Tip apex distance, hip screw placement, and neck shaft angle as potential risk factors for cut-out failure of hip screws after surgical treatment of intertrochanteric fractures

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Abstract

Purpose To describe the quality of osteosynthesis after intertrochanteric fractures evaluation of tip apex distance (TAD) and position of the hip screw have been established. Furthermore, a slightly valgus fracture reduction has been suggested to reduce the risk of cut-out failure. However, uniform recommendations for optimal screw positioning and fracture reduction are still missing. The purpose of our study was to confirm potential risk factors for cut-out of hip screws of intertrochanteric fractures and to provide recommendations for practical clinical use.

Methods A retrospective analysis of all patients with intertrochanteric fractures treated with a DHS or a gamma nail between January of 2007 and May of 2010 was performed at a level I trauma center.

Results Two hundred thirty-five patients with intertrochanteric fractures after intra- and extramedullary stabilization were analyzed. A TAD of more than 25 mm was demonstrated

to be the most important factor for cut-out in stable and unstable fractures. Fracture reduction with a valgus NSA of 5–10° was associated with a trend towards a lower rate of screw cut-out while an anterior placement of the screw (Parker's ratio index of <40) significantly increased cut-out incidence.

Conclusions According to our results, the TAD should not exceed 25 mm in stable (AO/OTA A1) as well as unstable (AO/OTA A2) fractures. An increased anterior hip screw placement should be avoided while fracture reduction with a slight valgus Neck Shaft seems favorable.

Introduction

Demographic development has resulted in an increased incidence of geriatric fractures [1, 2]. Moreover, intertrochanteric fractures have been described as one of the most debilitating injuries leading to increased mortality and a significant socio-economic burden [1, 2]. To prevent complications of immobilization, fracture fixation should allow early mobilization of the patient with immediate full weight bearing [3]. Since the 1960s, the sliding hip screw and side plate (DHS) has become the standard implant for surgical treatment of intertrochanteric fractures as it allows controlled fracture compression [4, 5]. Despite additional modifications, such as trochanteric support plates and anti-rotational screws, unstable fractures are less successfully treated by this method [3, 6]. Consequently, intramedullary stabilization techniques, such as the intertrochanteric cephalomedullary nail and the proximal femoral nail have been developed. Nevertheless, cut-out of the hip screw has been described as the most frequent mechanical failure for all implants [7–9]. Previous studies suggested a relationship

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of screw failure with technical and biomechanical aspects of the implanted hip screw as well as with the quality of fracture reduction [2, 10, 11].

In summary, a central-posterior placement of the implanted hip screw in the lateral radiographic view and a central-inferior position in the anteroposterior view are recommended by most authors [2, 5, 11, 12]. Furthermore, the quality of fracture reduction described by the neck shaft angle (NSA) has been evaluated [13, 14]. In general a varus displacement of 3.9° to 5.3° within the first six weeks after surgery compared to initial postoperative measurements is a common finding [3, 5, 12]. This suggests that an optimal fracture reduction should be performed in a slightly valgus position [3, 5, 12]. In addition, a valgus reduction is believed to diminish deforming forces by reducing the distance between the plate or nail and the weight bearing axis [13].

Despite these theoretical principles, with the exception of the tip apex distance, uniform recommendations for the optimal extent of valgus fracture reduction and optimal screw placement are lacking [15]. Therefore, we intended to quantify parameters for optimal screw placement (Parker's ratio, TAD) and fracture reduction in order to standardize clinical practice for treatment of intertrochanteric fractures.

Patients and methods

The present study follows the guidelines of the revised UN Declaration of Helsinki in 1975 and its latest amendment in 1996 (42nd general meeting).

Patients

A retrospective analysis of all patients with intertrochanteric fractures treated with a DHS (Synthes, Westchester, PA, USA) or a gamma 3 nail (Stryker, Mahwah, New Jersey, USA) between January of 2007 and May of 2010 was performed at a level I trauma center. Only primarily admitted patients were included.

Patients who sustained pathological fractures as well as polytraumatized patients (Injury Severity Score ≥ 9) were excluded from the study. Furthermore, patients were excluded because of in-hospital mortality, and missing or inadequate post-operative x-rays preventing accurate measurements. No patients were excluded based on age or comorbidities.

Fracture classification

Pre-operative radiographs and hospital records were evaluated to determine the type of fracture. Orthopedic Trauma

Association (AO/OTA) fracture classification [16] was used to evaluate fracture type. Radiographs were reviewed independently by two surgeons (H.A. and F.H.) using Centricity Enterprise Web (General Electric Medical Systems 2006, v. 3.0, Chalfont St Giles, Great Britain).

Osteosynthesis

All included intertrochanteric fractures were treated by DHS (135° plates, two or four screw holes) or gamma 3 nail (130°). The surgical indication for intramedullary or extramedullary stabilization was identified by the operating surgeon.

Evaluation for risk factors

Hip screw positioning was assessed by analyzing postoperative x-rays before weight bearing and recording the tip apex distance (TAD) described by Baumgaertner et al.. The TAD was defined as “the sum of the distance, in millimeters, from the tip of the hip screw to the apex of the femoral head measured on an anteroposterior and lateral radiograph after correction has been made for magnification” [10, 17]. Radiographic magnification was determined by dividing the known diameter of the lag screw with the measured diameter. The lag screw position in the femoral head was recorded according to Parker's ratio index [5, 11].

The projected NSA was defined as the angle subtended between the femoral neck axis and the femoral shaft axis on the anteroposterior radiograph [18]. Additionally, the difference relative to the contralateral side was documented [2]. NSA differences were categorized in five groups in order to evaluate the optimal extent of fracture reduction.

Cut-out was defined as projection of the screw from the femoral head by more than 1 mm [11]. (Figures 1, 2, 3, 4 and 5)

Fig. 1 Postoperative x-ray after DHS osteosynthesis

Fig. 2 Cut-out failure after DHS osteosynthesis

Statistical methods

Continuous values are presented as mean±standard deviation (SD). Differences between the groups were evaluated with Student's *t*-test or Wilcoxon rank sum test for continuous data, while Pearson's χ^2 -test was used for categorical values. To evaluate the relation between TAD and a cut-out, the odds ratio and its associated p-value and Wald confidence interval were calculated. NSA differences were categorized in five groups, the NSA differences were dichotomized and a global effect was evaluated. As no patient in the reference group sustained a cut-out, rate differences instead of odds ratios were computed. The associated confidence interval and the p-value were computed according to Agresti and Caffo [19]. Finally, differences in Parker's ratio index between patients with and without cut-out were evaluated with Wilcoxon rank sum test and a Hogdes-Lehmann confidence interval for the treatment effect. A two sided p-value <0.05 was considered to be significant and all confidence intervals are computed with a false positive rate of 0.05 (two-sided). Because of the explorative nature of this study, a multiplicity correction was

Fig. 3 Postoperative a.p. view after gamma nail osteosynthesis

Fig. 4 Postoperative lateral view after gamma nail osteosynthesis

omitted. R, Lucent Technologies, Vienna, Austria, version 2.10.1, and SPSS, IBM Inc., Somers, NY, USA, version 18, were used for the analyses.

Results

Demographic data

In total, 271 patients who had sustained an intertrochanteric fracture were treated during the study period. Eight patients had to be excluded due to in-hospital mortality (2.9 %) and 28 patients (10.3 %) had incomplete or qualitatively low x-rays preventing accurate measurements. Two hundred thirty-five patients were included in this study. Most individuals were female (70.2 %). Mean age was 80.8 ± 11.0 years.

Implants and cut-out of hip screw

The DHS was implanted in 80.0 % (188 patients) while intramedullary stabilization was performed in 20.0 % (47

Fig. 5 Cut-out failure after gamma nail osteosynthesis

patients). Eight patients (3.4 %) developed a cut-out of the hip screw. Following DHS osteosynthesis, cut-out was documented in six cases (3.2 %); following gamma nail osteosynthesis, two patients with cut-out were identified (4.3 %). There was no difference in gender distribution between cut-out and uneventful healing ($p=0.203$) while patients with cut-out were marginally younger (Table 1).

Follow up

Patients were seen in our outpatient clinic for follow up examination. In July 2011, all included patients have additionally been interviewed for potentially performed surgery and discomforts for study purposes.

Risk factors for cut-out according to the fracture classification

Fractures of AO/OTA type A1 were treated with a DHS in 101 patients and with a gamma 3 nail in five patients. As three patients with DHS stabilization developed a cut-out (2.97 %) no difference was elucidated between DHS and gamma nail ($p=0.153$). However, a TAD of more than 25 mm was associated with an increased risk for cut-out ($p=0.015$). Screw placement and a valgus neck shaft angle had no influence on secondary dislocation following DHS osteosynthesis. As no cut-out failure was ascertained after intramedullary surgery, only descriptive results could be documented (Table 2).

With regard to the fracture classification AO/OTA type A2, cut-out was observed in three DHS and two gamma nail patients ($p=0.350$). No difference in TAD could be demonstrated between patients with uneventful healing and cut-out (Table 2). However, assuming a TAD of 25 mm as a threshold, two patients with DHS cut-out ($p=0.078$) and

intramedullary cut-out ($p=0.081$) exceeded this limit. Furthermore, an increased anterior hip screw placement was measured in patients who developed cut-out after DHS (Table 2).

No cut-out failure was noted with regard to the fracture classification AO/OTA type A3.

Risk factors regardless of fracture classification

For all patients, a twenty-four times increased risk of cut-out was recorded if the established TAD limit of 25 mm was exceeded (Odds ratio 24.1, 95 %-CI [1.01; 1.41]; $p=0.003$). An anterior position of the hip screw (Parker's ratio <40) was associated with a higher incidence of screw cut-out (Hodges-Lehmann estimate $-7,867$; Hodges-Lehmann 95 % CI $[-15,650; -0,085]$; $p=0.047$) (Table 1). The overall NSA difference compared to the contralateral side ranged from -18° to 20° (Table 3). While the TAD remains almost consistently between the different groups, patients with a postoperative valgus NSA of $5-10^\circ$ did not develop a cut-out. Analyzing the dichotomized effect comparing the valgus reduction of $5-10^\circ$ versus the remaining NSA results, a statistical trend could be determined (risk difference = 3.4 %, 95 %-CI $[-0.1 \%; 8.2 \%]$; $p=0.091$).

Subgroup analysis

As the aforementioned 28 patients (10.3 %) were excluded due to missing or inadequate postoperative x-rays, we analyzed the operative notes and performed a follow up interview in order to evaluate a presumable subset. We found no differences in age or gender as well as the complications of interest.

Discussion

Surgical treatment of intertrochanteric fractures is associated with various complications such as mechanical failure and bone healing complications [1, 4, 12, 15]. Migration of the hip screw resulting in cut-out of the femoral head remains the most common mechanical failure, which is indisputable the most obvious sign of fracture and fixation instability [3, 5]. Patients with screw cut-out require secondary surgery they may be unable to endure based on the considerable incidence of preexisting comorbidities [15]. Therefore, precise information about the optimal position of the hip screw is of major importance for a successful treatment of these patients.

Focusing on screw cut-out failure, we were able to demonstrate the following results:

1. Hip screw cut-out was found in 3.4 % of our study population.
2. A TAD of more than 25 mm was demonstrated to be the most important factor for cut-out in stable and unstable fractures.

Table 1 Comparison of demographic and technical variables in patients with cut-out and uneventful healing

Variable	Cut-out	Uneventful healing	<i>p</i> -value
Number of patients	8	227	-
Age [years]	74.50±10.60	81.03±10.96	0.128
Gender distribution	29 % female	50 % female	0.203
TAD [mm]	26.99±6.09	19.65±7.76	0.009
Parker's ratio index [a.p.]	46.13±12.58	43.47±9.08	0.652
Parker's ratio index [lat.]	39.70±13.99	45.99±9.27	0.047

TAD Tip Apex Distance

a.p. antero-posterior

lat. lateral

Table 2 Risk factors for cut-out in stable and unstable intertrochanteric fractures

	DHS			Intramedullary devices		
	Cut-out	Uneventful healing	<i>p</i> -value	Cut-out	Uneventful healing	<i>p</i> -value
(AO/OTA 31-A1)						
n	3	98	-	0	5	-
TAD [mm]	27.67±2.08	17.78±6.90	0.015	-	17.45±8.07	-
Parker's ratio index [a.p.]	40.69±14.93	42.54±9.05	0.538	-	46.47±9.48	-
Parker's ratio index [lat.]	51.85±22.88	46.45±9.83	0.538	-	53.38±10.00	-
NSA after surgery [°]	134.67±1.53	131.28±5.13	0.257	-	129.00±6.96	-
NSA difference [°]	0.33±11.93	4.80±6.41	0.185	-	1.00±3.39	-
(AO/OTA 31-A2)						
n	3	83	-	2	32	-
TAD (mm)	23.00±8.19	20.04±7.12	0.483	31.95±4.31	22.89±9.01	0.176
Parker's ratio index [a.p.]	43.17±5.23	42.55±8.54	0.710	47.45±9.38	58.72±13.25	0.200
Parker's ratio index [lat.]	31.41±5.25	44.53±8.40	0.007	47.14±8.66	39.98±9.68	0.417
NSA after surgery (°)	128.67±1.53	130.41±5.61	0.594	132.50±0.71	130.31±5.51	0.584
NSA difference (°)	4.00±6.08	5.35±6.83	0.741	0.50±3.54	1.11±6.61	0.898

TAD Tip Apex Distance

NSA Neck Shaft Angle

a.p. antero-posterior

lat. lateral

- Fracture reduction with a valgus NSA of 5–10° was associated with a trend towards a lower rate of screw cut-out.
- An anterior placement of the screw (Parker's ratio index of <40) should be avoided due to a significantly increased cut-out incidence in these patients.

Within the last decade there was an ongoing controversy about the optimal treatment strategy of different fracture types of the proximal femur [7]. Opportunities of intramedullary and extramedullary strategies were analyzed by biomechanical and functional aspects as well as the incidence of mechanical failure [6, 7, 20, 21]. It is well accepted that DHS or an intramedullary nail can be used for stable fractures (AO/OTA A1), while controversy exists with regard to optimal osteosynthesis of unstable fractures (AO/OTA A2 and A3) [3, 6, 7]. However, cut-out failure as one of the most important mechanical complication is found after

intramedullary as well as extramedullary treatment [7–9, 22] with an incidence between 1.4 and 19 % depending on fracture type and used implants [9, 23]. Accordingly, in this study 3.4 % of patients developed a cut-out of the hip screw.

Stable vs. unstable fractures

In accordance with the current literature we found that TAD represents the most reliable predictor for screw cut-out in stable fractures [5, 10, 17]. Furthermore, our results confirmed the previously described critical threshold for the TAD of 25 mm [15]. This study also illustrated that there is no association between cut-out and screw placement in the anterior-posterior or superior-inferior position in stable fractures. However, patients with cut-out tended to have a more posterior screw position (Parker's ratio index 51.85).

Table 3 Analysis of the post-operative NSA difference to the contralateral side

	NSA Difference to the contralateral side	<i>n</i>	TAD mean ± SD	Cut-out frequency	Difference of frequency to 5° to 10° 95 % CI [%]	Difference of frequencies, 95 % CI and <i>p</i> -value versus 5° to 10°
	< -5°	20	17.82±8.71	5.0 %	-4.7; 20.0	3.40 % CI=[-0.1; 8.2] <i>p</i> =0.091
TAD Tip Apex Distance	-5° to 0°	39	21.02±7.42	5.1 %	-2.6; 14.2	
NSA Neck Shaft Angle	0° to 5°	57	20.22±7.88	5.3 %	-1.7; 12.3	
a.p. antero-posterior	5° to 10°	66	20.34±8.93	0 %	-	
lat. lateral	> 10°	53	19.00±6.12	3.8 %	-2.7; 10.6	

This descriptive result might be explained by recent findings of other studies, demonstrating an increased TAD if the screw is positioned inferior-posterior compared to an inferior-anterior position [5, 12]. However, a slightly central-posterior position is recommended by most authors in order to support the posteromedial cortex accepting an increased TAD [2, 5, 11, 12].

Beside these established parameters, we hypothesized that the NSA can influence the risk for cut-out in AO type I fractures. This hypothesis was based on the well described varus fracture displacement ranging from 3.9° to 5.3° due to mobilization within the first six weeks after surgery [3, 13]. Furthermore, a slightly valgus reduction was reported to diminish deforming forces by reducing the distance between the plate or nail and the weight bearing axis [13]. Despite these theoretical principles, definitive treatment recommendations for the postoperative NSA are missing. As suggested in the literature, we quantified the extent of the NSA reduction by calculating the difference between the postoperative NSA and the contralateral side before weight bearing [2]. However, we only found a statistical trend ($p=0.185$) with a valgus fracture reposition (4.8°) in patients with uneventful healing. To date, it seems unclear to which extent a valgus reposition should be achieved. Pajarinen et al. have recommended a fracture reduction in a slight valgus in order to achieve a NSA as normal as possible after weight bearing and fracture healing without providing a precise NSA [3]. The authors hypothesized that intramedullary stabilization may preserve the anatomic relations of the hip even better than the DHS if fractures are initially reduced to a valgus position. If so, a valgus reduction of stable fractures will consequently result in a gap at the inferior-medial aspect of the fracture. Parker has argued this debatable aspect as subsidiary for fracture healing because fracture support is provided laterally [13]. Weight bearing would now result in a controlled fracture collapse restoring medial continuity resulting in unrestrained healing. Advances named by Parker are optimized trabeculae angles of 170° enabling an enhanced weight bearing axis, a reduced risk of leg shortening and the prerequisite of an inferiorly placed hip screw. Therefore, Parker declared the valgus reduction as optimum position with advantages compared to anatomical reduction. According to the presented results only a trend towards a valgus fracture reduction at approximately 5° could be drawn but definitive treatment recommendation cannot be made based on the present data.

For unstable fractures, we found a significantly increased incidence of intramedullary techniques compared to fractures AO/OTA type I which is consistent with the current literature [7]. However, the incidence of cut-out failure was comparable for DHS osteosynthesis and intramedullary techniques ($p=0.350$). Our results reflect the partially controversial discussion about the optimal osteosynthesis of

unstable intertrochanteric fractures in the literature: For instance, Barton et al. currently suggested to consider DHS as the gold standard for osteosynthesis even of unstable fractures [7]. Conversely, recommendations have been made by Utrilla et al., suggesting the intramedullary stabilization by Gamma nail superior to DHS in unstable fractures [6].

Although we found no significant difference of the TAD between cut-out and uneventful healing, a strong trend towards the expected limit of 25 mm after DHS and intramedullary stabilization was identified. Consequently, we recommend the TAD as an important predictor for cut-out following extra- and intramedullary stabilization in unstable fractures which is consistent with recent findings [2]. Referring the hip screw position, we found a significant association between an increased anterior position and cut-out failure after DHS. However, the optimal positioning of the hip screw is still discussed in the current literature: Parker et al. have demonstrated an increased rate of cut-out after posterior positioning [11]. Contrary results have been presented by Baumgaertner et al., whose cut-out rates after anterior placement exceeded all previously reported rates [10]. At least, Guven et al. currently reported an increased cut-out incidence in case of too anterior position [5]. Consequently, anterior misplacement results in increased cut-out failure as demonstrated by the presented results. Nevertheless, increased peripheral placement, posterior as well as anterior, should be avoided. Interestingly, screw placement had no influence after intramedullary stabilization. This finding has to be interpreted with caution because Lobo-Escobar et al. have already considered an increased anterior placement as suboptimal osteosynthesis parameter [2]. With only two cut-outs in the intramedullary group, the number of patients is as a limiting factor restricting the validity of the presented results.

Treatment recommendations regardless fracture classification and implant

Finally, we analyzed all patients regardless of fracture classification or implants used. We intended to identify global risk factors that might be generally applicable for routine clinical practice in treatment of intertrochanteric fractures. Following this purpose, the influence of the TAD seems to be important, as a significantly increased TAD was measured in all patients who suffered cut-out as well as the aforementioned subgroups. The TAD seems to be the most considerable parameter surgeons should be aware of independent the type of fracture or implants used.

Referring to results of hip screw positioning in the femoral head, increased cut-out rates were noted if the screw was placed too anterior. In view of the fact that screw placement influenced cut-out only in case of DHS osteosynthesis, the overall result can only be interpreted with

caution. Nevertheless, in the context of this study regarding placement of the lag screw in too peripheral a location, both anterior as well as posterior should be avoided after extramedullary as well as intramedullary osteosynthesis. But, the overall significant result seems to be due to the small number of cut-outs in this study.

When analyzing the influence of the postoperative NSA, we were able to determine a statistical trend ($p=0.091$) towards an optimal valgus reduction of 5° to 10° relative to the contralateral side. Although only a trend has been illustrated, this study is presenting the first evaluation of the optimal extent of valgus fracture reduction.

Further limitations of this study can be attributed to inaccurate NSA measurements [18]: With an internally rotated femur, NSA estimation on radiographs is only accurate within 10° [14, 24]. As delineated by Marmor and others, external rotation of the femur can cause an over-estimation of NSA to be in valgus [14, 24, 25]. However, internally rotated femora are unlikely in the clinical routine situation. The estimations of our study are therefore reflecting the normal clinical setting [18].

In conclusion, our results support the established TAD as strongest predictor of cut-out after extramedullary and intramedullary stabilization in stable as well as unstable intertrochanteric fractures. Furthermore, too anterior hip screw placement should be avoided. For routine clinical use, we recommend that the TAD should be measured and the limit of 25 mm shall not be exceeded regardless of the implant used. Moreover, there was a trend toward decrease cut-out when an intra-operative reduction of the NSA into a valgus position of 5° – 10° relative to the contralateral side was achieved.

Conflict of interest The authors declare that they have no conflict of interest.

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