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Compression nailing for posttraumatic rotational femoral deformities: open versus minimally invasive technique

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Abstract Between January 1996 and December 1999, we performed 30 derotational osteotomies with compression nailing in 29 patients. In 18 cases (group 1), we used an intramedullary saw (minimally invasive technique), and in 12 cases (group 2), we used a conventional open technique. Follow-up included clinical, conventional radiological, and computer tomographical assessment. The mean angle of derotation was 28.6±12.3° in group 1 and 27.6±10.7° in group 2. The postoperative mean rotational deviation between left and right side was 7.9±6.7° in group 1 and 6.6±4.4° in group 2. There were five postoperative complications: two delayed unions, two insufficient corrections, and one infection. There was no significant difference between the groups. When using the minimally invasive technique, we recommend the derotation angle to be marked with Schanz screws instead of Kirschner wires, as soft-tissue resistance may lead to bending of these.

Résumé Entre janvier 1996 et décembre 1999, nous avons exécuté 30 ostéotomies fémorales de dérotation avec enclouage en compression chez 29 malades. Dans 18 cas (groupe 1), nous avons utilisé un scie intramédullaire (technique mini invasive) et dans 12 cas (groupe 2), nous avons utilisé une technique ouverte conventionnelle. Le suivi à était fait par estimation clinique, radiologie conventionnelle, et tomodensitométrie. L'angle moyen de dérotation était 28,6°±12,3 dans le groupe 1 et 27,6°±10.7 dans le groupe 2. La déviation rotationnelle moyenne postopératoire entre le côté gauche et le côté droit était 7,9°±6.7 dans le groupe 1 et 6,6°±4.4 dans le groupe 2. Il y avait cinq complications postopératoires: deux retards de consolidation, deux corrections insuffisantes et une infection. Il n'y avait aucune différence significative entre les groupes. Quand on utilise la technique mini invasive nous recommandons de marquer les angles de dérotations avec des vis de Schanz plutôt que des broches de Kirschner car la résistance des parties molles peut les courber.

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Introduction

Rotational deformities of the femur are frequently reported complications following fracture treatment, especially after closed intramedullary nailing. In general, it is difficult to diagnose rotational deformities accurately by clinical assessment alone; therefore, the incidence and the severity are often underestimated. Precise correction is technically demanding, and there is still some controversy surrounding the optimal choice of operative technique. Minor rotational deformities of the femur are mostly asymptomatic. Rotational deformities up to 15° are considered within the physiological range in central European adults [15]. Operative correction may be indicated for angles greater than 15–20°. Important clinical considerations are the range of internal and external hip rotation, but the nature and extent of the deformity, the associated functional deficit, and factors such as age, mobility, and past medical history must be taken into account. We evaluated the use of intramedullary compression nailing for stabilization of corrective osteotomies for posttraumatic femoral rotational deformities. We compared open osteotomy to a minimally invasive operative technique.

Materials and methods

Between January 1996 and December 1999, 29 patients (18 women, 11 men) with a mean age of 34.9 (range 18–62) years underwent operative correction of 30 femoral rotational deformities. In all cases, the deformity followed treatment of a femoral shaft fracture. Primary fracture care included intramedullary nailing in 19 cases, plate fixation in ten, and nonoperative treatment in one. The time between injury and correction of the deformity ranged from 5 months to 15 years, with a mean of 3.1 years. In all cases, complete fracture healing had occurred by the time of correction.

All patients underwent serial follow-up evaluations. Follow-up time ranged from 8 to 47 months, with a mean of 19.4 months after corrective osteotomy. The assessment included a physical examination, plain radiographs, and computed tomography (CT) scans. Fracture healing was defined as consolidation of at least three cortices. Nonunion was defined as a lack of bone consolidation 8 months following surgery. Postoperative femoral torsion was compared to preoperative values. Femoral torsion was determined by CT scans of the injured and unaffected sides in all patients using standardized proximal and distal reference points [2, 15]. A follow-up scoring system was developed, closely modelled on the Neer scoring system [14]. Evaluation included functional criteria and anatomical and radiological findings. The maximum possible score was 100. Scores of greater than 86 were considered excellent, scores between 85 and 71 were satisfactory, scores between 56 and 70 were unsatisfactory, and scores less than 55 were recorded as failures.

Operative technique

Rotational corrective osteotomy was performed at the level of the former fracture site using either an open technique or a closed minimally invasive technique. Existing hardware was removed prior to osteotomy. In the open technique, the femoral shaft was exposed via a posterolateral approach. The derotational angle was marked with Kirschner wires, and osteotomy was performed using an oscillating saw at the predetermined site. After correction of the angle, the fragments were stabilized with an antegrade intramedullary compression nail (Osteo AG, Selzach, Switzerland), and compression at the osteotomy site was applied [3].

For the minimally invasive technique, osteotomy was performed using an intramedullary saw (Fig. 1) [13]. First the d-rotational angle was marked with Kirschner wires percutaneously. After intramedullary reaming, the saw was introduced into the intramedullary canal and osteotomy was performed using a closed technique under fluoroscopic control. If the osteotomy could not be completed with the intramedullary saw alone, an osteotome was used via a small skin incision. After derotation, the osteotomy was stabilized by intramedullary compression nailing as described above for the open technique.

Postoperative management was similar for both techniques. Wound drains were removed on the second postoperative day. Physiotherapy was initiated on the same day, allowing weight bearing as tolerated. Sutures were removed on the 12th postoperative day. All patients had postoperative plain radiographs and CT scans followed by plain radiographs at 6 weeks, 3 months, and 6 months.

Results

We evaluated a total of 30 corrective rotational osteotomies (Fig. 2). The minimally invasive technique was performed in 18 cases (Table 1) and open osteotomy in 12.

Operative time ranged between 69 and 170 min, with a mean of 122±53 min for the open and 101±29 min for the minimally invasive procedure. This included hardware removal in 16 cases (12 open group, four minimally invasive group). In all 30 cases, compression nailing with compressed dynamic locking was performed. Hospital stay was 16.7 days for open and 14.5 days for minimally invasive procedures. Three patients of the minimally invasive group and two of the open group required blood transfusions.

Follow-up evaluations and scoring produced an overall mean score result of 84.9±6.9 points. Fifteen patients were recorded as having excellent scores, 13 as satisfactory, and two as unsatisfactory. There was no statistical difference in the clinical outcome between the two groups (minimally invasive group: mean score 82.5±6.8; open group: mean score 87.1±7.0).

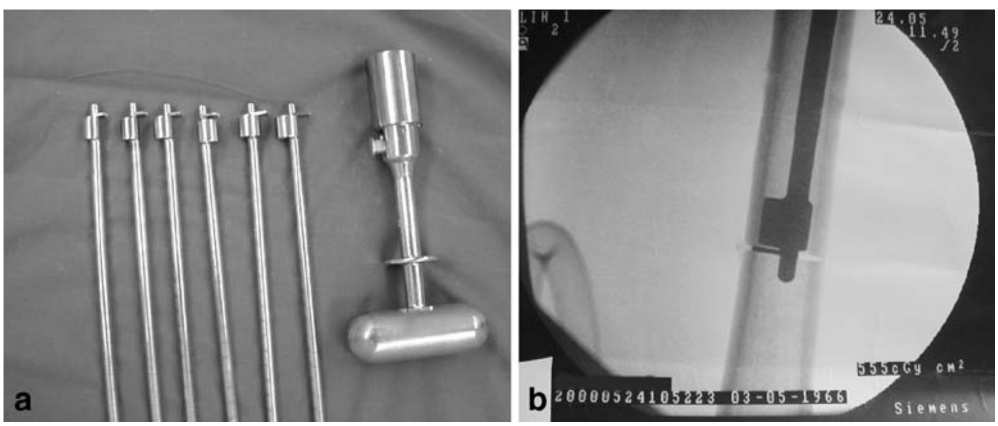

Fig. 1 **a** Intramedullary saw in different sizes. **b** Intramedullary osteotomy under fluoroscopic control.

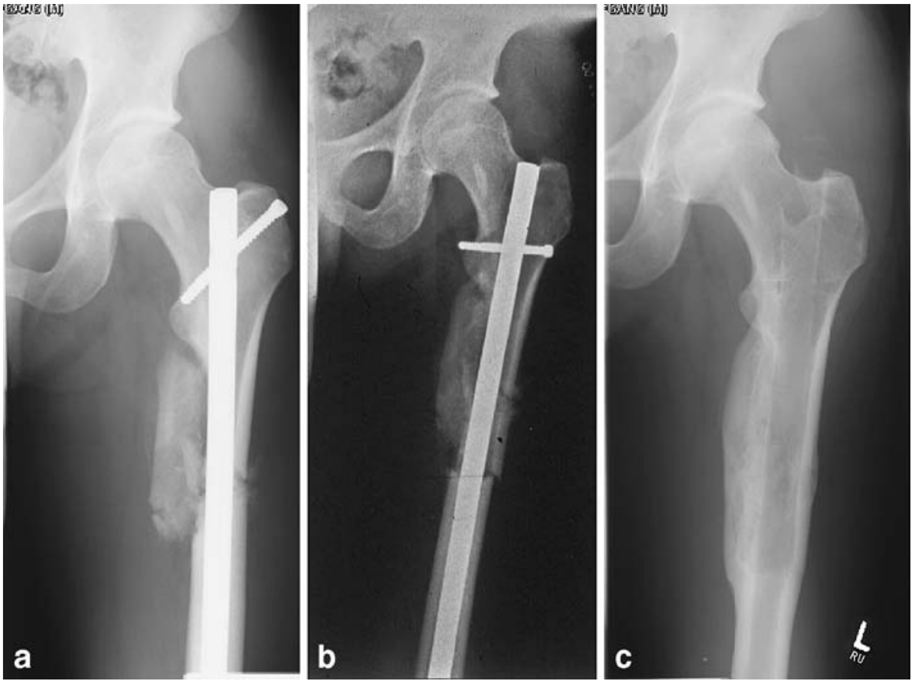

Fig. 2 **a** A 24-year-old patient with an external rotational deformity of 30° after intramedullary nailing of a proximal femoral shaft fracture 9 months ago. **b** After removal of the nail and reaming, the intramedullary osteotomy at the former fracture site was performed. After nail insertion and derotation, compression locking was applied. **c** X-ray controls verifying bone healing.

Measurements based on CT scans showed a postoperative mean correction angle of 28.1±11.4° (range 7–60°) with a mean rotational deviation between the left and right sides of 7.3±5.2°. Comparing the two techniques, the mean angle of derotation using the minimally invasive technique was 28.6±12.3° (range 7–60°) and for the open technique was 27.6±10.7° (range 9–43°). Postoperative mean rotational deviation between left and right sides was 6.6±4.4° for the open procedure and 7.9±6.7° for the minimally invasive group. There was no statistically significant difference between the groups. Two cases of insufficient correction (19 and 23°) occurred in the group that underwent the minimally invasive technique (Fig. 3).

Complications occurred in five cases. Delayed union was seen in two cases, insufficient correction in two, and infection in one. No statistically significant difference in complication rates was seen when comparing the minimally invasive technique to the open technique (p=0.317, Pearson chi-square).

Table 1 Patient data comparing the two techniques (minimally invasive vs. open)

	Minimally invasive technique	Open technique
Cases (n)	18	12
Deformity	18 rotational	12 rotational
Operative time	101±29 min	122±53 min
Planned derotation angle	28.6±12.3°	27.6±10.7°
Postoperative rotational deviation	7.9±6.7°	6.6±4.4°
Neer score	82.5±6.8	87.1±7.0
Complications	2 insufficient correction, 1 infection, 1 delayed union	1 delayed union

Discussion

Postoperative deformities are well-known complications after operative fixation of femoral shaft fractures [19]. Not only can angular deformities occur but also rotational and leg-length deformities. In particular, intramedullary nailing of the femur is associated with postoperative rotational deformities secondary to the difficulties in maintaining control over fracture torsion associated with closed reduction and fracture fixation [11, 19]. Femoral rotational deformities are difficult to diagnose accurately by clinical assessment alone [9, 22]. An evaluation by CT scans has demonstrated that the incidence of rotational deformities after intramedullary nailing of femoral shaft fractures is actually much higher than clinically suspected [19]. In a study by Strecker et al., the incidence of rotational malalignment greater than 15° was shown to be 26% [19]. Franzreb et al. showed that even among experienced clinicians, deviations of greater than 10° were found in 41% of cases comparing clinical assessment versus measurements based on CT scans [6]. Today, bilateral CT scans have been established as the gold standard for diagnosis of rotational deformities of the femur [2, 5, 9].

The indication for operative correction of posttraumatic rotational deformities is based on a variety of criteria. Careful physical examination with analysis of the leg geometry and hip joint motion is the basic essential, followed by radiographic and computer tomographic assessment. Impor-

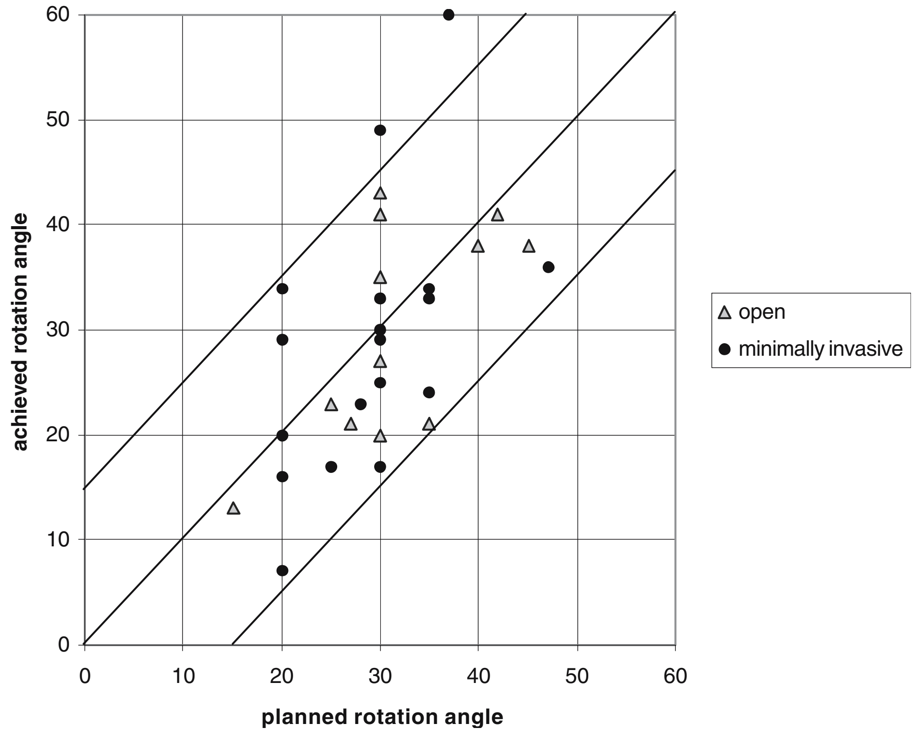

Fig. 3 Comparison between the planned and achieved derotation angle in open vs. minimally invasive technique. In the minimally invasive group, 2 patients showed insufficient correction of greater than 15°.

tant clinical criteria are the total amount of hip rotation and lack of internal or external rotation [18]. For interpretation of these results, it is important to bear in mind the physiological range of femoral torsion. Strecker et al. compared the rotational deviation between left and right femurs in healthy individuals and showed that it was 14.8° at the 99th percentile [17]. Therefore, most studies consider a combination of clinical symptoms and a rotational deformity of greater than 15–20° to be an indication for correction [1, 15, 17].

A variety of operative techniques for correcting lower-limb rotational deformities have been described in the literature; however, there are few specific studies on techniques for correction of posttraumatic rotational deformities in the femoral shaft. If the deformity is diagnosed in the early stages prior to fracture consolidation, operative revision of the osteosynthesis with intraoperative derotation is possible. After fracture healing is complete, osteotomy for correction of the deformity must be considered. The conventional approach is open exposure at the deformity level [12, 23]. The correction angle is planned on preoperative CT scans and intraoperatively marked on the bone with Kirschner wires or Schanz screws. Subsequently, a transverse osteotomy and derotation is performed [12]. For osteosynthesis, various fixation techniques can be used. Specifically addressing correction of rotational deformities of the femoral shaft after intramedullary nailing procedures, Strecker et al. described a technique in which the nail is left in place [16]. The locking screws of the nail are removed, and rotational correction after osteotomy is performed via a posterolateral approach and new locking screws are inserted. The corrected alignment is then stabilized with an additional six-hole dynamic compression plate to prevent correction loss. Gonschorek et al. described a minimally invasive technique for rotational deformity correction in the femoral shaft using an intramedullary saw for osteotomy combined with intramedullary compression nailing [7]. The intramedullary saw was first described by Thompson in 1954 and Küntscher in 1966. It allows closed osteotomy without stripping of the surrounding soft tissues [13, 20]. The periosteum is left intact, which improves callus formation and bone healing. Chapman and Winquist confirmed the beneficial results of the intramedullary saw for shortening osteotomies [4, 21]. Inadequate fixation of transverse osteotomies by standard intramedullary nails must be considered since standard screws have a certain amount of play within their locking holes. This amount of primary rotational instability can be minimized by the use of special nail designs, such as compression nails.

We evaluated our results by comparing pre- and postoperative rotation angles on CT scans. We achieved 28.1±11.4° mean correction angle. Overall, postoperative mean rotational deviation was 7.3±5.2°. In another series on correction of femoral rotational deformities, Strecker et al. [16] demonstrated a remaining mean postoperative difference between right and left femoral rotation of 6.4° in 15 patients and Grützner et al. of 7° in 30 patients [8].

Out of a total of 30 cases, the minimally invasive technique was used in 18 cases. The achieved mean rotational deviation between left and right side was 6.6±4.4° for the open and 7.9±6.7° for the minimally invasive group. There was no statistically significant difference in outcome between the two techniques. In the minimally invasive group, complications included two patients with rotational malalignment of greater than 15°. In both cases, the cause of insufficient correction was not clear. Whether the minimally invasive technique is associated with a higher incidence of insufficient correction can, therefore, not be definitely determined. Future studies involving larger case numbers might clarify this issue.

Our results demonstrate the feasibility of closed osteotomy and intramedullary compression nailing for the correction of femoral rotational deformities. However, more complex deformities can only be managed by open osteotomy. The open technique is also preferred in cases with previous plate osteosynthesis since hardware removal itself requires open exposure. It should be mentioned that despite the benefits of closed osteotomy, complete osteotomy is not always achieved with an intramedullary saw. This is particularly so in regions with abundant callus formation and at the diaphyseal–metaphyseal junction where often only a circumferential weakening of the bone is achieved using an intramedullary saw. In these cases, completion of the osteotomy is achieved with an osteotome via a small skin incision. In our study, three of 18 cases (16.7%) had to be completed with an osteotome.

The technique of marking the correction angle with Kirschner wires, as used in our study, is not without controversy. Kinzl showed that bending of the wires may occur, leading to false angulation [10]. In closed osteotomy, the soft-tissue resistance contributes to bending of the wires, altering the marked correction angle. In this case, the angle between the wires becomes greater at the bone than at the skin level, leading to over correction. In our study, the two insufficiently rotated cases had a planned correction angle of 30 and 37°, respectively. However, in eight other cases involving correction angles greater than 30°, use of the minimally invasive technique did not result in any malalignment. We could, therefore, draw no general conclusions about errors due to bending of the wires. Nevertheless, we now prefer using Schanz screws of 5 mm diameter instead of Kirschner wires.

Grützner et al. described another mechanism of error associated with the placement of Schanz screws versus Kirschner wires [8]. The key point in marking the correction angle is to consider the centre of the angle, i.e., the intersection of the wires should lie in the centre of the medullary canal, which is the rotational centre of the bone. Deviation of a few millimetres could result in clinically relevant errors. However, it cannot be concluded from these criteria that open derotational osteotomy should be favoured over a closed technique. Our results show that in 16 of 18 cases (89%), the minimally invasive technique resulted in deviations of less than 15° and in nine of these cases, the deviation was less than 5°. As an option for the future, surgical navigation may improve the possibility of intraoperative control and monitoring of the derotational angle.

Apart from CT analysis, most evaluations have focused on functional and anatomical criteria. In the Neer scoring system, six parameters are evaluated for a maximum score of 100 points. The average score in our study was 84.9± 6.9, which reflects an overall satisfactory (close to excellent >85) result. We saw unsatisfactory results in two cases. In both of these cases, the minimally invasive technique resulted in insufficient correction of the deformity.

In summary, postoperative results and complications were not significantly different between the open and closed technique. The complication rates of both groups are comparable to other results reported in the literature. In our study, the open technique always included hardware removal of plates in addition to the osteotomy and nailing procedure. Therefore, the open technique is associated with longer operating time and hospital stay. Achieving the planned angle of derotation is technically more demanding using the minimally invasive technique and, therefore, more prone to failure. Clear advantages of the technique are the closed osteotomy without stripping of the surrounding soft tissues and the resulting smaller skin incisions.

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