Importance of screw position in intertrochanteric femoral fractures treated by dynamic hip screw

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Summary
Background: Tip-apex distance greater than 25 mm is accepted as a strong predictor of screw cut-out in patients with intertrochanteric femoral fracture treated by dynamic hip screw. The aim of this retrospective study was to evaluate the position of the screw in the femoral head and its effect on cut-out failure especially in patients with inconvenient tip-apex distance.

Patients and methods: Sixty-five patients (42 males, 23 females; mean age of 57.6 years) operated by dynamic hip screw for intertrochanteric femoral fractures were divided in two groups taking into consideration the tip-apex distance less (Group A; 14 patients) or more (Group B; 51 patients) than 25 mm. Patient’s age and gender, follow-up period, fracture type, degree of osteoporosis, reduction quality of the fracture, position of the screw in the femoral head, number of patients with cut-out failure and Harris hip score were compared.

Results: The average follow-up time was 41.7 months. The mean tip-apex distance was 17.14 mm in Group A and 36.67 mm in Group B. One (7.1%) patient in Group A and three (5.8%) patients in Group B had screw cut-out. Except the screw position, no statistical differences were observed between two groups with regards to study data’s. The screw was placed in femoral head more inferiorly (p = 0.045) on frontal and more posteriorly (p = 0.013) on sagittal planes in Group B, while central placement of the screw was present in Group A. The common characteristic of three patients with screw cut-out in Group B was the position of the screw which was located in femoral head more superiorly and anteriorly after an acceptable fracture reduction.

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Introduction

The dynamic hip screw (DHS) has become a standard implant for fixation of intertrochanteric femoral fractures since 1960s. Despite alternative devices and surgical techniques are present, DHS is still the most frequently used implant in the surgical treatment of these fractures. The advantages of this implant include deep insertion of the screw, controlled compression and impaction at the fracture site without penetration of the femoral head [1]. However, reduction and internal fixation are a challenge to the surgeon, especially in unstable fractures [2]. There are reported mechanical failure rate changed between 1.9 and 23% in the literature including cutting out of the lag screw from the femoral head, pulling off of the plate from the femoral shaft, dissociation of the compression hip screw from the barrel and failure of the hip screw itself [1,3—8].

Cut-out of the lag screw has been shown to be the most common cause of failure and is related to the position of the screw in the femoral head [9]. There have been two published methods in the literature, which quantify the screw position, including tip-apex distance (TAD) [4] and the Parker’s ratio method [9]. TAD is the sum of the distance from the tip of the lag screw to the apex of the femoral head on anteroposterior and lateral radiographs after controlling for magnification. Baumgaertner et al. and Baumgaertner and Solberg [4,10] concluded that the distance greater than 25 mm was a strong predictor of cut-out. Otherwise, Parker [9] described a ratio method and reported that cut-out was more frequent when the screw was placed superiorly and posteriorly on the anteroposterior and lateral radiographs. Central placement of the implant was recommended by some authors [9,11—13], while others [14,15] recommended posterior placement. However, today, there is still no clear consensus about that.

To provide the TAD lower than 25 mm, the lag screw should be placed centrally as far as possible [4]. Although peripheral placement increases the tip-apex distance, it is not always related with cut-out failure. We reviewed the patients who were operated for intertrochanteric femoral fractures by internal fixation with DHS retrospectively and evaluated the position of the screw and its effect on the failure of fixation, particularly in patients with TAD more than 25 mm.

Patients and methods

The patient database was searched for the time period December 1997 to November 2007 for the patients who had undergone surgery for trochanteric femoral fractures. Hospital records and radiographs were reviewed and only those patients who were operated with DHS for intertrochanteric femoral fractures were included in the study. Exclusion criteria were the fractures treated conservatively and the pathological fractures secondary to tumour or Paget’s disease. Basicervical or subtrochanteric fractures and reversed or transverse fractures at the level of the lesser trochanter were excluded, because they were treated by other surgical methods such as hemiarthroplasty and proximal femoral nailing. The patients who died in the first postoperative year and who had incomplete radiographs and follow-up were also excluded. We identified 65 patients (42 males and 23 females) that met these criteria with a mean age of 57.6 years (range: 22 to 86 years). All patients gave a written informed consent to take part in the study.

Preoperative evaluation

Preoperative radiographs and hospital records were evaluated to determine the type of the fractures and the degree of osteoporosis. All fractures were classified according to the Jensen [16] modification of the Evans classification. Type 1 and type 2 fractures were stable fractures consisting of two fragments. Type 3 (lack of posterolateral support) and type 4 (lack of medial support) fractures consisted of three fragments and type 5 had four fragments. Types 3—5 were regarded as unstable. It could not be possible to measure bone mineral density before the operation. Therefore a subjective assessment of the degree of osteoporosis was made by evaluating the density of the bony trabeculae of the contralateral non-injured hip with Singh index [17] in which normal trabecular bone was defined as grade 6, whereas grade 1 according to this system was an index of severe osteoporosis. The Singh index was evaluated by one experienced orthopaedic surgeon (Kü) who did not know the outcome of the fracture fixation.

Postoperative evaluation

All patients in this series received a surgical treatment consisting of closed reduction under image intensification and internal fixation with 135° DHS. No additional fixation device such as a trochanteric stabilizing plate or cerclage wiring was used. The immediate postoperative radiographs were used to assess the accuracy of the fracture reduction and the position of the implant in the femoral head. The fracture reduction was assessed according to the Garden alignment index (GAI) [18] on the anteroposterior and lateral radiographs. An anatomical reduction was defined as the angle of 160° between the primary compressive trabeculae and the femoral shaft on the anteroposterior radiograph and as the angle of 180° between the midshaft of the femoral neck and
the femoral shaft on the lateral radiograph. The quality of the reduction was categorized as good, acceptable or poor [4]. For a reduction to be considered good, there had to be normal or slight valgus alignment on the anteroposterior radiograph, less than 20° of angulation on the lateral radiograph and no more than four millimetres of displacement of any fragment. An acceptable reduction was characterized by the criterion of a good reduction with respect to either alignment or displacement, but not both. A poor reduction met neither criterion.

The position of the screw was determined by the TAD described by Baumgaertner et al. [4]. The TAD was defined as the sum of the distance, in millimetres, from the tip of the lag screw to the apex of the femoral head, as measured on an anteroposterior radiograph and that distance as measured on a lateral radiograph, after correction had been made for magnification (Fig. 1). The amount of radiographic magnification was determined by dividing the known diameter of the lag screw with the diameter measured on the radiographs. The location of the screw was also recorded according to the ratio method described by Parker [9]. With this method, the femoral head was divided into thirds on the anteroposterior and lateral radiographs (Fig. 2). The ratio of the screw position gave a range of zero to 100 and a ratio greater than 66 was accepted as a superior and anterior position of the lag screw on the anteroposterior and lateral radiographs.

Radiographs of the fractures that were obtained at six weeks, three, six and twelve months postoperatively were used to demonstrate any failure of fixation. The cut-out was defined as projection of the screw from the femoral head by more than 1 mm [9]. Clinical evaluation of the final follow-up was based on the assessment according to the Harris hip score [19].
Table 1  Comparison of patients with a tip-apex distance more or less than 25 mm on the basis of the type of the fracture and Singh index.

<table>
<thead>
<tr>
<th></th>
<th>Group A TAD &lt; 25 mm</th>
<th></th>
<th>Group B TAD &gt; 25 mm</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>Singh index</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>35.7</td>
<td>6</td>
<td>11.8</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>28.6</td>
<td>14</td>
<td>27.5</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>14.3</td>
<td>11</td>
<td>21.6</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>14.3</td>
<td>8</td>
<td>15.7</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>7.1</td>
<td>11</td>
<td>21.6</td>
</tr>
<tr>
<td>Type of fracture according to Jensen</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>7.1</td>
<td>8</td>
<td>15.7</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>14.3</td>
<td>9</td>
<td>17.6</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>21.4</td>
<td>11</td>
<td>21.6</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>21.4</td>
<td>12</td>
<td>23.5</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>35.7</td>
<td>11</td>
<td>21.6</td>
</tr>
</tbody>
</table>

χ²: 5.54

χ²: 1.56

p = 0.811

p = 0.815

TAD: Tip-apex distance; n: Number of patient; χ²: Chi-square test. Jensen [16] reported as stable type 1 and type 2 fractures and types 3–5 as unstable. Singh index [17] applied on the contralateral non-injured hip rated trabecular bone from normal as grade 6 to grade 1 as an index of severe osteoporosis.

The patients were divided in two groups taking into consideration the TAD less (Group A) or more (Group B) than 25 mm. For both groups, we recorded and compared the patient’s age and gender, the follow-up period, the type of fracture, Singh index, quality of reduction according to the GAI, TAD, Parker’s ratio, number of patients with cut-out failure and Harris hip score. All the radiological and clinical assessments on the final follow-up were made by two surgeons (MG and UY), who were involved in the primary treatment of patients.

Statistical analysis

The statistical analysis was performed by using GraphPad Prisma V.3 program (GraphPad Software, San Diego, CA, USA). The data’s were analyzed using the following statistical parameters: definitions (mean, standard deviation), Mann-Whitney U test for comparison between two groups and chi-square test for comparison of the qualitative data. A p value of < 0.05 was considered to be statistically significant.

Results

The average follow-up time was 41.7 months (range: 12 to 132 months) in this series. The number of the patients with each type of fracture and Singh index is shown in Table 1. None of the patients developed early or late complications including infection, non-union or deep venous thrombosis. There was no breakage or bending of implants. All plates were sufficiently attached to the femoral shaft. GAI on the early postoperative period was 163° (range: 148° to 178°) on the anteroposterior and 173° (range: 150° to 204°) on the lateral radiographs on average. The reduction of 48 (74%) fractures was considered to be good. Fourteen (21.5%) fractures had an acceptable and three (4.5%) fractures had a poor reduction quality. The mean TAD was 32.47 mm (range: 7.37 to 71.28 mm). The ratio of the screw position was 43.7% (range: 20 to 66) on the anteroposterior and 47.4% (range: 28 to 69) on the lateral radiographs on average. The mean Harris hip score on the final follow-up was 88.9 (range: 63 to 97). Except for four (6.1%) patients with cut-out of the lag screw from the femoral head within the first postoperative year, none of the patients had failure of fixation on the final follow-up.

The mean TAD was 17.14 mm (range: 7.37 to 23.21 mm) in Group A (14 patients) and 36.67 mm (range: 25.74 to 71.28 mm) in Group B (51 patients). No statistical differences were observed between two groups with regards to the patient’s age and gender, follow-up period, Singh index, GAI and Harris hip score on the final follow-up (Table 2). The number of stable fracture was three (21.5%) in Group A and 17 (33.3%) in Group B, whereas the number of unstable fracture was 11 (78.5%) in Group A and 34 (66.7%) in Group B. There was no statistical difference between two groups with regard to the type of fracture (p=0.815) (Table 1). However, the position of the lag screw in the femoral head was statistically different between the groups. The lag screw was placed in the femoral head more inferiorly (p=0.045) on frontal and more posteriorly (p=0.013) on sagittal planes in Group B (Fig. 3), while central placement of the screw was present in Group A.

One (7.1%) of the 14 patients in Group A had cut-out failure. This patient was old and had an unstable fracture pattern with severe osteoporosis. The quality of fracture reduction was poor in this patient. The rate of cut-out for the remaining 51 patients in Group B was 5.8% (three patients). The common characteristic of these patients was the position of the screw, which was located in the femoral head more superiorly, and anteriorly after an acceptable fracture reduction. The data’s of the study for the patients with cut-out failure were shown on Table 3.
Position of the dynamic hip screw

Table 2  Compared study data’s between the patients with a tip-apex distance more or less than 25 mm.

<table>
<thead>
<tr>
<th></th>
<th>Group ATAD &lt; 25 mm: 14</th>
<th>Group BTAD &gt; 25 mm: 51</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients with cut-out failure</td>
<td>1 (7.1%)</td>
<td>3 (5.8%)</td>
<td>MW: 278.5 0.210</td>
</tr>
<tr>
<td>Age (year)a</td>
<td>63.14 ± 16.76</td>
<td>56.12 ± 16.6</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>6 (42.9%)</td>
<td>36 (70.6%)</td>
<td>χ²: 3.69 0.650</td>
</tr>
<tr>
<td>Female</td>
<td>8 (57.1%)</td>
<td>15 (29.4%)</td>
<td></td>
</tr>
<tr>
<td>Follow-up period (month)a</td>
<td>50.07 ± 22.96</td>
<td>39.39 ± 22.53</td>
<td>MW: 243.5 0.07</td>
</tr>
<tr>
<td>GAI on AP radiographa</td>
<td>162.93 ± 7.09</td>
<td>163.25 ± 6.94</td>
<td>MW: 341 0.797</td>
</tr>
<tr>
<td>GAI on lateral radiographa</td>
<td>173.43 ± 13.3</td>
<td>172.67 ± 7.08</td>
<td>MW: 338 0.76</td>
</tr>
<tr>
<td>PR on AP radiograph (%)a</td>
<td>48.93 ± 8.01</td>
<td>39.25 ± 12.52</td>
<td>MW: 221.5 0.045</td>
</tr>
<tr>
<td>PR on lateral radiograph (%)a</td>
<td>53.43 ± 7.99</td>
<td>41.75 ± 11.14</td>
<td>MW: 202 0.013</td>
</tr>
<tr>
<td>Harris hip scorea</td>
<td>88.71 ± 4.89</td>
<td>89.06 ± 7.65</td>
<td>MW: 311 0.458</td>
</tr>
</tbody>
</table>


a  The values are given as the mean and standard deviation.

Discussion

Migration of the lag screw with cut-out from the femoral head remains the most common mechanical complication after surgical fixation with DHS. Patient’s age, bone quality, pattern of the fracture, stability of the reduction, type and angle of the implant and position of the lag screw in the femoral head have all been related to this mechanism of failure [2,4,5,14]. While all named factors are important, there is general agreement in the literature that cut-out failure is strongly associated with malpositioning of the lag screw in the femoral head [4,5,10,14,20].

In 1995, Baumgaertner et al. [4] introduced the concept of the TAD. It describes the position of the lag screw within the femoral head and was shown to be highly predictive of fixation failure by screw cut-out. In their study, there were no incidences of screw cut-out in any patient who had a TAD of less than 25 mm. It was noted that 27% of their patients with a TAD of more than 30 mm suffered a screw cut-out while only 2% of patients with a TAD between 25 and 30 mm had this mechanical failure. The authors also concluded that there was an increased risk of cut-out failure in older or osteoporotic patients, those with unstable fractures and after poor reduction or fixation with an angle of 150° device. Afterwards, Pervez et al. [21] concluded that the TAD should be less than 20 mm.

However, not all incorrectly placed lag screws will cut-out, which indicates that other factors should be considered [20]. The average age was 77 years in Baumgaertner et al.‘s study [4]. They reported that the patients in whom the screw cuts out of the femoral head had an average age of 85 years. Pervez et al. [21] reported that the average age of their patients was 81 years for both of the patients with and without screw cut-out. The patients in our study were younger (average age 57.6 years) than the patients in these two reports. This difference may be the factor that affects the low rate of cut-out failure in our study. Therefore, we conclude that some other factors except the TAD should be
Table 3

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age</th>
<th>Type of Fracture</th>
<th>Singh Index</th>
<th>TAD (mm)</th>
<th>GAI on Anteroposterior Radiograph (°)</th>
<th>PR on Anteroposterior Radiograph (%)</th>
<th>GAI on Lateral Radiograph (°)</th>
<th>PR on Lateral Radiograph (%)</th>
<th>Harris Hip Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>86</td>
<td>Male</td>
<td>2</td>
<td>14.8</td>
<td>158</td>
<td>60</td>
<td>60</td>
<td>65</td>
<td>60</td>
</tr>
<tr>
<td>2nd</td>
<td>78</td>
<td>Male</td>
<td>3</td>
<td>32.3</td>
<td>156</td>
<td>55</td>
<td>60</td>
<td>60</td>
<td>65</td>
</tr>
<tr>
<td>3rd</td>
<td>68</td>
<td>Male</td>
<td>1</td>
<td>43.6</td>
<td>170</td>
<td>52</td>
<td>60</td>
<td>60</td>
<td>65</td>
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<tr>
<td>4th</td>
<td>33</td>
<td>Male</td>
<td>5</td>
<td>72.2</td>
<td>190</td>
<td>59</td>
<td>60</td>
<td>60</td>
<td>65</td>
</tr>
</tbody>
</table>

TAD: tip-apex distance; GAI: garden alignment index; PR: Parker ratio.

Parker [9] described another method to determine the screw position in the femoral head and reported that cut-out was more frequent when the screw was placed superiorly and posteriorly on the anteroposterior and lateral radiographs. However, today there is still no clear consensus about that. Many previous studies [4, 5, 9, 11-13, 21] have indicated that superior and anterior screw placement should be avoided and central placement of the lag screw in the femoral head was recommended. The highest rates of cut-outs occurred in the posterior-inferior and in the anterior-superior zones in Baumgaertner et al.'s study [4]. The rate of cut-out in either of these two peripheral zones was significantly higher than the rate in the center zone. They recommended central and deep insertion of the lag screw in the femoral head. On the contrary, Kaufer [14] advised to place the implant in the posterior-inferior quadrant of the femoral head. He concluded that this position placed the tip of the implant into the bone formed by the decussation of tension and compression trabeculae, thus assuring maximal proximal fragment control. However, Kaufer compared in his study the results of nail-plate implants (Jewett and Holt nails) and telescoping implants. He reported that nail-plate implants with a sharp tip were more likely to penetrate the proximal fragment and should not be inserted as deep as implants with a blunt end. Telescoping implants were least likely to penetrate into the joint and might therefore be inserted more deeply into the proximal fragment, thus affording maximal proximal fragment control.

In the presented study, three (5.8%) of the 51 patients who had a TAD more than 25 mm had cut-out failure, which was very low when compared with the other studies in the literature [1, 4, 10, 21]. The common feature of these patients was the position of the screw, which was located in the femoral head more superiorly, and anteriorly after an acceptable fracture reduction.

The DHS construct allows mechanical load transmission. In stable fracture patterns, it acts as a tension band producing more force transmission through the medial cortex, stressing the implant more in tension and less in bending [22, 23]. But, in unstable fractures, the lesser trochanter and the part of the calcar femoral are missing from the mechanical load transmission system because of the lack of bony support over the medial aspect of the femur. Peripheral placement of the lag screw in the femoral head inherently increases TAD. However, the placement of the screw in posterior and inferior locations of the femoral head supports the comminuted posteromedial cortex and the device allows impaction of the fracture surfaces, shortening the lever arm, decreasing the bending moment, as well as avoiding cut-out of the screw from the femoral head, consequently [22]. Thirty-four (66.7%) patients who had a TAD more than 25 mm had unstable fracture pattern in our study. Except three patients with screw cut-out, the screws were positioned more inferiorly and posteriorly in the femoral head for these patients.

There are some limitations to this study. Firstly, the Singh index is a subjective method for the evaluation of the bone quality [24]. However, the assessment of Singh index in our study was made by one author who did not know the responsible from the cut-out failure in our relatively young patient population.

Parker [9] described another method to determine the screw position in the femoral head and reported that cut-out was more frequent when the screw was placed superiorly and posteriorly on the anteroposterior and lateral radiographs. However, today there is still no clear consensus about that. Many previous studies [4, 5, 9, 11—13, 21] have indicated that superior and anterior screw placement should be avoided and central placement of the lag screw in the femoral head was recommended. The highest rates of cut-outs occurred in the posterior-inferior and in the anterior-superior zones in Baumgaertner et al.’s study [4]. The rate of cut-out in either of these two peripheral zones was significantly higher than the rate in the center zone. They recommended central and deep insertion of the lag screw in the femoral head. On the contrary, Kaufer [14] advised to place the implant in the posterior-inferior quadrant of the femoral head. He concluded that this position placed the tip of the implant into the bone formed by the decussation of tension and compression trabeculae, thus assuring maximal proximal fragment control. However, Kaufer compared in his study the results of nail-plate implants (Jewett and Holt nails) and telescoping implants. He reported that nail-plate implants with a sharp tip were more likely to penetrate the proximal fragment and should not be inserted as deep as implants with a blunt end. Telescoping implants were least likely to penetrate into the joint and might therefore be inserted more deeply into the proximal fragment, thus affording maximal proximal fragment control.

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There are some limitations to this study. Firstly, the Singh index is a subjective method for the evaluation of the bone quality [24]. However, the assessment of Singh index in our study was made by one author who did not know the
results of fracture fixation. Secondly, the rate of cut-out failure was low and we couldn’t compare the data’s of the study between the patients with and without cut-out failure. Therefore, we couldn’t have any conclusion about factors which do or do not influence cut-out failure. However, the current study had good comparability in the baseline characteristics between the groups which were considered to be comparable. Eventually, the importance of posterior and inferior locations of the lag screw in the femoral head took over.

Conclusions

There is general agreement in the literature that the TAD is highly predictive for the screw cut-out. However, it is not the only factor that determines the stability of the screw, particularly in a young patient population. Posterior and inferior locations of the screw may help to support the posteromedial cortex and calcar femoral in unstable intertrochanteric fractures and reduce the risk of cut-out failure consequently.

Conflict of interest

We don’t have any financial, personal relationship with the organization that sponsored the research.

References