ORIGINAL ARTICLE

Posterolateral wall integrity in reverse oblique intertrochanteric fracture fixation: A new perspective in evaluation

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ABSTRACT

BACKGROUND: Treatment of reverse oblique fractures has the highest complication rate among proximal femur fractures. Although intramedullary nailing is the preferred treatment option, a high failure rate has been reported. Previous studies have identified several contributing factors to these failures, yet the significance of posterolateral wall integrity in ensuring postoperative stability has not been emphasized. This study aims to investigate the impact of posterolateral wall integrity on the failure rates of reverse oblique intertrochanteric fractures treated with intramedullary nails (IMN) and assess the vulnerability of certain IMN designs to these failures.

METHODS: Between 2010 and 2016, 53 patients with reverse oblique fractures were analyzed to identify factors associated with IMN failure. Variables such as posterolateral wall integrity, quality of reduction, posteromedial support, and IMN design were considered as potential risk factors. Logistic regression analysis was conducted to evaluate these risk factors, with statistical significance defined as $p<0.05$.

RESULTS: Eleven cases of implant failure were identified. Univariate statistical analysis indicated that loss of posterolateral support ($p=0.002$), IMN with single-screw proximal fixation ($p=0.048$), poor reduction quality ($p=0.004$), and loss of posteromedial support ($p=0.040$) were associated with implant failure. Multivariate analysis confirmed loss of posterolateral support ($p=0.009$), poor reduction quality ($p=0.039$), and loss of posteromedial support ($p=0.020$) as independent risk factors for failure. However, IMN with single proximal fixation ($p=0.859$) did not significantly impact fixation failure.

CONCLUSION: Reverse oblique intertrochanteric fractures with compromised posterolateral support exhibit a high rate of mechanical failure when treated with IMN. Additionally, poor reduction quality and loss of posteromedial support increase the risk for failure of these fractures. An IMN design featuring dual separate proximal screw fixations could provide better stability compared to a design with a single proximal screw, thereby reducing the risk of mechanical failure.

Keywords: Hip fractures; proximal femoral fractures; intertrochanteric fractures; intramedullary nailing; implant failure.

INTRODUCTION

Reverse oblique intertrochanteric fractures are a unique pattern of extracapsular proximal femur fractures with distinct biomechanical characteristics. Originally described by Wright et al.[1] as indicative of intertrochanteric fractures, these injuries were further defined by Futamura et al.[2] as having lateral fracture lines that extend between the attachment of the medial lateral bundle of the iliofemoral ligaments. These fractures are characterized by severe medial and proximal displacement of the distal bone fragment. Futamura et al. also provided a more comprehensive delineation of these fractures in a novel

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classification system utilizing three-dimensional computed tomography (3D-CT) images.

Reverse oblique fractures are recognized as unstable intertrochanteric fractures that pose significant challenges for surgical intervention. The optimal treatment and selection of the appropriate implant remain subjects of debate. While earlier studies have highlighted the superiority of intramedullary implants over extramedullary implants,[3,4] more recent meta-analyses have shown no significant differences between them in terms of clinical outcomes.[5] Moreover, studies have reported a high failure rate (22-27%) of intramedullary nails in treating reverse oblique intertrochanteric fractures,[6,7] significantly impacting the morbidity and mortality of elderly patients with these fractures.[8]

Although numerous studies have associated poor reduction and loss of posteromedial support with a high failure rate,[7,9,10] the role of posterolateral support in the postoperative stability of reverse oblique intertrochanteric fractures treated with intramedullary nails has not been emphasized. This study aims to explore the impact of the integrity of the proximal femur's posterolateral wall on the failure rates of reverse oblique fractures after intramedullary nail fixation and to assess whether certain designs of intramedullary implants are particularly susceptible to these failures.

MATERIALS AND METHODS

We retrospectively evaluated the data of all patients admitted to our hospital with intertrochanteric fractures and treated with intramedullary nails from January 2010 to December 2016. Using both X-ray and 3D-CT images, we classified the fractures according to the system described by Futamura et al.[2] This classification system is preferred because it specifically addresses reverse oblique fractures as a distinct fracture type and delineates its subgroups. Four typical fracture patterns associated with reverse oblique fractures include a fracture across the intertrochanteric line, loss of posteromedial support, loss of posterolateral support, and a bony fragment encompassing both the greater and lesser trochanter. This study analyzed patients suffering from reverse oblique intertrochanteric fractures (Futamura type 3) to identify factors associated with the failure of intramedullary nail fixation. The inclusion criteria were: 1) acute reverse oblique intertrochanteric fracture; 2) intramedullary nail fixation; and 3) a follow-up period until bony union was confirmed or until the time of fixation failure leading to revision surgery. Exclusion criteria included patients with interrupted treatment, pathological fractures, concomitant fractures of the affected extremity, and fractures older than two weeks. Written consent was obtained from all participants. In accordance with the Declaration of Helsinki, the local Ethics Committee approved the study (decision number: 118, dated 25. 01. 2025), which was conducted retrospectively and conformed to legal standards, with all procedures being part of routine care. Potential risk factors for implant failure included age, sex, affected side, reduction method, quality of reduction, status of posteromedial and posterolateral support, and intramedullary implant design.

During the study period, a total of 504 patients with extracapsular hip fractures were admitted and underwent surgery with intramedullary nails at our hospital. Sixty-one patients had reverse oblique intertrochanteric fractures (Futamura type 3). Eight patients were excluded for various reasons: two had metastatic fractures, two suffered polytrauma, three died before union, and one was lost to follow-up. Among the remaining 53 patients, 11 did not present with the typical fractures, 34 exhibited loss of posteromedial support, 16 had loss of posterolateral support, eight sustained a secondary fracture across the intertrochanteric line, and five had a bony fragment including both the greater and lesser trochanter. Bony union was observed in all patients at the six-month follow-up, except for those who experienced mechanical failure. In our department, throughout the study, the primary surgical treatment for all patients with reverse oblique intertrochanteric fractures was intramedullary nailing. Patients were operated on in the supine position using a traction table. Two types of intramedullary nails were utilized for all extracapsular hip fractures: PROFIN (TST SAN, Istanbul, Türkiye) and TRIGEN INTERTAN® (Smith & Nephew, Memphis, USA). Although both have similar indications, they differ biomechanically. The proximal fixation of these two systems is different; the PROFIN system features two 8.5 mm diameter lag screws for proximal fixation, whereas the TRIGEN INTERTAN system incorporates integrated lag and compression screws, each 15.25 mm in diameter. Both nail systems were available concurrently. Given the lack of evidence favoring one system over the other, the choice of implant was determined by the operating surgeon's preference.

Immediate postoperative radiographic images (anteroposterior and lateral views) were taken to confirm the quality of reduction and implant positioning, and to assess the status of posteromedial and posterolateral support. Reduction quality was evaluated based on the alignment and displacement of the main fragments and was categorized as good, acceptable, or poor.[10] Criteria for normal alignment included a normal or slightly valgus neck-shaft angle in anteroposterior views and less than 20° of angulation in lateral views. Displacement criteria involved less than the thickness of the medial cortical layer in anterior-posterior views and less than the thickness of the anterior cortical layer in lateral views. Good reduction quality was confirmed when all criteria for normal alignment and displacement were met. Acceptable reduction quality was indicated when both alignment criteria and at least one displacement criterion were met. However, if only one or neither criterion for alignment or displacement was achieved, it signified poor reduction quality.

In the TRIGEN INTERTAN group, the tip apex distance (TAD) was determined by summing the distances from the

cannulated lag screw tip to the apex of the femoral head on both anteroposterior and lateral radiographic views. In the PROFIN group, which utilized two separate lag screws, measurements for TAD were taken using the tip of the proximal screw.[11] These measurements were adjusted for magnification based on the known diameter of the cannulated screws. A displacement less than the cortical thickness of the posterolateral wall suggested contact between the proximal and distal fragments and indicated intact posterolateral support. If this criterion was not met, the posterolateral support was considered disrupted. Similarly, posteromedial support was classified as intact only if the displacement of the posteromedial segment was less than the cortical thickness.

Postoperatively, patients were mobilized with protected weight bearing as soon as they could tolerate the pain. Full weight bearing was postponed until the fracture line displayed radiographic signs of callus formation. Follow-up assessments were scheduled at 3 weeks, 6 weeks, 3 months, 6 months, and annually, or sooner if an adverse reaction occurred. During each visit, clinical evaluations were conducted to assess pain at the fracture site, loss of motion, and difficulties in ambulation. Radiological imaging was employed to confirm union and to identify any loss of reduction or fixation failure. Bony union was defined as a fracture that was completely filled with callus and could support full weight bearing without pain. Fixation failure was characterized by screw back out, lag screw cut out, or implant breakage.

Statistical Analysis

Descriptive statistics were conducted using the Statistical Package for the Social Sciences (SPSS) 21.0 software (SPSS Inc., Chicago, IL, USA). A predictive analysis of all variables was performed using unconditional univariate logistic regression. When significant differences were found, multivariate logistic regression was subsequently applied to identify risk factors for implant failure in patients with reverse oblique fractures treated with intramedullary nails. Statistical significance was set at $p<0.05$.

RESULTS

Overall, 11 patients (20.75%) experienced mechanical failure postoperatively (Table 1). Two patients had implant fractures, three had screw cut-outs, four experienced screw-backs, and two suffered from varus collapse. None of these failures were attributed to infection. Except for one implant that healed despite excessive collapse, revision surgery was performed on all failed implants. Nine patients underwent conversion to partial hip arthroplasty, and one was revised using a 95° dynamic compression screw (DCS) plate.

The quality of reduction in the control group was classified as good for 25 patients, acceptable for 12, and poor for five; in the failure group, it was good for two, acceptable for three, and poor for six. The mean initial postoperative neck-shaft angle was 133.2±5.5° in the control group and 128.7±7.9° in the failure group. The mean initial postoperative TAD was 20.3±4.1 mm in the control group and 22.6±2 mm in the failure group.

Univariate statistical analysis indicated that loss of posterolateral support, nail design with single proximal screw fixation, poor reduction quality, and loss of posteromedial support were associated with fixation failure (Table 2). Multivariate analysis identified loss of posterolateral support, poor reduction quality, and loss of posteromedial support as independent risk factors for fixation failure. However, a nail design with a single proximal screw was not linked to fixation failure (Table 3).

Table 1. Summary of patients experiencing postoperative mechanical failures

Patient	Age	Implant	Reduction Quality	PM Support	PL Support	Complication	Time of Complication	Revision
S.B.	74	PROFIN Nail	Poor	Loss	Intact	Nail Breakage	>6 months	Arthroplasty
Y.Ç.	72	PROFIN Nail	Poor	Loss	Intact	Screw Cut-out	<4 weeks	Arthroplasty
G.Y.	66	INTERTAN Nail	Acceptable	Loss	Intact	Screw Cut-out	<4 weeks	Arthroplasty
S.K.	61	INTERTAN Nail	Poor	Loss	Loss	Screw Back-out	<4 weeks	Arthroplasty
A.K.	54	INTERTAN Nail	Acceptable	Loss	Loss	Screw Back-out	<4 weeks	Arthroplasty
D.Ö.	76	PROFIN Nail	Good	Intact	Loss	Screw Cut-out	<4 weeks	Arthroplasty
E.A.	79	INTERTAN Nail	Poor	Intact	Loss	Screw Back-out	<4 weeks	Arthroplasty
Ş.S.	82	INTERTAN Nail	Acceptable	Loss	Loss	Varus Collapse	3-6 months	None
M.A.	80	INTERTAN Nail	Good	Intact	Loss	Screw Back-out	<4 weeks	Arthroplasty
D.Ç.	66	INTERTAN Nail	Poor	Loss	Loss	Varus Collapse	3-6 months	Arthroplasty
D.K.	44	INTERTAN Nail	Poor	Loss	Loss	Broken Lag Screw	>6 months	DCP Plate

PM: Posteromedial; PL: Posterolateral.

Table 2. Univariate logistic regression analysis of patient characteristics and risk factors for implant failure

Variable	Control Group	Failure Group	p Value	Odds Ratio	95% Confidence Interval
Age	73 (52-78)	68.5 (44-82)	0.517	–	–
Gender					
Male	16	5		1.0	Reference
Female	26	6	0.407	0.82	0.42-2.20
Operative Side					
Right	22	4		1.0	Reference
Left	20	7	0.820	0.583	0.092-1.574
Reduction Method					
Closed	33	8		1.0	Reference
Open	9	3	0.324	2.652	1.424-5.867
Quality of Reduction					
Good	25	2		1.0	Reference
Acceptable	12	3	0.244	3.125	0.460-21.252
Poor	5	6	0.004	15.000	2.321-96.961
Posteromedial Support					
Yes	26	3		1.0	Reference
No	16	8	0.040	4.333	1.001-18.767
Posterolateral Support					
Yes	34	3		1.0	Reference
No	8	8	0.002	11.333	2.444-52.561
Implant					
Profin Nail System	26	3		1.0	Reference
Trigen Intertan System	16	8	0.048	1.16	0.098-1.536

Table 3. Multivariable logistic regression analysis of risk factors associated with mechanical failures

Parameter	Odds Ratio	95% Confidence Interval	p Value
Posterolateral Support Loss	21.451	2.173-211.788	0.009
Posteromedial Support Loss	2.072	0.869-37.992	0.020
Poor Reduction Quality	7.318	2.122-86.566	0.039
Trigen Implant System	0.842	0.127-5.573	0.859

DISCUSSION

This study explored the impact of the integrity of posterolateral support on the failure rates of reverse oblique intertrochanteric fractures treated with intramedullary nails, as well as the effect of different intramedullary implant designs on reducing fixation failures. Our results indicated that the loss of posterolateral support in reverse oblique intertrochanteric fractures increases the risk of fixation failure and subsequent revision surgeries, whereas designs featuring two separate proximal screws may mitigate this risk. Additionally, both loss of posteromedial support and poor reduction quality were linked to higher failure rates.

A key finding of our study is that posterolateral support of the proximal femur appears to play a significant role in the stability of reverse oblique intertrochanteric fractures treated with intramedullary nails. We found that nearly two-thirds of patients experiencing fixation failure had compromised posterolateral support, whereas only three of the 37 patients with intact posterolateral support encountered this complication. This could be explained by the posterolateral fracture potentially influencing the fixation stability or affecting the nail entry point. The resultant V effect may lead to varus angulation, which could progress to fixation failure.

Many studies do not clearly distinguish between pertrochan-

teric and intertrochanteric fractures,[12] and most of these studies utilize the AO/OTA (Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association) classification, which encompasses various proximal femoral fractures. Reverse oblique fractures are categorized into three classes: 31A3.1 (simple oblique), 31A3.2 (simple transverse), and 31A3.3 (wedge or multifragmentary). None of these classifications comprehensively describe the configurations of fracture fragments, especially the lateral wall of the proximal fragment.[12] This inconsistency may explain the wide variation in reported failure rates, which range from 0-29%.[7,13] The integrity of the lateral femoral wall, a predictor of intramedullary fixation failure,[14] provides rotational stability and prevents varus collapse.[15] Additionally, the preoperative identification of fracture patterns and understanding the location and direction of displacement greatly influence implant selection and reduction methods. Thus, lateral femoral wall integrity should be included in the intertrochanteric classification. Consequently, a more novel classification, proposed by Futamura et al.,[2] was employed in this study to describe the subgroups of reverse oblique fractures and their combinations.

The reduction quality of intertrochanteric fractures was defined by cortical continuity and anatomical alignment, which are crucial for resisting axial load and minimizing the risk of collapse. We applied the criteria outlined by Kim et al.[16] for the displacement of main fragments and those by Baumgaertner et al.[17] for alignment to assess reduction quality. Numerous studies have underscored the significance of achieving a high-quality reduction in reverse oblique intertrochanteric fractures to prevent implant failure.[10] In our study, among the six patients who suffered from the loss of posterolateral support and experienced poor reduction, four (66.6%) encountered mechanical failure. Our findings indicate that poor reduction is an independent risk factor for implant failure in patients with compromised posterolateral support who are treated with an intramedullary nail.

Prior research has highlighted the critical role of posteromedial support in stabilizing intertrochanteric fractures,[18] noting that its disruption increases the likelihood of fractures collapsing and shortening under axial load.[19] While one study demonstrated that the integrity of posteromedial support does not influence the outcomes in patients with intertrochanteric fractures treated with intramedullary nails,[20] more recent research indicates that a disruption in this support constitutes a risk factor for implant failure in patients with reverse oblique fractures receiving the same treatment.[10,14] Our findings align with these recent studies, showing that a loss in posteromedial support is an independent predictor of implant failure in reverse oblique fractures following intramedullary nail fixation.[21]

Although the largest published series of reverse oblique intertrochanteric fractures from the Norwegian hip fracture registry suggests that intramedullary nails are superior to extramedullary sliding hip screws,[22] a high failure rate has been reported.[23] Furthermore, two recent meta-analyses have concluded that additional studies are necessary to assess the effectiveness of intramedullary nails and to determine which design is more suitable for the fixation of intertrochanteric femur fractures.[24,25] It is important to note that maintaining fracture reduction during surgery is quite difficult and technically demanding.[26] Our clinical experience with reverse oblique fracture intramedullary nailing indicates that these fractures, particularly those with posterolateral fragments, present challenges. During the insertion of the nail or proximal lag screws, posterolateral fragments might displace, compromising postoperative stabilization. This displacement becomes more pronounced with a short posterolateral fragment that intersects the ideal entry point and trajectory of the lag screws (Fig. 1), potentially leading to early varus malalignment of the proximal fragment, medialization of the distal fragment, and cutting out or backing out of the lag screws (Fig. 2).

Figure 1. Reverse oblique fracture treated with Trigen InterTAN® (Smith & Nephew, Memphis, USA); Note that the integrated compression screw intersects with fracture line of the posterolateral fragment.

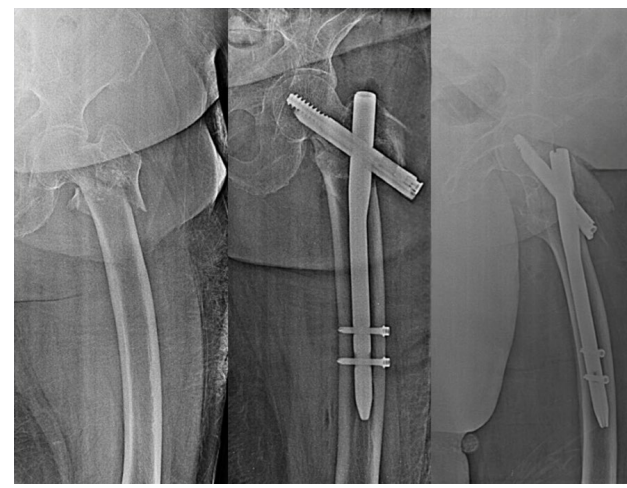

Figure 2. Reverse oblique fracture with posteriolateral support loss that treated by Trigen InterTAN® (Smith & Nephew, Memphis, USA); postoperative mechanical failure with varus malalignment of the proximal fragment, medialization of the distal fragment, and backing out of the lag screws.

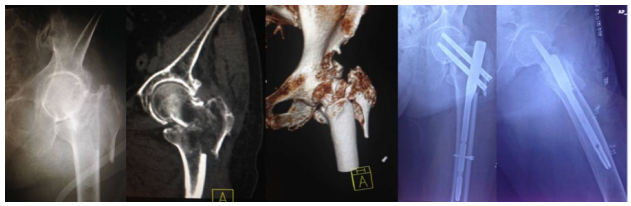

Figure 3. PROFIN (TST SAN, Istanbul, Turkey) with two lag screws optimal orientation of the screw entry point and better fixation of the posterolateral fragment.

Intramedullary nail designs featuring two separate proximal screw fixations may allow for optimal orientation of the screw entry point and better fixation of the posterolateral fragment (Fig. 3). Makki et al.[27] reported improved outcomes using a reconstruction system with two proximal screws compared to those using single proximal compression blade fixation in managing reverse oblique intertrochanteric fractures. This improvement may result from the thinner proximal portion of the reconstructed antegrade nail, which helps avoid displacement of the trochanteric fragment, and the smaller two-screw design, which enhances fracture reduction and stability. Moreover, compression-sliding nail systems such as the INTERTAN nail can disrupt and displace the posterolateral wall during insertion and fixation due to the compression force applied to the fractured posterolateral wall. The increased screw size of these proximal compression systems may also contribute to such displacement. In some fracture configurations, reconstructing the lateral wall is difficult, even with two separate screws; in such cases, using an extramedullary implant may be a viable alternative. Furthermore, a recent biomechanical study reported better biomechanical fixation with anatomic locking plates in reverse oblique intertrochanteric femur fractures with fragmented lateral cortices compared to intramedullary fixation.[28]

To the best of the authors' knowledge, this study is the first to underscore the importance of posterolateral support for the stability of reverse oblique intertrochanteric fractures treated with intramedullary nails. The main limitations of this study include its retrospective nature and relatively small sample size. Reverse oblique fractures are rare, making it difficult to collect data on a large number of patients with this type of fracture. Consequently, these fractures were not subgrouped in previous studies. Future research, including larger sample sizes and prospective clinical and biomechanical studies, is warranted to investigate optimal implants for these unstable intertrochanteric fractures.

CONCLUSION

In conclusion, reverse oblique intertrochanteric fractures with loss of posterolateral support are associated with a high rate of mechanical failure when treated with an intramedullary nail. Achieving good anatomical reduction and maintaining intact posteromedial support are crucial for preserving fracture alignment. When managing these fractures, surgeons should anticipate difficulties in reduction and potential loss of reduction during nail insertion and lag screw placement. A design featuring two separate proximal screws in an intramedullary nail may allow better fixation of the posterolateral fragment and improve outcomes.

Ethics Committee Approval: This study was approved by the Memorial Bahçelievler Hospital Ethics Committee (Date: 25.01.2024, Decision No: 118).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Ters oblik intertrokanterik kırık tespitinde posterolateral duvar bütünlüğü: Değerlendirmede yeni bir konu

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AMAÇ: Bu çalışmanın amacı intramedüller çivi (IMN) ile tedavi edilen ters oblik intertrokanterik kırıkların başarısızlık oranı üzerinde posterolateral duvar bütünlüğünün rolünü araştırmak ve bazı IMN tasarımlarının bu başarısızlıklara karşı özellikle duyarlı olup olmadığını belirlemektir.
GEREÇ VE YÖNTEM: 2010'dan 2016'ya kadar ters oblik kırığı olan 53 hasta, IMN başarısızlığıyla ilişkili faktörleri belirlemek için analiz edildi. Redüksiyon kalitesi, posteromedial destek durumu ve IMN tasarımının yanı sıra posterolateral duvar bütünlüğü de potansiyel risk faktörleri olarak değerlendirildi. Risk faktörlerini değerlendirmek için lojistik regresyon analizi yapıldı ve istatistiksel anlamlılık $p<0.05$ olarak tanımlandı.
BULGULAR: 11 vakada implant başarısızlığı tespit edildi. Çalışmamızda tek değişkenli istatistiksel analizde; posterolateral destek kaybı (p=0,002), tek vida proksimal fiksasyonlu İMN (p=0.048), kötü redüksiyon kalitesi (p=0.004) ve posteromedial destek kaybının (p=0.040) implant başarısızlığıyla ilişkili faktörler olduğu görüldü. Çok değişkenli analiz; posterolateral destek kaybının (p=0,009), kötü redüksiyon kalitesinin (p=0.039) ve posteromedial destek kaybının (p=0.020) başarısızlık için bağımsız risk faktörleri olduğunu ortaya çıkardı. Ancak tek vida proksimal fiksasyonlu İMN (p=0.859) fiksasyon başarısızlığı ile ilişkili değildi.
SONUÇ: Posterolateral duvar bütünlüğü kaybıyla birlikte ters oblik intertrokanterik kırık, IMN ile tedavi edildiğinde yüksek mekanik başarısızlık oranıyla ilişkilidir. Ayrıca kötü redüksiyon kalitesi ve posteromedial desteğin kaybı bu kırıkların başarısızlık riskini arttırmaktadır. İki ayrı proksimal vida fiksasyonuna sahip bir IMN tasarımı, tek proksimal vidalı bir IMN'ye göre daha iyi tespite izin verebilir ve bu da başarısızlık riskini azaltabilir.

Anahtar sözcükler: İntertrokanterik kırıklar; intramedüller çivileme; implant başarısızlığı; kalça kırıkları; proksimal femur kırıkları; ters oblik kırıklar.

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