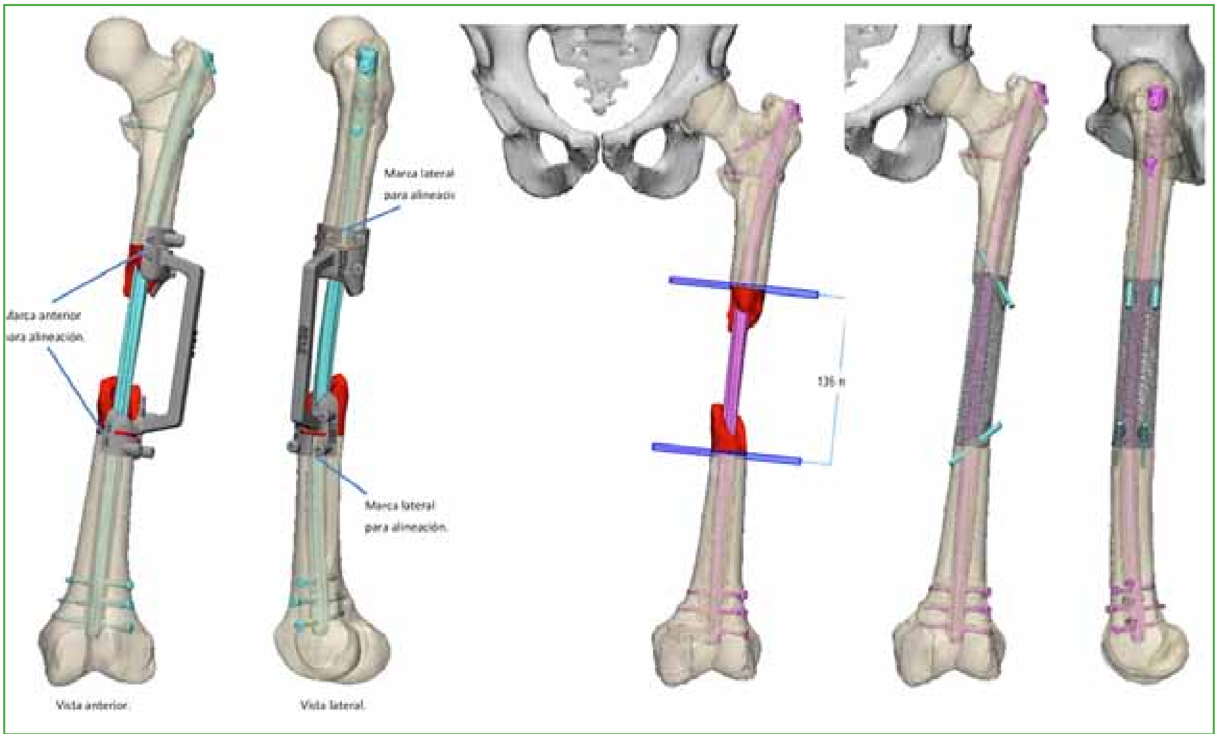

Figure 17. Development of the cutting guide that also contemplates the necessary rotation correction. In order to achieve it, the previous marks that indicate where the pins should be placed are observed and then they must be aligned in the same plane to achieve the axis correction.

Reconstruction

Once infection was ruled out by taking samples and puncture biopsy for culture and pathological anatomy, reconstruction surgery was scheduled.

Surgical technique

Preoperative period: We carry out a workshop preoperative planning with biomodelling of the anatomical segments to be treated and of the definitive implant developed in full-scale plastic. The surgical technique to be executed is reproduced with the entire surgical team, and the resections are practiced according to each caseIntraoperative period: The decision on the appropriate time to perform the reintervention is based on the infectious disease discharge of each patient, it is not possible to determine a fixed time. The antibiotic spacer/beads placed in the previous stage are removed according to bacterial isolation, adapting the approach according to the anatomical region, the need to extend it, and the possibility of using previous surgical incisions. Due to what has already been stated, the times usually exceed the ideal ones to make full use of the advantages of the induced membrane described by Masquelet. The opening of the membrane must be done in the axis of the limb in a meticulous way in order to preserve it. The correct preparation for the placement of the implant, by means of fibrosis exeresis and osteotomies for the regulation of fracture edges as necessary, is fundamental. The use of a femoral distractor or manual traction will be decided, as necessary.

The implant is placed in the place of the defect and the distractor traction is removed, leaving the cylinder as an interlayer, controlling the axis, rotation, and length of the limb and corroborating under fluoroscopy. Stabilization is performed according to the design (intramedullary nailing or regional plates). The maximum limit of effective osteoinduction of titanium is considered to be 8 cm in length. When longer implants are required to treat the defect, grafting becomes necessary. If the graft obtained by traditional means is not sufficient, special systems can be used, such as the RIA system (Synthes). In Case 3, it was used to harvest the intracanal graft from the contralateral femur and prepare the implant by seeding it.

RESULTS

The postoperative protocol consisted of physical kinesiotherapy rehabilitation seven days after the definitive surgery, which included joint mobility, magnetotherapy, and ultrasound.

This technique was used in five men and one woman (mean age 30 years, range 19-54). The median follow-up was 24 months (range 12-36).

All fractures were type C according to the Solomin and Slongo classification.[16]

In the immediate postoperative period, axis, length, and sufficient mechanical stability to initiate partial weight bearing were restored. Full weight-bearing according to the patient's conditions (pain, muscular strength) demanded an average of 25 to 30 days.

At 45 or 50 days, all patients were in rehabilitation and fully weight-bearing without using a cane or crutches.

At 60 days, we observed radiographic signs of incipient integration without signs of loosening. The patients had no pain or claudication.

At 90 days, they returned to their usual daily activities; the average score on the visual analog scale was 1.16.

After 120 days, all of them had range of motion in the physiological range of the joint adjacent to the operated limb, except for the patient in Case 3, due to joint stiffness secondary to a patella fracture.

At 150 days, complete bone incorporation was confirmed by computed tomography in all patients. Likewise, in simple radiographs, the bone 'engulfment' of the implant was observed, which was considered secondary to the inducing quality and the partial calcification of the membrane.

All patients resumed their previous activities in an average of 227 days. None presented shortening, angulation, or rotation of the affected limb.

Complications in the immediate postoperative period comprised a serous secretion from the wound (Cases 3 and 4). In both cases, exploration and surgical debridement with sample taking were carried out, the cultures of which were negative. This secretion occurred in patients who received a greater amount of cancellous bone graft.

There were no cases of infectious reactivation, intolerance to the material, or signs of loosening or fatigue requiring removal.

Two patients had an associated comminuted patella fracture. One (Case 5) has painless range of motion in the physiological range (extension 180º, flexion 95º), the other has full extension with limitation in flexion of 40º that limits him in his activities of daily living, but he preferred not to undergo another intervention.

DISCUSSION

In 2005, Attias et al. described the use of cylindrical metal mesh cages for the reconstruction of segmental bone defects in the humerus, with excellent outcomes.[17]

In 2011, Sewell et al. presented a retrospective study between 1998 and 2008 of 19 patients with a diaphyseal tibial tumor who had undergone oncological resection of the tumor and skeletal reconstruction with a titanium endoprosthesis. These were two-part implants that were joined with screws during surgery and contained stems at their ends that were fixed with cement and osteosynthesis plates if they were >4 cm long.[18]

In 2012, Van der Stok et al. described the use of trabecular titanium implants in rats and discussed the best structure and pore sizes.[19]

In 2015, Wieding et al. analyzed the advantages over other treatments in sheep.[20]

We used the benefits provided by the induced membrane by promoting groups of

vascular and ontogenetic inducing factors, and we added a trabecular titanium scaffolding that gave us the mechanical resistance that the graft alone cannot provide.

In 1991, Perren argued that the ideal metal should have good biocompatibility, optimal adhesion to reduce capsule formation and physical irritation of tissues, contain no allergenic components, and have a minimal rate of corrosion. The intrinsic characteristics of titanium to promote osteoinduction, osteoconduction, and osseointegration,[12] as well as its mechanical strength,[11] its minimal corrosive rate, and its resistance to infection[19,20] make it the material of choice.

Titanium implants are biologically superior, their good results in infected patients are clinically proven. Unlike surgical stainless steel, tissue adherence to titanium due to its biocompatibility and surface structure prevents the formation of dead space and biofilms[15] that promote harmful bacterial propagation.[14]

The choice to develop the implants in Ti-6Al-4V alloy was made respecting Perren's concepts. The 1-4 mm pore used is considered optimal to promote osteoconduction, osteoinduction, and osseointegration, so bone grafting is only necessary when the implant measures >8 cm.[13]

The properties of titanium in resistance to infection are evident, which allows its use in a previously infected segment.[14,15]

The recovery of the entire length of the defect in one stage, added to the biomechanical stability to tolerate early weight-bearing, has a positive effect on the reduction of rehabilitation times, with excellent functional outcomes. We observed a clear shortening of rehabilitation times compared to conventional techniques, such as grafting, Masquelet, and bone transport. In the different literature reports on the Masquelet technique, partial weight-bearing began between the 4th and 5th months and full weight-bearing, only after 6-8 months. The length of hospitalization is notably shorter when compared to elongation using tutors or another method.[5-7]

The use of the induced membrane concept and its advantages for callus formation is reflected in the presence of calcification encompassing the implant. Although we know that, around the third week, when the biological conditions are ideal for graft seeding and the highest levels of growth factors and adult stem cells (stem cells) are recorded in the membrane,[4,5] we are sometimes forced to exceed these times due to reasons related to infectious diseases.

The weaknesses of this study are its non-comparative retrospective design between different techniques for the treatment of segmental bone defects and the small size of the sample. Its strengths are the contribution of a new therapeutic option, the promising postoperative outcomes, and the low rate of complications.

CONCLUSIONS

We proposed a rare treatment option in our field, which provided sufficient biomechanical stability to tolerate early weight-bearing and recovered the full length of the defect in a single stage, with excellent functional outcomes. These results are considered advantages over the usual therapeutic options, such as bone transport or the induced membrane technique.

The cost of the implant and its development does not imply a higher expense than other therapeutic alternatives, since it shortens treatment and length of hospitalization and rehabilitation, especially in active working patients. This statement is currently under study.

Although this technique is promising to treat this type of injury, we understand that the number of cases to date is still scarce, but that it has a high potential for development. One difficulty is the long and detailed planning, as well as a demanding execution for the surgeon. It is necessary to have a greater number of cases and a control time to be able to define if this could be a method of choice for large bone defects.

FINAL COMMENT

A history of infection is not a contraindication to perform this type of treatment.

It is considered a highly demanding technique not only because of the surgical level, but also because of the development of the implant. The development of the interlayer implant requires extensive experience, knowledge, and permanent study of human biomechanics, and it is not only carried out by the medical team, but also by bio-engineers and designers.

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

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Fractures of the Distal Femur Associated With a Complete Quadricipital Tendon Injury: Report of Two Cases

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ABSTRACT
Fractures of the distal femur, especially open fractures, occur in association with high-energy trauma. The presence of associated injuries around the knee is common; however, the association with a complete quadricipital tendon injury has been poorly documented. Early diagnosis and adequate treatment of both injuries is essential to achieve good postoperative outcomes. We present two cases of exposed intra-articular distal femoral fractures associated with complete quadricipital tendon injuries. The repair of the associated tendon injury with transosseous tunnels after fracture fixation allows an early rehabilitation protocol, essential to obtain good functional outcomes.
Key words: Fracture; distal femur; injury; quadricipital tendon; extensor mechanism.
Level of Evidence: V

Fractura de fémur distal asociada con una lesión del tendón cuadricipital: reporte de dos casos

RESUMEN
Las fracturas de fémur distal, especialmente las abiertas, se asocian con traumas de alta energía. Las lesiones asociadas alrededor de la rodilla son frecuentes; sin embargo, la asociación con una lesión completa del tendón cuadricipital ha sido poco documentada. El diagnóstico temprano y un adecuado tratamiento de ambas lesiones son fundamentales para conseguir buenos resultados posoperatorios. Presentamos dos casos de fracturas intrarticulares de fémur distal expuestas asociadas con lesiones completas del tendón cuadricipital. La reparación de la lesión tendinosa asociada mediante túneles transóseos luego de la fijación de la fractura permite comenzar un protocolo de rehabilitación temprano, esencial para obtener buenos resultados funcionales.
Palabras clave: Fractura; fémur distal; lesión; tendón cuadricipital; aparato extensor.
Nivel de Evidencia: V

INTRODUCTION

Distal femur fractures are complex injuries that represent between 3% and 6% of all femur fractures.[1] 5-10% are open fractures, generally associated with high-energy trauma in young patients.[2] Different types of knee injuries associated with femur fractures have been described, such as ligament injuries, patella fractures, proximal tibia fractures, vascular injuries, etc.[3]

Although the most frequent location of the exposure wound is the anterior aspect of the knee, very few reports mention the association with a tendon injury of the extensor apparatus. The lack of an early diagnosis and adequate treatment of this associated injury may determine a poor postoperative outcome with serious sequelae for the patient.[4]

The objective of this article is to report two cases of open fractures of the distal femur associated with a complete injury to the quadriceps tendon.

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CLINICAL CASE 1

A 39-year-old man was admitted to our hospital 24 hours after a motorcycle accident. The initial diagnosis was an open fracture of the left distal femur associated with a fracture of the ipsilateral proximal ulna. At another institution, he had undergone surgical cleaning and stabilization of the distal femur fracture with an external fixator. The ulna fracture had been immobilized with a splint. Upon arrival at our hospital, the patient was hemodynamically stable. The exposure wound, about 10 cm long, located on the anterior aspect of the knee, was closed. The radiograph showed a comminuted fracture of the distal femur (type AO 33 C2) (Figure 1).

Figure 1. Anteroposterior and lateral radiographs of the distal femur upon admission. After placement of the transarticular external fixator, a type 33 C2 distal femur fracture is observed.

Antibiotic prophylaxis was indicated, and an exploration, a new surgical cleaning of the wound, and the reconfiguration of the external tutor were scheduled. During surgical exploration, a comminuted articular and metaphyseal fracture with loss of articular fragments of the external femoral condyle was confirmed (Figure 2).

Figure 2. Image taken during surgical debridement. The exposure wound and the complete quadriceps tendon injury can be seen.

At the same time, a complete avulsion of the quadriceps tendon was detected. The metaphyseal defect was initially treated with an antibiotic-loaded cement spacer and the fracture was stabilized with a transarticular fixator. The wound was closed primarily. 96 h after the initial treatment, definitive fixation was performed with a distal femur locking plate (Figure 3).

Figure 3. Intraoperative image of the definitive stabilization and tendon repair.

The exposure wound was used as the surgical approach. The eversion of the patella facilitated the complete exposure of the joint fracture. Following fracture reduction and fixation, the quadriceps tendon was repaired with transosseous high-strength sutures in the patella. For the first three weeks after surgery, the patient wore a continuous motion splint until 90° of knee flexion was achieved. After six weeks, he began progressive active knee extension exercises. Ten weeks after the intervention, the spacer was removed and the bone graft obtained from the contralateral femur by RIA (Reamer-Irrigator-Aspirator) was added via a retrograde approach,[5] and fixation was increased with a medial plate. At seven months, the fracture had healed (Figure 4) and knee range of motion was 0° to 100°.

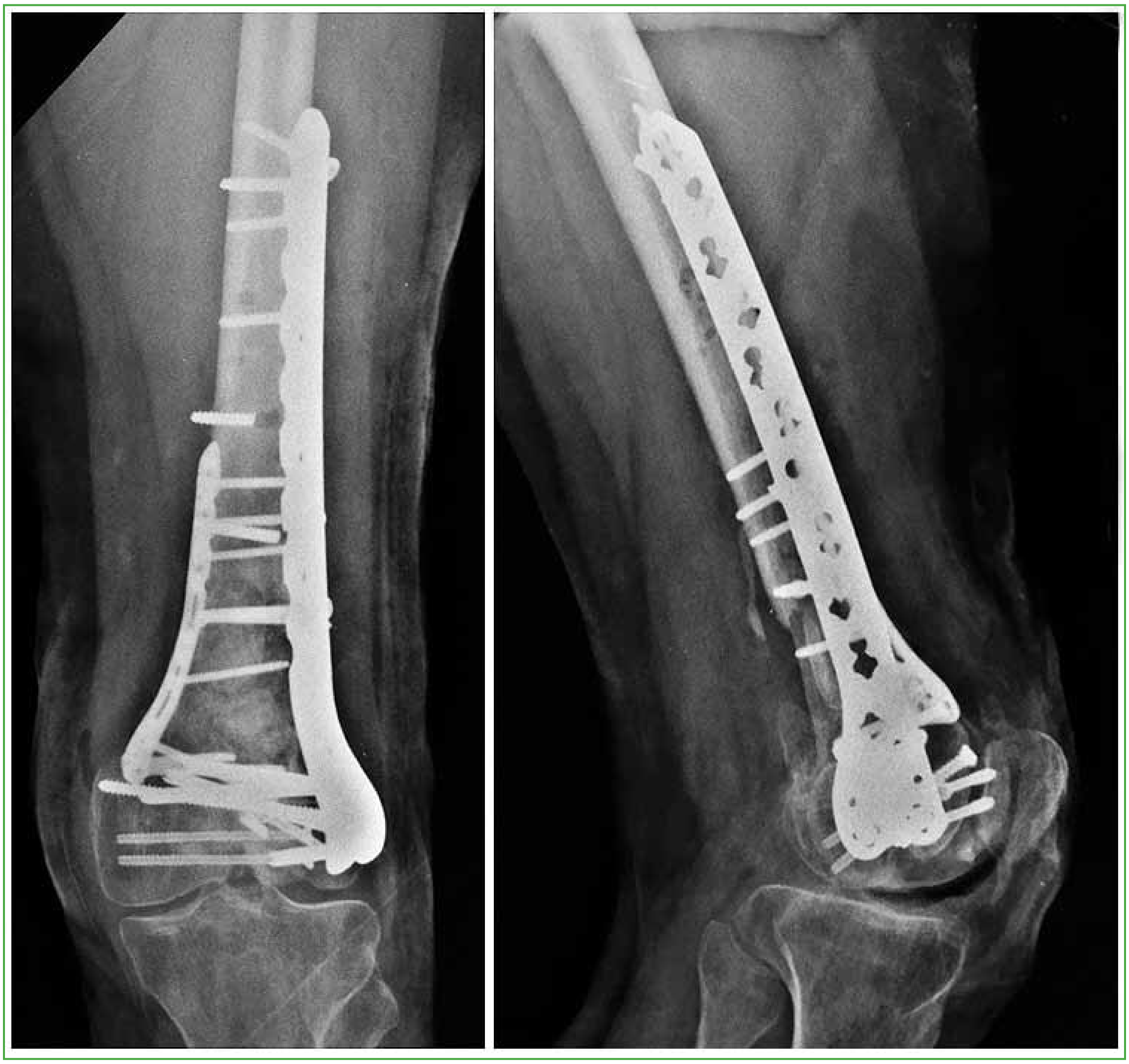

Figure 4. Postoperative anteroposterior and lateral radiographs of the distal femur showing bone consolidation.

CLINICAL CASE 2

A 41-year-old man arrived at our hospital 6 hours after a motorcycle accident. The only injury was an open fracture of the right distal femur. At the initial evaluation, he was hemodynamically stable. The exposure wound was 3 cm long and was located on the anterior aspect of the knee, proximal to the superior pole of the patella. The admission radiograph showed a fracture of the distal femur (type AO 33C2) (Figure 5). He received antibiotic prophylaxis with first-generation cephalosporin and underwent surgical debridement and temporary stabilization with an external tutor 3 hours after admission. During the surgical debridement of the wound, a complete injury to the quadriceps tendon was detected. After debridement, the wound was closed primarily without prior tendon repair. The fracture was stabilized with a transarticular fixator. At 72 h, definitive fixation was performed with a distal femur plate. The surgical approach was anterior with an external parapatellar capsulotomy that included the exposure wound (Figure 6).

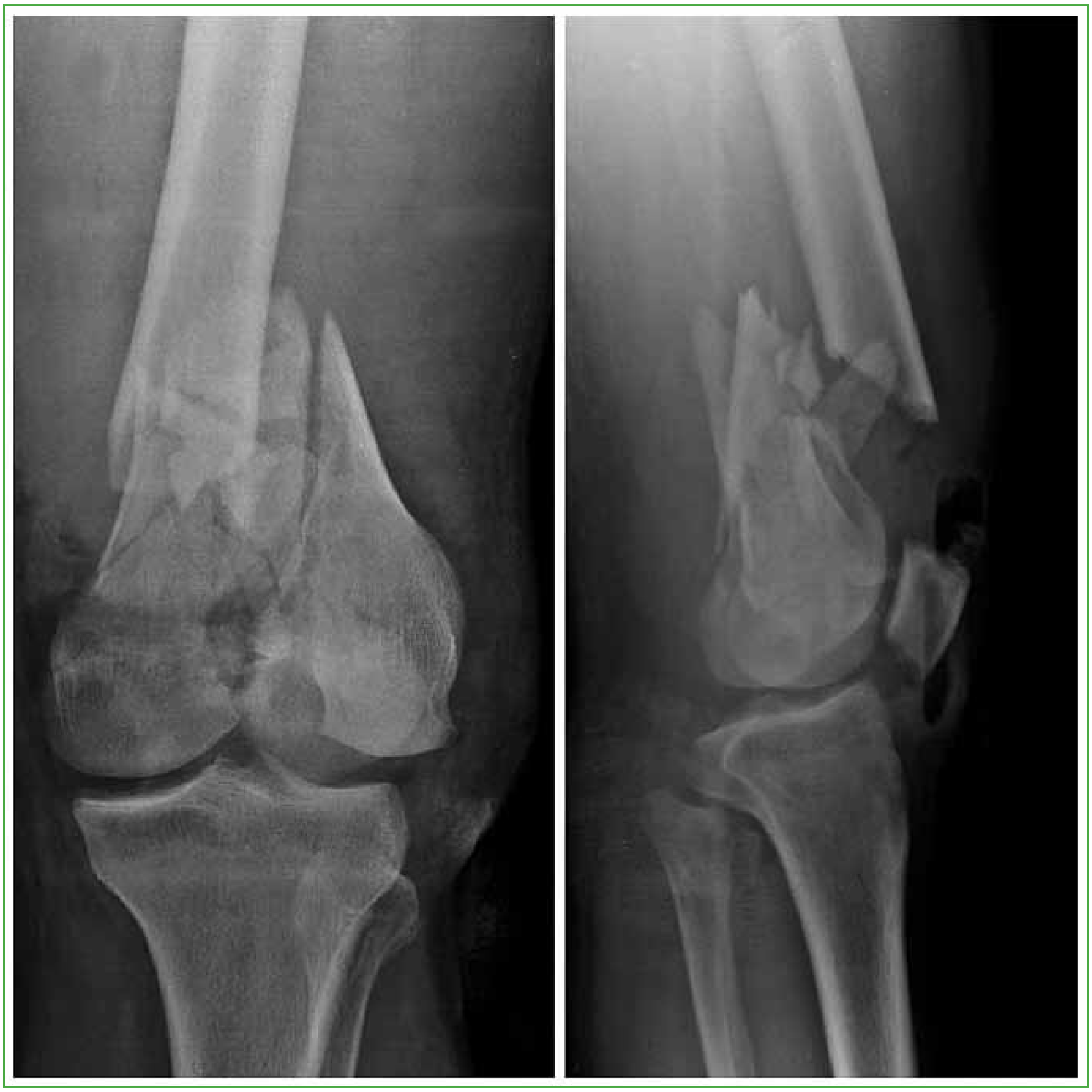

Figure 5. Anteroposterior and lateral radiographs of the distal femur upon admission. A type 33 C2 distal femur fracture can be observed.

After the reduction and fixation of the fracture, the tendon repair was carried out with the same technique described for the previous case. Postoperatively, the patient used a continuous motion splint for the first three weeks until 90° of flexion was achieved. After six weeks, active extension began; and after 12 weeks, with full weight-bearing, knee range of motion was 120° of flexion and full extension. At six months, the fracture had healed.

Figure 6. Continuous motion splint for postoperative rehabilitation.

DISCUSSION

Distal femur fractures, especially open ones, are associated with high-energy trauma.[2] Associated injuries around the knee are common; however, there are few reports documenting the association with a complete quadriceps tendon injury. This injury is rare, but serious if it goes unnoticed.[6,7] The description of these two cases seeks to alert to the possibility of a quadriceps tendon injury associated with an open fracture of the distal femur and to highlight fundamental aspects of its treatment.

An exposure wound to the anterior aspect of the knee, especially proximal to the superior pole of the patella, should raise suspicion for a possible quadriceps tendon injury. Certain fracture patterns, especially those with a supracondylar line from anterior to posterior and from distal to proximal, which generate a sharp edge of the anterior cortical bone of the proximal fragment, can produce the section of the tendon.[4] Regarding the mechanism of the tendon injury, it is also possible that the violent contraction of the quadriceps when the fracture occurs could cause injury by an avulsion mechanism. According to Nori, the quadriceps tendon can also be injured after trauma with pre-existing degenerative conditions of the tendon due to endocrinopathy, chronic renal failure, treatment with quinolones, diabetes mellitus, among other causes.[8] However, none of our patients had these backgrounds.

Karl et al. reported the case of a quadriceps tendon injury associated with a closed intra-articular fracture of the distal femur. The tendon injury was diagnosed at the time of the parapatellar surgical approach; therefore, the authors recommended, in all cases of joint fractures, broad approaches that allow assessing the integrity of the extensor apparatus.[4] In our patients, as they were open fractures, the tendon injury was diagnosed during surgical exploration of the wound. However, we agree with Karl et al. in recommending intraoperative exploration or preoperative evaluation with magnetic resonance imaging when there is a closed fracture of the distal femur with a supracondylar pattern from anterior to posterior and from distal to proximal (Case 2).

In both cases, the tendon repair was performed after reduction and fixation of the femoral fracture. This method has several advantages: first, the ability to completely evert the patella distally facilitates exposure of the articular surface. Second, after restoring femur length, it is easier to perform tenorrhaphy with adequate tension and thus avoid a knee extension deficit. Lastly, performing tenorrhaphy after fracture fixation allows us to more reliably assess the stability of the tendon repair during surgery and thus guide our postoperative rehabilitation protocol.

Different techniques have been described to achieve a stable tendon repair. Tenorrhaphy with high-strength sutures through transosseous tunnels achieves a stable repair that allows the establishment of an early mobility protocol with ranges of 90° flexion in the first three weeks.[6,9,10]

CONCLUSIONS

In the event of an open fracture of the distal femur, especially when the exposure wound is on the anterior aspect of the knee, it is essential to explore the possibility of an injury to the quadriceps tendon. Repair of the associated tendon injury with transosseous tunnels after fracture fixation allows the establishment of an early rehabilitation protocol, essential to obtain good functional outcomes.

Conflict of interests: The authors declare no conflicts of interest.

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Ryu and Debenham Type IV-A Proximal Tibia Epiphysiolysis. A Case Report

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ABSTRACT
Epiphysiolysis of the proximal tibia is a rare injury due to the surrounding structures that protect the area. In displaced fractures, the evaluation of vascular structures is mandatory to detect injury to the popliteal artery or the presence of compartment syndrome. We present a Salter & Harris type I epiphyseal injury of the proximal tibia in a 10-year-old boy.
Key words: Proximal tibia; epiphysiolysis; Kirschner wires; vascular injury; compartment syndrome.
Level of Evidence: IV

Epifisiólisis tibial proximal tipo IV-A de Ryu y Debenham. A propósito de un caso

RESUMEN
Las epifisiólisis tibiales proximales son un cuadro poco frecuente debido a la protección que aportan las estructuras circundantes de dicha zona. Por el desplazamiento que se origina es necesario realizar una exploración vascular junto a una reducción urgente para prevenir la lesión de la arteria poplítea y la aparición de un síndrome compartimental. Presentamos a un varón de 10 años con epifisiólisis de tibia proximal tipo I de Salter-Harris.
Palabras clave: Tibia proximal; epifisiólisis; agujas de Kirschner; lesión vascular; síndrome compartimental.
Nivel de Evidencia: IV

INTRODUCTION

Injuries the proximal epiphysis of the tibia are rare, accounting for 0.5-3% of all epiphyseal injuries.[1] The peculiarity of this type of injury lies in the arrangement of the ligaments of the knee, which protects the proximal tibial epiphysis. They are more frequent in male adolescents and the risk is higher in obese people who are growing rapidly.[1] There is a high risk of popliteal artery injury due to posterior displacement of the metaphysis and of developing compartment syndrome. Therefore, it is essential to carry out an exhaustive vascular evaluation, and reduce and stabilize the fracture urgently. Some added complications may be alterations in physeal growth, ligament and meniscal injury, and knee instability.[2]

We present the case of a 10-year-old male with a Salter-Harris type I epiphysiolysis of the proximal tibia.

CLINICAL CASE

A 10-year-old male was admitted to the pediatric emergency department due to trauma to his left knee while playing soccer. He reported amnesia for the episode.

Physical examination revealed significant knee swelling, inability to walk, intense pain with flexion-extension, and presence of distal vascular pulses. It was not possible to assess the stability of the knee due to pain.

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Anteroposterior and lateral radiographs of the left knee were requested, in which an epiphyseal fracture corresponding to type I Salter-Harris and type IV-A of the Ryu and Debenham[3] classification was observed (Figure 1). After informing the patient and his parents, urgent surgical treatment was decided. The fracture was treated with closed fixation with two Kirschner wires (Figure 2). There was no knee instability. The evaluation detected the presence of distal pulses and the pulse oximeter examination also showed values within normal limits. He was immobilized with a long leg splint.

Figure 1. Anteroposterior and lateral radiographs of the left knee.

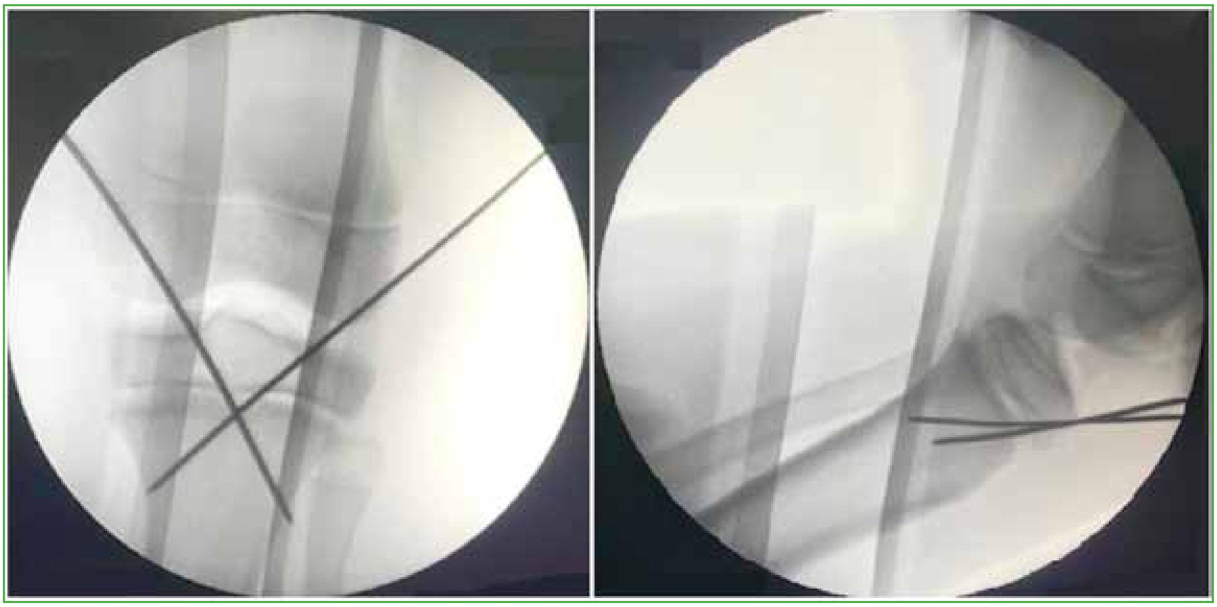

Figure 2. Control fluoroscopy of the reduction in the operating room.

When the patient recovered from the anesthesia, the pain had improved and finger mobility was painless. Immobilization was maintained for four weeks and no weight-bearing was allowed. Subsequently, the immobilization and the pins were removed, and free flexion-extension and walking aided by canes were allowed for two more weeks (Figure 3).

Figure 3. A and B. Postoperative control anteroposterior and lateral radiographs of the left knee. **C and D.** Anteroposterior and lateral radiographs of the left knee one month after the injury with needle removal.

Knee radiographs and physical examinations were performed monthly until six months post-injury, then biannually until two years post-injury. No alterations were seen in the proximal tibial physis and no angular alterations have appeared in the knee, which remains stable (Figure 4). Annual check-ups will be maintained until the patient reaches skeletal maturity to rule out growth disturbances.

Figure 4. Measurement of the lower limbs two years after the injury.

DISCUSSION

Epiphyseal fractures of the anterior tibia have a low incidence, representing 0.5-3% of all epiphyseal injuries.[1] This is because most physeal injuries are caused by ligament traction and the proximal tibial epiphysis lacks them (except the insertion of cruciate ligaments). In addition, the wide contact surface with the metaphysis and the circular protection provided by the structures adjacent to the proximal tibial physis reduce the risk of these injuries. Laterally, the proximal tibial epiphysis rests on the fibula, the inner part is on the distal insertion of the superficial layer of the medial collateral ligament and the insertion of the semimembranosus muscle, which protects the posteromedial angle. Anteriorly, the anterior tibial tuberosity assists in preventing posterior displacement of the tibia. Moreover, the inclined arrangement of the physis provides excellent stability.[4]

Traditionally, epiphyseal injuries of the proximal tibia have included those that affect the anterior tibial tuberosity and those caused by separation of the physis. Initially, the Salter and Harris classification, the Watson-Jones classification, and its subsequent modification by Ogden were used, but these were limited to involvement of the anterior tibial tuberosity until, in 1985, Ryu and Debenham included a new type (IV) characterized by propagation towards the posterior cortex (type IV-A without cortical involvement = Salter-Harris type I) (type IV-B with cortical involvement = Salter-Harris type II) (Figure 5).[3]

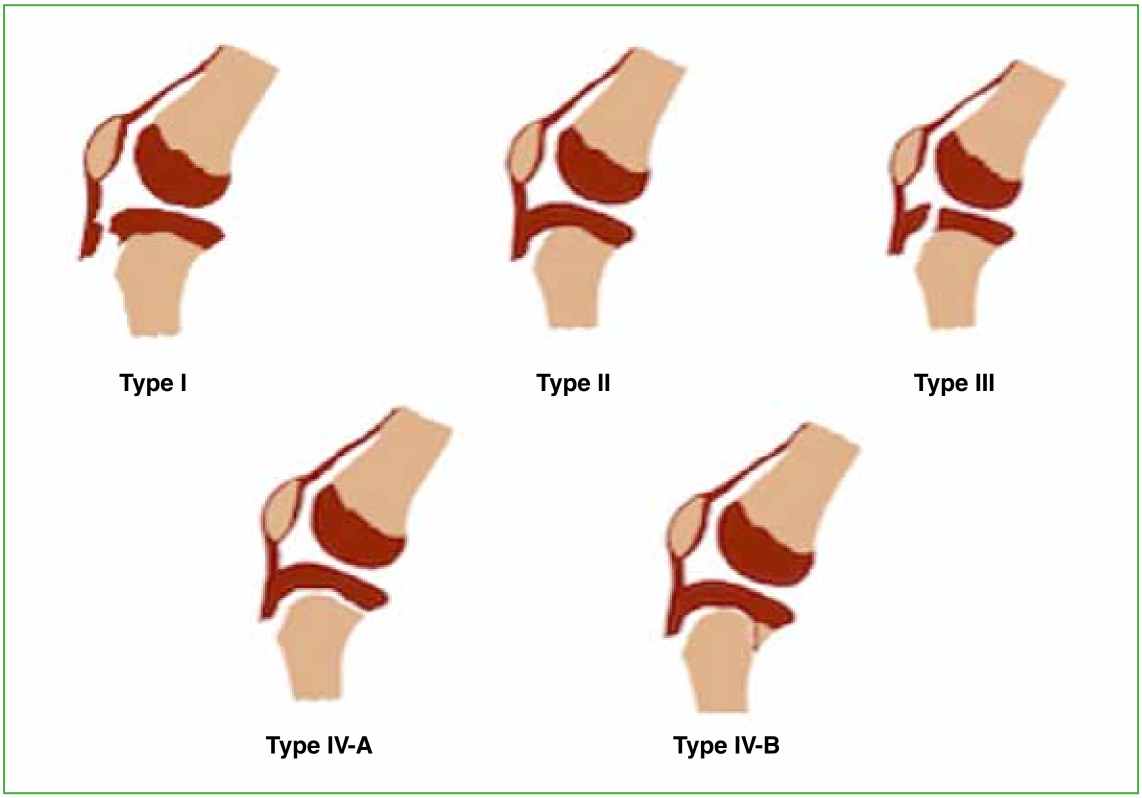

Figure 5. Ogden classification modified by Ryu and Debenham.

This type of fracture can be caused by a direct impact (traffic accident, direct blow during sports practice) or by indirect forces. In 1966, Silberman and Murphy[5] elaborated a hypothesis about its origin that consists of an avulsion caused by an overload of traction forces on the proximal tibial physis during the take-off phase of a jump in which the knee is in flexion. When analyzing these injuries in patients who played basketball (the sporting activity that is most frequently associated with this epiphyseal injury), Steiger and Ceroni[4] established that the pathophysiology would consist of an eccentric muscle contraction with which the muscle lengthens against resistance, absorbing energy that is transmitted to the proximal tibial epiphysis. This same principle would occur in the takeoff phase of the jump, as in landing or sudden stops. In older patients, a Salter-Harris type II epiphyseal fracture (Ryu and Debenham type IV-B) would occur due to ossification of the posterior region of the physis.

The risk is higher in adolescent and obese males.[1,4] This difference in distribution according to sex is due to the fact that these injuries occur more frequently in sports, especially when the physical demand is greater (adolescence). Women present a complete or almost complete ossification of the proximal tibial physis, and ligament injuries are more frequent.[4]

The initial diagnosis is based on anteroposterior and lateral radiographs of the knee. Initially, these tests will suffice, but if a type III or IV epiphyseal fracture is suspected, a computed tomography should be requested to assess the extent of the fracture and even an MRI to determine possible damage to soft tissues, such as the menisci or cruciate ligaments.

The treatment is based on achieving the anatomical reduction of the area to avoid alterations in the growth and stability of the knee. When there is no displacement, conservative treatment with a long leg plaster cast for 4-6 weeks can be chosen. If, on the other hand, the displacement is >2 mm, as in our case, reduction should be used, preferably closed, and fixation with Kirschner wires. This osteosynthesis must be introduced from proximal to distal through the non-articular part of the tibial epiphysis and must cross distal to the physis to achieve rotational stability.[6]

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The eventual posterior displacement of the tibial metaphysis increases the risk of injury to the popliteal artery, which is attached by firm connective tissue septa to the posterior aspect of the joint capsule, limiting its deviation to adaptation. For this reason, the injury must be reduced and stabilized and close attention must be paid to the vascular status by exploring the pulses.[7] Likewise, intracompartmental pressure can increase due to inflammation, increasing the risk of compartment syndrome. This increased pressure in the proximal tibial area is due to the possible injury of a recurrent branch of the anterior tibial artery that runs along the lateral border of the anterior tibial tuberosity.[8] The incidence varies considerably depending on the series consulted: 17-20% (Frey et al. and Palokoff et al.) and 4% (Pretell-Mazzini et al.).[9-11] The ligament structures, in principle more resistant than the physis, can be damaged, causing subsequent instability of the knee joint,[1,4] as well as meniscal injury. The incidence of injuries to these structures has not been published (they are fundamentally involved in type III or IV injuries) and are only reflected as case reports.[12,13]

Late complications may include limb length discrepancies and axial deformities. In different series, a difference in limb length >25 mm or axial deviation >5° was observed in 25% of patients.[14-16] This is due to a premature total or partial closure of the growth plate (Hasler, >30% of early closure in his series) or its overstimulation.[17] Periodic follow-up should be carried out with radiographs of both entire limbs to assess whether there are alterations and indicate early corrective measures. Follow-up should continue until complete ossification.

CONCLUSIONS

Epiphyseal fractures of the proximal tibia are rare. They are basically avulsions of the anterior tibial tuberosity. Male, overweight, and rapidly growing adolescents are at increased risk for this type of injury. The main complication is growth arrest in the long term; we must also pay attention to a possible injury to the popliteal artery. The goal of treatment is restoration of the anatomy either by closed reduction and immobilization, or open or closed reduction with internal fixation.

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Erosion of the Coracoid Process After Distal Clavicle Fracture Plate Fixation. An Unreported Complication

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ABSTRACT

Background: Several surgical techniques have been developed to reduce nonunion rates and improve functional outcomes after displaced distal clavicle fractures, including the use of a tension band, the modified Weaver-Dunn procedure, coracoclavicular screw fixation, or locking plates. None of these techniques have been universally accepted, and each one has its own complications. To our knowledge, there are no previous publications describing osteolysis of the coracoid process caused by the tip of a cortical screw of a distal LCP plate. **Case summary:** We present the case of a 29-year-old male patient who had been treated with an anatomic pre-contoured plate for a distal clavicle fracture. Six months later, he presented to our institution with limiting shoulder pain and tenderness upon the right coracoid process. Standard radiographs of the shoulder showed that the tip of a cortical screw was eroding the coracoid process. Surgery with hardware removal was then performed. One month after surgery, the patient was painless and with a full active shoulder ROM. **Conclusion:** Erosion of the coracoid process with plate screw fixation has never been described before. We suggest that extreme precaution should be taken in drilling and measuring the length of screws to avoid potential complications.

Key words: Coracoid erosion; clavicle fracture; complications; reduction; osteosynthesis.

Level of Evidence: IV

Erosión de la apófisis coracoides secundaria a osteosíntesis de fractura de clavícula distal. Reporte de un caso

RESUMEN

Introducción: El 10-30% de las fracturas de clavícula ocurren en el tercio distal. El diagnóstico se realiza con radiografías de hombro (de frente y de perfil, y proyección de Zanca). La mayoría de estas fracturas se tratan de forma conservadora, pero aquellas con gran desplazamiento, patrones transversos o conminutos pueden requerir tratamiento quirúrgico debido a la alta tasa de seudoartrosis. Se ha descrito diversos tipos de fijación para este grupo de fracturas. Si bien la osteosíntesis con placas logra resultados clínico-funcionales y de consolidación satisfactorios, no está exenta de complicaciones y las más frecuentes son: intolerancia al material de osteosíntesis (hasta un 30%), infección, lesión neurovascular y seudoartrosis. Sin embargo, según nuestro conocimiento, no existen reportes sobre la osteólisis de la apófisis coracoides secundaria a la osteosíntesis con placa LCP en fracturas del tercio distal de la clavícula. **Conclusión**: La erosión de la apófisis coracoides debido a la fijación con placa y tornillos es una complicación que no ha sido publicada previamente. Debe tenerse extrema precaución al realizar el túnel óseo y al medir la longitud de los tornillos para evitar potenciales complicaciones.

Palabras clave: Erosión de coracoides; fractura de clavícula; complicaciones; reducción; osteosíntesis.

Nivel de Evidencia: IV

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INTRODUCTION

Clavicle fractures represent 10% of all fractures and are usually caused by direct lateral trauma to the shoulder.[1] 10-30% of clavicle fractures occur in the distal third.[1] They are diagnosed with standard anteroposterior and lateral shoulder radiographs and clavicle radiographs with 15º of cephalic deviation (Zanca view).[1] Most clavicle fractures are treated conservatively, but those with large displacement or transverse or comminuted patterns may require surgery due to their high nonunion rate.[2] Various types of fixation have been described for this group of fractures, such as pre-contoured dynamic compression plates, tubular, or reconstruction plates.[2] Although plate osteosynthesis achieves satisfactory clinical-functional and consolidation outcomes, it is not exempt from complications.[3] The most frequent are intolerance to the osteosynthesis material (up to 30%), infection, neurovascular injury, and nonunion.[3] Likewise, other complications have been described, such as implant migration, acromial osteolysis, mechanical failure, pneumothorax, and adhesive capsulitis.[2,3] However, to our knowledge, there are no reports on osteolysis of the coracoid process secondary to osteosynthesis with locking compression plates in fractures of the distal third of the clavicle.

CLINICAL CASE

In 2018, a 29-year-old man underwent surgery in another Center due to a fracture of the right distal clavicle, with two fragments, secondary to a fall from his bicycle (Table). He underwent reduction and osteosynthesis with plate and screws, using an anatomically pre-contoured superior clavicle locking compression plate with angular stability and lateral extension (Depuy Synthes, Johnson & Johnson, USA). The patient underwent a postoperative kinesiology rehabilitation protocol that consisted of the use of a broad arm sling for two weeks, continued with pendulum movements of the shoulder, and ended with active abduction and controlled flexion up to 90° between the third and sixth weeks. Full active range of motion was authorized after six weeks and return to sports activity after 12 weeks. Initially, the patient returned to cycling and, progressively, to a recreational contact sport (soccer). He also stated that, as of the third postoperative month, he had not undergone any more clinical or radiographic controls and that he had been discharged.

Table. Classification of the patient's clavicle fracture

Classification	Type
Allman	2
Robinson (Edinburgh)	3A.1
Neer	2A
Cho	2A

Six months after surgery, he began experiencing limiting and increasing pain in his right shoulder, for which he decided to consult, at that time, in our institution. Physical examination revealed hypersensitivity at the level of the coracoid process with functional impairment of the shoulder due to severe pain, 9/10 on the visual analog scale. Radiographs of the clavicle and shoulder were taken in the anteroposterior, lateral, and Zanca views, in which the erosion of the coracoid process caused by contact with the distal end of the cortical screw used in the locking compression plate was observed (Figure 1). We decided to perform a three-dimensional computed tomography to correctly assess the extent of the lesion (Figure 2).

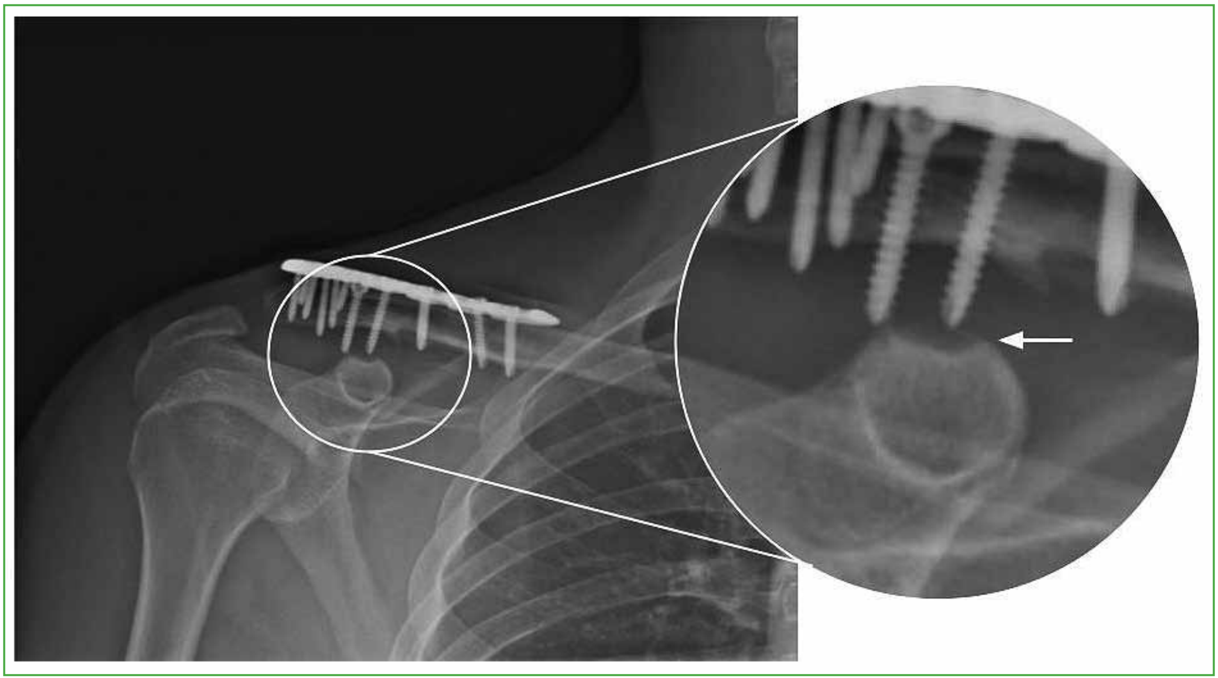

Figure 1. Anteroposterior radiograph of the right shoulder. The distal end of the cortical screw is seen eroding the coracoid process.

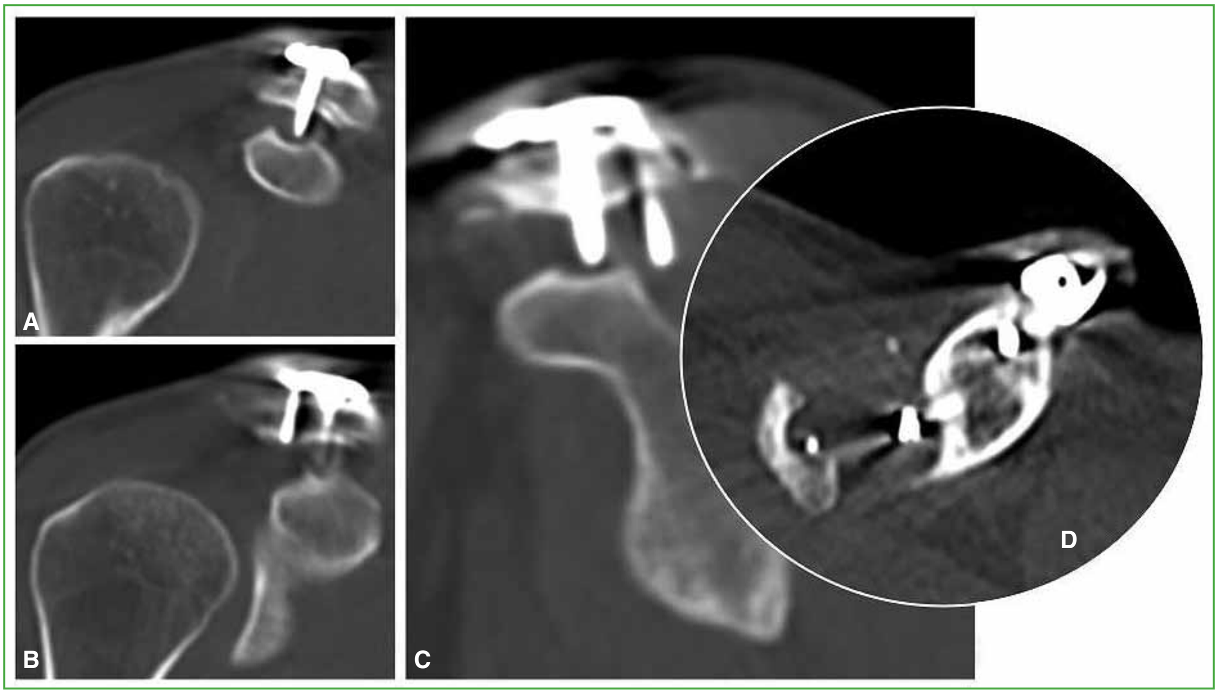

Figure 2. Preoperative 3D computed tomography of the right shoulder. **A and B.** Coronal sections. **C.** Sagittal section. **D.** Axial section showing >50% involvement of the coracoid process surface.

After the complementary studies, the osteosynthesis extraction surgery was scheduled 15 days after the initial consultation. To remove the plate and screw, the patient underwent sedation and a selective plexus block. The patient was placed in a beach chair position. The approach was performed over the previous incision and the osteosynthesis material was extracted under direct vision. The postoperative control radiographs were satisfactory (Figure 3). One month after surgery, the patient was pain-free and had full active range of motion, so he was able to resume activities of daily living and sports. He was discharged three months after surgery. The clinical-functional evaluation 12 months after the intervention included the Constant scale and the visual analog scale for pain. The results obtained were 96 and 1/10, respectively. No postoperative complications were detected.

Figure 3. Anteroposterior radiograph of a man after extraction of the osteosynthesis material.

DISCUSSION

Fractures of the distal third of the clavicle represent a challenge for the orthopedic surgeon.[4] The deforming forces caused by the weight of the upper limb, as well as the traction of the trapezius muscle, produce displacement of the fracture fragments.[4] In 1963, Neer classified distal clavicle fractures into five types.[5] Type II fractures occur medially or at the level of the coracoclavicular ligaments (type IIa and type IIb, respectively). Type V are comminuted fractures, with a free lower segment attached to the coracoclavicular ligaments, but not in continuity with the rest of the clavicle.[5] These two types of fractures are considered unstable and at high risk of nonunion, which is why Neer recommended surgical treatment for them.[5] Several studies have shown that the rate of consolidation with surgical treatment is greater than 90%, which is why most authors favor surgery.[6] However, others recommend conservative treatment based on the good clinical-functional outcomes achieved, despite the fact that the nonunion rate with this type of treatment is high.[6]

Different surgical treatment modalities have been described for distal clavicle fractures, including hook plates, intramedullary devices, subcoracoid suture, suture buttons (EndoButton®), harpoon fixation, coracoclavicular screws, locking T-plates and pre-contoured distal clavicle plates.[4] While there are multiple implant and surgical options, there is currently no consensus on which is best for treating Neer type II and type V clavicle fractures.[4,5] Anatomical (pre-contoured) locking distal clavicle plates have proven to be an acceptable surgical alternative with good clinical-functional outcomes.[2] However, such fixation is not exempt from complications, such as protrusion or mechanical failure of the implant, infections, poor aesthetics, nonunion, neurovascular injuries, pneumothorax, and refracture after removal of osteosynthesis in cases of intolerance to the material.[7]

During plate and screw osteosynthesis, the subclavian neurovascular bundle may be injured,[5] it can be damaged by the drill bit during bone drilling, or by screw placement.[8] This injury can go unnoticed and have devastating consequences.[8] Shackford and Connolly reported a critical ischemia of the upper limb secondary to a pseudoaneurysm due to erosion of the subclavian artery caused by the distal end of one of the screws.[8] To avoid such damage, it is recommended to use blunt retractors placed on the lower edge of the clavicle when drilling with the drill bit. Additionally, control over direction and depth during plate fixation is of paramount importance. Qin et al. attempted to determine safe drilling angles and depth by dividing the clavicle into three segments, from medial to lateral.[9] They used magnetic resonance imaging to determine the spatial relationship between the clavicle and the subclavian neurovascular bundle. They determined that segment I, from the sternoclavicular joint to point "N" (where the subclavian bundle passes below the midpoint of the clavicle) was the one with the greatest risk of injury, and that the perforation should not exceed 17 mm deep. Because the neurovascular bundle was well below the level of the coracoid process (>40 mm), in segment III, they did not determine the angulations or perforation depths.[9]

It is clear, then, that the intimate relationship between the clavicle and the underlying neurovascular structures puts the latter at risk during surgery. Technical caution is essential during bicortical screw placement. In a biomechanical study, Zaidenberg et al. compared the strength of locking plate fixation with bicortical versus unicortical screws in displaced fractures of the middle third of the clavicle, which would prevent this potential neurovascular complication.[10] In this study, they found that bicortical screw locking plates were biomechanically superior in terms of resistance to axial load (compression) and torsional forces. However, the authors concluded that unicortical fixation with locking plates may be a valid option to treat such fractures. Aside from avoiding subclavian neurovascular damage, Looft et al. considered that the use of unicortical screws could have other benefits such as the ease of removing the implant in case of intolerance and the possibility of conversion to bicortical fixation if revision surgery is necessary.[11]

The coracoclavicular screw fixation technique, first described in 1941 by Bosworth, has been a widely used surgical method for treating fractures of the distal third of the clavicle. Fazal et al. used temporary fixation with a 6.5 mm partially threaded coracoclavicular screw with a washer in 30 patients who had a displaced fracture of the distal third of the clavicle.[12] Adequate bone consolidation was achieved in all cases and patients returned to their previous level of activity within a year.[12] Although this technique manages to achieve good clinical-functional outcomes, it causes potential complications, such as screw loosening, limitation of the range of shoulder joint motion, fracture of the coracoclavicular apophysis, implant breakage, screw retraction, and the appearance of ossifications between the clavicle and the coracoid.[12] Fazal et al. emphasized the need to strictly adhere to the postoperative rehabilitation regimen, avoiding early scapulothoracic mobilization, as this can produce rotation and tilting of the fractured fragment that causes retraction (pull-out) of the screw.[12] Coracoid osteolysis as a complication from fixation with a coracoclavicular screw has not yet been described in the literature.[12-14] Due to these complications, rigid screw fixation has been replaced by flexible or dynamic fixation, with sutures, suture harpoons, tapes, or button sutures.[14] The main advantage of this type of fixation is that it does not require a new intervention to remove the implant. Although most publications report excellent clinical-functional outcomes, these techniques are not exempt from complications. The most frequent are the loss of reduction (in up to 19% of cases) and the erosion of the bone tunnels with the consequent osteolysis.[14]

In multiple systematic reviews, it has been determined that pre-contoured locking plate osteosynthesis provides the best clinical-functional outcomes and poses lower risks of complications than other fixation methods.[15-17] However, to date, there is no consensus on which of these fixation methods is the best.[15-17]

Erosion of the coracoid process as a consequence of plate and screw fixation of fractures of the distal third of the clavicle is a complication that has not been reported to date. We believe that it can be avoided through proper preoperative planning and proper measurement of the length of the screws. Likewise, and if possible, we recommend the use of an image intensifier during the surgical process.

CONCLUSION

Erosion of the coracoid process due to plate and screw fixation is a previously unreported complication. Extreme caution must be used when making bone tunnels and when measuring screw length to avoid potential postoperative complications.

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Complex Articular Fractures of the Distal Humerus. Recommendations to Optimize Outcomes and Reduce Complications

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ABSTRACT
Complex articular fractures of the distal humerus represent a real challenge for orthopedic surgeons. The complexity of the anatomy, fracture patterns, the presence of multiple fragments, and low bone density in the elderly represent some difficulties to address. The relatively low frequency of these fractures directly undermines training and systematization of the surgical procedure and therefore has an impact on the final functional outcome and complication rate. The aim of this article is to provide practical tools to the novel surgeon, through the review of the literature and the author´s experience, to reduce complications and optimize the treatment of these fractures.
Key words: Fractures; distal humerus; planning; osteosynthesis.
Level of Evidence: V

Fracturas articulares complejas del húmero distal. Recomendaciones para optimizar los resultados y disminuir las complicaciones

RESUMEN
Las fracturas articulares complejas del húmero distal suponen un gran desafío para el cirujano ortopédico. La complejidad de la anatomía, la presencia de múltiples fragmentos y la mala calidad ósea representan algunas de las principales dificultades para resolver. La relativa infrecuencia de estas fracturas atenta directamente contra el entrenamiento y la sistematización del procedimiento quirúrgico y, por consiguiente, tiene impacto sobre el resultado final y la tasa de complicaciones. El objetivo de esta comunicación es proporcionar herramientas al cirujano a través de la revisión de la bibliografía y la experiencia de los autores para disminuir las complicaciones y optimizar los resultados en el tratamiento de estas fracturas.
Palabras clave: Fractura; húmero distal; planificación; osteosíntesis.
Nivel de Evidencia: V

INTRODUCTION

Distal humerus fractures are relatively uncommon in adults and their treatment represents a challenge for the orthopedic surgeon. They have an estimated annual incidence of 5.7 per 100,000 adult inhabitants and represent between 0.5 and 7% of all fractures, and around 30% of fractures that occur around the elbow.[1,2] They have a bimodal presentation: in young people suffering from high-energy trauma and in the elderly with medium- and low-energy trauma.

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Surgical treatment is the method of choice for complex fractures of the distal humerus. However, in patients whose comorbidities significantly increase surgical risk or those who, due to their own factors or those of their environment, are not able to comply with the postoperative indications and rehabilitation, the classic 'bag of bones' conservative treatment is an option to consider that can provide acceptable functional outcomes in this group of patients with low functional demand. It consists of a short period of cast immobilization or the use of a sling, followed by mobilization as tolerated by the patient.[3,4]

Currently, there is consensus regarding the impact that the quality of fracture fixation and postoperative rehabilitation have on the final outcome of treatment. Although the evolution of the surgical technique and the development of implants have made it possible to significantly improve the quality of fixation and therapeutic outcomes, the relative infrequency of these fractures hinders the training of the surgical team and conspires against the 'systematization' of the procedure.

Finally, and despite this progress, there are still some controversial aspects regarding the ideal management of these fractures.

The objective of this publication is to list and describe the aspects that, based on our experience and review of the literature, we consider essential to optimize outcomes and minimize complications in the management of complex articular fractures of the distal humerus.

SITUATION DIAGNOSIS

The initial physical examination is vitally important and should be performed at the first consultation. It is essential to remove all immobilization and bandages in order to identify any associated soft tissue injury, whether directly related to the initial trauma or subsequent to it. Its possible relationship with an open fracture or with iatrogenic decubitus injuries caused by cast immobilization should be evaluated. The neurovascular examination should be performed in detail and documented in the clinical record, taking into account that up to 25% of complex joint fractures cause symptoms associated with the ulnar nerve.[5]

Anteroposterior and lateral radiological projections of the elbow are usually sufficient for diagnosis. In complex joint fractures, a computed tomography with three-dimensional reconstruction should always be requested, as it allows a better understanding of the fracture pattern and facilitates preoperative planning.[6]

The age, functional demand, and bone quality of the patient are three important aspects that must be considered for decision-making.[7] In patients with good bone quality, the treatment of choice is osteosynthesis. In the elderly with osteoporotic bone, or comminuted or very distal fracture patterns, in whom fixation may be technically difficult, total elbow arthroplasty is an option to consider, as it has achieved predictable outcomes for this group of patients.[8]

PREOPERATIVE PLANNING

Due to the relative rarity of these fractures and the wide variety of fracture patterns, preoperative planning is of paramount importance. Predicting and anticipating intraoperative difficulties and complications will have a direct impact on reducing surgical time.

Early understanding of the fracture pattern through imaging studies is very helpful. Traction radiographs, computed tomography, and especially three-dimensional reconstruction, provide valuable information for the surgeon in interpreting the injury (Figure 1).

The identification and preoperative drawing of the main fragments and the 'key' fragments are usually very useful to anticipate the dynamics of the reduction, anticipate and define the type of temporary fixation, and pre-establish the most convenient definitive arrangement of the implants.

Bone quality, the degree of metaphyseal or joint comminution, and the quantity and height of the fracture lines are aspects that we must take into account in planning and that will have implications for the surgical approach and the choice of implants according to their features.

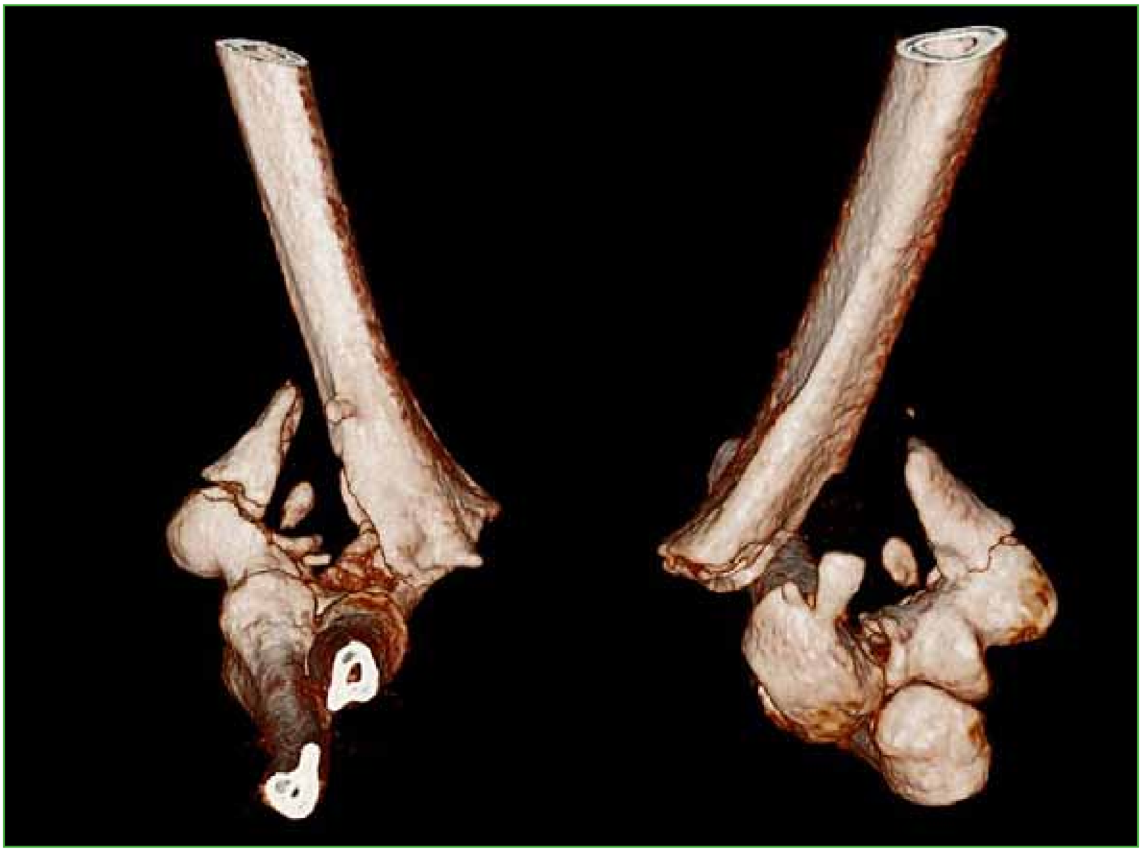

Figure 1. Computed tomography with three-dimensional reconstruction of an articular fracture of the distal humerus.

CHOICE OF IMPLANTS

The goal of surgical treatment of distal humerus fractures is to restore the anatomy and the relationship between the two columns and the articular surface through stable fixation. Although the use of 3.5 mm reconstruction plates is currently a valid option, the introduction and evolution in the designs of anatomical plates with angular stability have made it possible to improve the quality of osteosynthesis, mainly when there is comminution and poor bone quality.

The availability of these implants allows for adequate fixation even of those complex fractures that cannot be fixed with conventional implants. The incorporation of variable angle locking technology represents an additional benefit in the fixation of fractures with multiplanar and very distal lines, as it allows a fixation that is stable enough to be able to establish a rehabilitation protocol based on early mobilization.

However, many of the so-called 'anatomical' plates do not meet this characteristic, since not only do they not adapt to the anatomy of the distal humerus, but they also sometimes do not allow satisfactory fixation of the articular surface (Figure 2).

Therefore, we strongly recommend that surgeons who are beginning to take their first steps in the treatment of these fractures know the characteristics of the implants available in our market.

On the other hand, the availability and use of headless self-compressing cannulated screws should be foreseen in those fracture patterns that present coronal or axial lines at the level of the capitellum or the trochlea and that cannot be fixed by the screws arranged through the plates.

Figure 2. Plastic bone demonstration of poor anatomical reproduction and insufficient joint fixation of a given implant.

PATIENT POSITIONING

The procedure can be carried out with the patient in the prone position (Figure 3) or in the lateral position (Figure 4). The choice must take into account multiple factors, including the available equipment, the patient's physical characteristics and comorbidities, and, ultimately, the surgeon's preference.

The prone position has the advantage of improving the relationship between ventilation and perfusion, and allowing better ventilation of the patient; however, it makes airway access and instrumentation difficult. For these reasons, this last aspect must be considered when said position is chosen by the surgeon, because the procedure must be carried out under general anesthesia.

In our case, we prefer lateral decubitus, since it allows us to perform the surgery under regional anesthesia of the limb and with the patient awake, which represents an advantage if the procedure is to be carried out on an outpatient basis. It is worth clarifying that, if it is done in this way, a trained and familiarized team is required in order to optimize surgical time. In any case, if the time of surgery is prolonged as a result of some unforeseen event or complication, lateral decubitus allows good access to the airway for its instrumentation and conversion to general anesthesia, if necessary. We also recommend having an arm stabilizer support, because it facilitates the procedure regardless of the chosen position.

Figure 3. Patient placed in the prone position.

Figure 4. Patient placed in the lateral decubitus position.

SURGICAL APPROACH

The approach is determined by the 'personality' of the fracture, from which the degree of exposure necessary to achieve the previously planned synthesis is deduced. According to O'Driscoll, the entryway to the elbow is in the back (Figure 5) and, in published articles, the advantages of different posterior approaches have been described, although there is no clear consensus about the superiority of one or the other in terms of efficacy, safety and functional outcomes.

Dakouré et al. compared the percentage of exposure of the articular surface between the Alonso-Llamas bilateral paratricipital approach, the Campbell triceps division, and the olecranon osteotomy, with values of 26%, 37%, and 52%, respectively, which shows that olecranon osteotomy is the route that provides greater exposure of the joint surface.[9] The need for joint exposure should be evaluated in each case, taking into account that the overall rate of complications for the transolecranon approach is 36% and the revision rate is around 14%.[10] Therefore, the benefit of joint exposure must be considered taking into account this relatively high rate of complications.

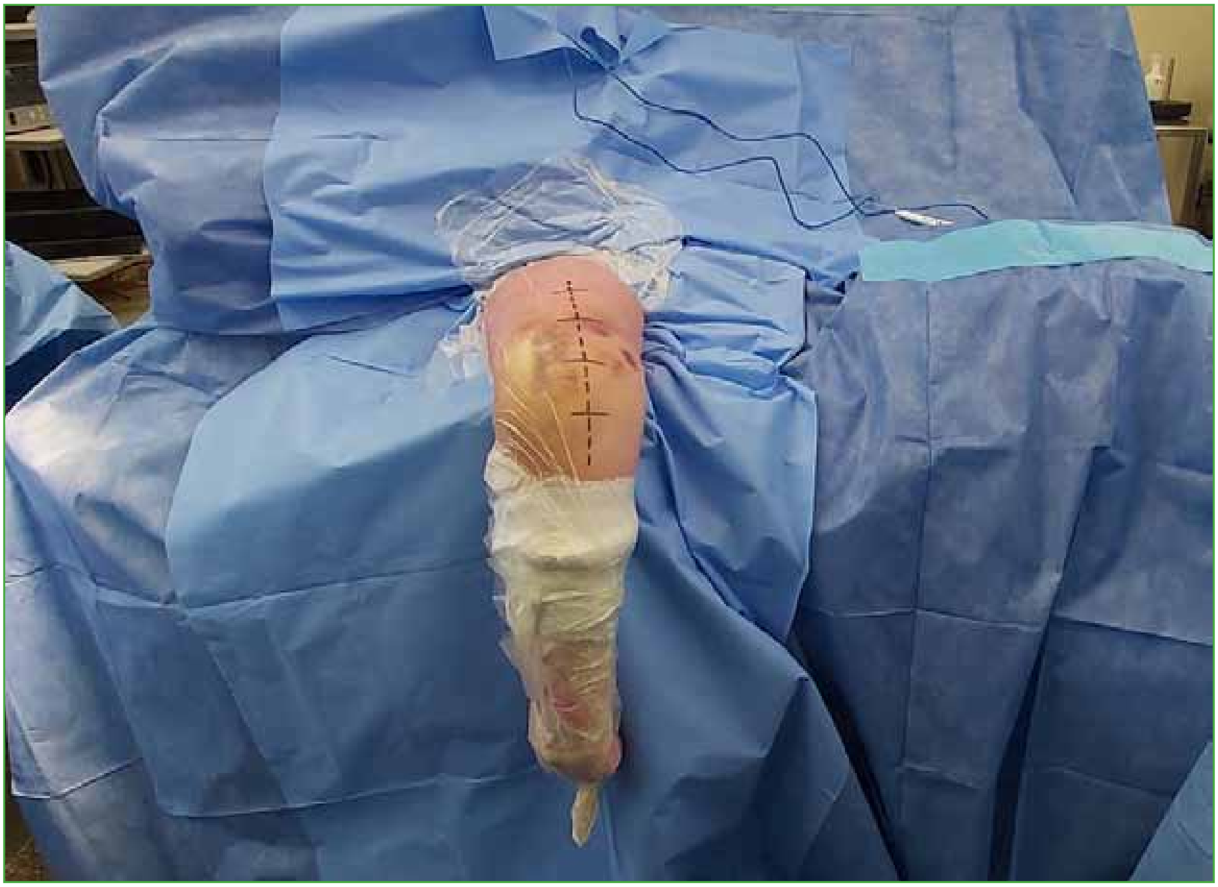

Figure 5. Posterior approach to the elbow.

In our practice, when we are faced with a type C1 or C2 fracture according to the AO classification, we avoid olecranon osteotomy and resort to a bilateral paratricipital approach, which allows good reduction of the articular surface and placement of the plates both orthogonally and in parallel (Figures 6 and 7).

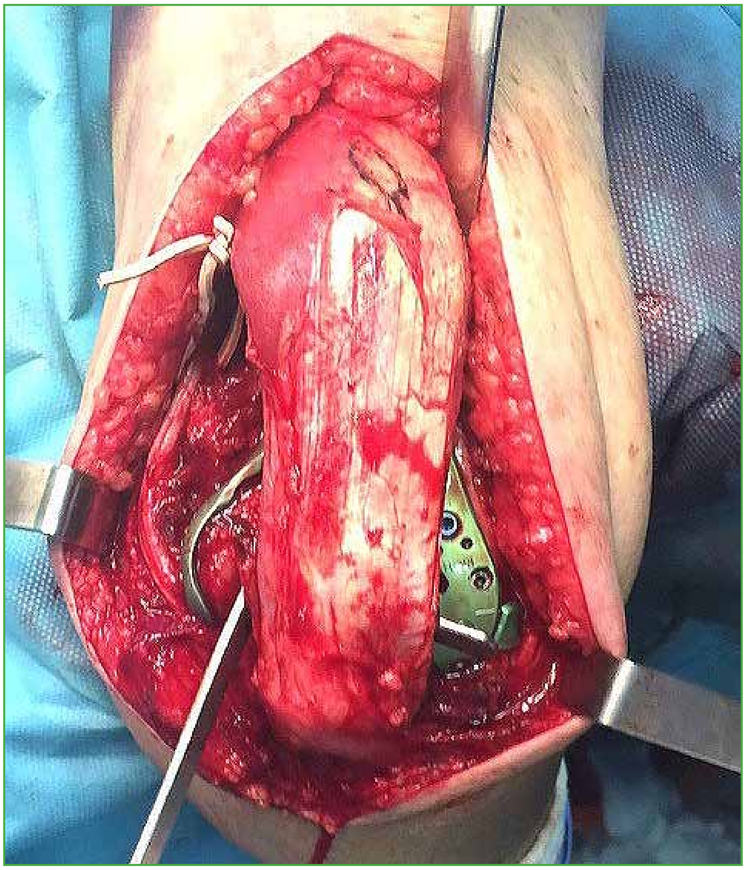

Figure 6. Arrangement of orthogonal plates using the paratricipital approach.

Figure 7. Arrangement of parallel plates using a paratricipital approach.

In the context of a type C3 fracture, bone quality and the degree of comminution must be evaluated, since these two variables condition the viability of osteosynthesis. When the bone quality is adequate and the fracture pattern allows its instrumentation to be foreseen, we opt for the chevron osteotomy of the olecranon (Figure 8).

On the other hand, when the scenario is that of an elderly patient with poor bone quality and extensive joint comminution or in very distal lines, arthroplasty may become an advisable option and, then, the approach with reflection of the extensor apparatus proposed by Bryan -Morrey may be the alternative of choice.

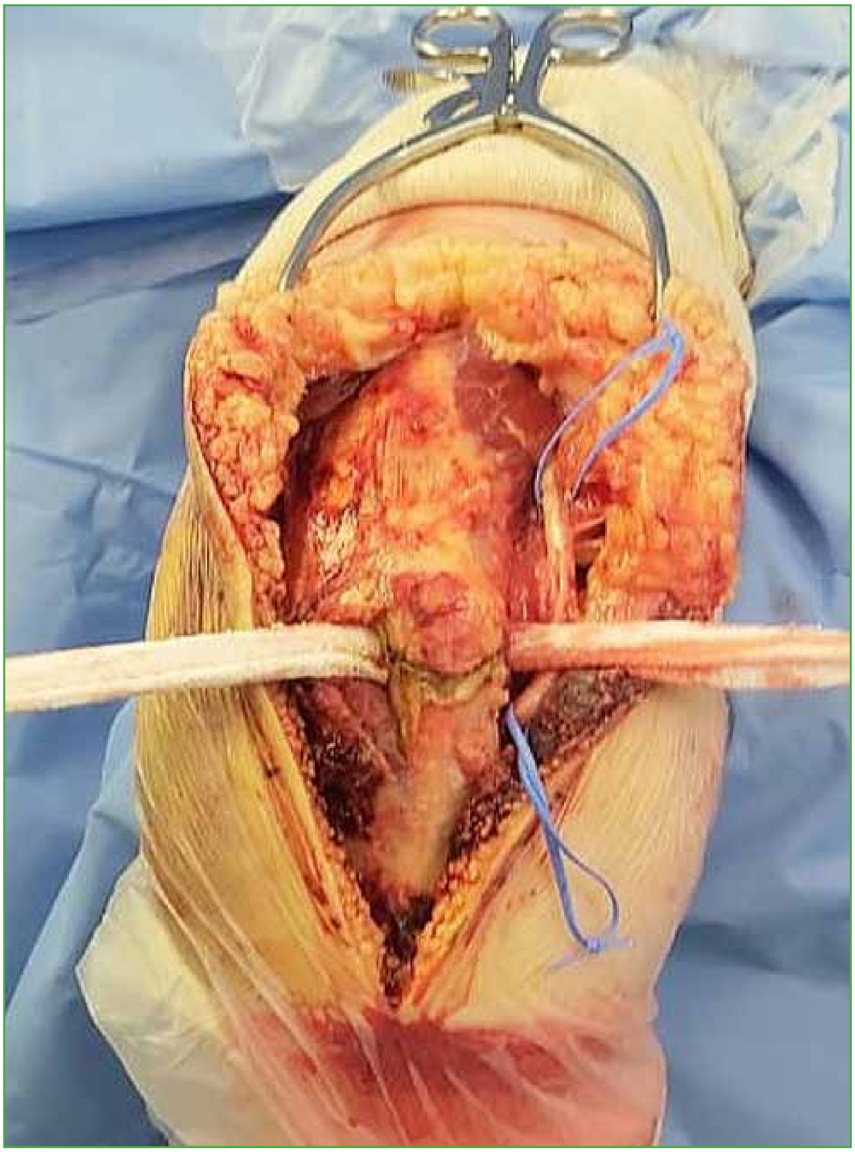

Figure 8. Preparation of the chevron olecranon osteotomy.

REDUCTION AND TRANSIENT FIXATION

Reduction should begin with the fragments that compromise the articular surface. The restoration of the anatomy at this level is essential to achieve a satisfactory outcome. Pointed forceps can be used, and sometimes a periodontal probe is helpful to maintain reduction and then temporarily fixate the articular surface with Kirschner wires. These wires must be placed strategically, in such a way that they do not interfere with the subsequent placement of the definitive plates. The triangle arrangement (Figure 9) is usually sufficient and effective to maintain reduction until definitive fixation.

Fixation using high-strength sutures for metaphyseal-diaphyseal fragments is a valid alternative that, according to our experience, is very useful and easy to perform, does not interfere with the subsequent placement of the plates as sometimes occurs with interfragmentary screws, and avoids the risk of migration that the pins present when used as a definitive method.

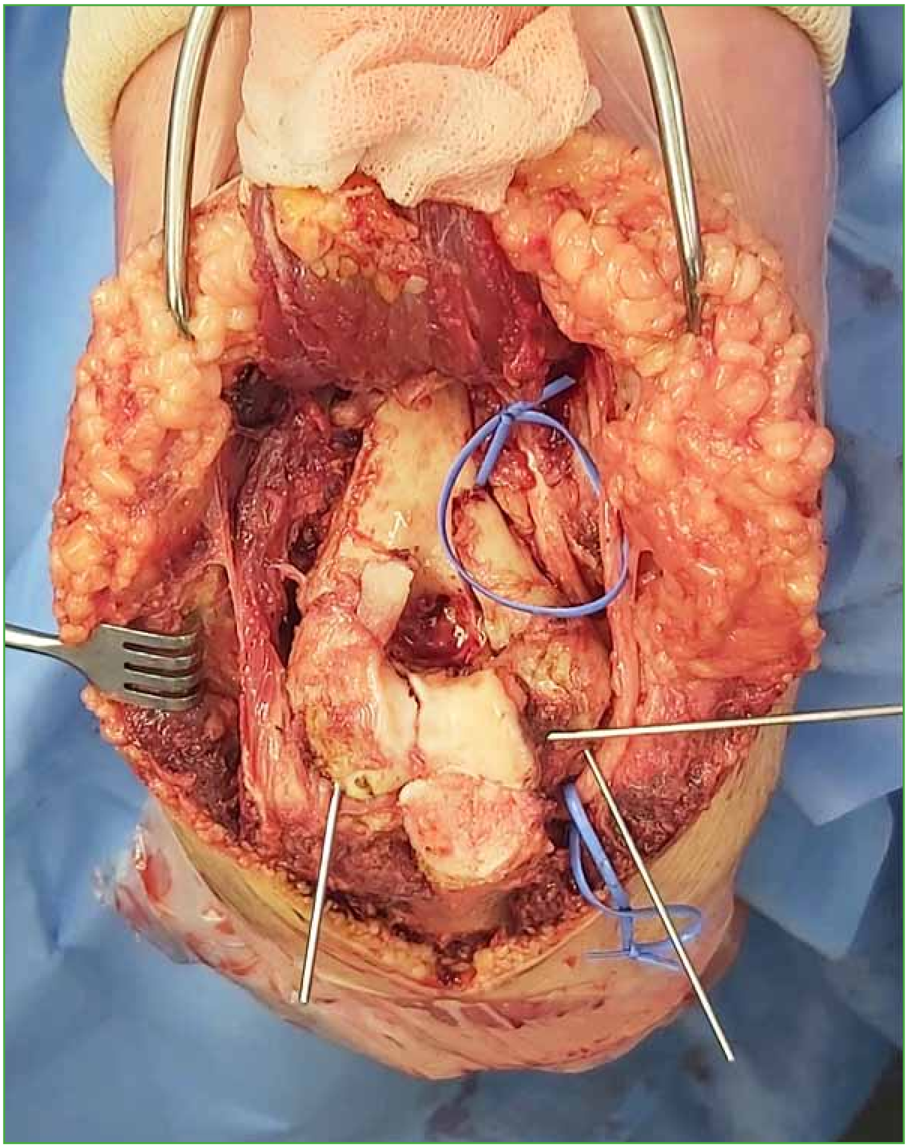

Figure 9. Temporary fixation using Kirschner wires in a triangular arrangement. Note that the arrangement of the wires does not interfere with the placement of the plates.

DEFINITIVE FIXATION

Once the articular surface has been temporarily reduced, fixated, and solidified to the metaphysis, the definitive fixation of the fracture must be carried out. The plates can be arranged in an orthogonal or parallel configuration, and this has probably been the most discussed topic in the last 20 years (Figures 10 and 11).

Multiple clinical and biomechanical studies have evaluated these two configurations. In a 2016 biomechanical study, Taylor et al. reported a significantly higher stiffness of the parallel plate configuration compared to the orthogonal ones.[11] One year later, Atalar et al. compared the biomechanical stability of both assemblies and did not find significant differences.[12] Through a prospective randomized clinical study, Lee et al. compared parallel and orthogonal fixation using locked implants, and found no significant differences in outcomes between the two groups after a minimum follow-up of two years.[12]

The most recent evidence supports that both arrangements are effective and that the parallel plate configuration could be superior to the orthogonal one in terms of bone union time.[14]

The choice of the construct type will depend on the fracture pattern. In our team, we prefer the arrangement of parallel plates proposed by O'Driscoll,[15] considering that interdigitation of the distal screws and taking the joint fragments from both sides allow achieving a solid and reliable construct for the range of motion of the joint.

As we mentioned in the choice of implants, we choose to place orthogonal plates when the lateral column presents associated traces in the coronal plane. Firstly, because the capitellum can be fixed with screws in the postero-anterior direction through the posterolateral plate, reducing to a minimum the need to place screws 'outside the plates'. The second reason is that we seek to avoid the placement of screws whose direction is in the same plane as the fracture, since, on occasion, they interpose themselves between the fragments on their way to the trochlea, and cause a diastasis that interferes with their reduction and fixation.

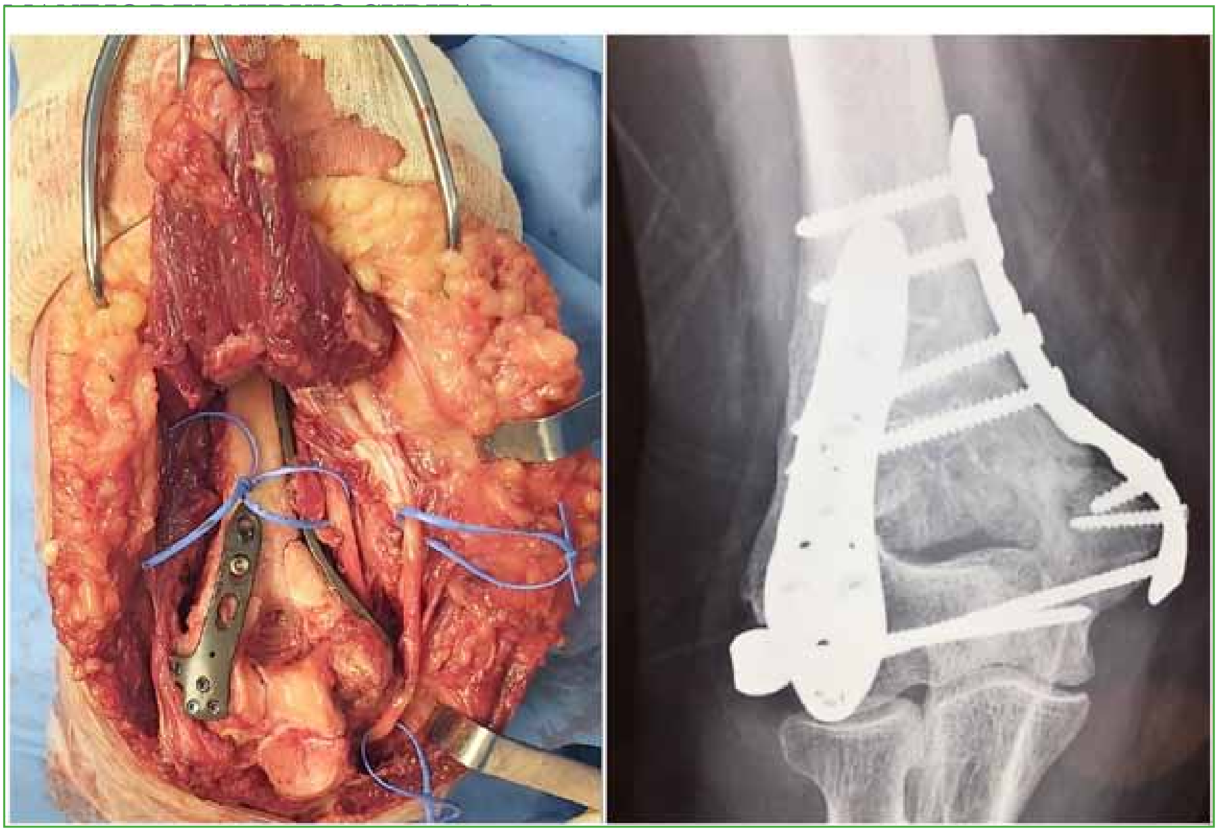

Figure 10. Definitive fixation through an arrangement of orthogonal plates.

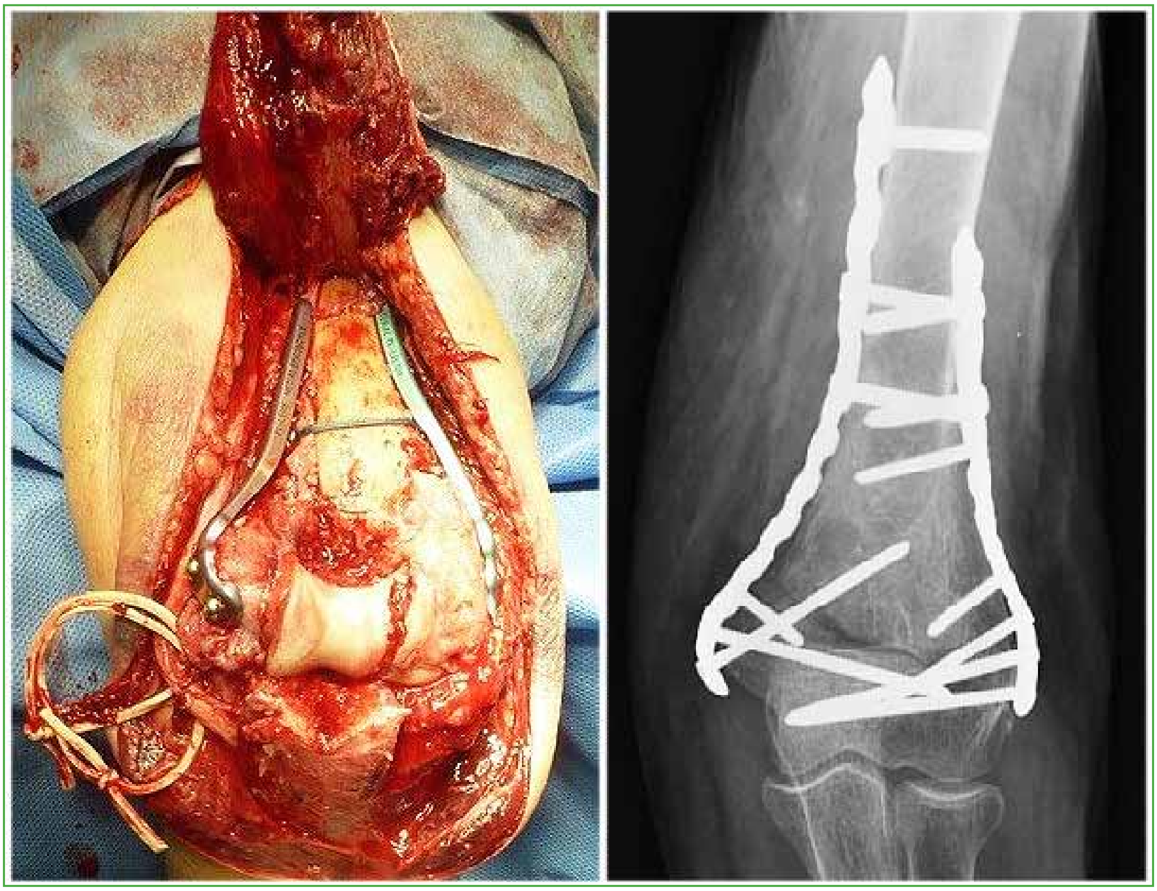

Figure 11. Definitive fixation by means of an arrangement of parallel plates.

MANAGEMENT OF THE ULNAR NERVE

As already mentioned, up to 25% of complex articular fractures of the distal humerus may present with symptoms related to the ulnar nerve and, for this reason, an adequate initial inspection is of the utmost importance to investigate these alterations, record them in the clinical history, and duly communicate them to the patient.

Early in the procedure, the identification, neurolysis, and repair of the nerve with rubber bands should be performed as a routine (Figure 12). Both traction and excessive or careless manipulation of the nerve during surgery are predisposing factors for the development of postoperative ulnar neuropathy that reaches rates of up to 38%.

Currently, the most appropriate method for intraoperative management of the ulnar nerve after fracture fixation is unknown. Both the anterior transposition and the *in situ* release have advocates and detractors. In 2018, Shearin et al. performed a meta-analysis that included 366 cases, and reported that postoperative ulnar neuropathy was higher in the anterior nerve transposition group (23.5%) than in the *in situ* decompression group (15.3%).[16] However, it is interesting to note that none of the publications included in this study discriminated between patients who had symptoms before surgery and those who did not.

Once the definitive fixation of the fracture has been carried out, the situation of the ulnar nerve must be evaluated by means of passive mobilization of the joint and it must be observed whether there is extensive contact with the medial implant or instability that may predispose it to irritation. If the nerve is unstable, according to what has been proposed in the literature,[17] we opt for anterior subcutaneous transposition of the nerve. On the contrary, if the nerve is stable upon passive range of motion, but has contact with the medial implant, we prefer, when the tissue allows it and unlike what was proposed by the aforementioned authors, to make a local flap of adipose tissue to cover the implant, keeping the nerve *in situ*.

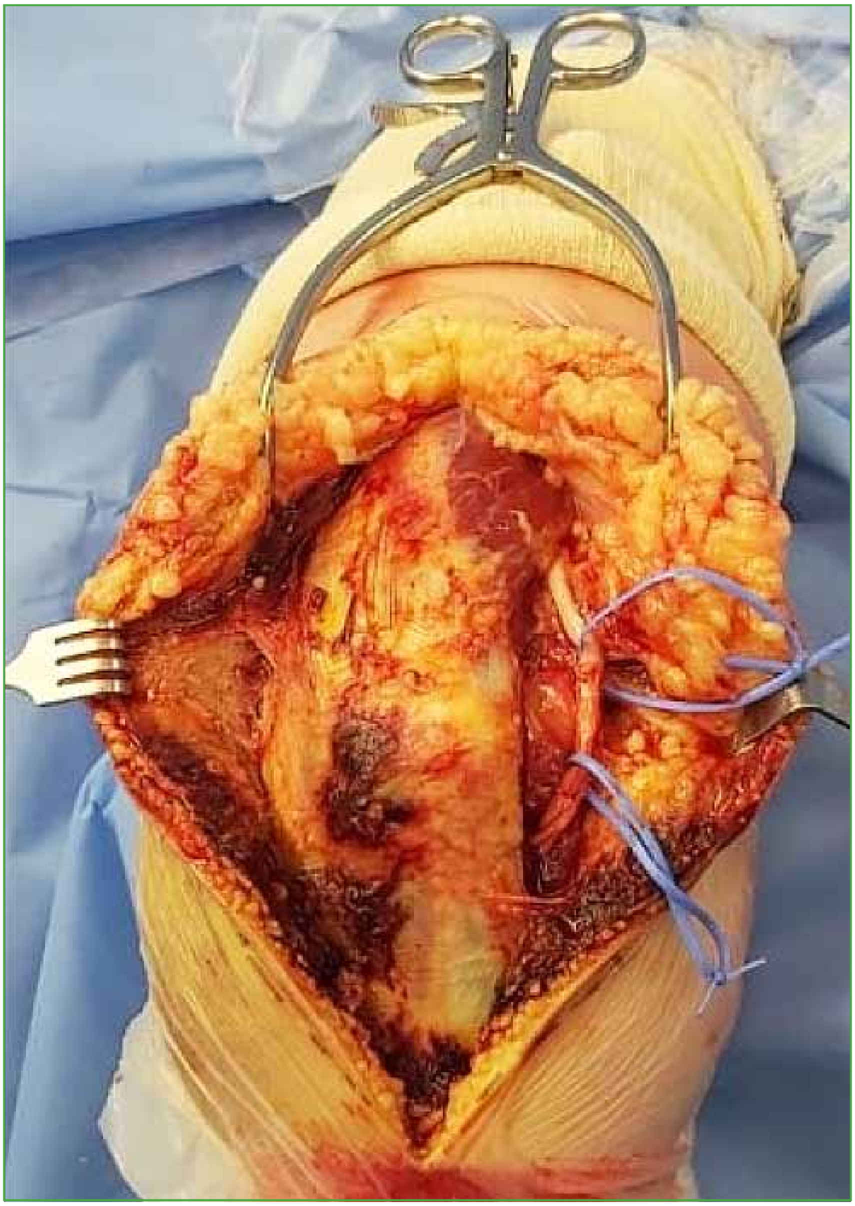

Figure 12. Identification and repair of the ulnar nerve with rubber bands.

On the other hand, the formation of edema and hematoma is recognized as a predisposing cause for the development of postoperative ulnar neuropathy; therefore, meticulous surgical technique and adequate hemostasis are of paramount importance.

POSTOPERATIVE PERIOD

In the immediate postoperative period, the elbow is immobilized in 90° flexion in order to protect the soft tissues, reduce edema and inflammation, and reduce pain. The immobilization time may vary according to the clinical evolution of the patient, but should not exceed 14 days. Early mobilization, as stated, is one of the key premises, since it will not only influence the final range of motion, but will also favor ulnar nerve gliding, reducing the formation of perineural adhesions and the development of postoperative neuropathy. For this, we use a self-adjusting articulated orthosis that allows the patient to move early within a controlled range and supervised by the surgeon and the therapist.

CONCLUSIONS

Articular fractures of the distal humerus pose a demanding scenario for the orthopedic surgeon. Their relative rarity, the complexity of the anatomy, and the rapid tendency of the elbow to stiffen lead to a high rate of both intraoperative and postoperative complications.

Determining the 'personality' of the fracture, the precise diagnosis of the fracture pattern by means of imaging studies, and adequate preoperative planning allow the selection of the most convenient surgical approach and the most appropriate arrangement of the osteosynthesis.

The training of the treating team and the systematization of the procedure could reduce surgical time and obtain more anatomical and stable fixations. This enables early rehabilitation and mobility, thus reducing the rate of complications and optimizing function

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Conflict of interests: The authors declare no conflicts of interest.

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Posteromedial Intergastrocnemius Approach to the Tibial Plateau. Description of the Surgical Technique

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ABSTRACT

Introduction: There are multiple approaches described in the literature for the treatment of fractures that involve the posterior columns of the tibial plateau. We present an anatomical intergastrocnemius approach for the treatment of all fractures involving the posterior component. It allows access with complete visualization of the entire posterior region, facilitating the reduction and placement of the osteosynthesis material necessary to achieve the most stable configuration. **Surgical technique:** We describe the posteromedial intergastrocnemius approach to access the tibial plateau performed by our team. **Conclusion:** We consider that this approach represents an option to consider when treating fractures that affect both posterior columns, some of them in isolation, or the tibial insertion of the PCL. Although the neurovascular structures require constant attention during the surgical procedure, their direct vision and their meticulous protection, performed by experienced surgeons, minimizes the risk of injury, and their manipulation is not a contraindication for using this approach.
Key words: Tibial plateau fractures; intergastrocnemius approach; posteromedial tibial plateau approach; posterior tibial plateau approach; tibial plateau osteosynthesis.
Level of Evidence: IV

Abordaje intergemelar posteromediano del platillo tibial. Descripción de la técnica quirúrgica.

RESUMEN

Introducción: Se han publicado múltiples abordajes para el tratamiento de las fracturas que involucran las columnas posteriores de los platillos tibiales. Presentamos un abordaje anatómico intergemelar para tratar todas las fracturas con compromiso del componente posterior. Este procedimiento permite el acceso con visualización completa de toda la región posterior facilitando la reducción y colocación del material de osteosíntesis necesario para lograr la configuración más estable. Se describe el abordaje intergemelar posteromediano de acceso al platillo tibial descrito por nuestro equipo. **Conclusiones:** Consideramos que esta vía de abordaje representa una opción por tener en cuenta al tratar fracturas que afecten ambas columnas posteriores, alguna de ellas de manera aislada o la inserción tibial del ligamento cruzado posterior. Si bien las estructuras neurovasculares requieren atención constante durante el acto quirúrgico, la visión directa de ellas y su protección meticulosa, realizada por cirujanos experimentados, reduce al mínimo el riesgo de lesión y su manipulación no es una contraindicación para la elección de esta vía.
Palabras clave: Fracturas de platillo tibial; abordaje intergemelar; abordaje posteromediano; abordaje posterior del platillo tibial; osteosíntesis.
Nivel de Evidencia: IV

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INTRODUCTION

Several approaches have been described for the treatment of fractures involving the posterior columns of the tibial plateaus. 7% of all tibial plateau fractures compromise the posterolateral column,[1] which, due to its anatomical features, is difficult to access. To date, no single approach has been described that allows the treatment of this entire sector. The management principles of all tibial plateau fractures are based on the anatomical reconstruction of the articular surface, the restoration of the mechanical axis and length of the tibia in the coronal and sagittal planes, and the absolute stability to allow early mobilization and avoid joint collapse.[2]

For many years, tibial plateau fractures were treated only anteriorly or using a posteromedial approach that allowed, with some limitations, to stabilize the posteromedial column. The use of posterior accesses was disregarded due to their technical difficulty associated with high complication rates. Surgery in the posterior region of the knee can be challenging due to the presence of neurovascular structures at risk, such as the tibial nerve, popliteal artery and vein, lateral and medial sural cutaneous nerve, anterior tibial vascular bundle (known as trifurcation), and the common fibular nerve, so it is rarely used in routine practice. A safe and successful posterior approach requires detailed anatomical knowledge of the location of these structures and their possible variants.[2-4] Tomaszewski et al.[5] proposed a classification based on the variations in the origin of the anterior tibial artery in relation to the popliteus muscle, which we consider very useful to know in order to reduce the risk of vascular injury.

Currently, multiplanar and 3D CT reconstructions are used for the evaluation of joint involvement.[6-10] Based on these new imaging advances, Luo et al.[11] proposed the three-column theory, emphasizing the relevance of fractures oriented in the coronal plane. Chang et al.[12] proposed dividing the articular surface into four quadrants to better understand these injuries.

The new Kfuri-Schatzker[13] classification brings these concepts together and introduces the idea of the "main fracture plane". The recognition of the main fracture plane is essential for preoperative planning, as well as the correct positioning of the patient, the choice of the surgical approach, and determining where to place the osteosynthesis material to achieve the most stable fixation.

We know that placing the osteosynthesis material in the fracture plane is essential to achieving correct stabilization of the tibial ring.[13,14] Direct access to the fracture site is the only way to achieve this. In cases of compromise of the posterior columns, not treating them by direct access leads to poor reduction and insufficient stabilization which translates into worse functional results.[15]

The objective of this study is to present a gastrocnemius splitting anatomic approach to treat all fractures with posterior component involvement. This approach achieves complete visualization of the entire posterior region, facilitating the reduction and placement of the osteosynthesis material necessary to achieve the most stable configuration.

Surgical technique

Patient position: The surgical position of choice is ventral decubitus, with a subsequent positional change of the patient for a lateral or medial anterior parapatellar approach depending on the involvement and need for implant placement; or a floating position (Figure 1) that allows the change in the position of the patient with external and internal rotation of the affected limb without the need to change the surgical fields.

Figure 1. Floating position. It allows changes in the position of the limb for intraoperative access to the posterior and anterior plateau as needed.

Description of the approach: Patient under subarachnoid anesthesia (spinal block). It is preferred not to use a hemostatic cuff, as this makes it easier to recognize the vascular structures, protect them during surgery, and perform correct hemostasis and the necessary ligatures for the release and mobilization of the popliteal neurovascular bundle. It also facilitates closure without soft tissue edema and minimizes the possibility of deep vein thrombosis.

Skin incision: A vertical approach centered on the midline is performed, taking the skin line between the gastrocnemius heads as a reference (Figure 2). The approach will be extended proximally and distally on demand as required by the fracture. An inverted L-shaped skin approach with a longitudinal branch at the medial level and a transverse branch at the level of the fold can also be used (Figure 3).

Figure 2. Dermographic marking of the medial posterior approach.

Figure 3. Dermographic marking of the inverted L-shaped posterior approach.

The superficial fascia is sectioned and the small saphenous vein is immediately visualized together with the sural cutaneous nerve running over the gastrocnemius midline (Figure 4).

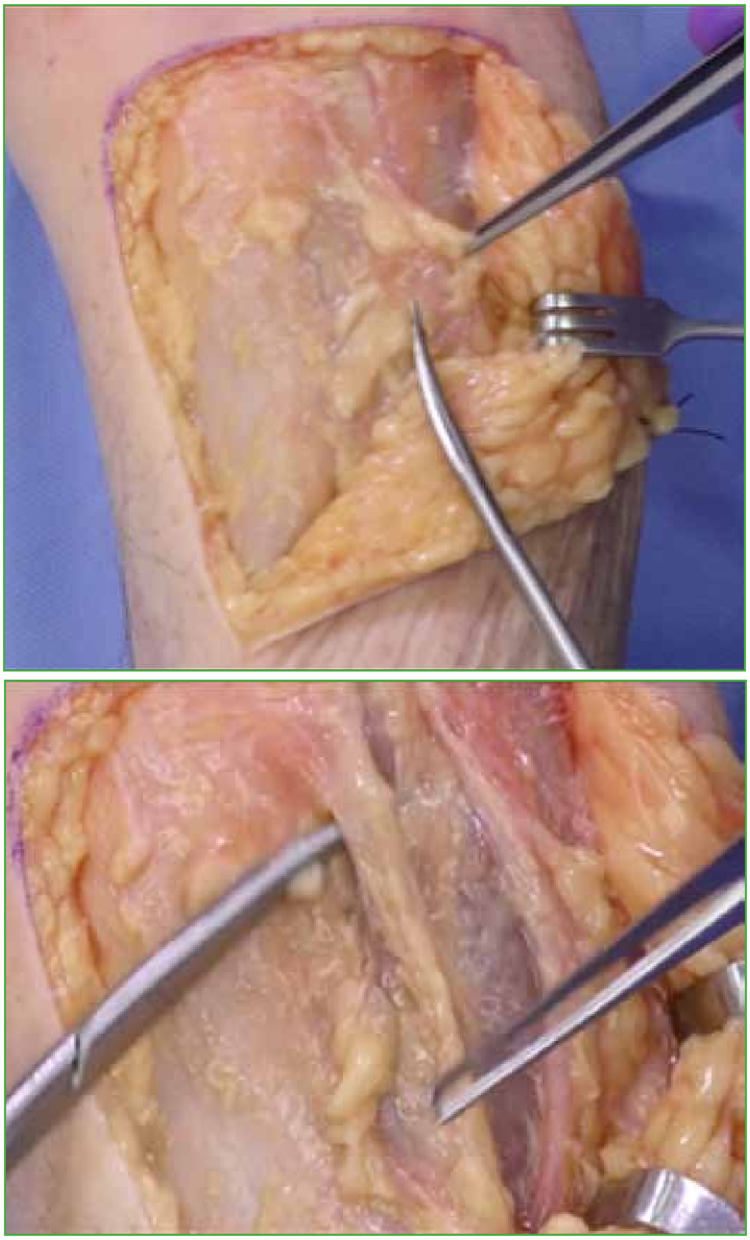

Figure 4. Opening of superficial fascia, visualization of the small saphenous vein and sural cutaneous nerve, and release for their repair.

By means of blunt dissection, the gastrocnemius heads are separated, exposing the popliteal fossa (Figures 5 and 6). The release of the popliteal neurovascular bundle in order to mobilize it usually requires ligation of its inferomedial and inferolateral genicular branches without compromising the irrigation of this anatomical sector due to its multiple anastomoses. It is advisable to perform this maneuver with slight knee flexion to avoid its tension. If necessary, the release can be extended to the soleus arch. Special care should be taken with the medial gastrocnemius nerve whose iatrogenic injury may cause its denervation and consequent atrophy.

Figure 5. Blunt dissection of both gastrocnemius bellies performed with the index finger.

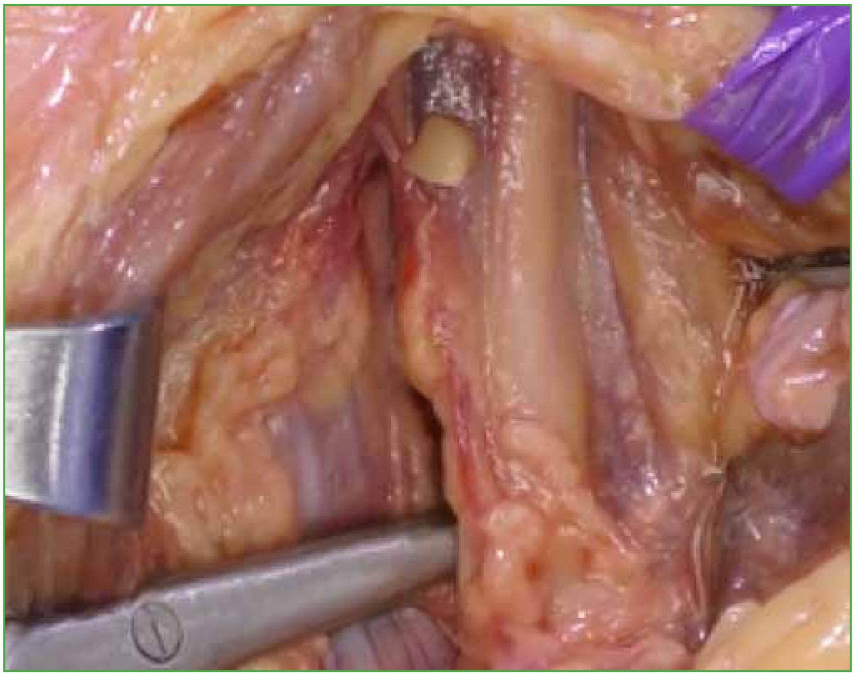

Figure 6. Popliteal neurovascular bundle recognition and release. If necessary, ligation of its collateral vessels is performed on demand to be able to mobilize the bundle as needed.

With a blunt separator, the popliteal bundle can be lateralized or medialized as required, thus creating two triangular working windows, one medial and one lateral. The medial window is framed by the popliteal bundle (artery) on its lateral side and the semimembranosus and medial belly of the gastrocnemius (Figure 7). The lateral window is framed by the popliteal bundle (nerve) on its medial side, the biceps femoris muscle, and the lateral belly of the gastrocnemius (Figure 8).

Figure 7. The medial window is completely exposed. The popliteal neurovascular bundle can be seen on the right side of the image forming the base of a triangle with its sides formed by the internal gastrocnemius and the semimebranosus at its upper part.

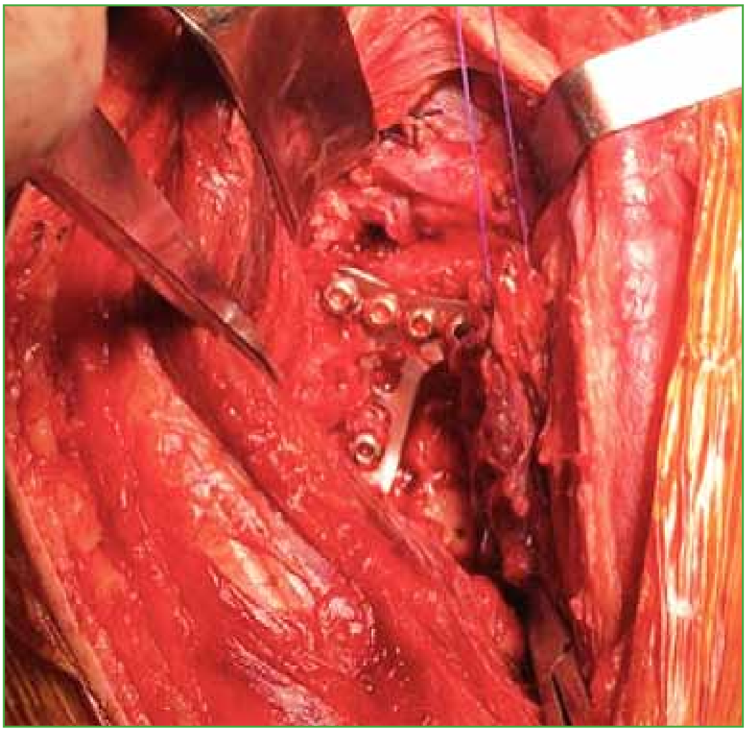

Figure 8. The lateral window is observed in its complete exposure. The image does not correspond to the same subject since the fracture did not require reaching the posterolateral wall. It is observed how the popliteal bundle is displaced medially, forming the base of the window, with its upper side formed by the biceps femoris and the common fibular nerve (external popliteal sciatic nerve) and its lower side formed by the external gastrocnemius.

To widen the approach, tenotomy of one or the other head of the gastrocnemius can be performed taking into account its subsequent reinsertion. The plantaris muscle can be split in the lateral window. The dissection of the popliteus muscle is performed from its insertion at the medial side in a superolateral direction towards the posterior side of the external plateau (Figure 9).

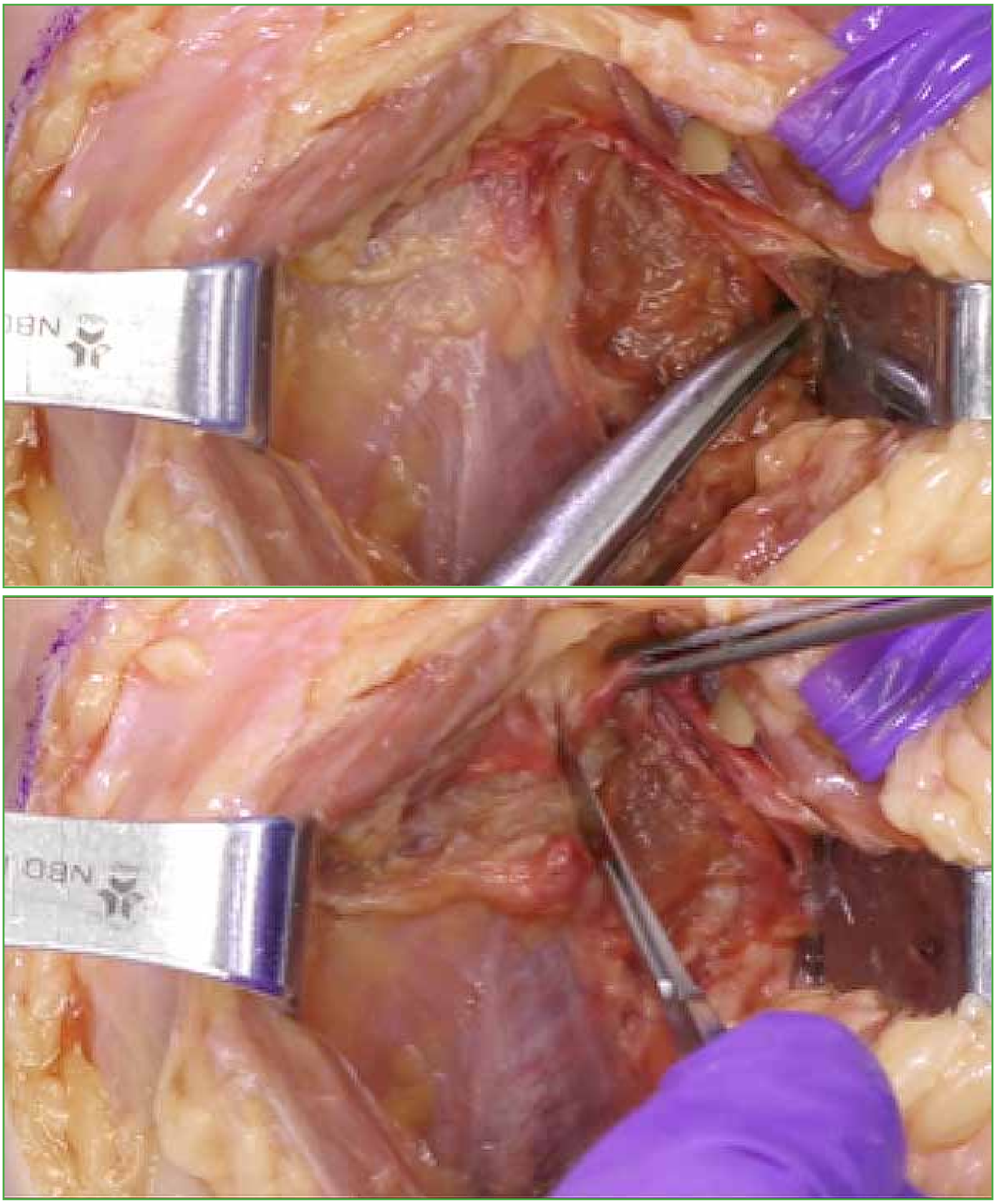

Figure 9. The dissection of the popliteus muscle is observed from the lateral end of the articular side of the plateau towards medial to expose the posterior aspect of the plateau.

The curettage of the popliteus muscle in a distal direction exposes the entire bone surface (Figure 10). This should be done neatly and with correct visualization to avoid any possible injury in case there is an aberrant anterior tibial artery below this muscle. If the approach is used to repair the PCL, it is not necessary to resect the popliteus muscle.

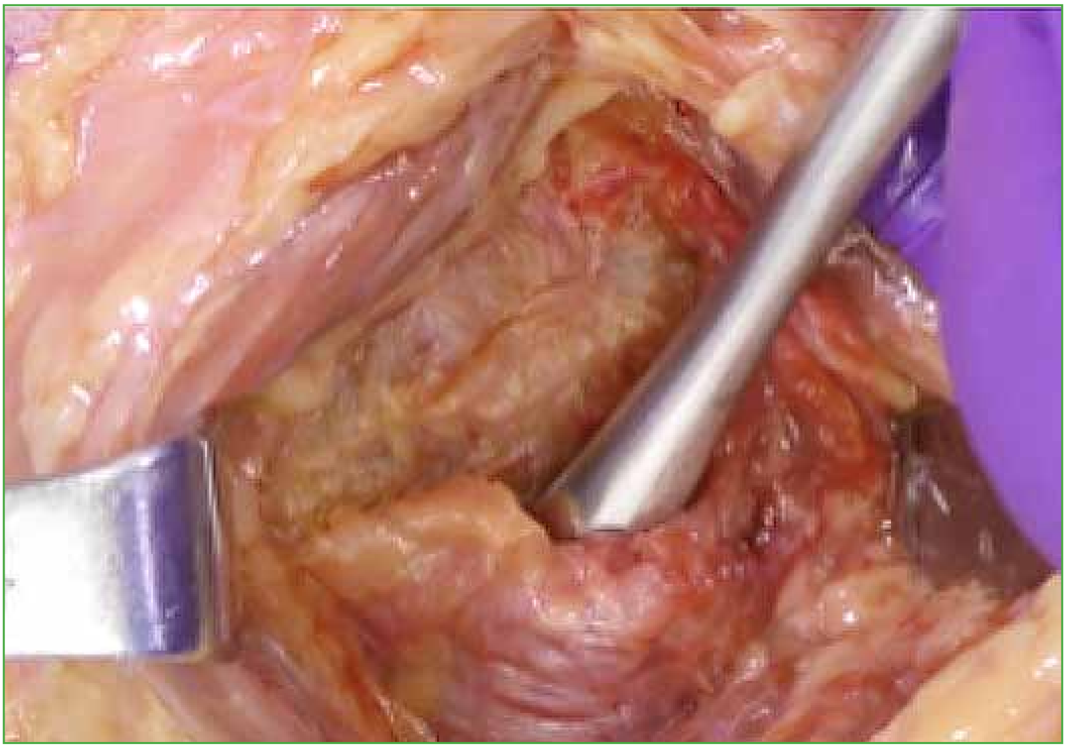

Figure 10. The curettage of the popliteus muscle leaves the entire bone surface exposed.

Capsulotomy allows the joint to be exposed in order to place the osteosynthesis material (Figures 11). We use the femoral distractor to obtain greater joint visualization.

For the closure, it is important not to forget to reinsert the popliteus muscle and the gastrocnemius heads in those cases where their dissection was necessary. Then, the deep and superficial fascia, subcutaneous cellular tissue, and skin are closed with simple sutures.

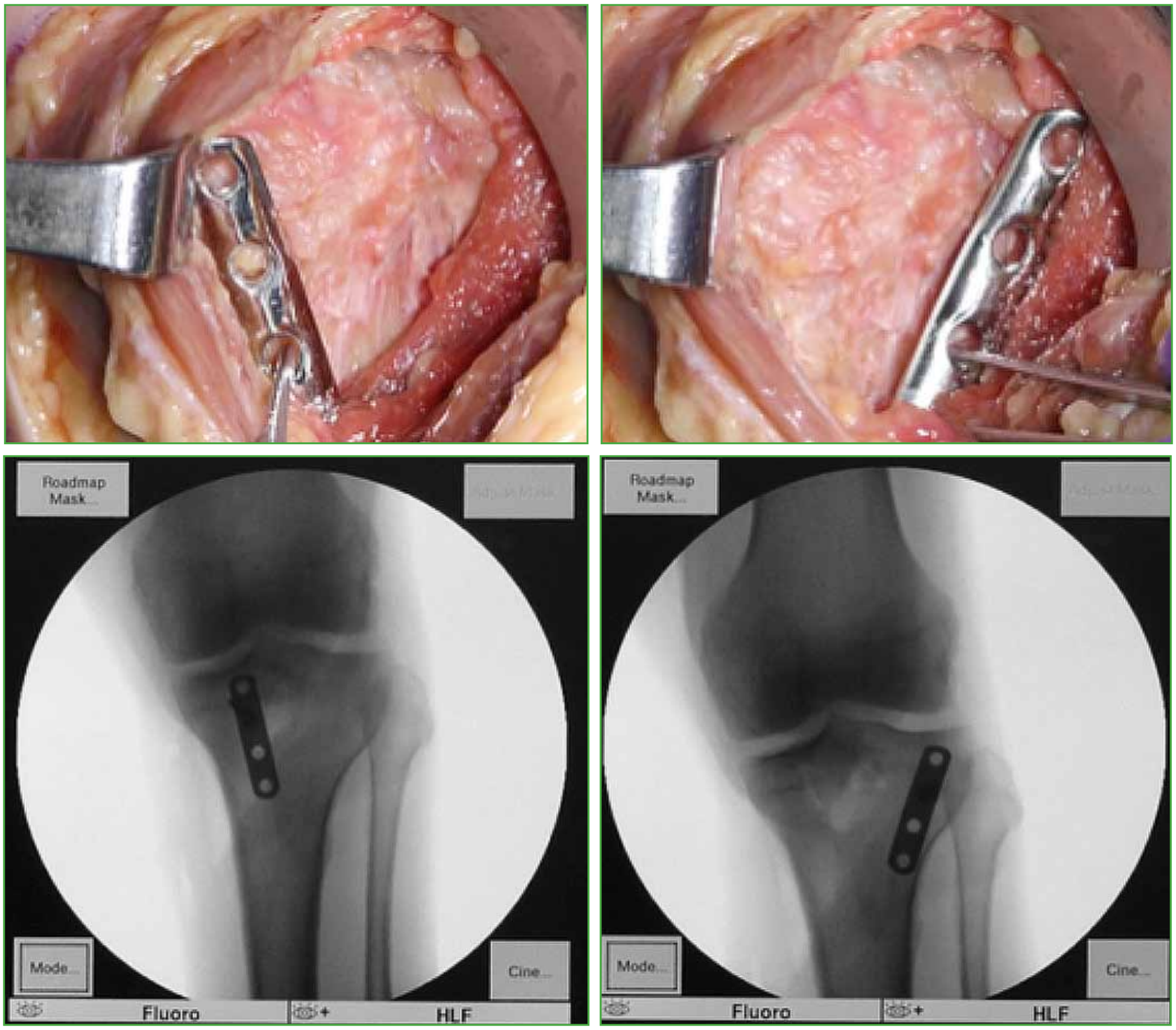

Figure 11. The posterior and lateral aspects and the possible placement of the osteosynthesis material with their respective radioscopic controls are observed.

DISCUSSION

Tibial plateau fractures account for about 1% of all fractures; 55-70% correspond to the lateral plateau; 10-23%, to the medial plateau; and 30% involve both.[16] The study by Yang et al.[1] revealed that of all posterior column injuries, 45.7% compromise the posteromedial column; 35.1%, the posterolateral column; and 19.2%, both posterior columns.

It is important to highlight the importance of understanding the anatomical variables of the popliteal artery and its branches as described in the research of Tomaszewski et al.[5] and Bose and Ramanathan[17]. The former proposed the classification based on the origin of the anterior tibial artery and its variants which we consider vital to understand in order to avoid any risk of vascular injury. We suggest including an angiotomography study for pre-surgical planning.

Open reduction and internal fixation are traditionally performed by anterolateral and medial approaches. Initially, posterior approaches were discouraged due to their technical difficulty due to both the complex anatomy of the region and the high risk of both vascular and nerve iatrogenic injury. Currently, not performing adequate stabilization of the fragments by posterior approach is understood as a failure in the treatment of the fracture, due to the worse functional outcomes.[18]

In the decade of 1960, Trickey[19] described the use of a similar interval to the approach proposed by our team for the reinsertion of the posterior cruciate ligament. The field of work was very limited and, due to its use, the modifications introduced by our team for the extension of the approach or the opening of the popliteus muscle to reach the posterolateral region were not necessary.

In 1993, Hoppenfeld and DeBoer[20] described a posteromedial approach that they did not initially use for the treatment of fractures. Continuing this line of work, in 1997, De Boeck and Opdecam[21] published an article about seven patients treated by this approach. Georgiadis[22] treated four patients with a double approach, anterior and posteromedial, for the said fragment.

In 1997, Lobenhoffer et al.[10] described an approach that allowed access to the posteromedial region of the tibial plateau and PCL, reproducible and relatively safe in vascular terms, by using the interval between the pes anserinus and the internal gastrocnemius. Its limitation is that it does not allow reaching the posterolateral region. At the same time, they described a posterolateral approach with osteotomy of the fibular neck, which improves the limited access described by Minkoff for the treatment of an osteoid osteoma and later modified to treat fractures together with Jaffe and Menendez.[23] The proximal fibular osteotomy achieves an acceptable working field, but it is a traumatic procedure that adds comorbidities, such as the release of the posterolateral angle and great periosteal separation, with important structures at risk, such as the common fibular nerve (external popliteal sciatic nerve).

In 2010, Frosch and Balcarek[24] described an approach without fibular osteotomy that allowed adequate visual access and reduced iatrogenic injury to the soft tissues and structures of the posterolateral angle. When using the interval between the biceps femoris muscle and the head of the lateral gastrocnemius, it is necessary to identify the common fibular nerve (external popliteal sciatic nerve) and its mobilization in the surgical procedure, with the risk of a possible intraoperative injury.

Our approach uses the intergastrocnemius interval, anatomically located in a medial position that allows access to both posterior columns at the same time. Thus, it offers an adequate surgical field that enables correct visualization and simplifies achieving adequate reduction and stabilization. The possibility of extending it and using the popliteal bundle as a mobile element, medializing it to generate a second working window, is useful when simple lateralization is insufficient to comfortably reach the posterolateral angle. This allows all fractures involving the posterior columns to be treated with a single approach and makes it a reproducible, useful, and versatile way of working. The presence of the popliteal bundle in the surgical field allows us to protect it correctly, reaching a high level of safety.

CONCLUSIONS

We believe that this approach represents an option to consider when treating fractures involving both posterior columns, either one of them in isolation, or the tibial insertion of the PCL. Although the neurovascular structures require constant attention during the surgical procedure, the direct vision of these structures and their meticulous protection, performed by experienced surgeons, minimizes the risk of injury and their manipulation is not a contraindication for the choice of this approach.

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Helical Plate Osteosynthesis in Distal Femur Fractures

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ABSTRACT
Introduction: The use of double osteosynthesis for the treatment of fractures of the distal femur with metaphyseal comminution (AO 33C2, C3) and periprosthetic fractures (Vancouver C) provides greater stability. The use of helical plates has increased in order to avoid vascular damage related to the approach. **Materials and Methods:** Between 2017 and 2021, six patients were treated by double plate osteosynthesis (helical plate by medial approach). The series consisted of four females and two males, 66% (4 patients) had distal femoral fractures, and the rest (33%, 2 patients) were diagnosed with Vancouver C periprosthetic fractures. **Results**: In all cases, radiographic consolidation was observed 6 months after surgery, with a normal return to activities of daily living. None of them presented an associated neurovascular injury. **Conclusion:** The helical plate is a great option in distal femur fractures and Vancouver C periprosthetic femoral fractures. By applying the basic principles of osteosynthesis, sophisticated materials can be supplied, obtaining good clinical, functional, and radiographic outcomes.
Keywords: Helical plate; distal femur fractures; femur osteosynthesis; periprosthetic fractures.
Level of Evidence: IV

Osteosíntesis con placa helicoidal en las fracturas de fémur distal

RESUMEN
Introducción: En pacientes con fracturas de fémur distal con alto grado de conminución metafisaria (AO 33C2, C3) y fracturas periprotésicas (Vancouver tipo C), el uso de doble osteosíntesis brinda mayor estabilidad a la fractura. Las placas helicoidales se emplean cada vez más con el objetivo de evitar dañar elementos nobles relacionados con el abordaje. **Materiales y Métodos**: Entre 2017 y 2021, seis pacientes fueron tratados mediante osteosíntesis con doble placa (por vía lateral y helicoidal por vía medial). La serie se compone de cuatro mujeres y dos hombres. El 66% (4 pacientes) tenían fracturas de fémur distal, y el resto (33%), fracturas periprotésicas tipo Vancouver C. **Resultados**: Se observó la consolidación radiográfica en todos los pacientes, a los 6 meses de la cirugía, con retorno normal a la activad previa. Ninguno sufrió una lesión vasculonerviosa asociada. **Conclusiones:** La placa helicoidal es una gran opción para las fracturas de fémur distal con conminución y las fracturas femorales periprotésicas tipo Vancouver C. Esto demuestra que, aplicando los principios básicos de osteosíntesis, con una técnica sencilla, se pueden suplir materiales más sofisticados, y obtener resultados radiográficos similares.
Palabras clave: Fracturas de fémur distal; placa helicoidal; osteosíntesis de fémur distal; fracturas periprotésicas.
Nivel de Evidencia: IV

INTRODUCTION

Distal femur fractures make up 6% of all femur fractures. The classic treatment consists of osteosynthesis with a plate via the lateral approach, which allows a stable configuration with a good rate of consolidation and achieves good outcomes.[1]

In some types of fractures, osteosynthesis via the lateral approach does not provide sufficient stability (complex articular fractures, with a high degree of metaphyseal comminution). In these cases, double osteosynthesis (laterally and medially) is preferred to provide greater stability to the fracture and prevent varus collapse.

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Loosening, bone necrosis, and nonunion have been reported in normal osteosyntheses in these distal femur fractures, so it may be necessary to develop new alternatives to treat them.[2]

The problem lies in the complications of performing osteosynthesis through a medial approach, with the use of smaller plates that, in certain cases, seem insufficient, taking into account the noble structures present.

In 2002, Fernández Dell'Oca described the biomechanical principles of helical implants. Regarding distal femur fractures, he proposed a helix-shaped implant, placed medially and ending on the anterior face of the proximal femur. In this way, the noble structures of the area are avoided and longer implants can be placed to provide greater stability (with a good rate of consolidation, without material fatigue and a low rate of nonunion).[3]

There is scant literature available on the subject of distal femur fractures, although the use of helical plates for humerus fractures has been widely analyzed.[3]

The objectives of this article are to describe a series of cases in which helical plate osteosynthesis was performed in patients with distal femur fractures, to explain its placement technique, and to communicate the results obtained.

MATERIALS AND METHODS

We carried out a descriptive study in a national referral center, on patients with distal femur fracture and periprosthetic fractures treated by double plate osteosynthesis (osteosynthesis by lateral approach and helical plate by medial approach), during the period between January 2017 and January 2020.

The inclusion criteria were: patients with open or closed type C2 and C3 fractures of the distal femur (according to the AO classification), or Vancouver type C periprosthetic fractures of the hip treated by double-plate osteosynthesis with a medial helical plate. Exclusion criteria were: pathological fractures, clinical or biochemical signs of infection, and follow-up <6 months.

We recorded the following variables obtained retrospectively from the archive of medical records and images: age, sex, fracture classification, pain in the last available control after consolidation according to the visual analog scale, stability and functionality of the knee. Stability was retrospectively evaluated by observing the rate of osteosynthesis failure, evaluating cases of nonunion (lack of radiographic consolidation, pain, focus mobility >3 months) and material fatigue (breakage of the osteosynthesis material). In all patients, the KOOS score (Knee injury and Osteoarthritis Outcome Score) was used, which allows estimating functional postoperative outcomes of the knee and quality of life.[4,5]

Surgical technique

Osteosynthesis was performed using a conventional lateral approach for the distal femur. To achieve the length and reduction of the fracture, a temporary external fixator was used (Figure 1). For osteosynthesis via the lateral approach, low-profile, locking anatomical distal femur plates were used.

The helical plates were crimped with straight plates with 12 to 15 3.5 mm holes (Figure 2).

From a small medial exposure, the helical plate was inserted through the submuscular space reaching the existing proximal exposure for the lateral implant. Both plates "bridge" the metaphyseal comminution zone.

Figure 1. Intraoperative images. The placement of the temporary external tutor to maintain the length is observed.

Statistical analysis

Categorical variables were described in number and percentage; and numerical variables, as median and range. For the analysis of the variables, the SPSS Statistics 25 program was used.

The confidentiality of the data was respected, adhering to the Declaration of Helsinki. The collection of information and the review of medical records were carried out with the prior consent of the patients.

Figure 2. Intraoperative image. Helical plate crimped to measure.

RESULTS

During the study period, six patients with a distal femur fracture were included. The series consisted of four (67%) women and two men (33%). Four (67%) had a distal femur fracture (one of them was a young patient with paraplegia from an early age) and two (33%) had a Vancouver type C periprosthetic fracture (Table 1).

Table 1. Sample Description

Variable	Outcomes
Cases	6
Age, median (range)	72 (38-81)
Sex, n (%) Female Male	 4 (66.6) 2 (33.3)
Diagnosis, n (%) Femur fracture Periprosthetic fracture	 4 (66.6%) 2 (33.3%)
Radiographic consolidation, n (%)	6 (100%)
Visual analog scale, median (range)	3 (2-4)
Osteosynthesis fatigue, n (%)	0
Nonunion, n (%)	0
Follow-up (months), median (range)	24 (6-36)

In all patients, radiographic consolidation was observed six months after definitive surgery. Two patients in the sample had, at the time of osteosynthesis, metaphyseal defects that were resolved with cement spacers and antibiotics, thus requiring a new intervention with the placement of a bank graft. In these cases, weight-bearing was delayed for six weeks, at which time the second surgical stage was performed, which consisted of spacer removal and filling of the defect with cadaveric bone graft. Again, weight-bearing was delayed for six weeks, and union was achieved in both cases. The rest of the patients started a progressive weight-bearing protocol that consisted of partial weight-bearing for three weeks and then full weight-bearing. None had an associated neurovascular injury (Figures 3-6).

Figure 3. Anteroposterior radiographs of the femur. A Vancouver type C periprosthetic hip fracture and the result after double medial and lateral osteosynthesis are observed.

Figure 4. Anteroposterior and lateral panoramic radiograph of the femur in the preoperative period. A fracture of the distal femur with metaphyseal comminution is visualized.

Figure 5. A. Anteroposterior radiograph of the femur. **B.** Anteroposterior radiograph of the knee. **C.** Lateral radiograph of the femur. Immediate postoperative period. Medially placed helical plate with 10 holes adapted to the distal femur and management of the metaphyseal defect with a cement spacer.

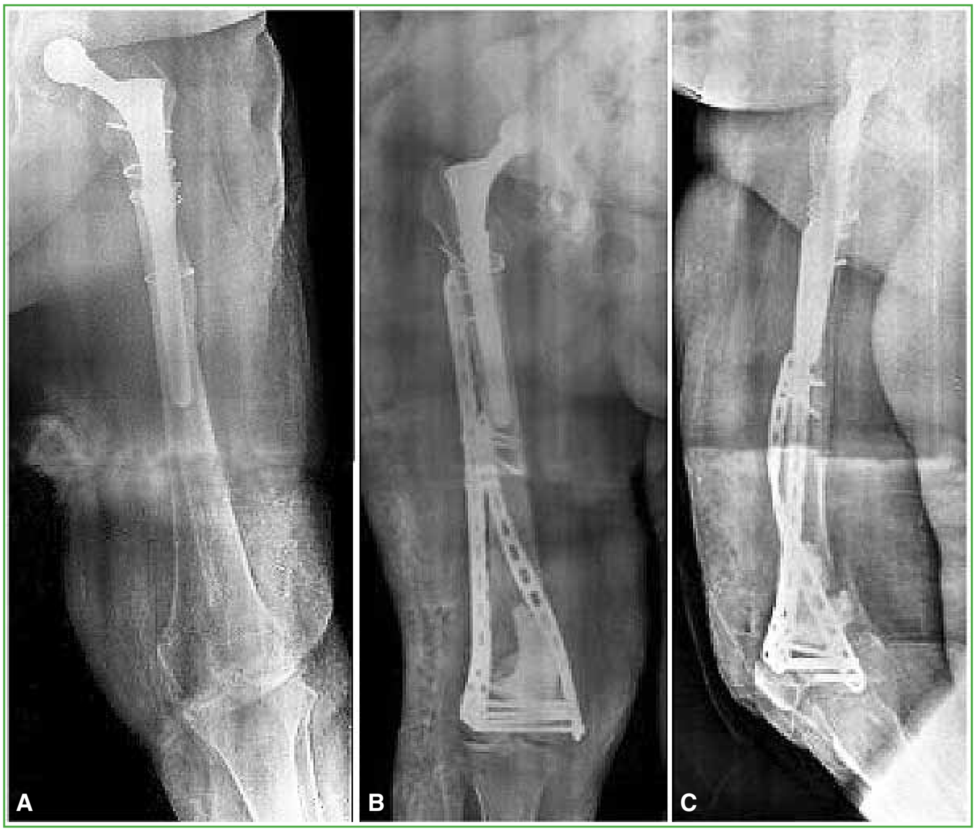

Figure 6. **A.** Anteroposterior panoramic radiograph of the femur in the preoperative period. A Vancouver type C periprosthetic hip fracture with compromise of the distal femur is observed. **B and C.** Anteroposterior and lateral radiographs of the femur in the postoperative period. Osteosynthesis with helical plate

The average postoperative pain score after fracture union was 3. The patient with quadriplegia was not evaluated in this regard (Table 2). The radiographic follow-up was performed in the immediate postoperative period, at 3 and 6 weeks, and at 3, 6, 12, 18, and 24 months. Table 3 describes the functional outcomes according to the KOOS score.[6,7] The median follow-up was 24 months (range 6-36).

Table 2. Description of the cases

Cases	Sex	Classification*	Pain (VAS)	Consolidation	Implant fatigue	Infected nonunion
1	F	AO 33 C2	-	Yes	No	No
2	F	AO 33 C3	2	Yes	No	No
3	F	Vancouver C	3	Yes	No	No
4	F	Vancouver C	3	Yes	No	No
5	M	AO 33C2	4	Yes	No	No
6	M	AO33C3	3	Yes	No	No

F = female, M = male, VAS = visual analog scale.
*Distal femur fractures were classified according to the AO classification system and the Vancouver classification for cases of periprosthetic fractures.

Table 3. KOOS (Knee injury and Osteoarthritis Outcome Score).

Patient	Pain	Activities of daily living	Function, sports, and recreational activities	Quality of life	Symptoms
1	-	96.88	65	87.5	82.14
2	91.67	94.12	55	88.5	71.3
3	92.53	91.78	75	81.25	78.57
4	87.67	94.36	65	75	89.29
5	93.48	90.15	65	93.75	92.86
6	85.32	88.24	55	75	77.47

DISCUSSION

The helical plate is a conventional, crimped straight plate. Its application provides rigidity to the system, as it improves resistance to axial load, and it has already been used successfully in various types of long bone fractures.[3] It acts as an internal fixator, it is an easy technique to apply and requires minimal additional exposure. It replaces the missing bone support by acting as a tension band; therefore, it supports and protects with an improved lever arm.[4] In our series, we used 3.5mm straight plates, with between 12 and 15 holes. We chose locking plates to obtain more rigidity in the fixation.

In their joint work, Fernández and Perren concluded that it provides an efficient discharge and its application causes minimal tissue trauma at the fracture site, thus avoiding the biological disadvantage of conventional double plating, that is, additional surgical exposure of the fracture site.[4,5] In our series, minimally invasive approaches allowed early recovery and provided satisfactory functional outcomes in short-term follow-up (Table 3).

In a biomechanical study, Sezek et al. compared straight plates with helical plates placed medially. They maintained that conventional straight osteosynthesis induces undue stress protection of the fractured bone and may cause weakening and loosening of the segment. Another disadvantage is the lack of torsional capacity, which makes plate placement difficult and can lead to a degree of malrotation of the fracture. These authors concluded that helical plates have greater stability against axial load and torsional forces compared to conventional straight plates; however, the straight plates had more resistance to flexion forces.[8] The latter is probably due to the fact that since helical plates are crimped, they are weaker at the points where the force was applied.[9] In our series, two patients presented severe metaphyseal defects of the distal femur, for which the use of double osteosynthesis increased the rigidity of the system, and allowed the patients to walk with immediate partial weight-bearing after definitive surgery and full weight-bearing at six weeks.

As in the initial study by Fernández Dell'Oca, Krishna stated that helical plates allow a better adaptation of the screws, mainly in oblique fractures, which improves their stability and resistance to rotational deformity.[10]

The limitations of this study are the small number of patients treated with this method, the follow-up and the analysis of short-term results. Several questions regarding the indications remain, such as the appropriate length of the plate, the number of screws required, the type of fracture appropriate for this technique, and the appropriate crimping angle.

CONCLUSIONS

We described six cases of osteosynthesis in the distal femur with a helical plate using a medial approach. Good clinical and radiographic outcomes were obtained in the short term, which coincides with the published series. The helical plate is a great option in patients with comminuted distal femur fractures or Vancouver type C periprosthetic femoral fractures. The application is simple, the effect is efficient, and the biology remains intact. This shows that, by applying the basic principles of osteosynthesis and with a simple technique, more sophisticated materials can be supplied, and similar radiographic outcomes can be obtained.

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

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I-Scores

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ABSTRACT
The Editorial Committee wants to provide its readers with an update on the commonly used scales. The use of tables and scales is a widespread practice in Orthopedics and Traumatology. The measurement and quantification of clinical, functional, and radiographic aspects have become an essential tool for decision-making in different aspects of healthcare activity. We carry out a review of the most used scales, defining their use and including original and updated literature.
Keywords: Scales; scores; tables; update.
Level of Evidence: V

I-Scores

RESUMEN
El Comité Editorial quiere brindar a sus lectores una actualización de las escalas de uso corriente. El empleo de tablas y escalas es una práctica muy extendida en la Ortopedia y Traumatología. La medición y la cuantificación de los aspectos clínicos, funcionales y radiográficos se convirtieron en una herramienta imprescindible para la toma de decisiones en diferentes aspectos de la actividad asistencial. Llevamos a cabo una revisión de las escalas más utilizadas, definiendo su uso e incluyendo bibliografía original y actualizada.
Palabras clave: Escalas; puntajes; tablas; actualización.
Nivel de Evidencia: V

INTRODUCTION

The Editorial Committee wants to provide its readers with an update on the commonly used scales. The use of tables and scales is a widespread practice in Orthopedics and Traumatology. The measurement and quantification of clinical, functional, and radiographic aspects have become an essential tool for decision-making in different aspects of healthcare activity

We carry out a review of the most used scales, defining their use and including original and updated literature.

GLASGOW SCALE

The Glasgow Coma Scale was created by Graham Teasdale and Bryan Janett, members of the Institute of Neurological Sciences at the University of Glasgow, in 1974. It uses three parameters: the verbal response, the ocular response, and the motor response. The lowest score is 3, while the highest value is 15. The systematic application of this scale at regular intervals makes it possible to obtain a clinical profile of the patient's evolution (Table 1).

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Table 1. Glasgow Coma Scale

Variable	Answer	Score
Eye opening	Spontaneous	4
	To speech	3
	To pain	2
	No response	1
Verbal response	Correctly oriented	5
	Confused	4
	Inappropriate words	3
	Incomprehensible sounds	2
	No response	1
Motor response	Obeys commands	6
	Moves to localized pain	5
	Withdraws from pain	4
	Abnormal limb flexion	3
	Abnormal limb extension	2
	Lack of motor response	1

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MESS

Kaj Johansen, a vascular surgeon, described the Mangled Extremity Severity Score (MESS) in 1990, which assesses soft tissue injury, limb ischemia, the presence and duration of shock, and the patient's age. A score greater than 7 defines the need to amputate the lower limb (Table 2).

Table 2. MESS Scale

A. Soft tissue/bone injury	
Low energy (stab, simple fracture, gunshot wound)	1
Medium energy (open fracture or multiple fractures, dislocation)	2
High energy (rifle shot wound, crush injury)	3
Very high energy (the above plus gross contamination, soft tissue avulsion)	4
B. Limb ischemia	
Reduced or absent pulse, but normal perfusion	*1
Pulseless, paresthesias, slow capillary refill	*2
Cold, paralyzed, numb fingers	*3
(*The score is doubled in case of ischemia of more than six hours)	
C. Blood pressure	
Systolic blood pressure >90 mmHg consistently.	0
Transient hypotension	1
Persistent hypotension	2
D. Age (in years)	
Over 30 years old	0
Between 30 and 50 years	1
Over 50 years old	2

Note: If possible, it should be performed 2 hours after the traumatic event for a single time, since it is not a scale that predicts the evolution of pathology. If performed after 6 hours of the traumatic event, the score obtained in segment B must be doubled.

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AIS SCALE

The Abbreviated Injury Scale (AIS) is a severity scoring system that divides the body into 9 regions (head, face, neck, chest, abdomen, spine, upper extremity, lower extremity, and unspecified), and assigns a value from 1 to 6 based on the state. (1. Minor, 2 Moderate, 3. Serious but not life-threatening, 4. Severe and life-threatening, 5. Critical, 6. Unsurvivable (Figure 1).

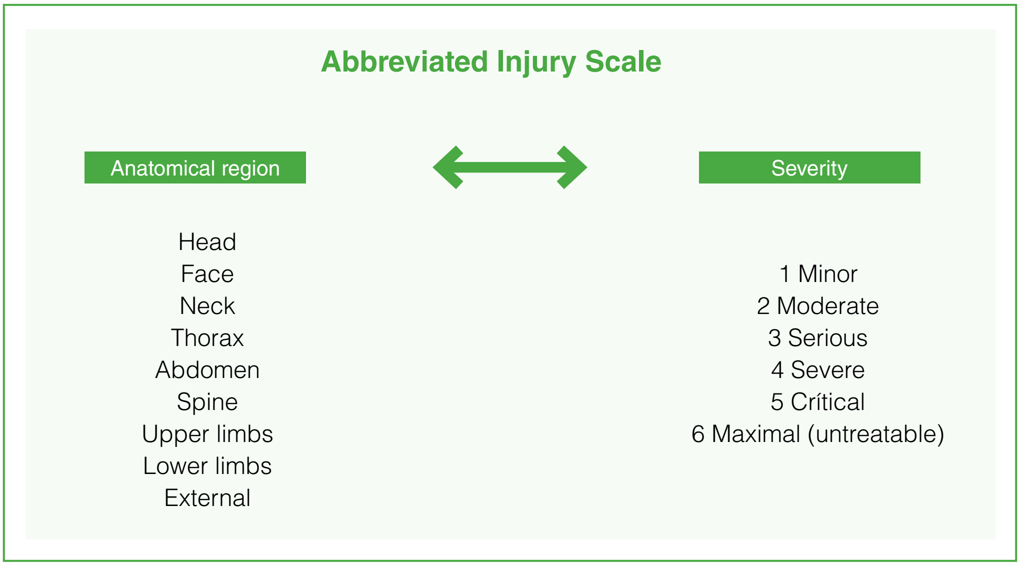

Figure 1. AIS scale.

INJURY SEVERITY SCORE (ISS)

The ISS is calculated by adding the square of the three lesions with the highest AIS scores from three different body regions (Figure 2). The score ranges from 1 to 75. An example is shown in Figure 3.

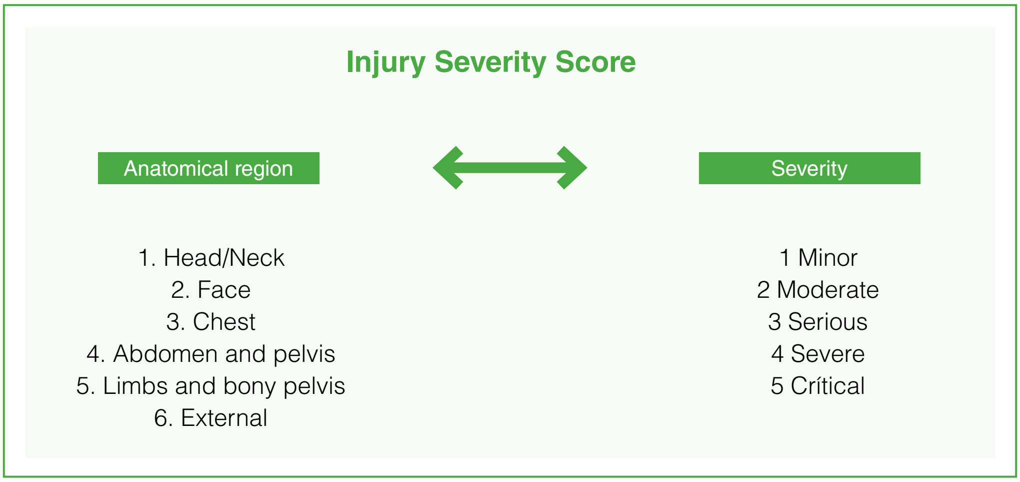

Figure 2. *Injury Severity Score* (ISS).

Injury Severity Score; ISS

Region	Injury description	AIS	Square Top Three
Head & neck	Cerebral contusion	3	9
Face	No injury	0	
Chest	Flail chest	4	16
Abdomen	Minor contusion of liver Complex rupture spleen	2 5	25
Extremity	Fractured femur	3	
External	No injury	0	
Injury Severity Score:			50

AIS Score	Injury
1	Minor
2	Moderate
3	Serious
4	Severe
5	Critical
6	Survivable

ISS	
1-8	Minor
9-15	Moderate
16-24	Serious
25-49	Severe
50-74	Critical
75	Maximum

Figure 3. Example of the Injury Severity Score (ISS).

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Case Resolution

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Case presentation on page 142.

DIAGNOSIS: C5-C6 fracture-dislocation.

DISCUSSION

In the computed tomography of the cervical spine (Figure 2) in the bone window with axial acquisition and sagittal and coronal reconstruction, an anterolisthesis of C5-C6 with bilateral facet dislocation and a left unilateral facet fracture was visualized.

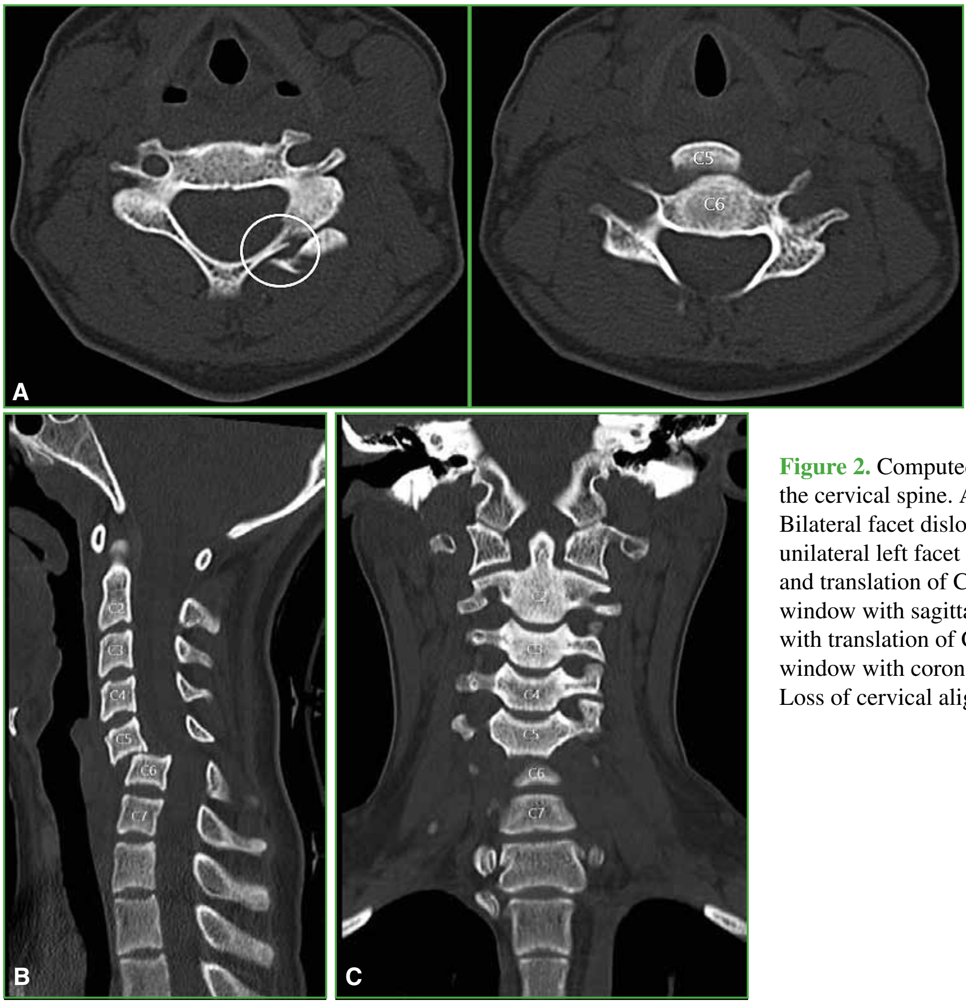

Figure 2. Computed tomography of the cervical spine. **A.** Axial planes. Bilateral facet dislocation with unilateral left facet fracture (circle) and translation of C5-C6. **B.** Bone window with sagittal reconstruction with translation of C5-C6. **C.** Bone window with coronal reconstruction. Loss of cervical alignment.

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The MRI of the cervical spine (Figure 3) included images in the sagittal plane in the T2-weighted, T1- weighted, and STIR sequences, where the loss of physiological cervical lordosis and the anterior and posterior ligament elongation continued to be seen, and partial spinal cord injury was confirmed.

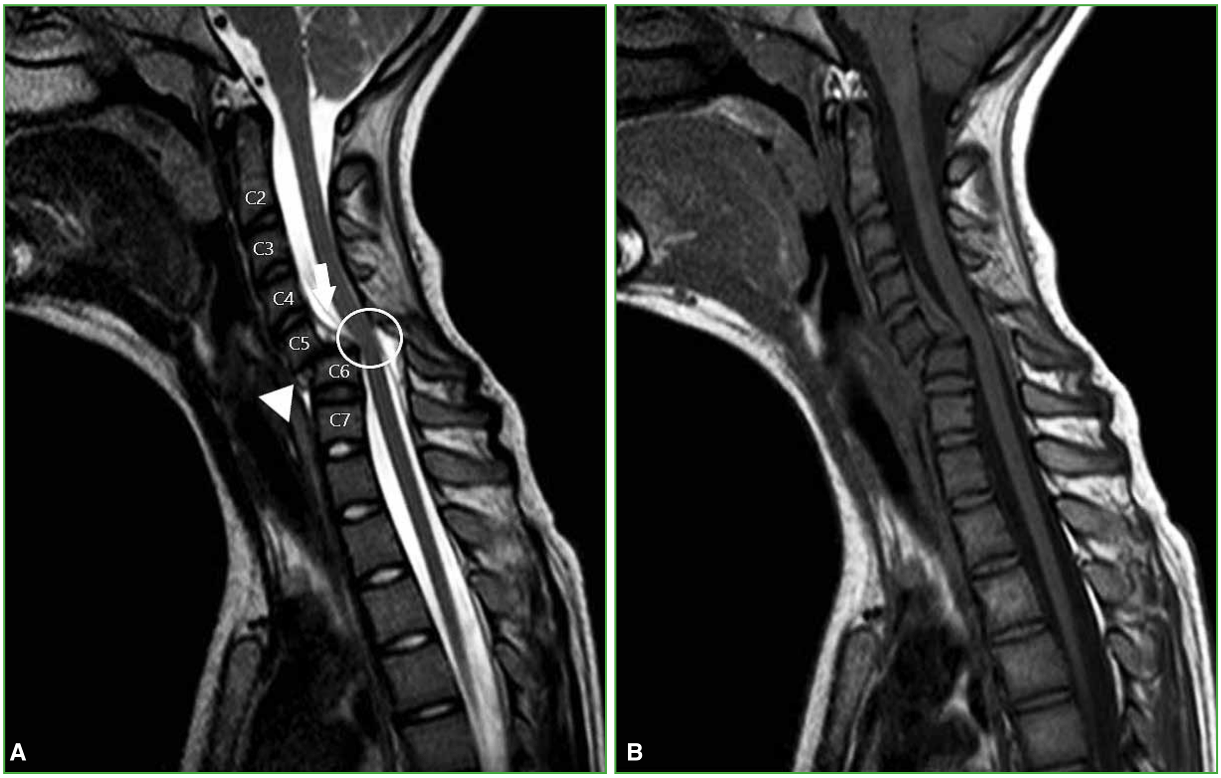

Figure 3. MRI of the cervical spine, sagittal plane. The loss of physiological cervical lordosis can be observed. **A.** T2. Anterior (arrowhead) and posterior (arrow) ligament elongation, confirming partial spinal cord injury (circle). **B.** T1. A fracture of the anterior column cannot be visualized. **C.** STIR. Loss of alignment due to translation involving all three columns (anterior longitudinal ligament: red; posterior longitudinal ligament: yellow; supraspinous ligament: light blue).

DIAGNOSIS

With all these findings, a C5-C6 fracture-dislocation was diagnosed.

Bilateral facet fracture-dislocation is one of the most severe and unstable spinal injuries. It is more frequent in C5-C6 due to a flexion and compression mechanism. It can present in isolation as a unilateral or bilateral dislocation, or be accompanied by fracture of the facets or the vertebral body with compromise of the anterior column. Imaging evaluation is important in order to schedule the corresponding treatment.

Traumatic cervical injuries account for 5-10% of all traumatic injuries and carry a high rate of morbidity and mortality, due to the fact that several vital structures can be damaged. It usually affects young people. The most common causes of traumatic spinal cord injury are traffic accidents and falls from heights. They can present with fractures, dislocations, and vertebral crushing, with secondary invasion of the spinal canal or spinal cord injury.

The neurological evaluation of the patient according to the algorithm proposed by the *American Spinal Injury Association* and the *International Spinal Cord Society* (ASIA/ISCoS) is very important, as well as describing the morphology, neurological status, and modifiers according to the *AOSpine Subaxial Cervical Spine Injury Classification*, which is the most widespread system today.

The algorithm proposed by the ASIA/ISCoS includes the assessment of strength and sensitivity below the level of the injury with the estimation of the degree of neurological impairment according to the impairment scale (*ASIA/ISCoS Impairment Scale*). The ASIA impairment scale includes five possible degrees: A (complete impairment of sensation and strength below the level of injury), B (incomplete impairment of sensation with total loss of strength below the level of injury), C (incomplete impairment of motor function and preservation of sensation below the level of injury. More than half of the muscle groups show severe weakness), D (incomplete motor impairment and preservation of sensation below the level of injury. Less than half of the muscle groups show severe weakness), and E (no impairment of strength or sensitivity below the level of injury).

The classification system proposed by AOSpine includes three types of fractures according to their morphology: A) Compression, fracture of the body without ligament compromise; B) Distraction: failure of the anterior or posterior tension band. There may be an associated type A vertebral body fracture and C) Displacement (subluxation/luxation) in one or more spatial planes.

This classification system also includes the assessment of the neurological status, the facet lesion, and the presence of modifiers. It classifies the neurological status into six subtypes: N0 (no neurological injury), N1 (transient neurological deficit), N2 (radiculopathy), N3 (incomplete spinal cord injury), N4 (complete spinal cord injury), and NX (unknown neurological status due to sedation, severe trauma, or intoxication).

It describes four possible subtypes of unilateral or bilateral facet injury: F1, facet fracture without displacement; F2, potentially unstable facet fracture; F3, floating lateral mass; and F4, facet subluxation/dislocation or perched (or mounted) facet.

Modifiers are clinical features that can change therapeutic decision-making; in the cervical spine, they include the following: M1, incomplete lesion of the posterior capsuloligamentous complex; M2, critical disc herniation; M3, metabolic disease/stiffness (diffuse idiopathic skeletal hyperostosis, ankylosing spondylitis, ossification of the posterior longitudinal ligament, ossification of the ligamentum flavum); and M4, vertebral artery anomaly.

The patient's initial neurological status was ASIA C. The fracture was interpreted as type C C5-C6 with dislocation of both articular facets and unilateral facet fracture. According to the nomenclature, it was described as C5-C6: C (bilateral F4; N3).

Surgery was considered due to the high instability of the lesion. Anterior and posterior arthrodesis of C5-C6 was performed (Figure 4).

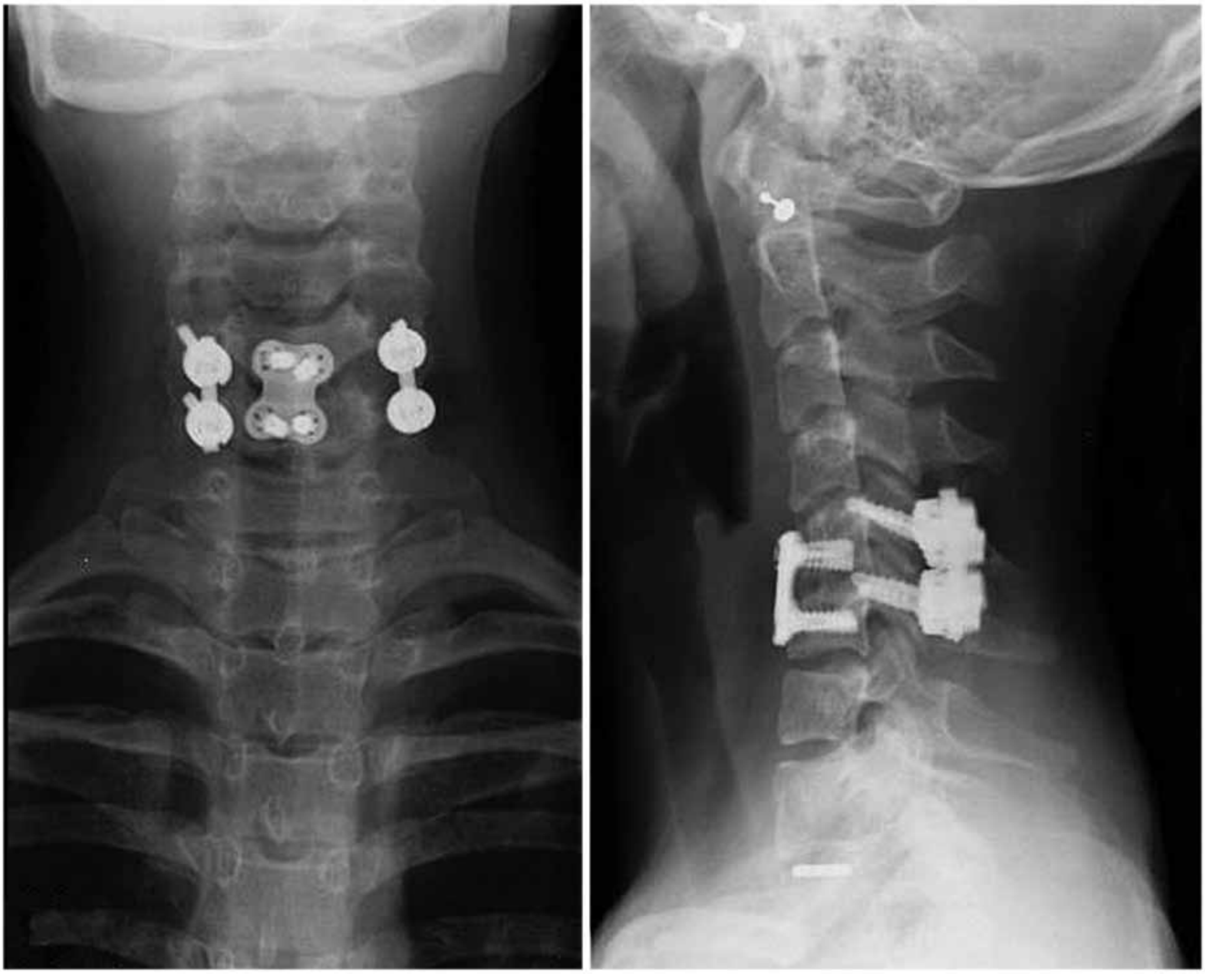

Figure 4. Anteroposterior and lateral radiograph of the cervical spine. Immediate postoperative control of the anterior and posterior arthrodesis of C5-C6.