Medical Journal of Bakırköy

Med J Bakirkoy 2023;19:86-92
DOI: 10.4274/BMJ.galenos.2023.2022.2-4

Research

Risk Factors for Complications in Trochanteric Femur Fractures Treated with Dyna Locking Trochanteric Nail

Dyna Locking Trokanterik Çivisi ile Tedavi Edilen Trokanterik Femur Kırıklarında Komplikasyonlar için Risk Faktörleri

Servet İğrek[1], Tolga Onay[2]

[1]Selahaddin Eyyubi State Hospital, Clinic of Orthopaedics and Traumatology, Diyarbakır, Türkiye
[2]University of Health Sciences Türkiye, Kartal Dr. Lütfi Kırdar City Hospital, Clinic of Orthopaedics and Traumatology, İstanbul, Türkiye

ABSTRACT

Objective: The propose of this study was to asses the factors leading to complications in trochanteric femoral fractures treated with Dyna locking trochanteric (DLT) nails in geriatric patients, with respect to fracture stability pattern, postoperative reduction, screw placement, tip-apex distance (TAD), bone quality, and patient positioning.

Methods: One hundred sixty nine patients operated using DLT nail, aged 65 years and older with a minimum follow-up of 12 months were screened retrospectively. The fracture patterns were grouped as AO Foundation/Orthopedic Trauma Association (AO/OTA) 31-A1, A2, and A3, and the patients were operated in the supine position using a traction table, in the supine position without using a traction table, or in the lateral decubitus position. Postoperative bone mineral density (BMD) measurements were performed in all patients. The Fogagnolo criteria, modified from Baumgartner, were used to evaluate the fracture reduction, and accordingly, the fracture reduction was subdivided into good, acceptable, or poor. TAD measurements were performed as described by Baumgartner. The position of the lag screw within the femoral head was determined according to Cleveland and Bosworth method, and the central-central and infero-central positions were evaluated as optimal and the other positions as suboptimal.

Results: A total of 57 complications were determined, of which 14 (8.2%) were cut-out, cut-through, and intrapelvic migration of the lag screw and distal peri-implant fractures requiring additional interventions. A statistically significant association was found between suboptimal lag screw placement, decreased BMD, TAD measurement >25 mm, and decreased reduction quality with cut-out, cut-through, intrapelvic migration, and varus collapse. Varus collapse was seen at a significantly low rate in AO/OTA 31-A1 type fractures and in surgeries performed with a traction table ($p=0.004$, $p<0.001$), although there was no association between cut-out, cut-through, intrapelvic migration and fracture type and patient positioning ($p=0.542$, $p=0.632$). The optimal lag screw placement and TAD measurements were statistically significantly better in patients who were treated on a traction table ($p<0.001$, $p<0.001$).

Conclusion: Decreased BMD, suboptimal lag screw position in the femoral head, a TAD of >25 mm, unstable fracture patterns, and poor reduction quality have an impact on complications. Performing the surgical intervention on a traction table ensures more favorable lag screw placement.

Keywords: Trochanteric, femur, fracture, DLT, cephalomedullary, complication

ÖZ

Amaç: Çalışmanın amacı geriatrik hastalardaki Dyna locking trokanterik (DLT) çivisi ile tedavi edilen trokanterik femur kırıklarında komplikasyona neden olan faktörleri kırık stabilite paterni, postoperatif redüksiyon, vida yerleşimi, tip-apeks mesafesi (TAD), kemik kalitesi ve hasta pozisyonu ile ilgili olarak değerlendirmektir.

Gereç ve Yöntem: Altmış beş yaş üzerinde minimum 12 ay takipli DLT çivisi kullanılarak opere edilen 169 hasta retrospektif olarak taranmıştır. Kırık paterni AO Vakfı/Ortopedik Travma Derneği (AO/OTA) 31-A1, A2 ve A3 olarak gruplandırılmış hastalar traksiyon masası ile supin pozisyonda, traksiyon masası kullanılmadan supin pozisyonda ya da lateral dekübit pozisyonunda opere edilmiştir. Hastaların tamamına cerrahi sonrası kemik mineral yoğunluğu (KMY) ölçümü yapılmıştır. Kırık redüksiyonunu değerlendirirken Baumgartner'den modifiye edilmiş Fogagnolo kriterleri kullanılmış ve buna göre kırık redüksiyonu iyi, kabul edilebilir ve kötü olarak gruplandırılmıştır. TAD ölçümleri Baumgartner tarafından tarif edilen

Address for Correspondence: Servet İğrek, Selahaddin Eyyubi State Hospital, Clinic of Orthopaedics and Traumatology, Diyarbakır, Türkiye
Phone: +90 553 649 65 25 E-mail: servetigrek@gmail.com ORCID ID: orcid.org/0000-0002-7952-4223

Cite as: İğrek S, Onay T. Risk Factors for Complications in Trochanteric Femur Fractures Treated with Dyna Locking Trochanteric Nail. Med J Bakirkoy 2023;19:86-92

Received: 03.02.2022
Accepted: 27.02.2023

ÖZ

şekilde yapılmıştır. Lag vidasının femur başı içerisindeki pozisyonu Cleveland ve Bosworth yöntemine göre belirlenmiş ve merkez-merkez, infero-merkez pozisyonlar optimal diğer pozisyonlar suboptimal olarak değerlendirilmiştir.

Bulgular: Çalışmada 57 komplikasyon tespit edilmiştir, bunlardan 14'ü (%8,2) ek müdahale gerektiren lag vidasının cut-out, cut-through ve intrapelvik migrasyonu ile birlikte distal peri-implant kırıklarıdır. Yapılan değerlendirmelerde suboptimal lag vidası yerleşimi, düşük KMY, TAD >25 mm ölçümü ve yetersiz redüksiyon kalitesi ile cut-out, cut-through, intrapelvik migrasyon ve varus kollapsı arasında istatistiksel olarak belirgin ilişki saptanmıştır. AO/OTA 31-A1 tipi kırıklarda ve traksiyon masası ile yapılan ameliyatlarda belirgin olarak düşük oranda varus kollapsı görülmüştür (p=0,004, p<0,001), ancak lag vidasının cut-out, cut-through ve intrapelvik migrasyonu ile kırık tipi ve hasta posizyonları arasında ilişki saptanamamıştır (p=0,542, p=0,632). Optimal lag vidası yerleşimi ve TAD ölçümleri ile traksiyon masasında tedavi edilen hastalar arasında istatistiksel olarak anlamlı ilişki saptanmıştır (p<0,001, p<0,001).

Sonuç: Düşük KMY, femur başına uygun olmayan lag vidası yerleşimi, TAD >25 mm olması, instabil kırık paterni ve kötü redüksiyon kalitesi komplikasyonların ortaya çıkmasında etkilidir. Traksiyon masası kullanılarak yapılan cerrahi müdehaleler ile daha uygun lag vidası yerleşimi sağlanabilir.

Anahtar Kelimeler: Trokanterik, femur, fraktür, DLT, sefalomedüller, komplikasyon

INTRODUCTION

Hip fractures in elderly patients are still a common and challenging issue. Early and appropriate surgical treatment thereby obtaining earlier mobility of these patients is essential to be able to avoid increased rates of complications and mortality (1).

Factors affecting the results of trochanteric hip fractures have been extensively studied in the literature. Bone quality, fracture stability and reduction, and proper selection and placement of the implant, have been defined as important determinants for better outcomes (2).

Intramedullary implants are the most preferred devices if internal fixation is applied to a trochanteric femoral fracture (3). The Dyna locking trochanteric (DLT) nail (U&I corporation, 20, Sandan-ro 76beon-gil, Uijeongbu-si, Gyeonggi-do, Korea) is one of the many intramedullary implants that provides better purchase in the osteoporotic femoral head and neck by using a lag screw with 3 wedge wings, thereby preventing complications.

There are very few published studies have reporting the results of trochanteric femur fractures treated with DLT nails (4,5). The aim of the present study was to evaluate the factors leading to complications in geriatric trochanteric femoral fractures treated with DLT nail, with respect to fracture stability pattern, postoperative reduction, screw placement, tip-apex distance (TAD), bone quality, and patient positioning during surgery.

METHODS

The orthopedic trauma database of a single center was retrospectively searched for patients who had sustained a hip fracture, including the femoral head, neck, peritrochanteric, and subtrochanteric femur fracture between January 2016 and December 2019. Approval was obtained from the Clinical Research Ethics Committee of Marmara University Faculty of Medicine (protocol code: 01.2020.578, date: 21.01.2020). Informed consent was provided by all patients, by their parents/legal guardians.

The study inclusion criteria were as follows:

1) Patients aged >65 years,

2) Followed up for at least 12 months,

3) Acute traumatic trochanteric femur fracture (AO 31-A1, A2, A3),

4) Treated with internal fixation with DLT nail.

The study exclusion criteria were defined as age <65 years, pathological fractures, patients with an associated fracture in the ipsilateral extremity, a follow-up period of less than 12 months, treated with implants other than DLT nail, or X-ray quality unsuitable for radiological evaluation. Data were retrieved from patient files related to age, fracture side, surgery time, blood loss, positioning during surgery, and duration of hospital stay.

The study was conducted on a total of 169 patients who met the criteria, comprising 72 males and 97 females with an average age at the time of injury of 78.6 years (range, 65 to 103 years) (Figure 1).

Surgical Technique

The operations of the patients evaluated in this study were performed by 7 surgeons. All surgeons are highly experienced in hip trauma. DLT nails were used in all cases as the implant for internal fixation. Surgical interventions were performed in three patient positions according to the surgeon's preference: the supine position with a traction table, supine position with manual traction, and lateral decubitus. The fracture reduction was achieved through

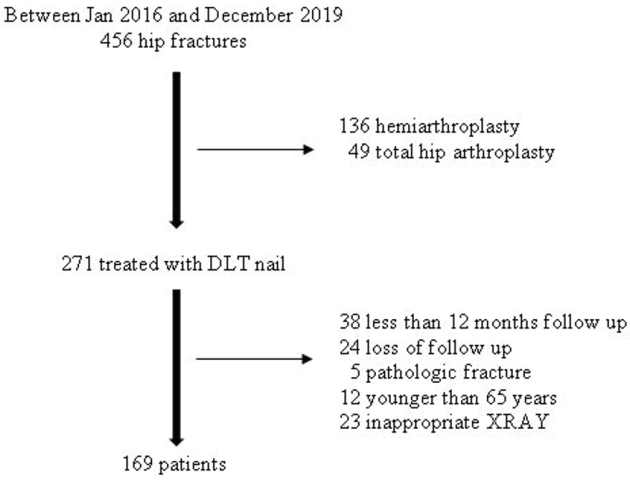

Figure 1. Flowchart showing the inclusion of the patients
DLT: Dyna locking trochanteric

the closed or open technique. Intraoperative fracture reduction and implant position were confirmed using C-arm fluoroscopy.

Radiological Evaluation

Fractures were classified according to the AO/OTA classification on preoperative anteroposterior (AP) and lateral radiographs of the hip (6).

On immediate postoperative AP and lateral radiographs of the hip,

- Fogagnolo criteria modified from Baumgartner were used to evaluate the fracture reduction. The reduction was sub-grouped as good, acceptable, or poor (7).

- Varus and valgus malalignment were evaluated by measuring the neck-shaft angle of both hips, with malalignment accepted as >5° varus or >15° valgus compared to the contralateral hip (8).

- TAD was measured as described by Baumgartner (9).

- The position of the lag screw was determined according to the Cleveland and Bosworth method, in which central-central and inferior-central placement of the lag screw is accepted as the optimal position, and any other placement is suboptimal (10).

All fracture classifications, radiological evaluations, and measurements were performed by an independent observer.

Follow-up Protocol

Immediate weight-bearing as tolerated was permitted for all patients. Follow-up examinations, both radiological and clinical, were carried out at 3-week intervals until the third month, and after that every 3 months until the end of the year. The patients were informed that if any complaints developed, they should attend immediately without waiting for a routine follow-up appointment. In all patients, bone mineral density (BMD) measurements were taken using dual energy X-ray absorptiometry within 3 weeks after surgery.

Statistical Analysis

Data were analyzed using SPSS for Windows (version 15.0) software (SPSS Inc., Chicago, IL, USA). The conformity of the data to a normal distribution was evaluated using the Kolmogorov-Smirnov test. For assessing the study data, in addition to descriptive statistical methods (average, standard deviation, median, frequency, ratio, minimum, maximum), the Independent samples t-test was used to compare normally distributed parameters between the groups and the Kruskal-Wallis test and Mann-Whitney U test were used to compare non-normally distributed parameters between the groups in the comparison of quantitative data. Categorical data were compared using the chi-square and Fisher's Exact tests. A value of $p<0.05$ was accepted as statistically significant.

RESULTS

The data of the patients, including fracture classification and reduction type, reduction quality of the fracture, lag screw position in the femoral head, TAD measurements, surgical position, and BMD measurements are shown in Table 1.

Complications

A total of 57 complications were determined, of which 14 (8.2%) were cut-out, cut-through, and intrapelvic migration of the lag screw, and distal peri-implant fractures requiring additional surgical interventions (Table 2).

Cut-out, Cut-through and Intrapelvic Migration

These complications were determined in 11 patients (6.5%), comprising 9 cut-out, 1 cut-through, and 1 intrapelvic migration, which required revision (Figure 2, 3). These complications were seen at a mean 3.6±4 months (range, 2 weeks -15 months) after surgery.

Varus Collapse

Varus collapse was accepted as a difference of >5° between the immediate postoperative and final follow-up X-ray measurements. Varus complication was the most frequently seen complication, determined in 36 patients at mean 2.5±1 months (range, 3 weeks-5 months) after surgery.

A statistically significant association was found between suboptimal lag screw placement, decreased BMD, TAD measurement >25 mm, and decreased reductin quality,

Table 1. Data related to fracture classification and reduction type, reduction quality of the fracture, lag screw placement in the femoral head, tip-apex distance measurements, patient positioning and bone mineral density measurements

		n	%
Fracture type	31-A1	31	18.3
	31-A2	125	74.0
	31-A3	13	7.7
Patient positioning	Lateral decubitus	48	28.4
	Supine, manual traction	38	22.5
	Supine, traction table	83	49.1
Reduction type	Open	4	2.4
	Closed	165	97.6
Reduction quality	Good	47	27.8
	Acceptable	102	60.4
	Poor	20	11.8
BMD	Normal	51	30.2
	Osteopenia	39	23.1
	Osteoporosis	79	46.7
Lag screw placement	Suboptimal	60	35.5
	Optimal	109	64.5
TAD	>25 mm	28	16.6
	≤25 mm	141	83.4

BMD: Bone mineral density, TAD: Tip-apex distance

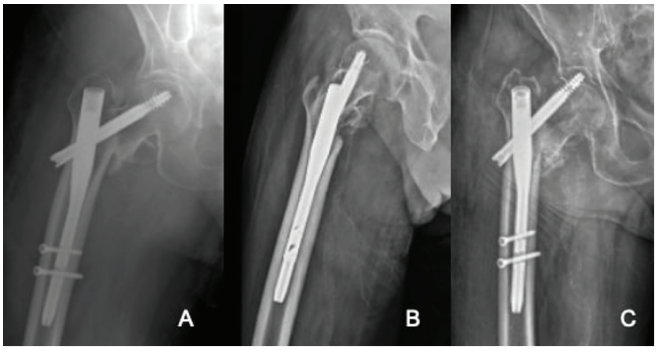

Figure 2 A, B, C. Immediate postoperative X-rays (A, B) showing suboptimal lag screw placement, TAD >25 mm and an acceptable reduction, resulted with cut-out (C) after 3 week
TAD: Tip-apex distance

with cut-out, cut-through, intrapelvic migration, and varus collapse (Table 3). Varus collapse was seen at a significantly low rate in AO/OTA 31-A1 type fractures and in surgeries performed with the use of a traction table (p=0.004, p<0.001). No association was determined between cut-out, cut-through, intrapelvic migration and fracture type and patient positioning (p=0.542, p=0.632) (Table 3).

The optimal lag screw placement and TAD measurements were statistically significantly better in patients who were treated on a traction table compared with the manual traction and lateral decubitus groups (p<0.001, p<0.001) (Table 4).

DISCUSSION

Hip fractures are one of the most common fractures requiring surgical intervention in the aging population and have an important place in routine orthopaedic practice worldwide. It can be defined as a fracture requiring urgent treatment as delayed treatment results in increased mortality rates (11).

The most appropriate implant for use in internal fixation of trochanteric femur fractures remains a matter of controversy (12-14). Osteoporosis and fracture stability are issues affecting whether cephalomedullary nail or extramedullary implants should be used (15). However, cephalomedullary nails are the most frequently preferred implants regardless of the experience of the surgeon, and the use of these nails has become accepted worldwide over the last three decades (3,16). Cephalomedullary nails have biomechanical superiority in respect to axial load sharing compared to extramedullary implants, and therefore have better failure resistance for unstable trochanteric fractures (17-19). In this study, DLT nail

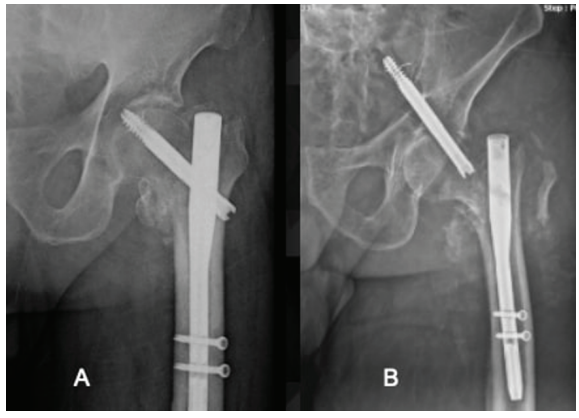

Figure 3 A, B. Cut-through (A) and intra pelvic migration of the lag screw (B) are less commonly seen complications, which are affected from surgeon dependent factors including fracture reduction, lag screw position and TAD
TAD: Tip-apex distance

Table 2. Complications of the patients

Complications			
Cut-out, cut-through and intrapelvic migration	**n (%)**	**Others**	**n (%)**
Cut-out	9 (5.3)	Varus collapse	36 (21.3)
Cut-through	1 (0.6)	Distal peri-implant fracture	3 (1.8)
Intrapelvic migration	1 (0.6)	-	-

Table 3. P-values for factors accompanying to cut-out, cut-through, intrapelvic migration and varus collapse

		Cut-out, cut-through and intrapelvic migration	p-value	Varus collapse	p-value
		n (%)		n (%)	
Lag screw placement	Suboptimal	10 (90.9%)	0.000*	36 (29.3%)	0.000*
	Optimal	1 (9.1%)		0 (0.0%)	
BMD	Normal	0 (0.0%)	0.028*	4 (7.8%)	0.000*
	Osteopenia	1 (9.1%)		6 (15.8%)	
	Osteoporosis	10 (90.9%)		26 (37.7%)	
TAD	≤25 mm	1 (9.1%)	0.000*	20 (14.3%)	0.000*
	>25 mm	10 (90.9%)		16 (88.9%)	
Reduction quality	Good	0 (0.0%)	0.000*	2 (4.3%)	0.000*
	Acceptable	2 (18.2%)		23 (23.0%)	
	Poor	9 (81.8%)		11 (100%)	
Patient positioning	Supine, traction table	1 (9.1%)	0.632*	7 (8.5%)	0.000*
	Supine, manual traction	6 (54.5%)		16 (50%)	
	Lateral decubitus	4 (36.4%)		13 (29.5%)	
Fracture type (AO/OTA)	31A1	1 (9.1%)	0.542*	2 (6.7%)	0.004*
	31A2	8 (72.7%)		28 (23.9%)	
	31A3	2 (18.2%)		6 (54.5%)	

*Chi-square test. BMD: Bone mineral density, TAD: Tip-apex distance, AO/OTA: AO Foundation/Orthopedic Trauma Association

Table 4. Lag screw placement according to the surgical patient positioning

Lateral decubitus		Patient positioning: Supine manual traction	Supine traction table		p-value
		n (%)	n (%)	n (%)	
TAD	≤25 mm	40 (83.3%)	20 (52.6%)	81 (97.6%)	0.000*
	>25 mm	8 (16.7%)	18 (47.4%)	2 (2.4%)	
Screw position	Optimal	30 (62.5%)	10 (26.3%)	69 (83.1%)	0.000*
	Suboptimal	18 (37.5%)	28 (73.7%)	14 (16.9%)	

*Chi-square test. TAD: Tip-apex distance

was used for all patients as the implant for internal fixation. This nail has three wedge wings on the lag screw for better purchase in the osteoporotic femoral head and has the biomechanical advantages of an intramedullary nail (4,5).

Many studies of trochanteric femur fractures in the geriatric patient population have focused on complications after internal fixation (8,20,21). In the current study cut-out, cut -through and intrapelvic migration was determined in 11 patients (6.5%), including 9 cut-out, 1 cut-through, and 1 intrapelvic migration. The cut-out rates are mixed for DLT nail, with a rate of 25% reported in one study, and no cases in another (4, 5). Some risk factors have been well described for cut-out, cut-through, and intrapelvic migration. A meticulous surgical technique including good reduction quality, TAD measurement <25 mm and central-central or inferior-central placement of the lag screw are modifiable and essential factors for avoiding complications and obtaining better surgical outcomes (2,8,22,23). The current study findings were similar to previous reports in the literature, which have shown a significant association between increased cut-out, cut-through, intrapelvic migration and suboptimal screw placement, TAD of >25 mm, and poor reduction quality.

The surgical interventions in the current study were performed in three different surgical positions according to the surgeons preference: supine with a traction table, supine with manual traction, and lateral decubitus position. The use of a traction table resulted in more favorable TAD measurements and lag screw placement compared with manual traction and the lateral decubitus position. Cut-out, cut-through, and intrapelvic migration were also seen to be fewer, but the difference was not statistically significant.

Varus collapse is another frequently seen complication resulting in femoral shortening and alterations in the gait (4,24,25). In a biomechanical study by Tisherman et al. (26), it was reported that distal locking of the nail could prevent collapse in cases with an osteoporotic unstable fracture pattern. Using a helical blade rather than a lag screw, especially in reverse oblique and transverse fractures, has also been suggested as another preventative method against collapse (25). Selecting the appropriate nail

diameter to fill the medulla has a movement-limiting effect, and may therefore slow the rate of varus collapse (27). As using a helical blade and selecting a large nail are methods that provide better purchase in osteoporotic bone, this suggests that BMD has an important impact on varus collapse. The findings of the current study support this view with the determination of a significant association between a higher rate of varus collapse and decreased BMD. The findings of the current study also revealed a relationship between suboptimal screw placement, TAD measurement >25 mm, poor fracture reduction, unstable fracture pattern, and a higher rate of varus collapse. Patients who underwent surgery on a traction table suffered less varus collapse, which could be attributed to more favorable lag screw placement.

Peri-implant fracture is another devastating complication reported at rates of 1.7% and 2.3% in two meta-analyses, and which was seen in 3 (1.8%) patients in the current study (14,28). Distal locking is a controversial issue in peri-implant fractures and has been thought to be due to the nail tip leading to increased stress concentration, and thereby causing secondary fractures (29). However, this hypothesis was disproved by the same author, suggesting that distal locking served to prevent postoperative femoral fractures (30). Using long nails and slotting of the distal tip of short nails has been shown to result in lower rates of peri-implant fracture (31,32). Increased femoral bowing was determined in all 3 patients in the current study. Skála-Rosenbaum et al. (30) stated that increased femoral bowing and the distal tip of the nail touching the anterior femoral cortex may cause fracture through increased stress concentration. As a technical trick, choosing a slightly anterior entry point in the sagittal plane may permit the nail tip to be oriented from anterior to posterior, and thus a space can be provided between the anterior femoral cortex and the distal nail tip.

There were some limitations to this study, primarily the retrospective design, and that only the results of DLT nail were presented without comparison with any other implant. The preoperative functional status, comorbidities, and postoperative functional outcomes of the patients were not assessed. The interventions were performed by several different surgeons. There is need for further prospective, randomized studies comparing the DLT nail with other implants to provide more valuable information. However, this study can be considered of value as it included the largest number of patients treated with DLT nails.

CONCLUSION

The complication rates for DLT nails are comparable to those for other implants. Decreased BMD, suboptimal lag screw position in the femoral head, a TAD >25 mm, unstable fracture patterns, and poor reduction quality impact complications. Performing the surgical intervention on a traction table provides more favorable lag screw placement. The DLT nail can be used safely for internal fixation of trochanteric femur fractures with care taken to apply a meticulous surgical technique.

ETHICS

Ethics Committee Approval: Approval was obtained from the Clinical Research Ethics Committee of Marmara University Faculty of Medicine (protocol code: 01.2020.578, date: 21.01.2020).

Informed Consent: Informed consent was provided by all patients, by their parents/legal guardians.

Authorship Contributions

Surgical and Medical Practices: S.İ., Concept: S.İ., T.O., Design: S.İ., T.O., Data Collection or Processing: S.İ., Analysis or Interpretation: T.O., Literature Search: S.İ., T.O., Writing: S.İ., T.O.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

REFERENCES

1. Chang SM, Hou ZY, Hu SJ, Du SC. Intertrochanteric Femur Fracture Treatment in Asia: What We Know and What the World Can Learn. Orthop Clin North Am 2020;51:189-205.
2. Haidukewych GJ. Intertrochanteric fractures: ten tips to improve results. J Bone Joint Surg Am 2009;91:712-9.
3. Niu E, Yang A, Harris AH, Bishop J. Which Fixation Device is Preferred for Surgical Treatment of Intertrochanteric Hip Fractures in the United States? A Survey of Orthopaedic Surgeons. Clin Orthop Relat Res 2015;473:3647-55.
4. Temiz A, Durak A, Atici T. Unstable intertrochanteric femur fractures in geriatric patients treated with the DLT trochanteric nail. Injury 2015;46 Suppl 2:S41-6.
5. Gunay C, Atalar H, Altay M, Yavuz OY, Yildirim AO, Oken OF. Does the wedge wing in the neck screw prevent cut-out failure in Ota/AO 31-A2 trochanteric fractures in elderly patients? Acta Orthop Belg 2014;80:26-33.
6. Meinberg EG, Agel J, Roberts CS, Karam MD, Kellam JF. Fracture and Dislocation Classification Compendium-2018. J Orthop Trauma 2018;32 Suppl 1:S1-170.
7. Fogagnolo F, Kfuri M Jr, Paccola CA. Intramedullary fixation of pertrochanteric hip fractures with the short AO-ASIF proximal femoral nail. Arch Orthop Trauma Surg 2004;124:31-7.

8. Ciufo DJ, Zaruta DA, Lipof JS, Judd KT, Gorczyca JT, Ketz JP. Risk Factors Associated With Cephalomedullary Nail Cutout in the Treatment of Trochanteric Hip Fractures. J Orthop Trauma 2017;31:583-8.

9. Baumgaertner MR, Curtin SL, Lindskog DM, Keggi JM. The value of the tip-apex distance in predicting failure of fixation of peritrochanteric fractures of the hip. J Bone Joint Surg Am 1995;77:1058-64.

10. Cleveland M, Bosworth DM, Thompson FR. Intertrochanteric fractures of the femur; a survey of treatment in traction and by internal fixation. J Bone Joint Surg Am 1947;29:1049-67.

11. Leer-Salvesen S, Engesæter LB, Dybvik E, Furnes O, Kristensen TB, Gjertsen JE. Does time from fracture to surgery affect mortality and intraoperative medical complications for hip fracture patients? An observational study of 73 557 patients reported to the Norwegian Hip Fracture Register. Bone Joint J 2019;101-B:1129-37.

12. Socci AR, Casemyr NE, Leslie MP, Baumgaertner MR. Implant options for the treatment of intertrochanteric fractures of the hip: rationale, evidence, and recommendations. Bone Joint J 2017;99-B:128-33.

13. Reindl R, Harvey EJ, Berry GK, Rahme E; Canadian Orthopaedic Trauma Society (COTS). Intramedullary Versus Extramedullary Fixation for Unstable Intertrochanteric Fractures: A Prospective Randomized Controlled Trial. J Bone Joint Surg Am 2015;97:1905-12.

14. Parker MJ, Handoll HH. Gamma and other cephalocondylic intramedullary nails versus extramedullary implants for extracapsular hip fractures in adults. Cochrane Database Syst Rev 2010:CD000093.

15. Krischak G, Dürselen L, Röderer G. Versorgung pertrochantärer Femurfrakturen: Biomechanische Überlegungen [Treatment of peritrochanteric fractures: biomechanical considerations]. Unfallchirurg 2011;114:485-90.

16. Bhandari M, Schemitsch E, Jönsson A, Zlowodzki M, Haidukewych GJ. Gamma nails revisited: gamma nails versus compression hip screws in the management of intertrochanteric fractures of the hip: a meta-analysis. J Orthop Trauma 2009;23:460-4.

17. Rosenblum SF, Zuckerman JD, Kummer FJ, Tam BS. A biomechanical evaluation of the Gamma nail. J Bone Joint Surg Br 1992;74:352-7.

18. Mahomed N, Harrington I, Kellam J, Maistrelli G, Hearn T, Vroemen J. Biomechanical analysis of the Gamma nail and sliding hip screw. Clin Orthop Relat Res 1994:280-8.

19. Curtis MJ, Jinnah RH, Wilson V, Cunningham BW. Proximal femoral fractures: a biomechanical study to compare intramedullary and extramedullary fixation. Injury 1994;25:99-104.

20. Liu W, Zhou D, Liu F, Weaver MJ, Vrahas MS. Mechanical complications of intertrochanteric hip fractures treated with trochanteric femoral nails. J Trauma Acute Care Surg 2013;75:304-10.

21. Horner NS, Samuelsson K, Solyom J, Bjørgul K, Ayeni OR, Östman B. Implant-Related Complications and Mortality After Use of Short or Long Gamma Nail for Intertrochanteric and Subtrochanteric Fractures: A Prospective Study with Minimum 13-Year Follow-up. JB JS Open Access 2017;2:e0026.

22. Lobo-Escolar A, Joven E, Iglesias D, Herrera A. Predictive factors for cutting-out in femoral intramedullary nailing. Injury 2010;41:1312-6.

23. De Bruijn K, den Hartog D, Tuinebreijer W, Roukema G. Reliability of predictors for screw cutout in intertrochanteric hip fractures. J Bone Joint Surg Am 2012;94:1266-72.

24. Gausden EB, Sin D, Levack AE, Wessel LE, Moloney G, Lane JM, et al. Gait Analysis After Intertrochanteric Hip Fracture: Does Shortening Result in Gait Impairment? J Orthop Trauma 2018;32:554-8.

25. Goodnough LH, Wadhwa H, Tigchelaar SS, Pfaff K, Heffner M, Van Rysselberghe N, et al. Cephalomedullary helical blade is independently associated with less collapse in intertrochanteric femur fractures than lag screws. Eur J Orthop Surg Traumatol 2021;31:1421-5.

26. Tisherman RT, Hankins ML, Moloney GB, Tarkin IS. Distal locking of short cephalomedullary nails decreases varus collapse in unstable intertrochanteric fractures - a biomechanical analysis. Injury 2021;52:414-8.

27. Durusoy S, Paksoy AE, Korkmaz M, Dağlar B, Elibol FKE. The effect of medullary fill on varus collapse in AO 31A3 intertrochanteric (reverse obliquity) fracture treated with cephalomedullary nails. Orthop Traumatol Surg Res 2021;107:102804.

28. Norris R, Bhattacharjee D, Parker MJ. Occurrence of secondary fracture around intramedullary nails used for trochanteric hip fractures: a systematic review of 13,568 patients. Injury 2012;43:706-11.

29. Skála-Rosenbaum J, Bartonícek J, Bartoska R. Is distal locking with IMHN necessary in every pertrochanteric fracture? Int Orthop 2010;34:1041-7.

30. Skála-Rosenbaum J, Džupa V, Bartoška R, Douša P, Waldauf P, Krbec M. Distal locking in short hip nails: Cause or prevention of peri-implant fractures? Injury 2016;47:887-92.

31. Soylemez MS, Uygur E, Poyanli O. Effectiveness of distally slotted proximal femoral nails on prevention of femur fractures during and after intertrochanteric femur fracture surgery. Injury 2019;50:2022-9.

32. Lindvall E, Ghaffar S, Martirosian A, Husak L. Short Versus Long Intramedullary Nails in the Treatment of Pertrochanteric Hip Fractures: Incidence of Ipsilateral Fractures and Costs Associated With Each Implant. J Orthop Trauma 2016;30:119-24.