ÖZGÜN ARAŞTIRMA ORIGINAL RESEARCH

Med J SDU / SDÜ Tıp Fak Derg ▶ 2020:27(1):31-38 doi: 10.17343/sdutfd.540669

PITFALL IN FEMORAL INTRAMEDULLAR NAIL APPLICATIONS IN ELDERLY PATIENTS

YAŞLI HASTALARDA FEMUR İNTRAMEDÜLLER ÇİVİ UYGULAMALARINDA TUZAKLAR

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Cite this article as: Ogur HU, Çiloğlu O, Seyfettinoğlu F,Tuhanioğlu Ü, Uslu H, Özyanyüz B. Pitfall In Femoral Intramedullar Nail Applications In Elderly Patients. Med J SDU 2020; 27(1): 31-38.

Öz

Amaç
Yaşlı osteoporotik hastalarda kalça bölgesi kırıkları kadar sık görülmesede femur cisim kırıklarıyla da karşılaşılmakta ve tedavi konusunda sorunlar yaşanabilmektedir. Çalışmanın amacı yaşlılarda düşük enerjili travma ile meydana gelen femur cisim kırıklarında kaynama problemlerini incelemek fiksasyon yönteminin yetersizliklerini değerlendirmektir.

Gereç ve Yöntem
2012- 2016 yılları arası femur cisim kırığı nedeniyle opere edilen 65 yaş üstü osteopenik ve osteoporotik (BMD≤-2) 34 hasta çalışmaya dahil edildi. 26 hastaya kapalı yöntemle kilitli intramedüller çivi(İMN), 8 hastaya açık cerrahi yöntemle kilitli İMN uygulandı, bunlardan 2'si plak yetmezliği sonrası sekonder çivi uygulaması yapılan hastalar idi. 28 kadın 6 erkek çalışmaya dahil edildi. Kırık sınıflamasında AO/OTA sınıflaması kullanıldı. 6 hasta 1/3 proksimal-orta birleşim, 20 hasta orta bölge, 8 hasta 1/3 distal-orta birleşim kesimde idi. Klinik, fonksiyonel skorlar, kaynama zamanı, desteksiz mobilizasyon süreleri ve komplikasyonlar değerlendirildi.

Bulgular
Çalışmaya katılan 34 hastanın yaş ortalaması 73.8, ortalama takip süresi 26 ay(12-36) idi. Erken dönem klinik sonuçlar,kan kaybı(187+/- 35 ml) ve kırık bölgesinde kallus görülmesi açısından kapalı uygulanan intramedüller çivilerle daha iyi sonuçlar elde edildi($p<0.001$). 6. ayın sonunda açık cerrahi ile İMN uygulanan 1 hastada kaynamama, 1 hastada kaynama gecikmesi görülürken, Primer kapalı İMN yapılan hastaların 4'ünde kaynamama ve revizyon gerekliliği oluştu. 2 hastada çivinin distalde anterior kortekse dayanması sonucu diz bölgesi ağrısı ve 1 hastada o bölgede fissür kırığı oluştu.

Sonuç
Yaşlı hastalarda osteoporoza bağlı kortekste incelme, medullada genişleme, kırık tespitinde zorluğa sebep olmaktadır. Artmış sagittal ve koronal plan eğrilikleri dolayısıyla intramedüler çivi uygulaması sırasında kırık riski artmakta, artmış sagital eğimde distalde anterior kortekse dayanma, kırık oluşturabilme ve kaynamama problemleri içerebilmektedir. Biyomekanik üstünlüklerine rağmen günümüzde mevcut olan yük paylaşıcı materyallerin (intramedüller çivi)hiçbirinin geriatrik femur diafiz kırıkları için optimum seviyede uygun olmadığı düşünülmektedir.

Anahtar Kelimeler: Femur intrameduller çivi, yaşlı hasta, tuzaklar

Abstract

Objective
Femoral shaft fractures are not seen in older patients with osteoporosis as often as fractures in the hip region, and problems may be experienced in treatment.

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Müracaat tarihi/Application Date: 15.03.2019 • Kabul tarihi/Accepted Date: 10.05.2019
Available online at http://dergipark.gov.tr/sdutfd
Makaleye http://dergipark.gov.tr/sdutfd web sayfasından ulaşılabilir.

The aim of this study was to examine union problems in femoral shaft fractures which occurred with low-energy trauma in the elderly and to evaluate deficiencies in the fixation method.

Material and Methods
The study included 34 patients with osteopenia and osteoporosis (bone mineral density ≤ -2), aged >65 years who underwent surgery for a femoral shaft fracture between 2012 and 2016. Locking intramedullary nailing (IMN) was applied to 26 patients with the closed method and to 8 patients with open surgery, and secondary nailing was applied in 2 of these patients, after plate failure. The patients comprised 28 females and 6 males. The fractures were classified according to the AO/OTA classification. In 6 patients, the fracture was in the proximal third -mid region, in 20 patients in the mid region, and in 8 patients in the distal third-mid region. The clinical and functional scores, time to union, time to unassisted mobilization, and complications were evaluated.

Results
The mean age of the 34 patients was 73.8 years, and the mean follow-up time was 26 months (range, 12-36) months. Better results were obtained from the patients who underwent closed IMN in respect of early stage clinical results, blood loss (187±35 ml) and visualization of callus in the fracture site ($p<0.001$). At the end of 6 months, non-union was seen in 1 patient and delayed union in 1 patient in the open surgery group. Non-union and revision was necessary in 4 patients of the primary closed surgery IMN group. Knee region pain developed in 2 patients as a result of the nail leaning on the anterior cortex and a fissure fracture formed in that area in 1 patient.

Conclusion
In elderly patients, difficulties in fracture fixation may be caused by thinning of the cortex and widening of the medulla, associated with osteoporosis. The risk of fracture during the application of IMN is increased because of increased sagittal and coronal plane inclines. In the increased sagittal slope, problems can include leaning on the anterior cortex, the development of fracture, and non-union. Despite the biomechanical superiority, none of the currently available load-distributing materials (IMN) can be considered appropriate at an optimum level for geriatric femoral diaphyseal fractures.

Keywords: Femoral intramedullary nail, elderly, pitfall,

Introduction

In elderly patients, proximal trochanteric region and distal femoral region fractures are seen more frequently and shaft fractures are relatively uncommon. However, in recent years, because of the increasing elderly population, the use of bisphosphonates, and various other reasons, the number of geriatric femur diaphysis fractures has increased (1-3). Stable internal fixation and a rapid start to rehabilitation are very important to avoid complications associated with immobilization in the elderly (4). There are some changes in the femur anatomy that occur together with ageing. In particular, widening is seen in the femoral medullary canal, thinning of the cortex, increased anterolateral bowing and changes in the medial femoral incline and the anatomic axis. The treatment of femur diaphysis fractures is made more difficult by these factors and they can create serious technical problems in intramedullary nailing (IMN). It should be noted that there may be insufficient fixation due to an enlarged medullary canal and femur may be broken due to increased inclination. Inspite of the technical difficulties, IMN is the most stable fixation method biomechanically, and it is applied with indirect reduction (5, 6).

The aim of this study was to investigate the complications that can be seen in elderly patients undergoing femoral IMN and to determine the ideal fixation method for this population.

Material and Methods

A retrospective evaluation was made of 34 patients (age >65 years) who underwent IMN nailing for a femoral shaft fracture between 2012 and 2016. The patients comprised 28 females (mean age: 74 years) and 6 males (mean age: 73.2years) with a mean age 73.8 (range, 65-84) years. The patients were evaluated for osteoporosis because of fractures due to low energy trauma. The degree of osteopenia and osteoporosis was determined according to the bone mineral density (BMD) value calculated from the dual-energy X-ray absorptiometry (DXA) measurements. According to the AO classification, fracture type, localization, and injury mechanism is shown in Table 1. Anteroposterior (AP) and lateral radiographs were taken of all patients and the knee and hip joints were evaluated. Patients who had to wait more than 2 days for surgery were treated with skeletal traction from the proximal tibia. The surgeries were performed by 2 different surgeons. Preoperative 1 gr cefamezin(ce-

fazolin sodium) prophylaxis was administered to all patients and completed at 24 hours in 4x1gr IV posology. Preoperative enoxaparin sodium 40 mg (clexane 0.4 mL subcutaneous, 1x1) was given and completed at 2 postoperative weeks. The clinical evaluation was made according to the Thoresen criteria (7) (Table 2). The BMD data, blood loss values, and pre-operative comorbidities of patients were recorded (Table 2, 3) and the Injury Severity Score (ISS) values were evaluated. The reasons for nonunion were investigated, and medullar expansion and increased inclination problems were evaluated.

Surgical Technique

All the patients underwent surgery in the lateral decubitus position and received a reamed antegrade intramedullary nail with trochanteric type access (Sanat Metal, Hungary). In 26 patients, IMN nailing was applied with closed fracture reduction, whereas in 8 patients IM nailing was applied with open reduction by opening the fracture line; closed reduction could not be achieved in 6 patients because of obesity, and fracture type, and in 2 patients in whom secondary nailing was applied because of plate failure. Distal and proksimal locking was provided by 2 screws.

Statistical Analysis

Data obtained in the study were analyzed statistically using the SPSS Ver. 21.0 software. Conformity of continuous variables to normal distribution was assessed using the Shapiro Wilk test. Mean differences between the groups were evaluated using Student's t-test. In the analysis of categorical data, the Chi-square test was applied, and the Fisher's exact test was used when <5 observations formed >20%. In all analyses, a value of $p<0.05$ was accepted as statistically significant.

Results

The mean follow-up time of the 34 patients was 26 months (range, 12-36). All the patients had osteopenia or osteoporosis (BMD ≤-2). There was a history of bisphosphonate use of only 1 year in 4 patients. No lateral cortex thickening and relative narrowing of the femur diaphysis diameter associated with long-term alendronate use was seen in any patients. All patients were mobilized with a walker on postoperative day one. When patients were mobilized independently with walkers, they were discharged with recommendations for home exercises. The Injury Severity Score (ISS) values were minor (1-8) in 30 patients and moderate (9-15) in 4. The mean length of hospital stay was 3 (range, 2-6) days. Better results were obtained in patients who underwent closed IMN in respect of early stage clinical results, blood loss and visualization of callus in the fracture site ($p<0.001$) (Table3). According to the Thoresen criteria, the results obtained at the final follow-up examination were evaluated as excellent in 12 of 26 patients (46%), good in 7 (27%), fair in 4 (15%), and poor in 3 (11%).

In the patients who underwent revision and open surgery (n=8), the mean blood loss value was high and callus was observed to take longer to form (Table 3). According to the Thoresen criteria, the results were evaluated as excellent in 4 of 8 patients, good in 1, fair in 2, and poor in 1. callus in the 3 cortex

Fracture union was evaluated according to the appearance of the callus at least in the 3 cortices. At the end of 6 months, non-union and, the need for revision was determined in 4 patients of the closed surgery IMN group (loosening and reversing in the distal locking screw in one patient: successful results were ob-

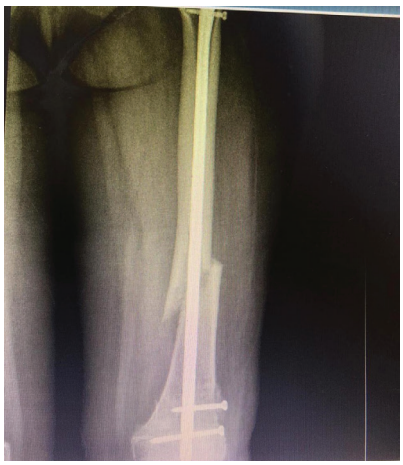

Figure 1A :
65 years old F, nonuion of fracture site

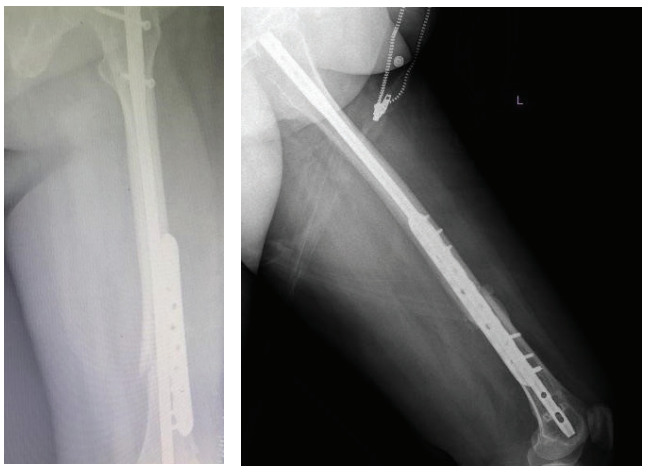

Figure 1B,C :
AP and lateral graphy after 3 month of plate augmentation

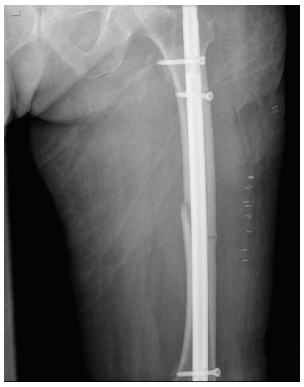

Figure 2A :
78 yr old M,femur mid-region fracture early postoperative AP radiograph after IMN

Figure 2B :
Lateral radiograph showing IMN leaning on the anterior cortex

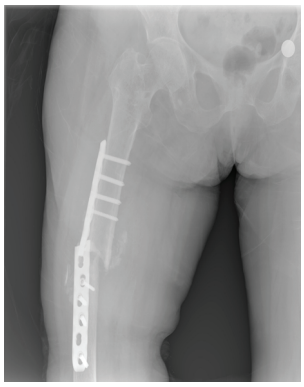

Figure 3A :
82 yr old F, Early postoperative radiograph showing failure of plate application in femur mid-region fracture

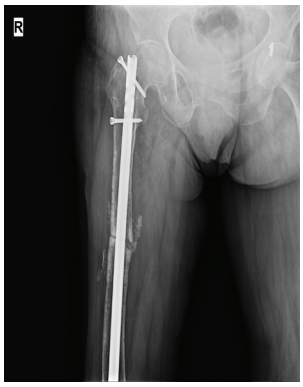

Figure 3B :
N on-union at 6 months postoperatively of IMN

tained by applying the plate without removing the nail) (Figure 1A, 1B, 1C). In 2 patients, the distal tip of the nail was leaning on the anterior cortex (Figure 2A,2B) and in 1 of these patients, a fissure fracture formed in that area. In the open surgery IMN group, delayed union was seen at the end of the 4th month in 1 patient (loosening in the distal locking screw) and non-union requiring revision was seen in 1 patient following plate failure (Figures 3A, 3B).

No statistically significant difference was determined between the patients who developed failure in respect of preoperative comorbidities (e.g. diabetes mellitus), degree of osteoporosis, history of steroid use, and smoking status ($p>0.05$) (Table 4).

Discussion

Osteoporosis is a systemic disease characterized by low bone quality and impaired bone micro-architecture. Although femoral shaft fractures are formed as a result of low-energy trauma in the elderly population, care must be taken in respect of neurovascular injury and hemodynamic instability (7-9). Moreover, the possibility of an overlooked femoral neck fracture has been reported at 5%-10% (10). The tubular structure of the femur makes intramedullary nailing the ideal method and biomechanical studies have shown the practical application and superiority of IMN in resistance to axial and torsional forces (8-12).

Before deciding on how an intramedullary implant can be used in elderly patients, the increased width of the femur, anterolateral bowing, medial femoral slope, and reasons for decreased bone density must be carefully examined on femur AP and lateral radiographs. In our patients, we observed increased femoral inclination, widened femur medullary canals, and high BMD values. Bisphosphonate and glucocorticoid- group drugs diminish the bone cycle, leading to reduced bone strength, causing the bone to be fragile and without resistance (13-16). Fractures occurring after alendronate use are known as alendronate fractures and a period of longer than 4 years' use is required for these (17). In these patients, transverse AO type 32 A3 fractures are seen more often (17-20). In the current study, as there were no patients with long-term (> 1 year) bisphosphonate use, the changes in the bone associated with these drugs (unicortical beak in the bone, thickening in the lateral cortex, narrowing of the femur diameter) were not seen and no fracture was identified as a bisphosphonate fracture.

Short oblique and transverse fractures have been seen to occur as a consequence of low-energy trauma associated with osteopenia and osteoporosis. In the current study, there was determined to be no sufficient callus in the fracture site in 4 patients who underwent locking IMN with the closed method, at the 16th week. It was seen that the bone which had not provided sufficient stability, had low union potential. Re-operation can be considered appropriate with a wider diameter intramedullary nail, taking into consideration the risk of fracture of the widened medullar canal, and with shortening and impaction if there is a medial defect.

In our study, although the alignment of the fracture was ensured, it was considered that there was a discrepancy between the nail and the sagittal slope of the femur because the intramedullary nail in the 2 patients leaned against the distal anterior cortex. Before making a decision about a medullar implant in elderly patients, evidence can be obtained from a careful pre-

operative evaluation of the femur anatomy taking AP and lateral images of the healthy contralateral side as reference.

Without taking age differentiations into account, previous studies have reported non-union rates of 0%-18% following locked IMN, and this rate is increased in unreamed nails (21, 22). In our study, we obtained a 15% (5/34) rate of non-union, similar to the literature. It can be predicted that more union problems will be encountered associated with changes in the bone metabolism in atypical femur fractures and osteoporotic bone fractures. As has been shown in experimental studies, even if the fracture healing and union of

Table 1 Fracture type, clasification and ethiology

AOFracture type	Localization of Femur Fracture	Etiology
32A1	Proximal1/3- mid region	Simple fall
32A3	Proximal1/3- mid region	Simple fall
32A3	Proximal1/3- mid region	Simple fall
32A2	Proximal1/3- mid region	Simple fall
32A3	Proximal1/3- mid region	Simple fall
32A2	Proximal1/3- mid region	Simple fall
32A3	Femur mid region	Simple fall
32A3	femur mid region	Simple fall
32A2	femur mid region	Simple fall
32A3	femur mid region	Simple fall
32A3	femur mid region	Simple fall
32A1	femur mid region	Simple fall
32A2	femur mid region	Simple fall
32A3	femur mid region	Simple fall
32B1	femur mid region	Mild severity trauma
32A2	femur mid region	Simple fall
32A1	femur mid region	Simple fall
32A3	femur mid region	Simple fall
32A1	femur mid region	Simple fall
32A3	femur mid region	Simple fall
32A2	femur mid region	Simple fall
32A3	femur mid region	Simple fall
32B1	femur mid region	Simple fall
32B2	femur mid region	Simple fall
32B1	femur mid region	Simple fall
32B1	femur mid region	Simple fall
32B1	Distal1/3-mid region	Simple fall
32B2	Distal1/3-mid region	Traffic accident
32B2	Distal1/3-mid region	Mild severity trauma
32A3	Distal1/3-mid region	
32B1	Distal1/3-mid region	Simple fall
32B2	Distal1/3-mid region	Trafic accident
32B1	Distal1/3-mid region	Simple fall
32B1	Distal1/3-mid region	Simple fall

Table 2 Classification system fort he result of treatment by Thoresen B.O. et al.,[1]

Particulars	Excellent	Good	Fair	Poor
Malalignment of femur				
Valgus or varus	5	5	10	>10
Antecurvatum or Recurvatum	5	10	15	>15
Internal rotation	5	10	15	>15
External rotation	10	15	20	>20
Shorteing of femur (em)	1	2	3	>3
Range of motion				
Flexion	>120	120	90	<90
Extension deficit	5	10	15	>15
Pain or swelling	None	minor	significant	severe

Table 3 Demographic and operating data for the different surgical methods

	Closed IMN		Open IMN		Total		
	Mean±SD	Min-Max	Mean±SD	Min-Max	Mean±SD	Min-Max	p
Age (years)	73.42±5.91	65.00-84.00	75.00±4.50	69.00-81.00	73.79±5.59	65.00-84.00	0.494
Blood loss (ml)	187.69±35.81	100.00-250.00	373.75±59.99	300.00-450.00	231.47±90.29	100.00-450.00	<0.001
Fracture callus observed	11.62±3.92	8.00-24.00	15.00±4.28	12.00-24.00	12.41±4.20	8.00-24.00	0.044
Osteoporosis	-2.63±0.43	-3.60-(-2.00)	-2.76±0.28	-3.20-(-2.40)	-2.51±0.97	-3.60-(-2.00)	0.411

p: Student's t Test

Table 4 Preoperative disease and risk factors for non-union of both groups

	Closed IMN		Open IMN		Total		
	n	%	n	%	n	%	p
Steroid							
Present	1	3.8	1	12.5	2	5.9	0.421
absent	25	96.2	7	87.5	32	94.1	
DM							
Present	12	46.2	3	37.5	15	44.1	1.00
Absent	14	53.8	5	62.5	19	55.9	
Smoking							
Present	7	26.9	2	25.0	9	26.5	1.00
Absent	19	73.1	6	75.0	25	73.5	
GIS disease							
Present	2	7.7	1	12.5	3	8.8	1.00
Absent	24	92.3	7	87.5	31	91.2	

p: Fisher Exact Test

osteoporotic bone are normal, the healing period is long (23).

While there are some studies that have reported non-unions treated with a thicker intramedullary nail (24), others have shown higher complication rates and low union rates in IMN compared with plating (25, 26). Other studies have reported high union rates with plate augmentation without removing the nail following the development of non-union after an IMN operation (27). Successful results were obtained with this method in 2 patients in this study. This method can be used in patients where a wide medullar canal is not sufficiently filled with IMN or in patients thought not to have sufficient stability after locking.

In a study of 46 patients who developed femoral non-union and a control group (n=92) with union, Taitsman et al. showed the reasons for non-union to be cigarette smoking, late weight-bearing, and open fractures (28). In the current study, even though non-union was seen more frequently in smokers, no statistically significant relationship was determined between smoking or use of medications and the development of non-union.

Conclusion

As a general principle in geriatric fractures, the weight-bearing material selected should be one with high load distribution properties. Coronal and sagittal plane deformities must be taken into consideration preoperatively and radiographs of the contralateral femur must be taken. Unfortunately, none of the currently available load-distributing materials are suitable for geriatric femur diaphysis fractures at an optimum level. In this respect, the development of specifically designed intramedullary nails could be a significant advance in the success of these types of fractures.
Study limitations: The limitations of this study were the retrospective design, the low number of patients, and the follow-up period of the patients was not sufficiently long. In addition, the grading of osteoporosis of the patients with non-union was made using BMD and other reasons were not investigated.

References

1. Court-Brown CM, Rimmer S, Prakash U, McQueen MM. The epidemiology of open long bone fractures. Injury 1998;29(7):529-534
2. Bengner U, Ekbom T, Johnell O, Nilsson BE. Incidence of femoral and tibial shaft fractures. Epidemiology 1950-1983 in Malmö, Sweden. Acta Orthop Scand 1990;61(3):251-254
3. Salminen ST,Pihlajamaki HK, Avikainen VJ, Böstman OM. Population based epidemiologic and morphologic study of femoral shaft fractures. Clin Orthop Relat Res. 2000;(372):241-249.
4. Helfet DL, Haas NP, Schatzker J, Matter P, Moser R, Hanson B. AO philosophy and principles of fracture management-its evolution and evaluation. J Bone Joint Surg Am 2003 85-A(6): 1156–1160
5. Heiney JP, Barnett MD, Vrabec GA, Schoenfeld AJ, Baji A, Njus GO .Distal femoral fixation: a biomechanical comparison of trigen retrograde intramedullary (i.m.) nail, dynamic condylar screw (DCS), and locking compression plate (LCP) condylar plate. J Trauma 2009;66:443–449
6. Giannoudis PV, Kanakaris NK, Tsiridis E. Principles of internal fixation and selection of implants for periprosthetic femoral fractures.Injury 2007;38:669-687
7. Thoresen BO, Alho A, Ekeland A, Stromsoe K, Folleras G, Haukebo A. Interlocking intramedullary nailing in femoral shaft fractures. A report of forty-eight cases. J Bone Joint Surg [Am] 19 8 5 ; 6 7 : 1313-20
8. Ostrum RF, Verghese GB, Santner TJ. The lack of association between femoral shaft fractures and hypotensive shock.J Orthop Trauma. 1993;7(4):338-42
9. Sartoretti C, Sartoretti-Schefer S, Ruckert R, Buchmann P. Comorbid conditions in old patients with femur fractures.J Trauma. 1997 Oct;43(4):570-7
10. Tornetta P 3rd, Kain MS, Creevy WR.Diagnosis of femoral neck fractures in patients with a femoral shaft fracture. Improvement with a standard protocol.J Bone Joint Surg Am. 2007 Jan;89(1):39-43
11. Lampropoulou-Adamidou K, Karampinas PK, Chronopoulos E, Vlamis J, Korres DS. Currents of plate osteosynthesis in osteoporotic bone. Eur J Orthop Surg Traumatol. 2014;24:427–33
12. Koseoglu E, Durak K, Bilgen MS, Kuçukkalp A, Bayyurt S. Comparison of two biological internal fixation techniques in the treatment of adult femur shaft fractures (plate-screws and locked intramedullary nail).Ulus Travma Acil Cerrahi Derg. 2011 Mar;17(2):159-65
13. Davis C, Stall A, Knutsen E, Whitney A, Becker E, Hsieh AH, O'Toole RV. Locking plates in osteoporosis: a biomechanical cadaveric study of diaphyseal humerus fractures. J Orthop Trauma 2012 26(4):216–221
14. Kim JH, Park YS, Oh KJ, Choi HS.Surgical treatment of severe osteoporosis including new concept of advanced severe osteoporosis.Osteoporos Sarcopenia. 2017 Dec;3(4):164-169
15. Martelli S, Pivonka P, Ebeling PR. Femoral shaft strains during daily activities: Implications for atypical femoral fractures. Clin Biomech(Bristol, Avon). 2014 Sep; 29(8):869-76
16. Sasaki S, Miyakoshi N, Hongo M, Kasukawa Y, Shimada Y. Low-energy diaphyseal femoral fractures associated with bisphosphonate use and severe curved femur: a case series. J Bone Miner Metab. 2012 Sep;30(5):561-7
17. Neviaser AS, Lane JM, Lenart BA, Edobor-Osula F, Lorich DG. Low-energy femoral shaft fractures associated with alendronate use J Orthop Trauma.2008 May-Jun;22(5):346-50
18. Einhorn TA, Bogdan Y, Tornetta P 3rd. Bisphosphonateassociated fractures of the femur: pathophysiology and treatment. J Orthop Trauma 2014;28:433-8
19. Graham J, Irgit K, Smith WR, Bowen TR. Diaphyseal femur fractures associated with bisphosphonate use. Acta Orthop Traumatol Turc 2013;47:255-60
20. Weil YA, Rivkin G, Safran O, Liebergall M, Foldes AJ. The outcome of surgically treated femur fractures associated with long-term bisphosphonate use. J Trauma 2011;71:186-90.
21. Clatworthy MG, Clark DI, Gray DH, Hardy AE. Reamed versus unreamed femoral nails. A randomised, prospective trial. J Bone Joint Surg Br. 1998;80:485–489
22. Wu CC, Shih CH, Ueng WN, Chen YJ. Treatment of segmental femoral shaft fractures. Clin Orthop Relat Res. 1993;287:224–230
23. Namkung-Matthai H, Appleyard R, Jansen J, Hao Lin J, Maastricht S, Swain M, Mason RS, Murrell GA, Diwan AD, Diamond

T (2001) Osteoporosis influences the early period of fracture healing in a rat osteoporotic model. Bone 28(1):80–86
24. Yu CW, Wu CC, Chen WJ Aseptic nonunion of a femoral shaft treated using exchange nailing. Chang Gung Med J 200225(9):591–598
25. Webb LX, Winquist RA, Hansen ST Intramedullary nailing and reaming for delayed union or non-union of the femoral shaft: a report of 105 consecutive cases. Clin Orthop 1986 212:133–141
26. Banaszkiewicz PA, Sabboubeh A, McLeod I, Maffulli N Femoral exchange nailing for aseptic non-union: not the end to all problems. Injury 2003 34(5):349–356
27. Choi YS, Kim KS Plate augmentation leaving the nail in situ and bone grafting for non-union of femoral shaft fractures. Int Orthop 2005 29(5):287–290
28. Taitsman LA, Lynch JR, Agel J, Barei DP, Nork SE. Risk factors for femoral nonunion after femoral shaft fracture. J Trauma. 2009 Dec;67(6):1389-92