International Orthopaedics (SICOT) (2004) 28: 347–353
DOI 10.1007/s00264-004-0590-x

ORIGINAL PAPER

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Femoral shaft medialisation and neck-shaft angle in unstable pertrochanteric femoral fractures

Received: 16 June 2004 / Accepted: 29 July 2004 / Published online: 10 September 2004

Abstract We analysed the time-dependent mean changes in the femoral neck length, neck-shaft angle and hip offset in a randomised study comprising 48 patients who were treated with the dynamic hip screw (DHS) or the proximal femoral nail (PFN) for an unstable intertrochanteric femoral fracture. As a consequence of fracture compression, the mean post-operative neck length was significantly shorter in patients treated with the DHS. During the first 6 weeks after the operation, a mean decrease of 4.6° was observed in the neck-shaft angle, but there was not a significant difference between the treatment groups. The radiographic measures remained virtually unaffected during the interval from 6 weeks to 4 months in both groups. When the operated hip was compared to the opposite hip, patients who had received the DHS showed significantly greater medialisation of the femoral shaft at 4 months than those treated with the PFN. We thus recommend that unstable intertrochanteric fractures should be initially reduced in a slight valgus position in order to achieve an outcome after healing that is as normal as possible. As a result of differences in operative technique and implant stability, the PFN may be superior to the DHS in retaining the anatomical relations in the hip region in unstable intertrochanteric fractures.

Résumé Nous avons analysé les modifications, en fonction du temps, des valeurs moyennes de la longueur du col fémoral, de l'angle cervico-diaphysaire et du bras de levier de la hanche dans une étude randomisée qui comprenait 48 malades traités avec une Vis Dynamique (DHS) ou un Clou Fémoral Proximal (PFN) aprés une fracture intertrochantérienne instable. Par suite de la compression de la fracture, la longueur du col était nettement plus courte chez les malades traités avec une DHS. Pendant les premières six semaines après l'opération, une baisse moyenne de 4.6° de l'angle cervico-diaphysaire a été observée mais il n'y avait pas de différence notable entre les groupes de traitement. Les mesures radiographiques sont restées pratiquement non affectées pendant l'intervalle de six semaines à quatre mois dans les deux groupes. Comparé à la hanche opposée, les malades qui avaient reçu une DHS ont montré à 4 mois une nettement plus grande médialisation de la diaphyse que ceux traités avec le PFN. Nous recommandons que ces fractures intertrochantériennes instables soient réduites en léger valgus pour avoir une situation aussi normale que possible après consolidation. Par suite de différences dans la technique opératoire et dans la stabilité de l'implant, le PFN semble supérieur au DHS pour rétablir l'anatomie de la région de la hanche dans les fractures intertrochantériennes instables.

Statement on conflict of interest: no benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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Introduction

The aim of treatment of femoral trochanteric fractures is a rigid fixation, which allows an immediate unlimited weight bearing and early mobilisation of the patient [8]. The dynamic hip screw (DHS) allows controlled fracture compression and has been widely used as the standard method of treatment for the last few decades. While stable AO/ASIF type A1 fractures are considered as rather benign fractures that commonly heal uneventfully, unstable fractures may be less successfully treated with this method [5, 9]. In order to overcome the problems associated with unstable pertrochanteric femoral fractures, several intra-medullary nails have been developed during the last decades. One of the most recent developments is the PFN. Several retrospective studies have yielded promising clinical results with this nail [2, 4, 6, 18], but current randomised studies have found only small differ-

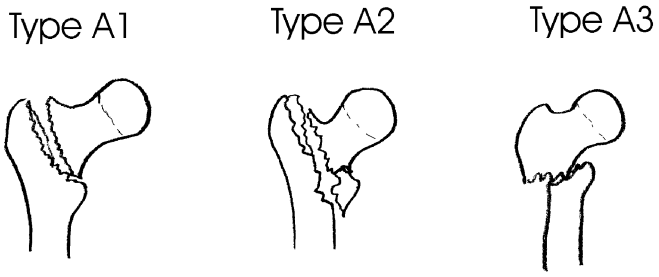

Fig. 1 AO/ASIF categorisation of pertrochanteric femoral fractures. Only unstable type A2 fractures were included.

ences in the intra-operative or post-operative outcomes when the PFN has been compared to the dynamic condylar screw (DCS) [15], the DHS [16] or the gamma nail [17].

Although the outcomes of the DHS have been well documented and the knowledge of the PFN is continuously increasing, a detailed comparison regarding post-operative changes in hip measurements is still absent. Therefore, we have initiated a randomised and prospective study that aims to evaluate the radiographic post-operative changes in the femoral neck length, neck-shaft angle and hip offset in patients treated with the DHS or the PFN following an unstable pertrochanteric femoral fracture.

Table 1 Characteristics of 48 patients with an unstable pertrochanteric femoral fracture treated with a dynamic hip screw (DHS) or a proximal femoral nail (PFN)

	All	DHS	PFN
n	48	24	24
Age: mean (SD)	79.4 (9.7)	79.8 (10.2)	78.8 (9.4)
Body mass index: mean (SD)	21.7 (3.6)	22.5 (3.9)	20.8 (2.7)
Treatment delay: mean (SD)	1.2 (1.4)	1.3 (1.9)	1.0 (0.7)
Operation time: mean (SD)	63 (32)	54 (19)	72 (41)
Blood loss: mean (SD)	391 (431)	408 (483)	380 (394)
Blood transfusions: mean (SD)	3.5 (2.3)	3.6 (2.0)	3.4 (2.6)
Gender			
Female	39 (81.2%)	19 (79.2%)	20 (83.3%)
Injury mechanism			
Fall indoors	46 (95.8%)	23 (95.8%)	23 (95.8%)
Side			
Right	25 (52.1%)	9 (37.5%)	16 (66.7%)
Previously diagnosed dementia	11 (22.9%)	7 (29.2%)	4 (16.7%)
Walking unaided	29 (60.4%)	16 (66.7%)	13 (54.2%)
Living at own home	31 (64.6%)	15 (62.5%)	16 (66.7%)
American Society of Anaesthesiologists score			
2	7 (14.6%)	4 (16.7%)	3 (12.5%)
3	29 (60.4%)	15 (62.5%)	14 (58.3%)
4	12 (25.0%)	5 (20.8%)	7 (29.2%)

Patients and methods

Fifty-six patients with an unstable, low-energy, extracapsular, pertrochanteric femoral fracture (AO category 31-A, class A2, Fig. 1) were randomised to be treated with the DHS (Synthes-Stratec, Oberdorf, Switzerland) or the PFN (Synthes-Stratec, Oberdorf, Switzerland) at our department. The ethics committee of the University Hospital approved the study plan, and informed consent was obtained from all study subjects before the operation. All patients admitted with a pertrochanteric fracture during the study period were considered candidates for the study, but those with a pathological fracture, polytraumatised pa-

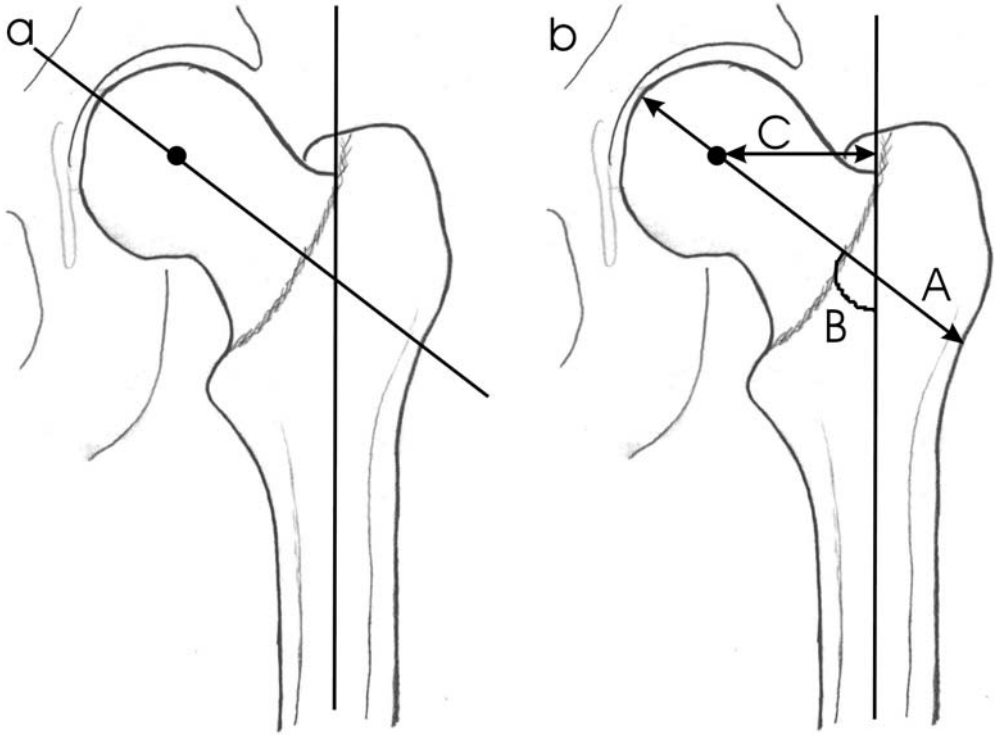

Fig. 2 Two lines were drawn to help evaluation of hip measures, one crossing the centre of rotation of the femoral head and the centre of the femoral neck and the other parallel to the femoral shaft **(a)**. Subsequently, femoral-neck length (A), femoral-neck-shaft angle (B) and hip offset (C) were measured **(b).**

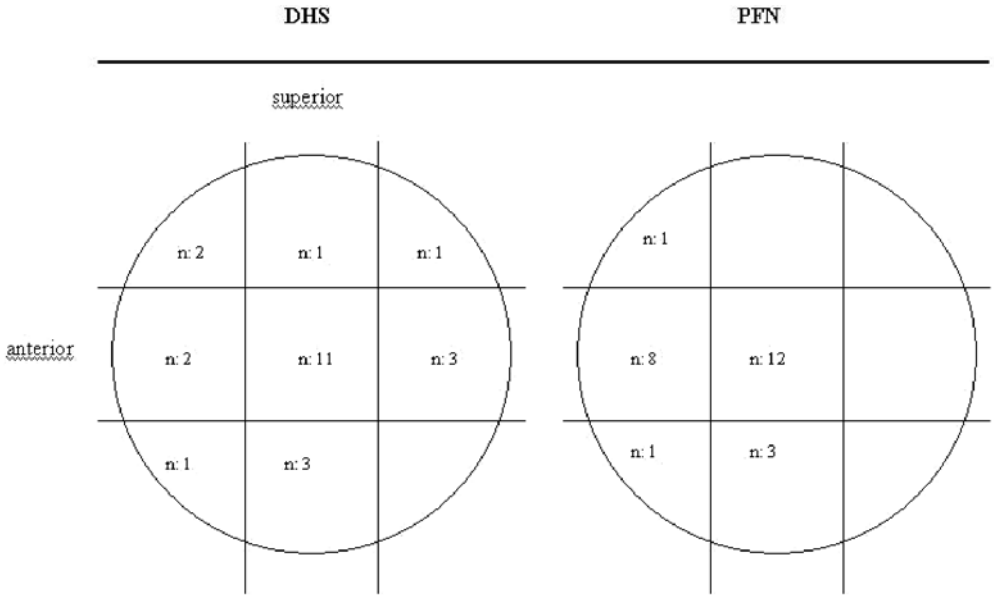

Fig. 3 Partition of the femoral head into nine zones and the number of the tip of the compression screws of the dynamic hip screw (DHS) and the neck screws of the proximal femora nail (PFN) in each zone.

tients, and patients who were not able to comprehend the given informed consent reliably or refused to participate were excluded. Moreover, stable fractures (class A1) and subtrochanteric fractures (class A3) were not included.

The treatment mode was determined by a strict randomisation of the patient at admission, and the predetermined operation took place, as a rule, within 2 days from admission. All fractures were reduced by closed means, and standard operative techniques were used in all operations. An intra-operative compression of the fracture was performed in cases treated with the DHS. A prophylactic dose of intravenous antibiotics was given to all patients, and the patients were also treated with low-molecular-weight heparin during their stay. A post-operative radiograph was obtained during the first or second post-operative day and was analysed together with the uninjured hip by one author as regards the length of the femoral neck, the neck-shaft angle and the femoral offset (Fig. 2). The position of the tip of the compression screw of the DHS and the neck screw of the PFN was determined by dividing the femoral head into nine zones [19] (Fig. 3). The tip-apex distance (TAD) [3] of the compression screw of the DHS and the neck screw of the PFN was also measured for all cases. Fracture reduction was considered satisfactory if the neck-shaft angle did not differ from the uninjured side by more than 5° and if the dislocation between the fragments, regardless of the lesser trochanter, did not exceed 2 mm in any projection.

Weight-bearing ambulation at the limits of pain was begun within the first or second post-operative day regardless of treatment mode. Patients were discharged when mobilisation was satisfactory and primary post-operative complications were excluded. Follow-up investigations were performed at 6 weeks and 4 months post-operatively consisting of a radiographic analysis similar to that of the uninjured hip and the fractured hip in the post-operative radiograph.

All statistical evaluations were performed using SPSS 11.0.1 for Windows. Mean values of numeric variables were compared between the groups and are reported as mean changes with 95% confidence intervals. *P* values were calculated using the two-tailed independent samples *t* test with equal variances assumed. Paired samples *t* test was used when measures from the injured hip were compared at different times. *P* values <0.05 were considered statistically significant.

Table 2 Measures from the uninjured and injured hip in 48 patients with a pertrochanteric femoral fracture treated with the dynamic hip screw (DHS) or the proximal femoral nail (PFN). The measures are reported as means and standard deviations

	uninjured hip		Injured hip in post-operative radiograph		Injured hip at 6 weeks		Injured hip at 4 months	
	DHS	PFN	DHS	PFN	DHS	PFN	DHS	PFN
Tip-apex distance[a]			24.6 (9.8)	22.8 (8.2)				
Femoral neck length (mm)	104.4 (7.0)	103.9 (7.0)	101.8 (14.0)	106.5 (5.9)	101.7 (10.0)	108.8 (7.2)	101.4 (12.1)	108.7 (8.4)
Neck-shaft angle (degrees)	128.0 (7.6)	125.5 (6.0)	134.5 (14.4)	125.3 (7.5)	129.2 (11.7)	121.3 (9.4)	130.7 (8.6)	121.8 (9.7)
Offset (mm)	42.5 (8.6)	44.0 (7.1)	37.1 (10.3)	47.5 (5.7)	35.1 (11.5)	47.6 (7.7)	34.4 (11.2)	49.1 (9.8)

[a]Compression screw of the DHS and neck screw of the PFN

Table 3 Changes of hip measures in 48 patients with a pertrochanteric femoral fracture as a function of time. All values are presented as mean with 95% confidence interval

Treatment mode	Mean change within the first 6 weeks		Difference between treatment groups			Mean change from 6 weeks to 4 months		Difference between treatment groups		
	DHS	PFN	Mean	95% CI	*P*	DHS	PFN	Mean	95% CI	*P*
Femoral neck shortening (mm)[a]	−0.1 (−4.6 to 4.4)	2.3 (−0.2 to 4.8)	2.4	−2.6 to 7.5	0.335	−0.3 (−2.9 to 2.2)	0.1 (−3.1 to 3.0)	0.3	−3.6 to 4.1	0.890
Neck-shaft angle (degrees)[a]	−5.3 (−9.3 to (−1.3))[b]	−3.9 (−6.6 to (−1.3))[b]	1.4	−3.3 to 6.0	0.556	1.5 (−2.1 to 5.1)	0.4 (−2.3 to 3.2)	1.1	−5.4 to 3.3	0.624
Offset (mm)[a]	−2.0 (−5.1 to 1.1)	0.1 (−1.8 to 2.1)	2.1	−1.5 to 5.7	0.250	−0.7 (−3.6 to 2.2)	1.5 (−0.5 to 3.5)	2.2	−1.2 to 5.7	0.193

[a] A negative value indicates a decrease in the measure and a positive value an increase in the measure during the interval

[b] Statistically significant

Results

Mean patient age was 79.8 (range 49–94) years. Forty-five (80.4%) of patients were women and 11 (19.6%) were men. Most fractures (*n*: 52, 92.9%) were caused by falling indoors from standing height. Eleven (19.6%) patients had previously diagnosed dementia, and the most frequent pre-operative American Society of Anaesthesiologists scoring (ASA) was three (*n*: 34, 60.7%). Both the DHS and the PFN were used in 28 operations. The skin-to-skin operation time averaged 53 (range 25–200) min, and the average blood loss was 300 (range 100–2,500) ml. Patients were discharged on average 5 (range 1–15) days post-operatively, usually to a rehabilitation hospital (51 patients, 91.1%).

Forty-eight (85.7%) of the 56 patients (Table 1) underwent radiographic analysis at 6 weeks and 4 months. Of the eight patients who were not analysed, two had died, five were too ill to attend, and one had been revised at 3 months due to a significant compression of the fracture and sliding of both screws of the PFN in a case with unsatisfactory reduction (Fig. 4). No screw cut-outs in the femoral neck or head were observed. All patients had been mobilised during the first 6 weeks post-operatively, although all patients had not regained their previous walking ability.

Radiographic findings are presented in Table 2, including measures from the uninjured hip as well as measures from the injured hip at first post-operative day, at 6 weeks and at 4 months. The neck-shaft angle of the operated femur decreased significantly in both groups during the first 6 weeks post-operatively, whereas the measured mean values remained virtually unaffected during the period from 6 weeks to 4 months regardless of the implant used (Table 3). When the final outcomes at 4 months were compared to the uninjured hip, a significant difference was observed between the groups (Table 4). Fracture reduction or the TAD did not correlate significantly to the mean change within the follow-up.

Discussion

Since the DHS came into general use in the treatment of trochanteric femoral fractures, a great deal of emphasis has been aimed at the function of the implant in unstable cases. Several earlier studies have analysed in detail the correlation between the risk of screw cut-out and the location of the compression screw in the femoral neck. The central position of the screw in the coronal plane and central or inferior position in the frontal plane are generally accepted as optimal positions [13, 20]. In the present series, the compression screws of the DHS and neck screws of the PFN were in most cases situated acceptably, although there was a tendency to an anterior location of the neck screw of the PFN (Fig. 3). However, the distribution of the implant in the different zones was too wide to allow a statistical analysis of the decrease in the neck-shaft angle in association to implant position.

Table 4 An analysis of hip measures at 4 months post-operatively when compared to the uninjured hip in 48 patients with an unstable pertrochanteric femoral fracture treated with the dynamic hip screw (DHS, *n*: 24) or the proximal femoral nail (PFN, *n*: 24)

	Mean difference (with 95% CI) between uninjured and operated hip at 4 months post-operatively		Difference between treatment groups		
Treatment mode	DHS	PFN	Mean	95% CI	*P*
Femoral neck shortening (mm)[a]	−3.0 (−7.3 to 1.4)	4.9 (0.2 to 9.5)[b]	7.9	1.6 to 14.0	0.014[b]
Neck-shaft angle (degrees)[a]	2.7 (−1.1 to 6.4)	−3.7 (−8.3 to 0.8)	6.4	0.7 to 12.1	0.029[b]
Offset (mm)[a]	−8.1 (−12.4 to −3.8)[b]	5.1 (−0.3 to 9.9)	13.2	6.9 to 19.5	<0.001[b]

[a]A negative value indicates a decrease in the measure and a positive value an increase in the measure
[b]Statistically significant

The cut-out of the screw is indisputably the most obvious sign of fracture and fixation instability in view of the fact that it is the ultimate result of the migration of the fixation screw within the femoral neck. The most obvious change that occurs during screw migration is a decrease in the neck-shaft angle with a possible subsequent alteration of the femoral offset. The most important finding of the present series was that the mean neck-shaft angle decreased in both treatment groups significantly within the first 6 weeks post-operatively. This decrease was more distinct in the DHS group, but the difference to patients treated with the PFN was not significant. This finding is in contrast to the recent results of Madsen et al. [10] who observed a significant decrease in the neck-shaft angle during fracture healing more frequently in patients treated with the gamma nail than in those treated with the DHS. On the other hand, Olsson et al. [12] reported that 16 of 40 patients treated with a compression hip screw showed a varus angulation of more than 5° compared to the contralateral hip at 4 months. However, neither of the previous studies reported in detail the mean value of the change in the neck-shaft angle. While previous data of post-operative changes associated with the use of DHS may allow some interpretations, when added to the results of the present study, previous data regarding secondary valgus in fractures treated with the PFN are much more sparse. Herrera et al. [7] reported an incidence of a valgus exceeding 10° in nine of 125 fractures treated with PFN. However, this series comprised both stable and unstable fractures, and no conclusions as regards the stability of the PFN in unstable pertrochanteric fractures can thus be made. To our knowledge, the present study is the first in which post-operative changes in hip measures over a given time have been investigated and compared in detail between two implants. Our results suggest that both the DHS and the PFN are prone to a substantial post-operative decrease in femoral neck-shaft angle. Most of this decrease occurred during the first few weeks after the operation, and subsequently became stable.

In post-operative comparison to the uninjured hip, patients in the DHS group showed a shorter mean femoral neck length than those treated with the PFN (Table 2). This finding apparently reflects the differences in operative technique, which includes an intra-operative compression

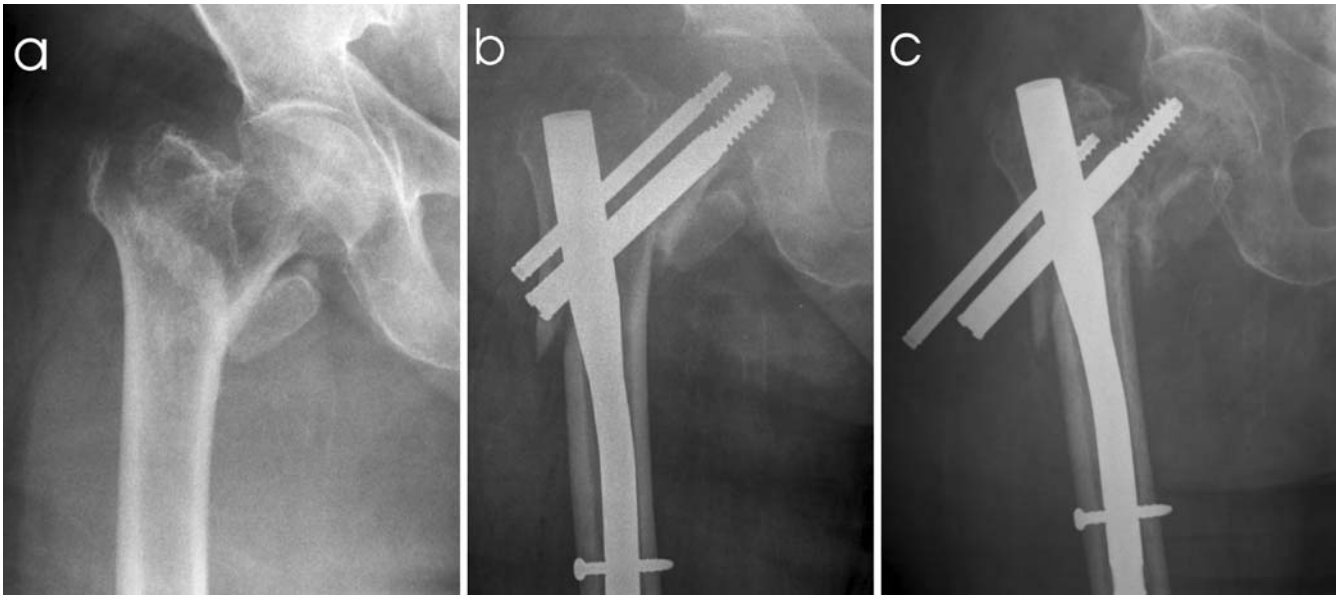

Fig. 4 Failure of fixation in an unstable pertrochanteric femoral fracture **a** treated with the proximal femoral nail (PFN). **b** Primary reduction was not satisfactory, and **c** the screws of the PFN backed out within 3 months. The patient was re-operated 3 months from primary fixation.

of the fracture with the DHS. As expected, the femoral neck length did not change significantly during the follow-up in these patients. Perhaps more unexpectedly, the mean femoral neck length did not decrease in the PFN group either, which may suggest that fracture compression is not of major importance in the healing of the pertrochanteric fracture, at least if the PFN is used.

In the post-operative radiograph, fractures treated with the DHS were in a valgus position when compared to the uninjured hip whereas fractures treated with the PFN showed a nearly anatomic neck-shaft angle. As a summation of the post-operative position and the changes in the measures during the following 4 months, the final outcome in the treatment groups was very different (Table 4). In addition to a significant difference in the neck-shaft angle, fractures treated with the DHS showed a significant medialisation of the femoral shaft when compared to those treated with the PFN. Although the groups differed significantly, we cannot conclude that either implant preserved the post-operative fracture position better than the other, in contrast to a recent randomised study comparing the compression hip screw and the gamma nail [1]. In our opinion, conclusions as regards the superiority of position maintenance are inadequate since clinical data about the importance an altered neck-shaft angle compared to medialisation of the femoral shaft is missing, although it is known that femoral offset correlates to the biomechanical properties of the hip [11]. We suggest that pertrochanteric fractures should initially be reduced in a slight valgus in order to achieve a neck-shaft angle that is as normal as possible after fracture healing, as also stated by Parker [14]. Moreover, since fractures treated with the PFN showed, on average, no medialisation of the femoral shaft, it may be hypothesised that this implant may preserve the anatomic relations of the hip better than the DHS if the fractures were initially reduced to a valgus position.

A follow-up of 4 months may be considered too short if clinical data is to be evaluated. However, in an elderly population such as ours, the drop-out frequency increases significantly with time and may thus impair the interpretation of the results. On the other hand, the follow-up of a few months seemed to be adequate for a study of post-operative changes in hip measures since the positions only changed within the first 6 weeks. With a longer follow-up, the number of patients would have most likely decreased significantly due to reasons associated to this high-age population.

In conclusion, our results suggest that a significant decrease in neck-shaft angle occurs during the first 6 weeks post-operatively in unstable pertrochanteric fractures both with the DHS and the PFN. The outcome differed significantly between treatment groups when the final measures were compared to the uninjured hip, and femoral shaft medialisation was more significant if the DHS was used for fracture fixation. Due to the general decrease in the neck-shaft angle, we recommend that unstable pertrochanteric fractures should be initially reduced to a slight valgus position in order to achieve a position as normal as possible after fracture healing.

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