ORIGINAL ARTICLE

The effect of bone morphology on fracture type and treatment result in patients with intertrochanteric femur fracture aged over 65 years

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ABSTRACT

BACKGROUND: We aimed to investigate the effect of bone morphology on fracture type and treatment result in patient with intertrochanteric fracture (IFF) treated with intramedullary nailing (IMN) aged over 65 years. Primary outcome of study was to investigate the relationship between fracture type (stable or unstable) and bone density.

METHODS: This was a retrospective cohort study conducted at single trauma center which included patients aged >65 years, minimum 3 months' control postoperatively, patients with simple fall by evaluating the patient data from 2010 to 2021. All fractures were classified based on the AO classification system. Proximal femoral nail anti-rotation was used between 2010 and 2016, while InterTAN was used after 2016 in our clinic practice. For the evaluation of the bone morphology, we measured the canal-to-calcar ratio (CCR) and cortical thickness index (CTI) and classified with Dorr morphology on anteroposterior (AP) hip radiograph of both the fracture side and contralateral sides. Complications were also evaluated on radiological view. Failures were defined as non-union or failure of fixation. Excessive collapse and screw/blade prominence also evaluated by hip radiograph on the 3rd month control visit.

RESULTS: One hundred and fifty females and 59 males were included in this study. The average age was 81.6±8.8 years. One hundred and forty-four patients were treated with InterTAN and 65 patients with helical blade type IMN (PFN-A®). There were 78 patients with stable IFF type A1 fracture and 131 patients with unstable IFF (109 patients with A2 and 22 patients with A3 AO type fracture). The mean CTI was 0.469±0.09 and 0.510±0.09 in the fracture and unaffected side femurs, respectively (p<0.001), the CCR was 0.636±0.15 and 0.568±12 in the fracture and unaffected side femurs, respectively (p<0.001). There were 36 patients with Dorr type A, 115 patients with Dorr type B, and 48 patients with Dorr type C in fracture side and 65 patients with Dorr type A, 123 patients with Dorr type B, and 21 patients with Dorr type C in non-affected side (p<0.001). There were 29 (13.9%) patients with screw (n=14) and blade (n=15) prominence. Excessive collapse was seen 30 patients (14.4%) and 16 patients (7.7) evaluated as a failure.

CONCLUSION: We found a significant difference in the failure rate between unstable group than stable group which higher in unstable group according to the AO classification. In addition, the mean CTI, CCR, and Dorr index were significant difference in fractured side than unaffected side which indicated lower bone quality at fracture side.

Keywords: Bone morphology; failure; geriatric fracture; intertrochanteric fracture.

INTRODUCTION

Hip fractures are known to have a significant impact morbidity and mortality in the patients with aged over 65 years.[1] Intertrochanteric femur fracture (IFF) which is an extra-capsular hip fracture is a major global issue, especially in elderly patients, and the incidence of IFF is steadily rising.[2] An intramedullary nail (IMN) is widely used as a surgical treatment option for these fractures in elderly patients due to less invasive and more stable.[3]

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Despite the advances in orthopedic devices and operative intervention, failure rates up to 56% have been reported in the literature.[4] Fixation failure can lead to increased pain, immobility, and the need for additional surgical intervention. The previous studies have demonstrated that various related factors, including bone quality, fracture morphology, fracture reduction, fixation type, and implant placement, are associated with the implant failures of ITF.[5,6] The lag screw and helical blade have been developed to prevent failure in the treatment of IFF. Many studies have been investigated the failure ratio of treatment results of IFF.[7,8]

In this study, we aimed to investigate effect of bone morphology on fracture type and treatment result in patient with IFF treated with IMN aged over 65 years. The primary outcome of study was to investigate the relationship between fracture type (stable or unstable) and bone density. The secondary outcome was to investigate relationship between treatment result (complications) and also bone density and treatment modality.

MATERIALS AND METHODS

After obtained an approval from our Institutional Review Board (April 5, 2021), we retrospectively examined of trauma department for selecting data of patients who were treated with IMN for IFF. This was a retrospective cohort study conducted at single trauma center by evaluating the patient data from 2010 to 2020. Oral and written informed consent was obtained from each patient. Medical histories and hip radiography were assessed from the patients' medical registration files. Patients aged >65 years, minimum 3 months' control postoperatively, and patients with simple fall were included for this study. Patient with patients treated conservatively, with radiographic follow-up <90 days, patients death in the first 3rd month postoperatively, history of hip surgery on the fracture side, bilateral hip fracture or surgery history of unaffected side, fracture due to high-energy trauma, patients treated with hemiarthroplasty, history of malignancy, or pathological fracture were excluded from this study. In general, patients with hip fracture are monitored with overall health status in hospital stay, 3-month radiological and functional outcome, and 1-year mortality. Hence, we determined that the 3-month period following surgery can identify the majority of complications after surgery.

Operative Procedure

All patients were operated in the supine position with traction table with general or regional anesthesia. Closed reduction was performed after anesthesia procedure completed. Standard 2 g cefazolin was administered for surgical prophylaxis. After sterile preparing the patients with draped using antimicrobial drape, a guidewire was inserted in the appropriate entry site with the help of fluoroscopy view, then, 5 cm incision was performed just proximal to the greater trochanter and the trochanteric region reaming was performed. Short sized nail was inserted over the guide wire. Following the insertion of the nail, the reduction of the fracture was assessed with fluoroscopic AP and lateral view. Proximal locking screws (InterTAN® [Smith and Nephew, Memphis, TN]) (Fig. 1) or helical blade (Synthes, Oberdorf, Switzerland) (Fig. 2) was inserted after the release of traction. Finally, distal locking was done. We used these two implants in our clinic between different dates. Proximal femoral nail anti-rotation (PFNA) was used between 2010 and 2016, while InterTAN was used after 2016. All patients were admitted to intensive care unit for post-operative follow-up.

Follow-up

All patients were not allowed to bear weight but allowed to walk using a walker on post-operative day 2. After discharge, patients were followed at the outpatient clinic at 2, 4, 6 weeks and third months.

All fractures were classified based on the AO classification system.[9] According to this classification system, 3-1-A1 type was considered stable fracture while A2 and A3 were

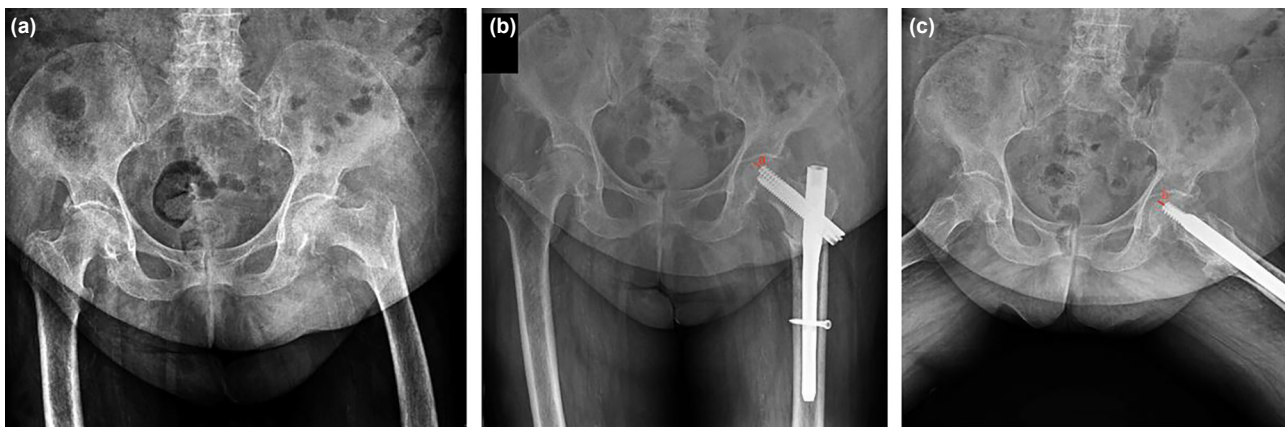

Figure 1. Pre-operative **(a)** and post-operative hip radiographs **(b** and **c)** of InterTAN group. Tip apex distance was measured anterior **(b)** and lateral **(c)** hip radiographs.

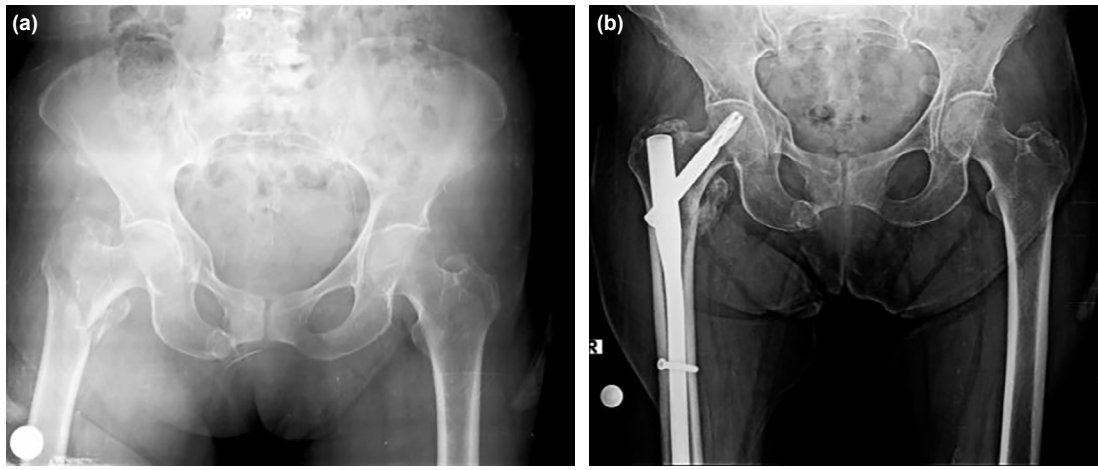

Figure 2. Pre-operative **(a)** and post-operative **(b)** hip radiographs of proximal femoral nail anti-rotation group.

considered unstable IFF. We assessed the relationship between femoral bone quality and fracture pattern and treatment results. For evaluation the bone morphology, we measured the canal-to-calcar ratio (CCR) and cortical thickness index (CTI) and classified with Dorr morphology on AP hip radiograph of both the fracture side and contralateral sides (Figs. 3 and 4).

Dorr Morphology

Type A is defined as <0.5 CCR, Type B as 0.5–0.75 CCR, and Type C as >0.75 CCR. Type A is defined as having thick cortical width and a narrow and funnel shape of the proximal femoral. Type B shows thin medial and posterior cortices, frequently with irregular endosteal surfaces. Type C has dramatically thin medial and posterior cortices with a more cylindrical shape to the proximal femoral canal.[10]

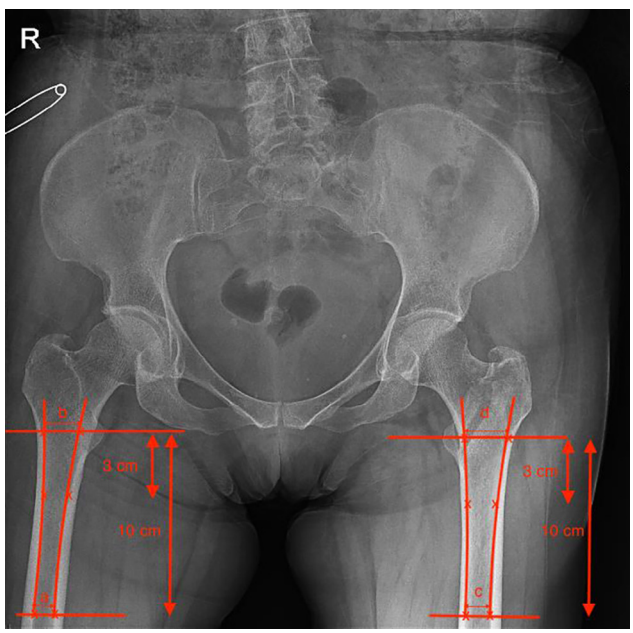

Figure 3. The figure showed the measurement of canal-to-calcar ratio. Lines at both the medial and lateral aspects of the medullary canal were placed at 3 cm and 10 cm, respectively. Lateral and medial lines were connected, and the distance between the intersections of these lines with the mid-lesser trochanteric line was measured as the calcar width. The intramedullary femoral canal width was measured as the distance between the medial and lateral markers at the 10 cm level. The canal-to-calcar ratio was calculated as the fraction of the 10 cm level width divided by the calcar canal width.

Tip Apex Distance (TAD)

TAD was also measured for all cases on AP and lateral hip radiographs taken on post-operative 1st day. The radiological evaluation and measurement were done only 1 time by two different authors independently. The inter-class correlation coefficients were found as 0.991, 95% confidence interval [CI]= 0.987–0.995).

Figure 4. Cortical thickness index was measured the intramedullary width and divided by the diaphysis width at the 10 cm below of mid-lesser trochanter (A/B ratio in fracture side and C/D non-affected side).

Complications were also evaluated by same authors independently on radiological view. Failures were defined as non-union or failure of fixation. Failure of fixation was defined as superolateral cutout or medial cutout. Excessive collapse and screw/blade prominence also evaluated by hip radiograph on the 3rd month control visit.

Statistical Analyses

All the statistical analyses were performed using the SPSS version 28.0 statistics software program (IBM Corp, 2011, Armonk, New York). Descriptive statistical methods were used to evaluate study data. Normality of distribution was tested using the Shapiro–Wilk test. Student's t-test was used for comparison of two groups of quantitative data with normal distribution; Pearson Chi-square test, Fisher-Freeman-Halton exact test, and Fisher's exact test were used to compare qualitative data. P<0.05 was considered statistically significant. Pearson correlation test was also used for association between the radiological parameters.

RESULTS

A total of 209 patients (150 females and 59 males) were included in this study. The average age was 81.6±8.8 (range 65–104) years. One hundred and five patients had left side and 104 patients with right side fracture. One hundred and forty-four patients were treated with InterTAN and 65 patients with helical blade type IMN (PFN-A®). Seventy-eight patients with stable IFF type A1 fracture and 131 patients with unstable IFF (109 patients with A2 and 22 patients with A3 AO type fracture) (Table 1).

Table 1. Baseline demographics data of all patients

n=209	Mean±SD	Min–Max	
Age, year	81.62±8.8	65–104	
Female/male	150 (71.8%)/59 (28.2%)		
Side; left/right	105/104		
Implant, intertan / PFNA	144/65		
Fracture type			
31 A1	78		
1, n	24		
2, n	48		
3, n	6		
A2	109		
1, n	36		
2, n	57		
3, n	16		
A3 22			
1, n	10		
2, n	4		
3, n	8		
Tip apex distance, AP	12.4±4.6	2.2–27	
Tip apex distance, lateral	11.5±4.7	1–26	
Cortical thickness index, fracture side	0.469±0.09	0.19–0.97	p<0.001
Cortical thickness index, unaffected side	0.510±0.09	0.27–0.81	
Canal-to-calcar ratio, fracture side	0.636±0.15	0.34–1.33	p<0.001
Canal-to-calcar ratio, unaffected side	0.568±12	0.28–0.95	
Dorr index, fracture side A/B/C	36/115/48		p<0.001
Dorr index, unaffected side A/B/C	65/123/21		
Screw/blade prominence, n	29		
Excessive collapse, n	30		
Failure ratio, n	16		
Re-operation surgery, n	5		

SD: Standard deviation; Min: Minimum; Max: Maximum; AP: Anteroposterior.

The mean CTI was 0.469±0.09 (range 0.19–0.97) and 0.510±0.09 (range 0.27–0.81) in the fracture and unaffected side femurs, respectively (p<0.001), the CCR was 0.636±0.15 (range 0.34–1.33) and 0.568±12 (range 0.28–0.95) in the fracture and unaffected side femurs, respectively (p<0.001).

There were 36 patients with Dorr type A, 115 patients with Dorr type B, and 48 patients with Dorr type C in fracture side and 65 patients with Dorr type A, 123 patients with Dorr type B, and 21 patients with Dorr type C in non-affected side (p<0.001). According to the Dorr classification, fracture side has significantly lower bone quality than contralateral hip.

There were 29 (13.9%) patients with screw (n=14) and blade (n=15) prominence. Excessive collapse was seen 30 patients (14.4%) and 16 patients (7.7) evaluated as a failure.

Baseline Characteristic Difference According to Stability of Fracture According to the AO Classification

Seventy-eight patients (60 females and 18 males) with stable IFF and 131 patients (90 females and 41 males) with unstable IFF. The mean age was 81.06±10 years in stable group and 81.95±7.8 years in unstable group. There was no significant difference between stable and unstable fracture group regarding bone morphology including CCR, CTI, and Dorr classification either fracture or unaffected femur. The baseline database of both groups was exhibited in Table 2. There was only difference which was found in the failure rate between groups which was significant higher in unstable group than stable group.

Baseline Characteristic Difference According to Implant Type

One hundred and forty-four (102 females and 42 males) patients with InterTAN group and 65 patients (48 females and 17 males) with PFNA group. The baseline database of both groups is exhibited in Table 3. The mean age was 80±9.7 years in InterTAN group and 85.2±4.5 years in PFNA group. PFNA group has significantly higher bone quality than InterTAN group in fracture side according to CCR and Dorr classification. However, there was no significant difference between the groups regarding CCR and Dorr at unaffected side. The TAD was also significant higher in InterTAN group than PFNA group in AP and lateral measurement. Although the TAD was significant shorter in PFNA group, less blade prominence was detected in the InterTAN group (p=0.010).

Fracture type and unaffected side CTI were significant correlation with failure rate (p=0.005, r=0.195; p=0.043 r=−0.143, respectively). Statistically significant relationships were found between fracture side CCR and collapse rate (p=0.014, r=0.171).

Table 2. Comparison of radiological parameters between stable and unstable group

	Stable Group (n=78)		Unstable group (n=131)		p value
	Mean±SD	Min–Max	Mean±SD	Min-Max	
Age, years	81.06±10	65–99	81.95±7.8	65–104	0.482
Gender, female/male	60/18		90/41		0.131
Treatment modality, intertan/PFNA	62/16		82/49		0.003
Fracture side					
Cortical thickness index	0.477±0.11	0.27–0.97	0.469±0.08	0.26–0.69	0.606
Canal-to-calcar ratio	0.634±0.17	0.36–1.33	0.638±0.15	0.34–1.06	0.814
Dorr type, A/B/C	15/44/19	21/81/29			0.728
Unaffected side					
Cortical thickness index	0.517±0.09	0.31–0.81	0.508±0.09	0.27–0.73	0.672
Canal-to-calcar ratio	0.581±0.13	0.28–0.95	0.559±0.11	0.31–0.89	0.270
Dorr type, A/B/C	21/47/10		44/76/11		0.429
Tip apex distance, AP					0.787
Tip apex distance, lateral					0.276
Screw/blade prominence	11		18		0.548
Excessive collapse	7		23		0.087
Failure ratio	2		14		0.026*
Revision surgery	1		4		0.383

SD: Standard deviation; Min: Minimum; Max: Maximum; AP: Anteroposterior; PFNA: Proximal femoral nail anti-rotation.

Table 3. Comparison of radiological parameters between Intertan and PFNA group

	Intertan Group (n=144)		PFNA group (n=65)		p value
	Mean±SD	Min–Max	Mean±SD	Min-Max	
Age, years	80±9.7	65–99	85.2±4.5	80–104	<0.001*
Gender, female/male	102/42		48/17		0.392
Stable/unstable	62 / 82		16/49		0.008*
Fracture side					
Cortical thickness index	0.485±0.09	0.27–0.72	0.476±0.10	0.28–0.97	0.309
Canal-to-calcar ratio	0.647±0.17	0.35–1.33	0.568±0.11	0.34–0.93	<0.001*
Dorr type, A/B/C	20/79/45		16/46/3		<0.001*
Unaffected side					
Cortical thickness index	0.530±0.09	0.31–0.81	0.476±0.09	0.27–0.67	<0.001*
Canal-to-calcar ratio	0.550±0.13	0.28–0.95	0.567±0.11	0.35–0.82	0.908
Dorr type, A/B/C	43/84/17		22/39/4		0.433
Tip apex distance, AP, mm	13.30±4.05	4–22.9	10.4±3.9	2.2–18.8	<0.001
Tip apex distance, lateral, mm	13.2±4.6	4–26.6	9.41±4	1–19	<0.001
Screw/blade prominence, n	14		15		0.010*
Excessive collapse, n	23		7		0.220
Failure, n	10		6		0.374
Re-operation, n	3		2		0.496

SD: Standard deviation; Min: Minimum; Max: Maximum; AP: Anteroposterior; PFNA: Proximal femoral nail anti-rotation.

DISCUSSION

Increasing of age may cause the thinning of cortex and the increasing of medullary cavity especially in proximal femur which is result of osteoporosis.[11] Low bone mineral density was closely related to hip fracture. The risk for hip fracture increases by a 2.6-fold for each standard deviation decrease in bone mineral density.[12] The CTI was most commonly used radiographic parameter to assess bone density.[13] In this study, we compared the bone density of the fractured side with the unaffected side of the patient who treated for intertrochanteric femur fracture due to a simple fall. In addition, we compared the bone density of stable and unstable fractures by evaluating IFFs according to the AO classification. We found that mean CTI, CCR, and Dorr index were significant difference in fractured side than unaffected side which indicated lower bone quality at fracture side.

The CTI is a good predictive value as bone mineral density which can be used for estimating osteoporosis status and prediction of fracture risk status in elderly population.[14] The CTI is also a key determinant of bone strength and fracture risk.[15] Feola et al.[16] investigated femoral cortical index for used an alternative method for indicate fracture risk using femur X-ray in 152 patients with hip fragility fractures. Similar to our result, they found a statistically significant difference between fracture side and opposite side regarding femoral cortical index. In addition, they reported that a significant correlation among low values of femoral cortical index, comorbidities, and severe hypovitaminosis D in these patients. Zhuang et al.[17] reported a study about the differences in proximal femoral geometry between femoral neck fractures (n=69, 20 men and 49 women) and trochanteric fractures (n=48 patients, 16 men and 32) in 117 fragility fractures. In that study, they found a significant difference in the cortical thickness between the two groups which CTI lower in trochanteric fracture group and emphasized that cortical thickness thinning in proximal femur may be one of the relevant factors causing different types of hip fracture in these patients. Contrary to this study, Bayram et al.[18] reported a study evaluation between radiological parameters including CTI, CCR, and survival of patients with hip fracture in 304 patients (120 patients with femoral neck fracture and 184 patients with IFF). In that study, they found no significant difference between IFF and femoral neck fracture group regarding CTI, CCR, and Dorr type. Nyholm et al.[19] investigated association between bone quality and reoperation risk in 654 patients with femoral neck fracture. In that cohort study, they reported no significant association between CTI and reoperation risk, however, CTI was related with death after surgery. In our study, we compared fracture and unaffected side of proximal femur measurement and found that mean CTI, CCR, and Dorr index were significant difference in fractured side than unaffected side which indicated lower bone quality at fracture side. In addition, fracture type and unaffected side CTI were significant correlation with failure rate.

There are many studies about analyses of treatment result of IFF after different types of implant regarding IMN. Serrano et al.[20] reported a study about treatment result using either a single sliding lag screw or an integrated compressed and locked, dual screw, and cephalomedullary nail construct in patient with IFF. They found that IMN with two integrated proximal screws that can be compressed and then locked seems to maintain initial IFF reduction and subsequent position over time, with less varus collapse and less shortening than a single screw device. Liu et al.[21] reported a meta-analysis about comparison of PFNA versus InterTAN nail for the treatment of IFF which consisted of two randomized controlled studies and seven observational studies including 681 patients treated with PFNA and 651 patients with InterTAN. In that study, according to the literature, the risk of the screw migration, the varus collapse of the femoral head, and femoral shaft fracture treated by InterTAN nail were significantly decreased. Another study, Onggo et al.[22] investigated a meta-analysis and systematic review about the safety and efficacy of dual lag screw IMN compared with single lag screw IMN including InterTAN, PFNA, and Gamma-3 Nails which included 15 studies and consisting of 2643 patients. In that study, InterTAN was associated with lower complication rates in terms of all-cause revisions, cutouts, and medial or lateral screw migration and emphasized that dual lag screw IMNs are associated with fewer revisions and complications. In our study, PFNA group has significantly higher bone quality than InterTAN group in fracture side according to CCR and Dorr classification. The TAD was also significant higher in InterTAN group than PFNA group in AP and lateral measurement. Although the TAD was significant shorter in InterTAN group, less blade prominence was detected in the InterTAN group.

This study had several limitations. First, our study was a small sample size and retrospective nature. Our patients had shorter post-operative follow-up period, more complications could be detected with longer follow-up. We could not obtain the weight-bearing status in these patients which the weight-bearing time is also correlated with implant failures. Finally, body mass index and bone mineral density were not assessed which affect the post-operative results.

Conclusion

In this study, we assessed bone morphology of patients with IFF aged over 65 years treated with IMN and relationship with fracture type and treatment result. We found a significant difference in the failure rate between unstable groups than stable group which higher in unstable group according to the AO classification. We found that mean CTI, CCR, and Dorr index were significant difference in fractured side than unaffected side which indicated lower bone quality at fracture side. Patients treated with PFNA group have significantly higher bone quality than InterTAN group in fracture side according to CCR and Dorr classification. Although the TAD was significant shorter in InterTAN group, less blade prominence was detected in the InterTAN group. Statistically significant relationships were found between fracture side CCR and collapse rate.

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Ethics Committee Approval: This study was approved by the İstanbul University İstanbul Faculty of Medicine Clinical Research Ethics Committee (Date: 05.04.2021).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: G.P.; Design: S.B.; Supervision: H.D.; Data: Y.S.G., O.A., A.K.; Analysis: S.B.; Literature search: G.P.; Writing: S.B.; Critical revision: G.P., H.D.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Altmış beş yaş üstü intertrokanterik femur kırığı hastalarında kemik morfolojisinin kırık tipine ve tedavi sonucuna etkisi

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AMAÇ: İntramedüller çivileme (IMÇ) ile tedavi edilen 65 yaş üstü intertrokanterik kırıklı hastada kemik morfolojisinin kırık tipine ve tedavi sonucuna etkisini araştırmayı amaçladık. Çalışmanın birincil sonucu, kırık tipi (stabil veya stabil olmayan) ile kemik yoğunluğu arasındaki ilişkiyi araştırmaktır.
GEREÇ VE YÖNTEM: Bu, tek travma merkezinde yürütülen, 2010–2021 yılları arasında hasta verilerinin değerlendirildiği, ameliyat sonrası en az üç aylık kontrol, ameliyat sonrası en az üç ay kontrolü olan hastaları içeren, tek bir travma merkezinde yürütülen geriye dönük bir kohort çalışmasıdır. Tüm kırıklar AO sınıflandırma sistemine göre sınıflandırıldı. Kliniğimizde 2010–2016 yılları arasında PFNA, 2016 yılından sonra ise intertan kullanılmıştır. Kemik morfolojisinin değerlendirilmesi için hem kırık tarafının hem de karşı tarafın ön-arka kalça radyografisinde kanal-kalkar oranını (KKO), kortikal kalınlık indeksi (KKİ) ölçüldü ve Dorr morfolojisine göre sınıflandırıldı. Komplikasyonlar da radyolojik olarak değerlendirildi. Başarısızlıklar kaynamama veya fiksasyon yetersizliği olarak tanımlandı. Üçüncü ay kontrol vizitinde kalça grafisi ile aşırı kollaps ve vida belirginliği de değerlendirildi.
BULGULAR: Bu çalışmaya 150 kadın ve 59 erkek dahil edildi. Ortalama yaş 81.6±8.8 yıldı. Yüz kırk dört hasta Intertan ile ve 65 hasta bıçak tipi IMÇ (PFNA) ile tedavi edildi. Stabil intertrokanterik (A1 tipi) kırığı olan 78 hasta, stabil olmayan olan 131 hasta (A2 tipi 109 hasta ve A3 AO tipi kırığı olan 22 hasta) vardı. Ortalama KKİ kırık ve etkilenmemiş femurlarda sırasıyla 0.469±0.09 ve 0.510±0.09 ($p<0.001$), KKO kırık ve etkilenmemiş femurlarda sırasıyla 0.636±0.15 ve 0.568±12 idi ($p<0.001$) olarak saptandı. Kırık tarafında 36 hasta Dorr tip A, 115 hasta Dorr tip B ve 48 hasta Dorr tip C ve kırık olmayan tarafta is 65 hasta Dorr tip A, 123 hasta Dorr tip B ve 21 hasta Dorr tip C olarak saptandı ($p<0.001$). Vida (n=14) ve bıçak (n=15) belirginliği olan 29 (%13.9) hasta vardı. Otuz hastada (%14.4) aşırı kollaps görüldü ve 16 hastada (7.7) yetersizlik saptandı.
TARTIŞMA: AO sınıflamasına göre stabil olmayan kırık grubunda stabil gruba göre istatistiksel olarak anlamlı olarak daha fazla yetersizlik saptadık. Ortalama KTİ, KKO ve Dorr indeksinin etkilenmeyen tarafa göre kırık tarafta anlamlı olarak düşük saptandı ki bu durum kırık tarafta daha düşük kemik kalitesi olduğunu gösterir.
Anahtar sözcükler: Geriatrik kırık; intertrokanterik kırık; kemik morfolojisi; yetersizlik.

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