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Advances in the Restoration and Fixation of Lateral Femoral Wall Fracture

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Abstract: Hip fractures, especially intertrochanteric fractures, are more common with aging. After decades of progress, it is a general consensus to carry out internal fixation for this group of patients. However, the recent focus is on unstable intertrochanteric fractures to ensure better prognosis and prevent internal fixation failure. The lateral femoral wall, as a novel concept, is often disregarded. Many scholars have recognized that the lateral wall of the proximal femoral plays a crucial role in the stability of internal fixation for intertrochanteric fractures. In this paper, the historical evolution, definition, clinical significance, injury classification, choice of internal fixation, and possible prognosis of lateral femoral wall fracture are reviewed in order to provide clinicians strong evidence of treatment strategies.

Keywords: Intertrochanteric fracture; Lateral femoral wall; Hip fracture; Surgery

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1. Introduction

Intertrochanteric fracture occurs at the base of the femoral neck between the greater and lesser trochanters [1]. It frequently occurs in the elderly, in which the most frequent and severe fracture among all fractures is caused by osteoporosis, resulting in disability, poor prognosis, and even death [2]. With the continuous improvement of living standards, although the age-standardized incidence rate of intertrochanteric fractures in many countries is declining, the incidence rate is skyrocketing with aging [3]. However, the treatment of intertrochanteric fracture has seen a shift from non-operative conservative treatment to surgical treatment in view of its high mortality and complications. Surgical intervention has become the preferred treatment for intertrochanteric fractures [4]. In order to obtain better outcomes and prevent internal fixation failures, the research focus has shifted to unstable intertrochanteric fractures. In the early days, intertrochanteric fractures were often fixed with extramedullary fixation with a long force arm, which provides support through the posterior medial bone fragment containing the femoral calcar and the lesser trochanter. Therefore, it was believed that the key factor determining the stability of internal fixation was the integrity of the internal structure, especially that of the posterior medial bone fragment, including the lesser trochanter and the femoral calcar [4,5]. With the introduction of internal fixation devices, intramedullary fixation has gradually replaced extramedullary fixation, which was the mainstream treatment for intertrochanteric fractures. The placement of the main nail of the intramedullary nail system in the proximal femoral medullary cavity shifts the center of gravity inward, shortening the force of the arm and reducing the internal fixation stress as well as the failure rate to a certain extent. However, compared with external fixation, intramedullary fixation has higher requirements for the stability of external structures.

For intertrochanteric fractures with lateral wall fracture, the failure rate of intramedullary pin fixation remains high. Research has shown that the integrity of the lateral wall is also a key factor that constitutes the stability of intertrochanteric fractures, which necessitates surgeons to pay close attention to when considering the use of intramedullary nails [6-8].

2. Insights into the lateral wall of the proximal femur

The lateral wall of the proximal femur, which is positioned at the proximal femur, rises upward from the femur to the lateral femoral bone cortex. Although research has long focused on the lateral wall of the proximal femur, it has recently gained popularity in academic circles. The proper assessment of this distinctive, unique anatomical feature remains a contention.

In 1991, Ritter *et al*. [9] discovered that inserting a blade through the lateral femoral cortex into the neck of the femur with an angled plate in the treatment of intertrochanteric fractures frequently caused iatrogenic greater trochanter fracture. However, the concept of "lateral femoral cortex" still received little attention at that time. In 1996, Parker [10] investigated failure instances of dynamic hip screws (DHS) in treating femoral intertrochanteric fractures and discovered that medial femoral shaft sliding might greatly increase the operation failure rate; additionally, he felt that the bone cortex outside the proximal femur could prevent femoral shaft sliding and improve internal fixation stability. However, he was not responsible for introducing the concept of the lateral wall. Instead, Gotfried [11] was the one who proposed the concept of the lateral wall in 2004. He was credited for establishing the concept of the lateral wall, a concept that is now generally accepted. He suggested that sliding compression screws should be inserted into the femoral head via the lateral cortex of the proximal femur. The lateral wall of the proximal femur, described as the extension of the femoral stem to the proximal end, provides vital support. Gotfried initially abstracted the notion of lateral femoral wall fracture from complicated unstable fracture types, attracting attention from researchers and a series of follow-up investigations. However, he merely conceived the lateral wall as a surgical concept for the use of sliding compression screws (such as DHS); he did not provide specific descriptions of the starting or ending point of the lateral wall. In 2007, Palm *et al*. [12] proposed that the lateral femoral wall extends from the distal femoral cortex to the lateral muscle crest. In 2014, Haq *et al*. [13] defined the lateral wall as follows: if a tangent line is drawn on a hip X-ray film along the upper and lower cortices of the femoral neck, the region produced by the junction of the two tangent lines with the lateral aspect of the femur is called the lateral wall; the tangent lines form the lateral wall with the lateral side of the femur. Many experts have deliberated the definition of the lateral wall. According to Zhang *et al*. [14], the lateral wall anatomically refers to the proximal lateral cortex of the femur far from the lateral femoral muscle crest, *i.e.*, the lateral cortex of the femur above the plane of the lesser trochanter; the line of the lower boundary of the lateral wall to the midpoint level of the lesser trochanter [15]. It has been recommended that the lateral wall shall be defined as a 2-cm distance from the lateral femoral crest to the lower margin of the lesser trochanter [16]. These definitions of the lateral wall are all based on hip X-ray films. In 2018, Zhou *et al*. [17] proposed the extent of the lateral wall based on three-dimensional (3D) computed tomography (CT) reconstruction of hip fractures; the upper boundary of the lateral wall is the lateral femoral muscle crest, while the lower boundary is the intersection of the tangent line of the bone cortex at the lower edge of the femoral neck with the lateral femoral cortex; the area between the upper and lower boundaries is the lateral wall. The advantage of this classification is that the cortical bone is below the lateral femoral muscle crest, and it is thus more straightforward to recognize clinically. In contrast, fractures below the lower boundary are clinically classed as femoral subtrochanteric fractures. Using the

CT volumetric rendering technique, the anterior and posterior borders of the lateral wall have been identified.

3. Clinical significance of the lateral wall

Currently, most femoral intertrochanteric fracture fixation procedures include tension screws, helical blades, or other internal fixation devices that are inserted into the femoral head and neck via the lateral wall of the proximal femur. An intact lateral wall ensures fixation stability, provides lateral support to the femoral head and neck at the proximal end of the fracture, as well as limits the sliding of the femoral head and neck along the axis of the tension screw so that the bone fragments are in close contact, thus promoting healing. When the bone fragments are forced against one other, they can resist the inward movement of the femoral shaft, preventing the collapse and rotation of bone fragments [14]. When the lateral wall fails, the femoral neck fracture fragment slips laterally while the femoral stem moves medially, undermining the entire internal fixation mechanism and consequently resulting in screw withdrawal and internal fixation failure. The lateral wall can offer three-point external action points for the tension screw or helical blade and minimize lever stress at the interface between the medial femoral head and the middle intramedullary nail, preventing the screw from cutting out and the main nail from bending and fracturing [11,14]. Furthermore, when the lateral wall is shattered, the tension screw or helical blade may be pushed from the broken line of the bone, dispersing the bone fragments with unsatisfactory reduction and an increased risk of internal fixation failure. Abram *et al*. [16] presented a three-point stable proximal femur structure: tip apex distance (TAD). The integrity of the lateral wall and the entrance point of the major nail are essential factors in determining the effectiveness of treatment, followed by TAD. Hsu *et al*. [17] evaluated the criteria for predicting the stability of internal fixation for fractures, in which lateral wall thickness was found to be the essential element among several parameters, including the patient's age, fracture type, gender, lateral wall thickness, and maximum distance.

The idea of the lateral femoral wall has made people aware that there are five sections in the anatomical structure of the proximal femur: femoral head and neck, femoral stem, greater trochanter, lesser trochanter, and lateral wall [14].

4. Classification of intertrochanteric fractures in relation to lateral wall fractures

Intertrochanteric fractures are common fractures whose treatment has evolved through time with the progress of knowledge and advances of internal fixation devices. There are various classifications for intertrochanteric fractures depending on age, and they are constantly evolving. The idea of classification has shifted from emphasizing on the stability of the posterior medial bone mass to the integrity of the lateral wall. However, there are only a few classifications for intertrochanteric fractures involving the lateral wall as the research on lateral femoral wall fracture started relatively late. Jensen *et al*. [18] hypothesized that the involvement of both greater and lesser trochanters is related to the stability of intertrochanteric fractures. As a result, the original Evans classification has been modified, and intertrochanteric fractures are classified into five categories. Type III represents a three-part fracture with separation of the great trochanter, while Type V represents a four-part fracture with separation of the greater and lesser trochanters. Although the classification involves lateral wall fractures, the concept of the lateral wall was not introduced at the time and Jensen did not describe lateral wall fractures in his classification.

According to the Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association (AO/OTA) intertrochanteric fracture classification [19] (**Figure 1**) in 1990, Palm *et al*. [12] proposed three categories of intertrochanteric fractures depending on the integrity of the lateral wall of the proximal femur. This classification has been recognized by several scholars [13,20,21].

(1) Intact lateral wall (type A1): 31A1.1, 31A1.2, 31A1.3, and 31A2.1. These fractures are not prone to intraoperative lateral wall fractures, and the prognosis is good.
(2) Weak lateral wall (type A2): 31A2.2 and 31A2.3. These two types of fractures are prone to intraoperative lateral wall fractures, and the prognosis is relatively poor.
(3) Lateral wall fracture (type A3): 31A3.1, 31A3.2, and 31A3.3. These three types of posterolateral wall fractures are preoperative fractures, and the term posterolateral wall was not used in the original classification.

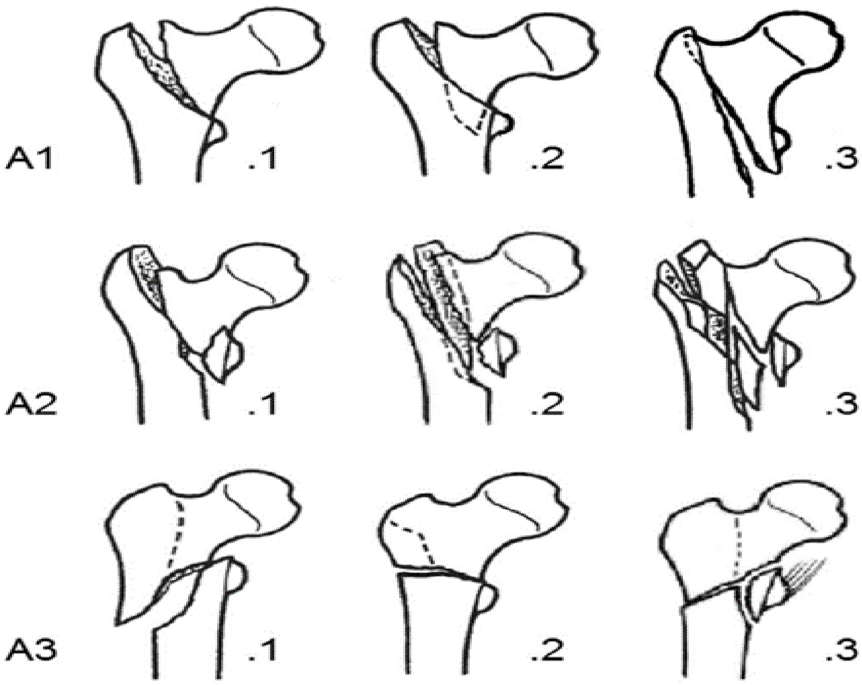

Figure 1. Schematic diagram of the 1990 version of the AO/OTA intertrochanteric fracture classification

Gu *et al*. [22] proposed a classification of intertrochanteric fractures based on the involvement of the lateral wall and the posterior medial bone mass. According to Gu *et al*., type I is a simple comminuted fracture of the lateral wall, involving the screw entry point of the spiral blade, but the medial support basically exists after reduction. Type II is considered when there is lateral wall splitting along with femoral calcar fracture. The bone condition is acceptable and can stabilize the spiral blade, but the inner side lacks support. Type III represents a comminuted fracture of the lateral wall and subtrochanteric femur, involving the screw entry point of the spiral blade on the lateral wall after fracture reduction, but the inner side also lacks support. Different treatment plans are proposed according to this typology.

Zhang *et al*. [23] proposed a 3D CT reconstruction-based subtype of lateral femoral wall fractures: type A, intact lateral wall; type B, partial lateral wall fracture; and type C, complete lateral wall fracture. However, no detailed criteria have been put forward for differentiation between subgroups.

In 2018, the AO/OTA classification was revised [24]. For type A3 fractures, the 2018 classification is consistent with that of the 1990 classification, but for type A1 and A2 fractures, the classification method in the 2018 classification is based on whether or not the lesser trochanter is intact and whether the lateral wall is intact or weak (also known as lateral wall danger) as the basis for differentiating between type A1 and type A2 fractures; it also provides a method of measuring lateral wall weakness [25]. The new AO/OTA classification affirms the role of the lateral wall in the stability of intertrochanteric fractures, reflecting the current situation in which more attention is paid to the importance of the lateral wall. The disadvantage is that the method of measuring lateral wall thickness is dependent on X-ray films, which have stringent criteria over the patient's posture when the radiograph is taken. If the anterior and posterior X-ray films are not standardized, it may impair the accuracy of the measurement. In addition, it may be difficult to determine if there is a coronal fracture of the lateral wall based only on anterior and posterior X-ray films.

Zhang *et al.* [26] proposed a regional classification method based on the integrity of the lateral wall of the proximal femur and the presence of an independent fracture mass on the posterior medial side. It is a classification of the proximal femur by the Third Hospital of Peking Medical College. There are four types of proximal femoral fractures. Type I fractures are known as intertrochanteric fractures since the lateral femoral fracture line is located between the base of the femoral neck and the lateral pole of the greater trochanter. Type Il is an intertrochanteric fracture since the lateral femoral fracture line is located between the lateral pole of the greater trochanter and the corresponding lateral femoral cortex at the distal end of the lesser trochanter; additionally, the lateral wall is fractured. Type III is referred to as subtrochanteric fracture since the lateral femoral fracture line is located between the lateral femoral cortex corresponding to the distal end of the lesser trochanter and the lateral femoral cortex corresponding to 7.5 cm away from the lesser trochanter. Type IV is referred to as a complex fracture since the lateral femoral fracture line is located in the subtrochanteric region, and it is a complex fracture, *i.e.*, type III + type I, type III + type II, and type III + type I + type II.

Each type is classified into two categories A and B based on whether or not there is an independent fragment on the posterior medial side. Subtype A represents the full posterior medial side, while subtype B represents an independent fragment on the posterior medial side. The classification system represents the clinical features of various types of fractures and guides the selection of internal fixation techniques. In order to minimize misunderstandings, the 2018 AO/OTA classification of hip fractures has been universally accepted.

5. Selection of internal fixation for lateral wall fracture

5.1. Dynamic hip screw

Since its inception, DHS has been regarded as a traditional approach for treating intertrochanteric fractures [27]. The advantages of DHS include easy surgery, short operating time, and sliding compression, which promotes fracture healing in stable intertrochanteric fractures. However, for unstable intertrochanteric fractures, particularly those with non-intact lateral wall, it is believed that the extent of soft tissue stripping is large during DHS, which would affect the blood supply at the broken end of the fracture, and the wrapping effect of soft tissue on the lateral wall fragment will be lost, making the lateral wall fracture more prone to displacement [28].

The triple drill bit used in pressing the nail head is relatively thick, which may increase the degree of crushing and displacement of lateral wall fractures. More crucially, lateral wall fractures are still being repaired with DHS, and the lag screw's sliding axis is consistent with the direction of the fracture line. Due to the loss of support and obstruction of the lateral wall, the proximal femoral head and neck fragment will slide excessively along the sliding axis of the lag screw, resulting in uncontrollable outward retreat, outward movement, and collapse as well as relative inward movement of the distal femoral shaft, leading to loss of fracture reduction, cutting out of the lag screw, or extraction and fracture [14]. Experts have thus agreed that traditional DHS is ineffective in the treatment of lateral intertrochanteric wall fractures [29].

5.2. Extramedullary nail plate system

The extramedullary nail plate system mainly consists of the early-stage inverted femoral less invasive stabilization system (LISS), discovered by Zhou *et al.* [30,31], and the late-stage proximal femoral locking plate (PFP) and percutaneous compression plate (PCP), specifically created for trochanteric fractures (PCCP). Inverted LISS fixes intertrochanteric fractures by utilizing a minimally invasive internal fixation technology initially intended for distal femoral fractures. It employs the biological fixation concept of minimally invasive placement. Screws are used to fix the exterior wall bone fragment, resulting in robust fracture fixation, while minimizing injury to the bones and the surrounding soft tissues as well as providing an environment favorable for callus formation.

In PFP, four locking screws are placed in the lateral wall of the proximal femur, and a 6-mm incision is made [32]. When the plate is inserted percutaneously and PCCP is used, two lag screws are placed in the lateral wall of the proximal femur to fix the femoral head and neck. The surgical incision is about 25 cm [33-35]. The placement of screws can disperse the stress on the lateral wall, and the screws are easily held by the bone cortex of the lateral wall. At the same time, there is less soft tissue peeling over the lateral wall with the smaller incision. The protection of soft tissue over the lateral wall prevents the excessive displacement of the lateral wall bone fragment [36]. Both PFP and PCCP adhere to the concepts of minimally invasive placement and multiple stabilizing screws, which not only meet the needs of lateral wall stabilization, but also take into account of biological fixation and reliable stability; thus, they can be used in the treatment of lateral intertrochanteric wall fractures.

Han *et al*. [37] compared 52 cases of lateral femoral wall fractures treated with inverted LISS and Gamma intramedullary nails, respectively, and discovered that there was no statistical difference between the two groups in terms of fracture healing time, complications, hospital stay, and Harris hip score one year after surgery. In another study, PFP was used to treat 98 cases of intertrochanteric fractures, comprising 22 cases of stable type and 76 cases of unstable type [32]. After a year of follow-up, all fractures had healed without inversion or screw removal. Knob *et al*. [38] conducted a prospective controlled experiment, in which 108 cases of type 31A2 intertrochanteric fractures were treated differently, with PCCP and proximal femoral nail anti-rotation (PFNA). There was no statistical difference between the two groups in terms of internal fixation failure rate, hip joint function, or mortality; however, the lateral wall fracture rate in the PCCP group was 7%, compared to 30% in the PFNA group. PCCP was thought to provide improved lateral wall protection. After analyzing the clinical efficacy of 97 cases of A1 to A2.2 intertrochanteric fractures, Gotfried [34] concluded that the use of PCCP in the treatment of intertrochanteric fractures, particularly unstable ones, is interesting and can be used as another option for the treatment of such fractures.

5.3. Intramedullary nail system

In this period, it is widely assumed that intramedullary fixation for lateral femoral wall fractures will result in better prognoses [12,39,40]. The intramedullary nail technique has several advantages in the treatment of lateral wall fractures: (1) less soft tissue stripping, which allows soft tissue to protect the lateral wall, strengthen the wrapping effect, and prevent further displacement of lateral wall fractures [40]; (2) thin nail head, resulting in less bone damage to the posterolateral wall during drilling and nail placement [41]; and (3) the thick main rod of the intramedullary pin provides some lateral support to the femoral neck bone mass and prevents outward dislocation [41,42], *i.e.*, a "metal lateral wall" [43].

Haq *et al*. [13] carried out a randomized controlled trial of 40 patients with type A2.2 to A3.3 intertrochanteric fractures, assigning them to different treatment groups: intramedullary nail system or DHS system. The intramedullary nail group considerably outperformed the DHS group in terms of operation duration, blood transfusion, fluoroscopy time, reoperation rate, and hip function score. In a study by Sadowski *et al*. [44], 39 cases of type A3 intertrochanteric fracture were randomized to receive different treatments: dynamic hip screw or intramedullary nail. Although there was no significant difference in hip function between the two groups after one year of follow-up, the intramedullary nail group performed considerably better than the dynamic hip screw group in terms of operation duration, blood transfusion, hospital stay, and reoperation rate. Several researchers have also demonstrated the effectiveness of intramedullary nail in treating lateral femoral wall fractures [45-47]. Recently, InterTan intramedullary needle has shown promising results in the treatment of lateral femoral wall fractures [48,49].

However, the intramedullary nailing approach may not be a universal treatment for lateral femoral wall fractures. Ciufo *et al*. [50] retrospectively reviewed the data of 362 patients who had intramedullary nailing for intertrochanteric fractures, among which 6% had screw removal following surgery. According to the regression analysis, even with the intramedullary nail system, lateral wall fracture remained the most important risk factor for screw cut-out (OR = 8.0), outweighing unsatisfactory neck stem repositioning (OR = 4.3) and incomplete posterior medial bone mass (OR = 3.6). Although the intramedullary nail has mechanical benefits for lateral wall fractures, it cannot adequately fix the bulk of the lateral wall fracture, thus making early lateral wall stability improbable. As a result, using the intramedullary nail method may still require surgeons to protect and reconstruct the lateral wall as much as possible, achieving sufficient reduction and appropriately positioning the internal fixation.

5.4. Lateral wall reconstruction

It ought to be emphasized that lateral wall reconstruction refers to a surgical approach to dealing with lateral wall fracture fragments rather than a specific internal fixation procedure. In any sort of fracture, poor reduction is associated with internal fixation failure. In intertrochanteric fractures, an inadequate reduction of bone fragments in the lateral wall may result in delayed bone healing, reduced intertrochanteric fracture stability, and internal fixation failure. Lateral wall reduction and fixation can restore lateral wall support, enhance the stability of intertrochanteric fractures, and improve the prognosis. Gupta *et al*. [51] used DHS in combination with a trochanteric protection plate to treat 46 patients with lateral femoral wall fractures. It has been hypothesized that lateral wall restoration can minimize internal fixation failure rates and enhance postoperative hip function. The function of lateral wall reconstruction in the treatment of lateral wall fractures should be considered. Kulkarni *et al*. [52] divided 154 patients suffering from unstable intertrochanteric fracture into two groups. In the first group (lateral wall reconstruction group), lag screws and steel cable were employed to reconstruct the lateral wall, whereas intramedullary nail fixation was used in the second group (control group). The lateral wall reconstruction group outperformed the control group in terms of fracture non-healing rate, screw resection rate, and reoperation rate. Wang [53] used a combination locking plate for lateral wall reconstruction and discovered that lateral wall reconstruction, when compared to PFNA fixation alone, can minimize internal fixation failure rate, shorten fracture healing time, and improve hip function. Scholars, both at home and abroad, have attempted various methods to reconstruct the lateral wall (including but not limited to DHS combined with trochanter protection plate, lag screw, steel cable, intramedullary nail combined with locking plate, steel cable, single or combined application of proximal femoral plate, *etc*.), but there are still dissensions on the need for reconstruction in lateral wall fractures and how it should be done.

As of now, there is no unanimous conclusion as to whether all lateral wall fractures of the proximal femur require a one-stage lateral wall reconstruction. Kim *et al*. [54] discovered that some lateral wall fracture fragments reduce spontaneously without additional fixation and proposed that the recovery of vastus lateralis strength may form a point similar to a hinge at the lateral femoral muscle crest and exert a force similar to a door closing to reduce bone fragments. On this basis, it is arguable that if the displaced lateral wall fracture can be spontaneously reduced with only intramedullary nail fixation, then the lateral wall bone fragment can be repaired without further reconstruction. According to Wu *et al*. [55], for fractures with lateral wall displacement, it is necessary to pay attention to the posterior medial bone fragment of the lesser trochanter. Suppose the displacement is small and there is a possibility of healing, in that case, reconstructing the lateral wall is unnecessary, such as that seen in cases where the posterior medial bone mass is displaced or a continuing shift during follow-up. When there is a possibility of non-union, the lateral wall should be reconstructed.

6. Conclusion and prospects

The lateral femoral wall is represented by the upward continuation of the bone cortex from the femoral shaft to the lateral femur. Internal fixation devices are often placed into the femoral head and neck by surgeons. There is no one hypothesis that defines its upper and lower boundaries, anterior and posterior boundaries, thickness, and biomechanical strength. However, with the ongoing research on lateral wall, many physicians and researchers are beginning to comprehend the importance of the lateral wall and direct their attention to such unstable fractures. Through this, we can successfully avert future treatment failures. This may be an essential objective and point of reference for us to investigate in reference to the lateral wall. Furthermore, scientists have yet to develop a clearer understanding in the classification of lateral wall fractures. We conclude that there is an urgent need to develop a more clinical and unambiguous classification of lateral wall fractures in order to provide better treatment for lateral wall fractures.

Intramedullary nailing is still considered the gold standard for treating proximal femoral fractures. However, for proximal femoral fractures with lateral wall fractures, multicenter prospective cohort studies and appropriate biomechanical studies are still required. There are also significant dissensions on the need for lateral wall reconstruction and how it should be done. Surgeons should ensure personalized treatment when dealing with lateral wall fractures of the proximal femur, fully evaluate the pathology, carefully formulate management plans, protect the external wall during surgery, reduce and fix it as much as possible, and ensure close follow-up after the surgery to prevent complications and ensure satisfactory prognoses.

Disclosure statement

None of the authors has potential conflict of interest.

References

[1] Attum B, Pilson H, 2022, Intertrochanteric Femur Fracture, StatPearls Publishing, viewed on December 30, 2022, https://www.ncbi.nlm.nih.gov/books/NBK493161/

[2] Carpintero P, Caeiro JR, Carpintero R, et al., 2014, Complications of Hip Fractures: A Review. World J Orthop, 5(4): 402–411. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4133447/

[3] Kanis JA, Odén A, McCloskey EV, et al., 2012, A Systematic Review of Hip Fracture Incidence and Probability of Fracture Worldwide. Osteoporos Int., 23(9): 2239–2256.

[4] Martinho T, Stoffel K, 2021, Treatment of Intertrochanteric Femur Fractures with Hip Arthroplasty in Older Patients: A Narrative Review of Indications and Outcomes. Medicina, 57(8): 763.

[5] Sonawane DV, 2015, Classifications of Intertrochanteric Fractures and Their Clinical Importance. Trauma International, 1(1): 7–11.

[6] Knobe M, Gradl G, Ladenburger A, et al., 2013, Unstable Intertrochanteric Femur Fractures: Is There a Consensus on Definition and Treatment in Germany?. Clin Orthop Relat Res, 471(9): 2831–2840.

[7] Zhao JG, Wang J, Wang C, et al., 2015, Intramedullary Nail Versus Plate Fixation for Humeral Shaft Fractures: A Systematic Review of Overlapping Meta-Analyses. Medicine (Baltimore), 94(11): e599.

[8] Boopalan PRJVC, Oh JK, Kim TY, 2012, Incidence and Radiologic Outcome of Intraoperative Lateral Wall Fractures in OTA 31A1 and A2 Fractures Treated with Cephalomedullary Nailing — Korea University. Journal of Orthopaedic Trauma, 26(11): 638–642. https://koreauniv.pure.elsevier.com/en/publications/incidence-and-radiologic-outcome-of-intraoperative-lateral-wall-f

[9] Ritter G, Degreif J, 1991, Basic Considerations in Fractures of the Trochanter Major in and After Angle Plate Osteosynthesis. Unfallchirurgie, 17(2): 106–110.

[10] Parker MJ, 1996, Trochanteric Hip Fractures Fixation Failure Commoner with Femoral Medialization, a Comparison of 101 Cases. Acta Orthopaedica Scandinavica, 67(4): 329–332.

[11] Gotfried Y, 2004, The Lateral Trochanteric Wall: A Key Element in the Reconstruction of Unstable Pertrochanteric Hip Fractures. Clinical Orthopaedics and Related Research, 425: 82–86.

[12] Palm H, Jacobsen S, Sonne-Holm S, et al., 2007, Integrity of the Lateral Femoral Wall in Intertrochanteric Hip Fractures: An Important Predictor of a Reoperation. J Bone Joint Surg Am, 89(3): 470–475.

[13] Haq RU, Manhas V, Pankaj A, et al., 2014, Proximal Femoral Nails Compared with Reverse Distal Femoral Locking Plates in Intertrochanteric Fractures with a Compromised Lateral Wall; a Randomised Controlled Trial. Int Orthop, 38(7): 1443–1449.

[14] Zhang S, 2010, The Concept of Lateral Wall in Intertrochanteric Fractures and Its Clinical Significance. Chinese Journal of Orthopaedic Surgery, 2010(17): 1489–1492.

[15] Ma Z, Zhang S, 2012, Research Progress on Lateral Lateral Wall of Femoral Tuberosity. International Journal of Orthopaedics, 33(4): 221–224.

[16] Abram S, Pollard T, Andrade A, 2013, Inadequate "Three-Point" Proximal Fixation Predicts Failure of the Gamma Nail. The Bone & Joint Journal, 95–B(6): 825–830.

[17] Hsu CE, Chiu YC, Tsai SH, et al., 2015, Trochanter Stabilising Plate Improves Treatment Outcomes in AO/OTA 31-A2 Intertrochanteric Fractures with Critical Thin Femoral Lateral Walls. Injury, 46(6): 1047–1053.

[18] Jensen JS, Michaelsen M, 1975, Trochanteric Femoral Fractures Treated with Mclaughlin Osteosynthesis. Acta Orthopaedica Scandinavica, 46(5): 795–803.

[19] Müller ME, 1991, The Comprehensive Classification of Fractures of Long Bones, in Manual of Internal Fixation, 3rd Edition, Springer-Verlag, New York.

[20] Pradeep AR, KiranKumar A, Dheenadhayalan J, et al., 2018, Intraoperative Lateral Wall Fractures During Dynamic Hip Screw Fixation for Intertrochanteric Fractures-Incidence, Causative Factors and Clinical Outcome. Injury, 49(2): 334–338.

[21] Sun LL, Li Q, Chang SM, 2016, The Thickness of Proximal Lateral Femoral Wall. Injury, 47(3): 784–785.

[22] Gu H, Yang J, Wang W, et al., 2016, Treatment Strategies for Unstable Intertrochanteric Lateral Wall Fractures. Chinese Journal of Orthopaedic Trauma, 18(8): 679–684.

[23] Ma Z, Yao X-Z, Chang S-M, 2017, The Classification of Intertrochanteric Fractures Based on the Integrity of Lateral Femoral Wall: Letter to the Editor, Fracture Morphology of AO/OTA 31-A Trochanteric Fractures: A 3D CT Study with an Emphasis on Coronal Fragments. Injury, 48(10): 2367–2368.

[24] Meinberg EG, Agel J, Roberts CS, et al., 2018, Fracture and Dislocation Classification Compendium—2018. Journal of Orthopaedic Trauma, 32: S1–S10.

[25] Díaz VJ, Martín IA, García JP, et al., 2021, Does the Fracture of the Lateral Wall Affect the Degree of Collapse and the Degree of Sliding of the Cephalic Plate, in Pertrochanteric Fractures Treated by Intramedullary Interlocking? Radiological Study and Review of the Literature. Rev Esp Cir Ortop Traumatol, 65(2): 108–115.

[26] Zhang Z, Zhang T, Zhou F, et al., 2020, Classification Method of Proximal Femoral Fracture Based on the Integrity of the Proximal Lateral Wall of the Femur: With 888 Case Analysis. Chinese Journal of Bone and Joint Surgery, 13(3): 196–204.

[27] Butler M, Forte M, Kane RL, et al., 2009, Treatment of Common Hip Fractures. Evid Rep Technol Assess, 2009(184): 1–85.
[28] Morris AH, Zuckerman JD, 2002, National Consensus Conference on Improving the Continuum of Care for Patients with Hip Fracture. JBJS, 84(4): 670–674.
[29] Russell TA, Sanders R, 2011, Pertrochanteric Hip Fractures: Time for Change. J Orthop Trauma, 25(4): 189–190.
[30] Zhou F, Zhang ZS, Yang H, et al., 2012, Less Invasive Stabilization System (LISS) Versus Proximal Femoral Nail Anti-Rotation (PFNA) in Treating Proximal Femoral Fractures: A Prospective Randomized Study. Journal of Orthopaedic Trauma, 26(3): 155–162.
[31] Zhou F, Zhang Z, Tian Y, et al., 2006, A Preliminary Report of a Minimally Invasive Internal Fixation System in the Treatment of Complex Trochanteric Fractures. Chinese Journal of Orthopaedic Trauma, 8(12): 1113–1117.
[32] Zha GC, Chen ZL, Qi XB, et al., 2011, Treatment of Pertrochanteric Fractures with a Proximal Femur Locking Compression Plate. Injury, 42(11): 1294–1299.
[33] Varela-Egocheaga JR, Iglesias-Colao R, Suárez-Suárez MA, et al., 2009, Minimally Invasive Osteosynthesis in Stable Trochanteric Fractures: A Comparative Study Between Gotfried Percutaneous Compression Plate and Gamma 3 Intramedullary Nail. Archives of Orthopaedic and Trauma Surgery, 129(10): 1401–1407.
[34] Gotfried Y, 2000, Percutaneous Compression Plating of Intertrochanteric Hip Fractures. Journal of Orthopaedic Trauma, 14(7): 490–495.
[35] Langford J, Pillai G, Ugliailoro AD, et al., 2011, Perioperative Lateral Trochanteric Wall Fractures: Sliding Hip Screw Versus Percutaneous Compression Plate for Intertrochanteric Hip Fractures. Journal of Orthopaedic Trauma, 25(4): 191–195.
[36] Zha GC, Chen ZL, Qi XB, et al., 2011, Treatment of Pertrochanteric Fractures with a Proximal Femur Locking Compression Plate. Injury, 42(11): 1294–1299.
[37] Xu S, Han L, Hu Y, et al., 2017, Comparison of Efficacy of Inverted Minimally Invasive Internal Fixation System with Gamma Nail in the Treatment of Intertrochanteric Fracture of the Femur with Lateral Wall Fracture. Chinese Journal of Trauma, 33(1): 57–62.
[38] Knobe M, Drescher W, Heussen N, et al., 2012, Is Helical Blade Nailing Superior to Locked Minimally Invasive Plating in Unstable Pertrochanteric Fractures?. Clinical Orthopaedics and Related Research®, 470(8): 2302–2312.
[39] Tawari AA, Kempegowda H, Suk M, et al., 2015, What Makes an Intertrochanteric Fracture Unstable in 2015? Does the Lateral Wall Play a Role in the Decision Matrix?. Journal of Orthopaedic Trauma, 29: S4–9.
[40] Haidukewych GJ, 2009, Intertrochanteric Fractures: Ten Tips to Improve Results. JBJS, 91(3): 712–719.
[41] Mereddy P, Kamath S, Ramakrishnan M, et al., 2009, The AO/ASIF Proximal Femoral Nail Antirotation (PFNA): A New Design for the Treatment of Unstable Proximal Femoral Fractures. Injury, 40(4): 428–432.
[42] Harrington P, Nihal A, Singhania AK, et al., 2002, Intramedullary Hip Screw Versus Sliding Hip Screw for Unstable Intertrochanteric Femoral Fractures in the Elderly. Injury, 33(1): 23–28.
[43] Zhang S, Ma Z, Du S, et al., 2016, Anatomical Study of the Proximal Lateral Wall of the Femur and Its Significance for Internal Fixation of Intertrochanteric Fractures. Chinese Journal of Clinical

Anatomy, 34(1): 39–42.

[44] Sadowski C, Lübbeke A, Saudan M, et al., 2002, Treatment of Reverse Oblique and Transverse Intertrochanteric Fractures with Use of an Intramedullary Nail or a 95 Screw-Plate: A Prospective, Randomized Study. JBJS, 84(3): 372–381.

[45] Min WK, Kim SY, Kim TK, et al., 2007, Proximal Femoral Nail for the Treatment of Reverse Obliquity Intertrochanteric Fractures Compared with Gamma Nail. Journal of Trauma and Acute Care Surgery, 63(5): 1054–1060.

[46] Al-Yassari G, Langstaff RJ, Jones JWM, et al., 2002, The AO/ASIF Proximal Femoral Nail (PFN) for the Treatment of Unstable Trochanteric Femoral Fracture. Injury, 33(5): 395–399.

[47] Schipper IB, Steyerberg EW, Castelein RM, et al., 2004, Treatment of Unstable Trochanteric Fractures: Randomised Comparison of the Gamma Nail and the Proximal Femoral Nail. The Journal of Bone and Joint Surgery British Volume, 86(1): 86–94.

[48] Zhang H, Zhu X, Pei G, et al., 2017, A Retrospective Analysis of the Intertan Nail and Proximal Femoral Nail Anti-Rotation in the Treatment of Intertrochanteric Fractures in Elderly Patients with Osteoporosis: A Minimum Follow-Up of 3 Years. Journal of Orthopaedic Surgery and Research, 12(1): 1–8.

[49] Xu R, Zhu G, Cheng L, et al., 2011, A Preliminary Efficacy Analysis of Intertan Intramedullary Nail in the Treatment of Intertrochanteric Fractures of the Femur. Bioorthopedic Materials and Clinical Research, 8(6): 16–19.

[50] Ciufo DJ, Zaruta DA, Lipof JS, et al., 2017, Risk Factors Associated with Cephalomedullary Nail Cutout in the Treatment of Trochanteric Hip Fractures. Journal of Orthopaedic Trauma, 31(11): 583–588.

[51] Gupta RK, Sangwan K, Kamboj P, et al., 2010, Unstable Trochanteric Fractures: The Role of Lateral Wall Reconstruction. International Orthopaedics, 34(1): 125–129.

[52] Kulkarni SG, Babhulkar SS, Kulkarni SM, et al., 2017, Augmentation of Intramedullary Nailing in Unstable Intertrochanteric Fractures Using Cerclage Wire and Lag Screws: A Comparative Study. Injury, 48: S18–22.

[53] Wang Z, Xu X, Chen Q, et al., 2017, Effect of Proximal Lateral Femur Reconstruction on Surgical Efficacy for Type A3 Intertrochanteric Fracture. Journal of Huazhong University of Science and Technology: Medical Edition, 46(3): 332–335.

[54] Kim Y, Bahk WJ, Yoon YC, et al., 2015, Radiologic Healing of lateral Femoral Wall Fragments After Intramedullary Nail Fixation for A3.3 Intertrochanteric Fractures. Archives of Orthopaedic and Trauma Surgery, 135(10): 1349–1356.

[55] Wu K, Tang J, 2019, Accurate Understanding of Intertrochanteric Femoral Fractures “Lateral Wall”. Chinese Journal of Reparative and Reconstructive Surgery, 33(10): 1210.

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