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Predictors of Failure Following Fixation of Trochanteric Fractures

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Abstract

BACKGROUND: Trochanteric fractures are frequent and mainly affect the elderly causing autonomy loss. Their incidence is increasing, and they are associated with substantial morbidity and high cost.

AIM: The aim of our study was to identify epidemiological, radiological, and technical predictors of failure of trochanteric fracture fixation in the elderly.

METHODS: We conducted a retrospective study including 188 patients aged over 65 years, who underwent surgery for trochanteric fractures, in the period between 2015 and 2020 at the orthopedics department of the Military Hospital of Tunis. The minimum follow-up was 12 months.

RESULTS: Thirty-four patients had a mechanical failure (18.1% of cases), including 12 cases of cephalic screw migration (CSM) (6.4%), 12 cases of disassembly (6.4%), eight cases of malunion (4.3%), and four cases of non-union (2.1%). Bone fragility with a Singh index ≤III was associated with CSM, disassembly of fixation material, and malunion (respectively, $p < 0.001$; $p = 0.01$ and $p = 0.044$). Reduction quality was associated with disassembly ($p < 0.001$) and CSM ($p = 0.004$). Eccentric screw positioning on anteroposterior ($p < 0.001$) and lateral views ($p = 0.018$), high tip-apex distance (TAD) ($p < 0.001$), and calcar-referenced TAD ($p < 0.001$) were predictive of CSM. Logistic regression analysis showed that poor reduction quality was an independent factor associated with the occurrence of mechanical complications. Functional outcomes were assessed using Parker and Postel Merle d'Aubigné scores.

CONCLUSION: To minimize the risk of mechanical complications, the surgeon must pay close attention to the fracture reduction and to the correct positioning of the cervical screw.

Introduction

Hip fractures are a major public health problem [1]. They mainly affect the osteoporotic elderly following a minor trauma [2]. Trochanteric fractures account for approximately 2/3 of all these fractures and they are associated with high morbidity and mortality rates ranging from 15% to 30% at 3 months [3], [4].

Operative techniques may encounter mechanical difficulties affecting functional outcomes [5]. The etiopathogenic of these complications remain insufficiently known and controversial. Few studies have analyzed the predictive factors for their occurrence [6].

To avoid and limit the risk of these complications, it is fundamental for the orthopedic surgeon to be aware of the mechanical complications of trochanteric mass fixation, and to analyze the failure predictors related to the patient and the surgical technique.

The aim of our study was to identify the main epidemiological, clinical, and technical factors predictive of fixation failure, and establish a plan to prevent it.

Methods

Study design and setting

We have conducted a monocentric, retrospective, and analytical study at the orthopedic surgery and traumatology department of the Military Hospital of Instruction of Tunis, starting from January 2015 up to January 2020, with a minimum follow-up of 12 months.

Study population and sampling technique

We have included all patients aged over 65 years, operated on for a trochanteric fracture by Gamma nailing or DHS plating, through non-probability consecutive sampling. Pathologic fractures and isolated greater or lesser trochanteric fractures were excluded.

The study population is resumed in Figure 1.

Data collection methods

Data were collected on a pre-formed groundwork. Informed written consent was obtained

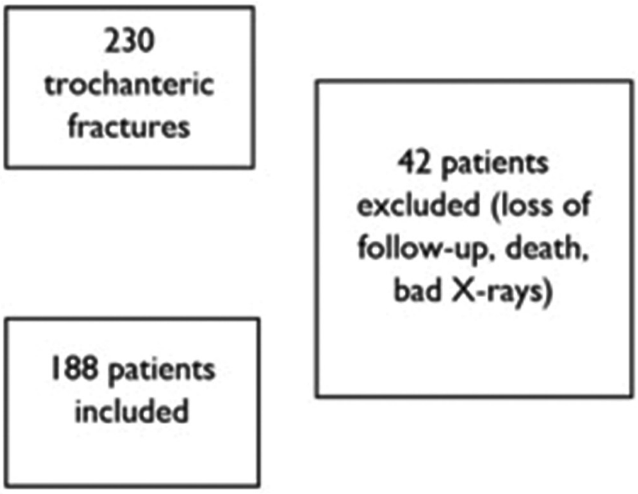

Figure 1: Flow chart

from the patient, or a family member (in case the patient was unable to give consent). Patients' confidentiality was strictly maintained.

Radiological analysis

Preoperatively, trochanteric fractures were classified according to ENDER classification into eight types [7]. Unstable fractures were defined by comminution of the calcar and lesser trochanter, and subtrochanteric fracture line for trochanteric varus fractures. Bone quality was assessed using the Singh index [8].

Postoperatively, radiological evaluation was performed on the pelvis and hip radiographs on the anteroposterior and lateral views, in the operating room, at 3, 6, and 12 months postoperatively.

The position of the cervical screw was assessed by three parameters: tip-apex distance (TAD) (Figure 2), Parker's ratio method (PRM), and the calcar-referenced (Cal TAD) (Figure 3) [9], [10], [11].

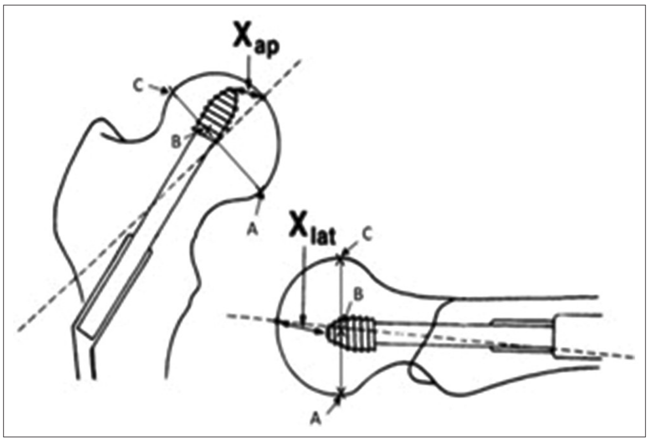

Figure 2: Tip-apex distance (TAD): sum of distances (mm) from lag-screw tip to femoral head summit on AP (Xap) and lateral views (Xlat). Parker's Ratio Method (PRM): AB/AC ratio x 100 on each view. AC: femoral head equatorial diameter (A: inferior/posterior pole; C: superior/anterior pole) B: center of the screw through AC line. PRM 0-0.33: screw in inferior/posterior; PRM 0.34-0.66: central position; 0.67-100: superior/anterior position

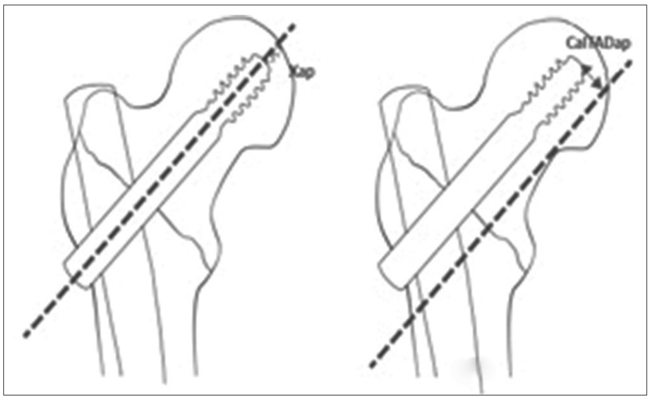

Figure 3: The calcar-referenced tip-apex distance (CalTAD) is a novel measurement tool that uses the same measurement technique as the TAD in the lateral view but differs in the AP view. (a) TAD in the AP view (Xap). (b) CalTAD in the AP view (CalTADap) is measured (in mm) by a guideline adjacent to the medial cortex of the femoral neck. TAD in the lateral view (Xlat) is added to CalTADap to obtain CalTAD

The quality of the reduction was put into three categories based on a modified Baumgaertner *et al*. method [12]. The first criterion used was an AP neck angle ranging from 120° to 135° and a lateral angulation <20°. The second criterion used was <4 mm displacement of any fragments in the AP and lateral views. The reduction was judged good if both criteria were present, acceptable if only one criterion was present, and poor if neither was present.

Other radiological parameters were assessed: the delay and quality of union (delayed union, non-union, and malunion) as well as implant-related complications: cephalic screw migration (CSM) and disassembly of fixation material.

Functional evaluation

Pre- and postoperative functional evaluations were performed using the pre-trauma Parker score and the Postel Merle d'Aubigné (PMA) score [13], [14].

Statistical analysis

Statistical analysis was performed using SPSS version 21.0 (IBM Company; Chicago, Illinois).

We performed a global description of each variable with a frequency evaluation for the qualitative variables and a mean, standard deviation, and median evaluation for the quantitative variables. To compare two qualitative variables, we used Pearson's Chi-square test. As for quantitative parameters, we used the Student's t-test. Correlations between quantitative variables were evaluated using the Pearson correlation coefficient.

The significance threshold was set at $p < 0.05$.

Multivariate analysis was performed including variables found significant at $p < 0.05$ on univariate analysis; the model was constructed by logistic regression.

Results

Descriptive study

We included 188 patients of whom 43.6% were men and 56.4% were women.

The average age was 76 years with a minimum of 65 years and a maximum of 93 years.

The average pre-trauma Parker score was 8.04/9. Domestic accidents were responsible for the trauma in 93.6% of cases.

According to the ENDER classification, the most common fractures were type II (36.2%) followed by type III (19.1%). Fractures were considered unstable in 81.9% of cases.

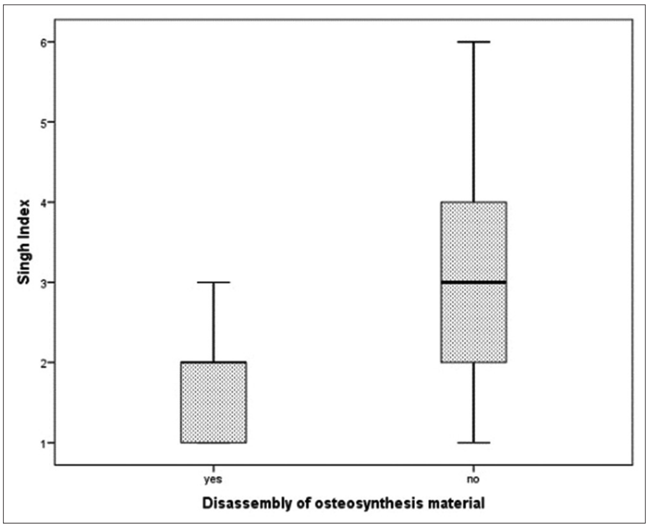

Figure 4: Association between cephalic screw migration with TAD and CalTAD

71.3% of the patients had radiological signs of osteoporosis according to the Singh index.

58.5% of our patients were operated on with a Gamma nail and 41.5% with a DHS plate.

Postoperative radiological evaluation showed that the position of the cephalic screw in the AP view was central in 87.3% of cases with an average PRM of 47%. In 91.5% of the cases, the screw position was central in the lateral view with an average PRM of 49%. The mean TAD and Cal TAD were 22.3 and 24.2 mm, respectively. Reduction quality was acceptable in 61.7% of cases, good in 21.3%, and poor in 17%.

The mean postoperative Parker score at the last follow-up was 7.45/9. The mean PMA score was 15.7/18.

Mechanical complications were seen in 18.1% of cases. We identified four types of complications: disassembly of the fixation material in 6.4% of cases, CSM in 6.4% of cases, malunion in 4.3% of cases, and non-union in 2.1% of cases.

Table 1: Univariate analysis of factors for cephalic screw migration

Factor	No cephalic screw migration (n = 176), n (%)	Cephalic screw migration (n = 12), n (%)	p
Age	76.2 (65–93)	73.6 (65–86)	0.262
Gender			
Male	80 (45.5)	2 (16.7)	0.052
Female	96 (54.5)	10 (83.3)	
Ender classification			
Cervicotrochanteric (type I, IV and V)	38 (21.6)	2 (16.7)	0.465
Pertrochanteric (type II, III, VI and VII)	122 (69.3)	10 (83.3)	
Subtrochanteric (type VIII)	16 (9.1)	0	
Fracture stability			
Stable	32 (18.2)	2 (16.7)	1.000
Unstable	144 (81.8)	10 (83.3)	
Singh osteoporosis index			
I	8 (4.5)	0	0.010
II	56 (31.8)	2 (16.7)	
III	66 (37.5)	2 (16.7)	
IV	26 (14.8)	8 (66.6)	
V	12 (6.8)	0	
VI	8 (4.5)	0	
Fixation type			
Gamma nail	104 (59.1)	6 (50)	0.380
DHS	72 (40.9)	6 (50)	
AP screw position			
Central	160 (90.9)	4 (33.3)	<0.001
Superior	2 (1.1)	8 (66.7)	
inferior	14 (8)	0	
LAT screw position			
Central	162 (92)	2 (16.7)	0.018
Anterior	4 (2.3)	10 (83.3)	
Posterior	10 (5.7)	0	
PRM (AP)	0.466 (0.266–0.673)	0.662 (0.583–0.742)	<0.001
PRM (LAT)	0.49 (0.296–0.674)	0.543 (0.47–0.682)	0.085
TAD	21.58 (16.5–26)	33.78 (32.5–35)	<0.001
CalTAD	23.46 (16–27)	35.73 (34.2–38)	<0.001
Reduction quality			
Good	40 (22.7)	0	0.004
Acceptable	110 (62.5)	6 (50)	
Poor	26 (14.8)	6 (50)	

Significant p values in bold. TAD: Tip-apex distance, PRM: Parker's ratio method, CalTAD: Calcar-referenced tip-apex distance, AP: anteroposterior view, LAT: Lateral view, DHS: Dynamic hip screw.

Univariate analysis

The study of factors associated with mechanical complications showed that patients who presented disassembly, CSM, and mal union had grade ≤ III osteoporosis according to the Singh index ($p < 0.001$; $p = 0.01$ and $p = 0.044$, respectively) (Figure 4). Similarly, poor reduction was related to disassembly and CSM ($p < 0.001$ and $p = 0.004$, respectively); (Tables 1 and 2). Superior cephalic screw position in the AP view ($p < 0.001$), anterior cephalic screw position in the lateral view ($p = 0.018$), TAD > 29.25 mm ($p < 0.001$), and Cal TAD >30.6 mm ($p < 0.001$) were predictive factors of CSM in our population (Table 1, Figure 5). In contrast, age, gender, fracture type, and fixation method were not predictors of mechanical complications.

Analysis of factors related to functional outcome showed that the more independent the patient was before trauma (high pre-trauma Parker score), the better the functional outcome was ($p < 0.001$). There was also a correlation with age (Parker and PMA scores at last follow-up: $p < 0.001$) and Singh osteoporosis index (Parker score at last follow-up: $p < 0.001$; PMA score: $p = 0.008$). However, we found no relationship between functional outcome, fracture type, and mechanical complications.

Table 2: Univariate analysis of factors for disassembly of fixation material

Factor	No disassembly of osteosynthesis material (n = 176), n (%)	Disassembly of osteosynthesis material (n = 12), n (%)	p
Age	76.2 (65–93)	74.6 (65–85)	0.503
Gender			
Male	74 (42)	8 (66.7)	0.096
Female	102 (58)	4 (33.3)	
Ender classification			
Cervicotrochanteric (type I, IV and V)	40 (22.7)	0	0.066
Pertrochanteric (type II, III, VI and VII)	120 (68.2)	12 (100)	
Subtrochanteric (type VIII)	16 (9.1)	0	
Fracture stability			
Stable	34 (19.3)	0	0.128
Unstable	142 (80.7)	12 (100)	
Singh osteoporosis index			
I	4 (2.3)	4 (33.3)	<0.001
II	52 (29.5)	6 (50)	
III	66 (37.5)	2 (16.7)	
IV	34 (19.3)	0	
V	12 (6.8)	0	
VI	8 (4.5)	0	
Fixation type			
Gamma nail	92 (56.8)	2 (16.7)	0.054
DHS	76 (43.2)	10 (83.3)	
AP screw position			
Central	154 (87.5)	10 (83.3)	0.338
Superior	10 (5.7)	0	
Inferior	12 (6.8)	2 (16.7)	
LAT screw position			
Central	162 (92)	0	0.165
Anterior	6 (3.5)	10 (83.3)	
Posterior	8 (4.5)	2 (16.7)	
PRM (AP)	0.481 (0.29–0.742)	0.443 (0.266–0.616)	0.241
PRM (LAT)	0.495 (0.31–0.682)	0.466 (0.296–0.62)	0.398
TAD	22.4 (16.5–35)	21.75 (18.5–24.5)	0.904
CalTAD	24.2 (16–38)	24.91 (24–27)	0.258
Reduction quality			
Good	40 (22.7)	0	<0.001
Acceptable	114 (64.8)	2 (16.7)	
Poor	22 (12.5)	10 (83.3)	

Significant p values in bold. TAD: Tip-apex distance, PRM: Parker's ratio method, CalTAD: Calcar-referenced tip-apex distance, AP: Anteroposterior view, LAT: Lateral view, DHS: Dynamic hip screw.

Multivariate analysis

To identify specific relationships between factors and complications, we performed a multivariate logistic regression analysis that kept only significant factors.

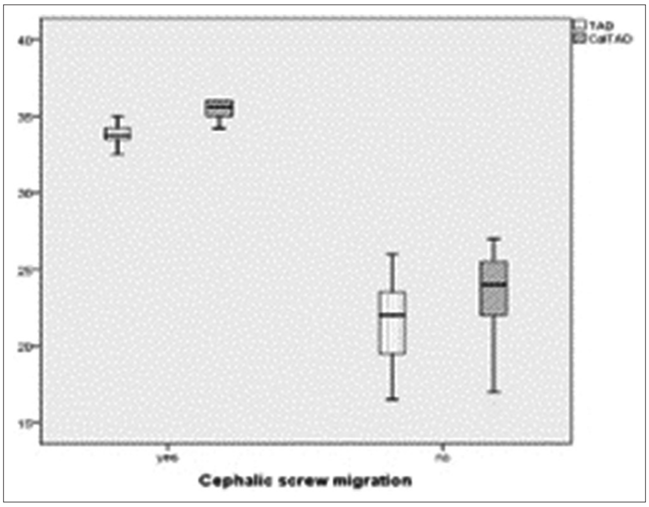

Figure 5: Disassembly of fixation material

To avoid collinearity between these factors, we selected the main variables: grade <III Singh osteoporosis, superior position of the cervical screw in AP view, anterior position of the cervical screw on lateral view, PRM >58% in AP view, TAD >29.25 mm, Cal TAD >30.6 mm and poor reduction quality.

After adjustment, the model identified a single risk factor independently associated with specific complications: reduction quality with $p < 0.001$, OR = 12.62, and CI of 3.92–40.58.

Discussion

Our study is one of the few studies assessing predictive factors of fixation failure of trochanteric fractures by analyzing various mechanical complications [15], [16], [17]. In addition, we also studied factors that may influence functional outcomes.

In our study, the rate of these mechanical complications was 18.1%. This was comparable to the studies conducted by Nikoloski *et al*. [18] (19%) and Mao *et al*. [19] (20.4%). In contrast, a lower frequency was found in the study of Siwach *et al*. [20] which was only 7.8%.

CSM was seen in 6.4 % of the cases in our study, whereas it ranged from 0 to 23% in the literature [21], [22]. Disassembly of fixation material is a complication that has not been frequently reported in the literature, with a rate ranging from 0 to 7.9% [6], [23], and 6.4% in our study. Trochanteric fractures do not have the same non-union risk as femoral neck fractures, because the metaphyseal zone is well-vascularized [24]. In our series, 2.1% of the patients presented non-union, which is comparable to the literature [3], [25]. Most studies found that disassembly of fixation material; osteoporosis and poor fracture reduction were the cause of malunion [26]. The malunion rate in our study was comparable to the literature (4.3%) [27], [28].

In our series, we found a significant association between poor fracture reduction and mechanical complications, which was also found in the literature [29], [30], [31].

It is well known that poor bone quality increases the risk of mechanical complications, however, this is still debatable by some authors [32], [33]. Escolar *et al*. [34] identified a statistically significant association between osteoporosis severity and the occurrence of CSM. This association was also found in our study with all mechanical complications except non-union. This goes along with Kim *et al*. study [23]. These results can be criticized, however, by the weak correlation between the Singh index and osteoporosis reported by some authors.

It has been proven in several studies that a malposition of the cephalic screw was predictive of CSM. In our study, we found that the superior and anterior positions of the screw were predictive of screw migration. This was in accordance with the studies of Baumgaertner *et al*. [12] and Pervez *et al*. [21].

The association between TAD and screw migration is still controversial: Baumgaertner *et al*. [12] concluded that there is a high risk of CSM if the TAD is >25 mm. Kraus *et al* [35] showed a significant relation if the TAD is higher than 30 mm. In our study, we found this correlation starting from a value of 29.25 mm. However, several other studies did not find this relationship. Goffin *et al*. [36], [37] and Li *et al*. [38] explained this discrepancy by the fact that the TAD has to be adjusted according to the size of the femoral head, which can vary according to the gender and anthropometric characteristics of the patient.

Kuzyk *et al*. [39] introduced the calcar-referenced (Cal TAD). These authors recommended an inferior screw position in the AP view and central position in the lateral view. In our study, we found a statistically significant association between Cal TAD and CSM. This is similar to the studies of Hancıoğlu *et al*. [40], Kashigar *et al*. [11], and Caruso *et al*. [41].

Bruijn *et al*. [29] showed in a series of 215 patients operated on for trochanteric fractures with Gamma nails or DHS plates, that unstable fractures had 14 times more risk of CSM. This was explained by the difficulty of reducing these unstable fractures. This was in line with several works in the literature [6], [11], [15], [19], [34]. However, in our series, we did not find this association.

The association between age and mechanical complications was not found in the majority of studies in the literature [6], [15]. This was also the case in our study. On the other hand, an association between the disassembly of fixation material and the age of the patients was found in Traore *et al*. study [42]. This association was also found with the CSM in Hsueh *et al*. study [30].

Morvan *et al*. [10] found in their study an association between CSM and gender with a higher incidence in men. This association was also found in Caruso's study but with a higher incidence in the women group [41]. In our series, we have not found an association between gender and mechanical complications.

Different previous comparative studies have established the superiority of the dynamic screw plate over the intramedullary system in the fixation of trochanteric fractures [43], [44].

During the past years, the use of intramedullary implants has increased dramatically. They are recommended for both stable and unstable fractures [45].

These intramedullary implants limit secondary impaction of the fracture and may have an advantage in terms of stability as they fill the proximal medullary canal [46]. In addition, the operative time is shorter limiting the invasiveness of the approach and allowing earlier rehabilitation compared to extramedullary implants. However, control of the closed reduction is not always simple and reduction defects and other mechanical complications have been described [47].

In our series, 58.5% of our patients were treated with intramedullary nailing. Most of the patients who presented disassembly of fixation material were treated with a medullary nail (83.3%) versus only 16.7% with a DHS plate with no significant difference (p = 0.054).

We did not find any association between the type of fixation and other mechanical complications, which is the case in the studies of Kashigar *et al*. [11], Caruso *et al*. [41], and Waast *et al*. [3]. However, the studies conducted by Bojan *et al*. [31] and Bhandari *et al*. [48] found a statistically significant association between the type of implant used and the occurrence of mechanical complications with the superiority of intramedullary nail designs.

Most studies agreed on the effectiveness of fixation in verticalizing patients with trochanteric fractures and preventing decubitus complications [49], [50], [51]. In our study, the mean Parker score decreased from 8.04/9 before trauma to 7.45/9 at the last follow-up. This regression in autonomy was significant (p < 0.001). Our results were in line with the literature [5], [15]. These results confirmed the importance of fixation in maintaining some autonomy after trochanteric fractures, although the recovery was not total. Several studies have shown a relationship between age and functional results [52], [53], [54]. This was consistent with our study with a negative correlation between age, Parker, and PMA scores. In terms of osteoporosis, we found a positive correlation between the Parker score at the last follow-up and the Singh index (Pearson correlation = 0.266; p = 0.008). This relationship was also established with the PMA score, which was in line with the literature [55], [56].

Limitations

There are several limitations to this study:

1. It has the disadvantages of any retrospective study caused by methodological biases
2. Although our study was conducted over 5 years, the sample size was small compared to various studies in the literature causing a low complication frequency. This did not allow us to have significant associations of several parameters compared to other series
3. It was difficult to classify osteoporosis according to the Singh index. Standard radiographs taken in emergency conditions were of poor quality and the bone trabeculae were difficult to visualize. An assessment by bone densitometry would have provided more accurate results
4. The mean age of our population was 75 years old, which is a relatively advanced age, associated with difficulties in assessing pain and hip stability scores.

Conclusion

The present study identified a major mechanical failure predictor of trochanteric fractures in people aged over 75 years which is poor reduction quality. In addition, it highlights the importance of screw positioning. TAD and CalTAD are reliable predictors of CSM.

Special attention should therefore be paid to fracture reduction and screw positioning, through intraoperative measurement of TAD and CalTAD to limit the risk of mechanical complications, especially CSM, which is a cause of surgical revision. Effective post-operative rehabilitation and prevention of osteoporosis could improve the functional prognosis of patients after trochanteric fractures.

Informed Consent

Written informed consent was obtained from all subjects or their legally authorized representatives (in case the patient was unable to give consent) before study initiation.

Ethics Approval and Consent to Participate

As per university standard guideline, participant consent and ethical approval have been collected and preserved by the authors.

Consent for Publication

Participant consent and ethical approval have been collected and preserved by the authors.

Availability of Supporting Data

The data supporting our findings are available and can be found in the orthopedics department of the Military Hospital of Tunis.

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