Leg length discrepancies in adult femoral shaft fractures treated with intramedullary nailing

İntramedüller çivileme uygulanan erişkin femur diafiz kırıklı olgularda ekstremite uzunluk eşitsizliği

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BACKGROUND
To evaluate the leg length discrepancy (LLD) retrospectively in adult femoral shaft fractures treated with intramedullary nailing (IMN).

METHODS
Sixty-three patients (58 male, 5 female; mean age 29.9±12.4; range 15 to 77 years) were included in the study. Fractures were identified according to the Winquist-Hansen (W) system and AO classification. 16 W0, 18 WI, 16 WII, 7 WIII, and 6 WIV fractures and 35 type A, 22 type B, and 6 type C fractures were repaired. Thirty-one (49.2%) patients had multiple injuries. Fourteen patients sustained an open fracture. LLDs were measured on physical examination and using orthoroentgenography.

RESULTS
The mean follow-up was 90.2±29.9 (39-193) months. The mean LLD was 12.3±15.2 [12-(-60)] mm using orthoroentgenography and 12.9±13.7 [10-(-60)] mm according to manual measurement. In seven cases, no LLD was observed. Twenty-seven shortenings and one lengthening were observed in the 28 femurs with a discrepancy greater than 10 mm (44.4%). There was no statistical correlation between LLD and open or closed fracture (r=0.02, p=0.86), polytrauma (r=-0.09, p=0.47), or delayed surgery (p=0.31), but there was a tendency to a greater discrepancy in comminuted fractures (WIII, IV) (r=0.33, p=0.007).

CONCLUSION
LLD may be seen in high rates in adult femoral shaft fracture cases treated with IMN. Static IMN following absolute restoration of the length may prevent this problem in femoral diaphysis fractures, especially comminuted WIII and IV types.

Key Words: Femoral shaft fractures; intramedullary nailing; leg length discrepancy.

AMAÇ
İntramedüller çivileme uygulanan erişkin femur diafiz kırıklı olgularda ekstremite uzunluk eşitsizliği (EUE) geriye dönük olarak değerlendirildi.

GEREÇ VE YÖNTEM
Altmış üç hasta (58 erkek, 5 kadın; ort. yaş 29,9±12,4; dağılım 15-77) çalışma grubunu oluşturdu. Kırıklar Winquist-Hansen (W) ve AO sınıflamalarına göre tanımlandı. 16 W0, 18 WI, 16 WII, 7 WIII, 6 WIV ve 35 tip A, 22 tip B, 6 tip C kırık tedavi edildi. Olguların 30'una konvansiyonel, 18'ine distal kilitli, 12'sine statik ve 3'üne proksimal kilitli çivileme uygulandı. Ekstremite uzunluk eşitsizliği fiziksel inceleme ve ortoröntgenografi ile değerlendirildi.

BULGULAR
Ortalama izlem süresi 90,2±29,9 (dağılım 39-193) ay, ortalama EUE ortoröntgenografi ile 12,3±15,2 [12-(-60)] mm, fiziksel inceleme ile 12,9±13,7 [10-(-60)] mm bulundu. Yalnız yedi olguda EUE saptanmadı. 10 mm'den fazla uzunluk eşitsizliği tespit edilen 28 femurda 27 kısalık ve 1 uzunluk vardı (%44,4). Açık ve kapalı kırıklar (r=0,02, p=0,86), politravma (r= -0,09, p=0,47) ve geç cerrahiye alınma süresi (p=0,31) ile uzunluk eşitsizliği arasında anlamlı ilişki saptanmadı. Bununla birlikte, parçalı kırıklar (WIII, IV) (r=0,33, p=0,007) ile anlamlı ilişki saptandı.

SONUÇ
İntramedüller çivileme uygulanan erişkin femur diafiz kırıklı olgularda EUE yüksek oranda görülebilmektedir. Özellikle parçalı (WIII, IV) femur diafiz kırıklarında mutlak kemik uzunluğunun sağlanmasından sonra yapılacak statik intramedüller çivileme uygulaması bu sorunun önüne geçebilir.

Anahtar Sözcükler: Femur diafiz kırığı; intramedüller çivileme; ekstremite uzunluk eşitsizliği.

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The basic principles in the treatment of fractures of the femur include restoration of position and alignment, maintenance of length, immobilization until bony union occurs, and restoration of normal function after union.

Reamed anterograde intramedullary (IM) nailing is the current treatment of choice for adults with open or closed fractures of the femoral shaft.[1] IM nailing has a high rate of union (99%) and a low rate of infection and malunion (<1%).[1-3] Indeed, the results of care involving femur fractures constitute the majority of orthopedic malpractice claims. Malpractice suits related to femur fracture management account for nearly 30 million dollars in claims paid each year in the United States. Most claims are related to technical problems of fracture care, specifically, shortening and malrotation.[4]

A review of the literature has revealed that limb length inequalities are not emphasized and often disregarded,[2,3,5-8] although there are a few studies that have focused on shortening.[9-11]

In the current study, our results regarding leg length discrepancies (LLDs) associated with adult femoral fractures treated by antegrade IM nailing were evaluated retrospectively.

MATERIALS AND METHODS

We retrospectively analyzed patients who underwent procedures using reamed antegrade IM nailing for femoral shaft fractures between November 1990 and July 2003.

Nineteen patients were excluded from the study. Nine patients could not be followed up, seven patients had an ipsilateral fracture, one patient had bilateral femur fractures, and nonunion occurred in two patients. Thus, a total of 63 patients (5 females, 58 males), with a mean age of 29.9±12.4 (range: 15-77) years were included in the present study. Thirty-one (49.2%) patients had multiple injuries. Fractures were identified according to the Winquist-Hansen (W) system and the AO classification. Sixteen (25.4%) W0, 18 (28.6%) WI, 16 (25.4%) WII, 7 (11.1%) WIII, and 6 (9.5%) WIV fractures and 35 type A, 22 type B, and 6 type C fractures were repaired. There were no associated vascular or neurologic injuries. Fourteen of the 63 patients sustained an open fracture, all of which were classified according to Gustillo Anderson. Patient demographics and injury details are shown in Table 1.

The definitive surgical procedure was performed when the patient's physical condition permitted. The mean duration between trauma and surgery was 7.02±3.63 (range: 1-15) days. The type of nail used was at the discretion of the surgeon who performed the surgery; a review of the medical records revealed no data indicating the rationale for nail preference. The distance between two reproducible landmarks, such as the tip of the greater trochanter and the adductor tubercle of the intact contralateral femur, was used to determine nail length. The authors routinely performed reamed antegrade IM nailing of the femur without the use of a fracture table. Surgery was performed in the lateral decubitus position. Open reduction and conventional IM nailing was performed in 30 patients. Mini-open reduction was the preference of the surgeon in two of 18 distal locking and two of 12 static locking patients. The remaining distal locking and all of the proximal locking (n=3) patients were treated with closed reduction. Further dynamization was performed when union was not observed at the end of the third month.

At final follow-up evaluation, the first author examined each patient. With the patient supine and the pelvis squared, a tape measure was used to measure the difference in distance between the anterior superior iliac spines and the medial malleoli. Rotational malalignment of the femur was measured clinically by comparing the internal and external rotation of the injured and uninjured hips. These measurements were done with the patient prone, with the hip extended. Orthoroentgenographic films were obtained. The measurements were made by the same author.

Table 1. Patient demographics and injury details

Gender	58 (92.1%) male, 5 (7.9%) female
Age-median (range)	29.9 (15-77)
Mechanism of injury	
Motor vehicle accident	31.7%
Pedestrian hit by a car	30.2%
Blunt trauma	15.9%
Motorcycle accident	9.5%
Gunshot injury	7.9%
Fall	4.8%
Open injuries	14 (22.2%)
Type 1	5
Type 2	4
Type 3A	5
Associated injuries	31 (49.2%)

Table 2. Comparison of leg length discrepancy and intramedullary nailing technique with number

	2 cm ↑	1.0-1.9 cm	0.1-0.9	0	+0.1 ↑
Conventional	6	6	8	6	4
Proximal	1	–	1	–	1
Distal	7	1	5	–	5
Static	3	3	–	1	5
	17	10	14	7	15

Statistical analyses were performed by the Pearson test and Fisher's exact chi-square test using SPSS, version 13.

RESULTS

The length of the hospital stay was 15.7±5.6 (range: 6-40) days and the mean follow-up period was 90.2±29.9 (range: 39-193) months. The mean LLD was 12.3±15.2 [12-(-60)] mm by orthoroentgenography and 12.9±13.7 [10-(-60)] mm by manual measurement (all fracture types included). The correlation between orthoroentgenographic and manual measurements was significant at the 0.01 level. In seven cases, LDL was not observed. The greatest shortening was 60 mm and greatest lengthening was 12 mm for the 28 (44%) femurs with a LLD greater than 10 mm (27 shortenings, 1 lengthening). The fractures types were type A (7/35), type B (16/22), type C (5/6), or W0 (4/16), WI (4/18), WII (9/16), WIII (6/7), and WIV (5/6). A comparison between the LLD and the IM nailing technique is shown in Table 2, and details about the patients with a shortening of 10 mm or more are shown in Table 3. There was no statistical correlation between LLD and

Table 3. Details regarding patients with shortening of 10 mm or more

Shortening (mm)	Gender (m/f)	Age (years)	Winquist	AO	Fracture location	Treatment
60	m	17	II	B_2	Distal	Distal locking
55	m	30	II	B_2	Distal	Distal locking
42	m	24	III	B_3	Mid	Distal locking
38	m	41	IV	C_1	Mid	Static*
36	m	39	I	B_2	Mid	Conventional
35	m	30	III	B_3	Mid	Distal locking
33	m	38	II	B_2	Mid	Conventional
33	m	25	IV	C_3	Mid	Distal locking
29	f	63	I	B_1	Mid	Conventional
27	m	37	II	B_2	Distal	Distal locking
24	f	41	II	B_2	Distal	Distal locking
24	m	44	IV	C_1	Mid	Static
22	m	47	IV	C_1	Mid	Conventional +cerclage
21	m	33	II	B_2	Mid	Static*
21	m	19	III	B_2	Mid	Conventional
20	m	29	III	B_1	Proximal	Proximal locking
20	m	25	II	B_3	Mid	Conventional
18	f	15	0	A_3	Mid	Conventional
17	m	77	III	B_2	Mid	Conventional
17	m	28	III	B_3	Mid	Static*
15	m	33	IV	C_1	Mid	Static
14	m	37	II	B_2	Mid	Conventional
13	m	22	0	A_1	Mid	Conventional
13	m	61	I	A_2	Mid	Static*
10	f	51	0	A_2	Distal	Distal locking
10	m	40	II	B_3	Mid	Conventional
10	m	22	0	A_3	Mid	Conventional

* Further dynamization.

Table 4. Thoresen et al. classification system for the results of treatment and patient evaluations at the last follow-up

	Results			
	Excellent	Good	Fair	Poor
Malalignment of the femur (degree)				
Varus or valgus	5°	5°	10°	>10°
Antecurvatum or recurvatum	5°	10°	15°	>15°
Internal rotation	5°	10°	15°	>15°
External rotation	10°	15°	20°	>20°
Shortening of the femur (cm)	<1	<2	<3	<3
Range of motion of the knee (degrees)				
Flexion	>120°	120°	90°	<90°
Extension deficit	5°	10°	15°	>15°
Pain or swelling	None	Sporadic, minor	Significant	Severe
Patient results	46.0%	23.8%	17.5%	12.7%
(n=63)	(n=29)	(n=15)	(n=11)	(n=8)

open or closed fractures or polytrauma, although there was a tendency for a greater discrepancy in comminuted fractures. The cases were divided into two groups showing the time to operation as ≤7 and >7 days. LLD <1 cm was accepted as no discrepancy and LLD ≥1 cm as significant discrepancy. There was no significant difference in LLD with regard to time to operation (p=0.31).

There were three cases of malrotation (> 20°) in two distal dynamically locked fractures (B_2-WII and B_3-WIII) and one non-locked fracture (B_2-WIII). There were no varus/valgus malalignments >10 mm.

At the last follow-up visit, 44 patients (69.8%) were rated as excellent or good, according to the criteria of Thoresen et al.[12] (Table 4). Despite this, we observed some rotational deformities that resulted in shortening. However, 76.5% (n=13) of cases with shortening more than 2 cm (n=17) had low back pain.

DISCUSSION

In the past decades, IM nailing has become the standard of care in the management of open and closed femoral shaft fractures.[11] The introduction of the interlocking nailing has widened the spectrum of fracture patterns that can be stabilized with closed IM nailing.[9] A review of a larger series in the literature suggested that complications following IM nailing of femoral shaft fractures are relatively uncommon.[1-3,5-8,13] The incidence of malunion (rotational deformity, angulation, and LLD) ranges from 6-27%.[5,14-18]

Of 520 femoral fractures reported by Winquist[2] treated prior to the advent of interlocking nail techniques, shortening of more than 2 cm was noted in 10 patients (2%). Wolinsky et al.[3] did not routinely measure or specifically inquire about LLD during follow-up evaluations; however, five patients (0.9%) required an operative procedure for the treatment of a significant LLD (4 cases resulted from technical errors and 1 case was due to an error in intraoperative care). All LLDs occurred in statically locked fractures. In Alho's study,[5] there were eight shortenings of 3-4 cm that were graded as fair and one shortening of 9 cm that was graded as poor; six of the shortenings occurred in dynamically locked fractures. It is difficult to achieve the exact length of the bone in severe comminuted fractures, so failure to appropriately interlock unstable injuries can lead to malunion from postoperative shortening and malratotation.[4,19,20] In our series, the WIII and WIV or AO B (particularly B_2) and C fractures that were repaired using conventional and static or dynamic interlocking IM techniques had the greatest shortening. Careful preoperative measurement using an anteroposterior radiograph of the intact contralateral femur for reference can help to avoid significant LLD.[9] If fracture length cannot be judged intraoperatively by using an X-ray to line up fracture fragments, as is the case for most Winquist III or IV fractures, it is imperative to know the length of the femur or to use a C-arm to fluoresce the IM nails of different lengths held over the intact femur. If extensive comminution is present and the proper length is not known before surgery, the femur will be nailed short. It is important to use the length nail as measured off the intact femur and not adjust based on intraoperative findings because the femur will often end up short. If both femora are fractured, length is judged by using

the less comminuted side, and two nails of the same size are used. If the length of the fracture is unstable and shortens even with the nail seated, both distal locks should be placed first. The nail can then be driven in completely and proximally locked.[18]

In our patients, shortening of 10 mm or more occurred in both statically and especially dynamically locked fractures, indicating that the shortening problem was not eliminated with the use of static locking. Shortening is a potential problem, particularly in WIII and WIV fractures, but dramatic shortenings can be avoided when static locking is used after reconstruction of the length.[6] Dynamization is a method that can be tried to improve fracture healing in femoral fractures showing delayed healing after interlocking nailing. However, patients must be examined regularly after dynamization to avoid significant shortening. Dynamization is suggested for patients without segmental bony defects. Dynamization carries the risk of significant bone shortening.[5,21] In our series, we observed four shortenings in which static locking and further dynamization were performed. Although further dynamization was not performed following static locking in two patients, shortening was observed. The cause of this condition may be due to insufficient intraoperative reduction.

Dynamic interlocking has become the recommended method for WO, WI, and WII fractures, which are considered to be stable.[17,22,23] However, in our series, seven of 17 patients who had shortness of more than 20 mm had WII fractures and four of the patients had distal dynamic locking (Table 3, cases 1, 2, 10, and 11). In two of these four cases, 60 mm and 55 mm of shortening were observed consequently. This may be due to the distal location of the fracture and intraoperative technical error. However, we observed no significant effect of the time to operation on LLD.

Furthermore, there were four cases with shortening between 10 and 18 mm who were classified as W0 and AO A fractures and were repaired with conventional (3 cases) and distal dynamic (1 case) locking techniques. Therefore, after determining leg length equality, static locked IM nailing may be the preferred method in all femoral shaft fractures in adults. Because necrosis may occur in the fracture ends during the inflammation phase of fracture healing, in addition to muscle contraction, this may result in shortening in the axial plane or screw breakage in stable cases.[4,24,25]

Leg length inequality may occur after IM nailing of femur fractures and may cause discomfort. A difference in the length of the legs of a patient could alter the alignment of the spine and make it more vulnerable to shock forces generated by running.[26,27] A LLD of sufficient magnitude may lead to a number of problems, including an increased expenditure of energy in gait,[28] cosmetically-disturbing gait,[29] equinus contracture of the ankle on the short leg side,[30] late degenerative arthritis of both the long leg hip and knee,[31] low back pain,[26] and compensatory scoliosis.[27] The degree of LLD that is clinically significant remains controversial. Although generally assumed to be of little clinical significance, LLD of as little as 5 mm has been reported to be associated with low back or hip pain.[26] A simulated LLD of as little as 10 mm can lead to a significant shift of the mean center-of-pressure position and an increase in postural sway while standing at rest.[32] Furthermore, these deformities can lead to disabling symptoms, in some cases necessitating further surgery or altered footwear.[6,17,33]

The difference in shortening and rotational deformity was due, at least in part, to the different techniques used for placement of the nail. Classically, IM nailing is done with use of a fracture table. Alternatively, IM nailing can be performed on a radiolucent table. Traction can be applied manually or with the use of a femoral distractor, although it takes almost as long to apply the distractor as it does to perform the entire nailing procedure and manual traction is usually sufficient to regain length.[34] However, compared with fracture-table traction with the patient in a supine position, manual traction for IM nailing of isolated fractures of the femoral shaft is an effective technique that decreases anesthesia time, positioning and preparation times, and actual operative time, and improves the quality of the reduction.[35] With either method, the patient can be placed in the lateral decubitus or supine position. An advantage of the lateral decubitus position is the improved access to the piriformis fossa, especially in obese patients.[34]

We found that nailing without a traction table creates difficulties in control of length and rotation. Although a femoral distractor can be used during antegrade nailing to correct the length, rotation in unstable fractures is difficult to judge.

Indeed, there were several limitations to the present study. First, this was a retrospective study with several surgeons performing the procedures. Thus,

their preferences had a major impact on the results. Second, the fracture type was not standard between patients. Both these factors were a source of bias. Nevertheless, by reviewing the literature, we found that most of the studies pertaining to this subject failed to measure leg lengths. Therefore, we were attentive to this complication. Prospective trials may result in more definitive conclusions.

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