

# Straight Proximal Femoral Nails Mismatch with the Anterior Bowing of the Femur

## Düz proksimal Femur Çivileri Femurun Anterior Eğimi ile Uyumsuzdur

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### ABSTRACT

**Objective:** Increased anterior bow of the femur due to advanced age and osteoporosis impinges with the distal part of the non-anatomic, standard proximal femoral nails (PFN), which is one of the most preferred implant for the fixation of trochanteric fractures (TF) of the elderly. The relation between increased femoral bowing and standard PFN application was investigated.

**Methods:** Radiographs of 111 patients (59 men, 52 women; mean age 74.5), who were treated with PFN due to TF between 2011 and 2015, were evaluated retrospectively. Relation between the nail and the anterior cortex was determined by measuring the angle between distal anatomical axes of the nail and the femur (ADA). The patients were divided into two groups according to their ADA (Group I ADA $\leq$ 4° and group II ADA>4°). Functional results and pain was evaluated using Harris hip score (HHS) and visual analog scale (VAS). Complications were also recorded.

**Results:** The mean amount of ADA was 4.5° $\pm$ 1.5°. Forty-seven patients were classified in group I and 64 patients were in group II. The mean HHSs were 80.6 and 79.3 (p=0.464), and the mean VAS scores were 2.13 and 5.35 (p<0.001), respectively. Five patients revised due to cut-out of the lag screws (total hip arthroplasty in two patients and revision of the nails in three patients). Union was achieved in all patients without infection.

**Conclusion:** Because straight femoral nails impinges anterior cortex of the femur with increased bowing, new design PFN with anterior curve is needed especially for shorter or osteoporotic people, or Caucasian population.

**Keywords:** Femur, trochanteric fracture, proximal femoral nail, anterior bowing

### ÖZ

**Amaç:** Yaşlıların trokanterik kırıklarının (TF) tespitinde sıklıkla tercih edilen anatomik olmayan, düz, standart proksimal femur çivilerinin (PFN) distal ucu, ileri yaş ve osteoporoz nedeniyle eğimi artmış femurun anterior korteksi ile sıkışmaktadır. Bu çalışmada standart PFN uygulaması ile artmış femoral eğim arasındaki ilişki araştırıldı.

**Yöntemler:** 2011 ile 2015 yılları arasında TF nedeniyle PFN uygulanmış olan 111 hasta (59 erkek, 52 kadın; ortalama yaş 74,5) geriye dönük incelendi. Anterior korteks ve çivi arasındaki ilişki çivi ve femurun distal anatomik aksları arasındaki açının (ADA) ölçümü ile değerlendirildi. Hastalar ADA açalarına göre iki gruba ayrıldı (Grup I ADA $\leq$ 4° ve grup II ADA>4°). Fonksiyonel sonuçlar ve ağrı Harris kalça skoru (HHS) ve görsel analog skala (VAS) ile değerlendirildi. Komplikasyonlar kaydedildi.

**Bulgular:** Ortalama ADA 4.5° $\pm$ 1.5° olarak bulundu. Grup I'de 47 ve grup II'de 64 hasta mevcuttu. Grup I ve grup II'de ortalama HHS sırasıyla 80,6 ve 79,3 (p=0,464) ve ortalama VAS skoru 2,13 ve 5,35 (p<0,001) olarak bulundu. Beş hasta lag vidasının sıyrılması nedeni ile revize edildi (iki hasta total kalça artroplastisi ile ve üç hasta çivi revizyonu ile). Tüm hastalarda enfeksiyon olmadan kaynama elde edildi.

**Sonuç:** Femurdaki artmış eğimin, düz çivilerin anterior kortekste sıkışmasına neden olması nedeniyle özellikle Kafkas toplumlarındaki gibi göreceli olarak kısa boylu insanlarda ya da ileri osteoporotik olanlarda anterior eğimli yeni dizayn çivilere ihtiyaç duyulmaktadır.

**Anahtar Kelimeler:** Femur, trokanterik kırık, proksimal femur çivisi, anterior eğim

### Introduction

In the treatment of TFs, stable fixation is mandatory to achieve a safe and early mobilization, which is important for patients returning to their previous activity levels (1, 2). Al-

though choice of the implant varies according to the type of TFs, many studies report that unstable pertrochanteric fractures of the femur, i.e. 31-A2 without medial support, and 31-A3, i.e. intertrochanteric fractures, can be treated successfully with intramedullary (IM) implants. IM fixation devices

Cite this article as: Yıldız F, Güzel Y, Erden T, Kara D, Elmadağ NM. Straight Proximal Femoral Nails Mismatch with the Anterior Bowing of the Femur. Bezmialem Science DOI: 10.14235/bs.2018.2241

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Geliş Tarihi / Received : 15.11.2017  
Kabul Tarihi / Accepted : 26.02.2018  
Çevrimiçi Yayın Tarihi  
Available Online Date : 26.04.2018

have become increasingly popular due to biomechanical advantages in the treatment of unstable TFs compared with extramedullary fixation (3-5).

TFs are very usual in the elderly population and its incidence increases twice in every decade after the age of 50 (6). Although increase in the anterior femoral bow by advanced age has been proved in the literature, the proximal femoral nails in the market have still straight designs on the sagittal plane (7, 8). Non-anatomic shapes of the PFNs sometimes make the surgeries difficult or can cause additional intraoperative fractures around the tip of the nail because they may impinge to the anterior cortex of the femur and increase the stress at this area due to increased femoral bowing (7-10). This problem is more apparent in shorter patients with shorter femurs, especially in the Asian or Caucasian population. We hypothesized that non-anatomical, straight PFNs impinge anterior femoral cortex and cause anterior tight pain in patients with increased femoral bow due to increased age and osteoporosis.

The primary outcome of this study was to determine the rate of femoral anterior cortical encroachment after stabilization of the proximal femur in a consecutive series of patients using a short straight PFN. Secondary outcome was to discuss whether PFNs need some improvements in their design for the geriatric population.

### Methods

This retrospective study was performed according to Declaration of Helsinki. One hundred and eleven patients with the diagnosis of TF (31-A2.1-3 or 31-A3.1-3 according to AO/ASIF classifications) (11), who had been treated using PFN between 2011 and 2015, included in the study. The data were collected using files of the patients and the digital database of the hospital. Patients with high-energy trauma, a neoplastic reason for the fractures, open fractures, multiple fractures, American Society of Anesthesiologists (ASA) score of V, inability to walk before the injury, degenerative osteoarthritis/arthrosis in the injured hip were excluded from the study. The patients who could not be reached or lost to follow up were also excluded.

The mean age of the patients (59 male and 52 female) was 74.4 (range, 65 to 95). The left hip was involved in 72 cases, and the right hip was involved in 39 cases. The etiologies were simple fall from standing position in 106 patients and pedestrian accidents in five patients.

Experienced orthopedic trauma surgeons in a university hospital operated all patients in a standard way. The surgeries were performed using fracture table and under the fluoroscopy. After closed or open reduction (if acceptable reduction could not be achieved by closed reduction techniques), the PFN (InterTAN, Smith&Nephew, Memphis, Tennessee, USA) was inserted in all patients. Its proximal lag screws and distal static locking screws were placed with the appropriate sizes. Final positions of the fractured fragments and the im-

plants were checked under the fluoroscopy before the patients leave the operating rooms. At the first day postoperatively, an antero-posterior (AP) and lateral X-ray was taken and the patients were allowed walking with weight bearing as they could tolerate.



**Figure 1.** Lateral anatomic axis of the femur at the level of the tip of the nail was determined as the line between the two points which were placed three cm distal and proximal to the tip of the nail and placed at the middle of the anterior and posterior cortices of the femur. Lateral longitudinal axis of the nail is drawn as a line along the anterior border of the nail. ADA was the angle between the lateral anatomic axis of the femur and the nail. a- ADA=2°, b- ADA=8°



**Figure 2.** Cut-out of the lag screw in a 72 year old female 2b: Revision with total hip arthroplasty

The digital AP and lateral radiographs taken the day after surgery and at the sixth months of follow-up were used for the radiographic measurements. The quality of reduction of the fracture (Garden alignment index) was classified as good, acceptable or poor (12). Position of the proximal screws in the femoral head, by measuring the tip–apex distance (TAD), and the neck-shaft angle (NSA) was measured to evaluate loss in reduction during the follow up (13). Clinical evaluations were performed using Harris hip score (HHS) and the visual analog scale (VAS) (14). Loss of reduction, implant failure and complications were recorded.

The angle between the anterior longitudinal axis of the nail and central anatomic axis of the femur at the level of the distal tip of the nail was measured digitally on the lateral radiographs to describe the relation between the anterior of the nail and anterior cortex of the femur. This angle was defined as ‘angle of distal axes (ADA)’. We divided all of the patients into two groups according to their ADA: group I includes patients with  $ADA \leq 4^\circ$  and group II includes patients with  $ADA > 4^\circ$ . All of the radiographs were measured by the same orthopedic surgeon.

#### Statistical analysis

HHS and VAS scores between the group I and the group II were compared with Kruskal-Wallis test. NSAs on the second day postoperatively and at the sixth months of follow up radiographs were compared using Wilcoxon Signed Ranks test.  $P < 0.05$  was accepted as the level of significance.

#### Results

Quality of reduction was good in 32 patients, acceptable in 12 patients and poor in three patients of the group I, and good in 43 patients, acceptable in 15 patients and poor in six patients of the group II. The mean TAD were  $18.3 \pm 8.25$  mm and  $19.7 \pm 7.41$  mm in group I and group II, respectively.

In group I and group II, the mean early postoperative NSAs were  $128.8^\circ \pm 4.5^\circ$  and  $130.1^\circ \pm 3.7^\circ$  ( $p=0.08$ ) and the mean final NSAs were  $126.8^\circ \pm 6.8^\circ$  and  $128.7^\circ \pm 4.1^\circ$  ( $p=0.078$ ), respectively. Between the group I and group II, the mean NSAs were similar initially and at the final follow ups.

The mean amount of ADA was found as  $4.5^\circ \pm 1.5^\circ$ . Forty-seven patients were classified in group I (Figure 1a) and 64 patients were in group II (Figure 1b). The mean HHSs were found as  $80.6 \pm 2.17$  point (range, 78 to 84) in group I and  $79.37 \pm 3.26$  (range, 72 to 86) in group II ( $p=0.464$ ). The mean VAS scores were  $2.13 \pm 0.62$  (range, 1 to 3) and  $5.35 \pm 0.78$  (range, 4 to 7), in groups I and II, respectively ( $p < 0.001$ ). Although the mean HHSs were not significantly different between the groups, the VAS scores were found to be significantly lower in group I than the group II.

As the complication, cut-out of the lag screws were observed in five patients. In three of these patients, the nails were removed and the fractures were re-reduced and fixed with new

PFNs. However, in two patients, the fractures were treated with total hip arthroplasty (Figure 2a and 2b). During the follow up period, union was achieved in all patients including PFN revisions, except two patients with arthroplasty. Surgical site infection was not observed in any patient. Intraoperative or postoperative fracture of the femur around the distal tip of the nail did not occur in any patient.

#### Discussion

This retrospective study evaluates 111 patients with TFs who were treated with non-anatomic, straight proximal femoral nails. The main goal of the study was to investigate whether straight nails impinge with the anterior femoral cortex due to its anatomic bowing or not. Secondary aim of the study was to evaluate the clinical relevance of this possible impingement. The mean ADA was found as  $4.9 \pm 1.5$ , and it was  $> 4^\circ$  (grade III to V) in 64 patients (57.6%) which was thought as anterior cortical impingement.

Success of the IM short nails in the treatment of TFs has already been proved. Especially in the unstable fractures, they provide proximal femoral anatomy and reduction against the deforming forces (15, 16). It is more preferred than the sliding hip screws in the treatment of unstable fractures, including reverse oblique fractures (A3 AO-OTA), because the PFN provides higher stability and its use is easier (16, 17). Successful results of the PFN in high volume series have been published although it has some complications such as intraoperative fractures, cut-out of the lag screws and varus collapse, non-union and malunion (3, 5, 15, 16, 18). In the treatment of proximal femoral fractures, anterior cortical encroachment of the cephalo-medullary nails have been described before however, to our knowledge, the relation between anterior cortical impingement and short PFN have not been reported before (19). Similar to the literature, in the current study, successful results of the used PFN have been obtained in 111 patients with unstable TFs (31-A2.1-3 and 31-A3.1-3 AO-OTA) with the total complication rate of 4.5% (11).

In the treatment of TFs with proximal nailing, the most frequent complications are varus collapse of the proximal femur, cut-out of the lag screw, shortening of the femur, non-union, secondary fracture of the femur or greater trochanter, thigh pain, screw fracture, and Z-effect or reverse Z-effect of nails with two lag screws (20, 21). In our series, cut-out of the lag screw was seen in five patients, two of them were treated with arthroplasty and in three patients the nails were revised. Although the amount of varus collapse at the final radiographs compared to initial radiographs, which was about  $2^\circ$ , was statistically significant ( $p < 0.001$ ) in both groups, it did not have clinical or radiological importance in the results. According to alignment index of Garden, quality of reduction was good in 89% of the patients but poor in 9% of the patients (12). ADA was correlated to thigh pain and VAS scores, which was higher in the group II ( $p < 0.001$ ). This result shows the clinical importance of the anterior impingement of the PFN.

It has been well documented that PFNA (Synthes, Switzerland) may cause femoral fractures or valgus impingement of the lateral cortex, especially in the Asian population (9, 22-24). Because of these data in the literature, its proximal diameter, lateral bending angle and lateral surface have been revised and improved, and reproduced as PFNAII which has been shown to be more appropriate for the Asian population. In the treatment of unstable TFs, biomechanical and clinical studies resulted superiority of InterTan PFN because of its rotational strength and low rate of malunion (25-28). Anterior cortical impingement or destruction of the femoral nails can lead to potential complications such as thigh pain and disability and serve as a stress riser for future fractures (19, 29). Similar problems may occur with straight non-anatomic nails on the sagittal plane (PFNAII or InterTAN) due to mismatch of the anterior femoral bowing. It has been proved that anterior femoral bowing increases with the increased age and osteoporosis in the elderly, therefore short, straight nails can impinge with the anterior cortex, however the design of the proximal femoral nails have not been changed, yet (7-10).

Chang et al treated 158 patients with unstable TFs using PFNAII and found encroachment of the distal tip of the nail to the anterior cortex in 55 patients (34.8%) (29). Hwang et al. reported mismatch of PFN/PFNA with the anterior and lateral cortices of the femur in four patients in their series (9). Radiological studies have also been reported mismatch between the femoral nails and increased femoral bowing with advanced age (7, 8). Our study showed anterior cortical impingement of the nail in 57.6% of the patients and statistically significantly higher rate of tight pain in this group. In the literature, groin or tight pain after hip nailing is not rare in this group of patients. Inappropriate stress distribution between the femur and the implant is thought to be a reason for the tight pain (29-32). Similarly, in our patients tight pain can be related to increased stress over the anterior cortex of the femur. For this reason we recommend using shorter or curved nails in order to decrease the stress between the implant and the anterior cortex, which can decrease tight pain and possible fractures around the distal tip of the nail.

In this study we had some limitations. First, evaluation of the anterior tight pain could be more objective. Second, stress distribution over the anterior cortex could be evaluated with a biomechanical study to report a measurable data. Third, standardization of the radiological measurements was difficult. ADA was measured on the lateral radiographs, which may change with the rotation of the femur.

## Conclusion

Straight, non-anatomic femoral nails impinges anterior cortex of the femur due to increased sagittal bowing of the femur by age and these nails are not appropriate for the shorter people, especially in the Caucasian population. New design proximal femoral nails with anatomic bow can solve these problems.

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