Tip-Apex Distance as a Predictor of Failure Following Cephalo-Medullary Fixation for Unstable Fractures of the Proximal Femur

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Abstract

Current research has been unable to confirm that intramedullary fixation provides greater stability for unstable fracture configurations of the proximal femur than extra-medullary devices. We present a retrospective analysis of the outcome of proximal femoral fractures treated with the Proximal Femoral Nail (PFN, Synthes) with particular reference to implant position and adequacy of reduction. Between May 2002 and October 2004, 61 patients with low-energy unstable proximal femoral fractures underwent surgery at a mean 2.4 days. Mean age was 78 years, 74% were female. Four (6.9%) implants failed secondary to proximal cut out of the hip screw. All of the failures occurred in patients who had sustained AO/OTA type 31. A3 fractures. In patients with A3 fracture patterns, there is a significant relationship between increasing Tip-Apex distance ($p = 0.023$), varus mal-reduction ($p = 0.038$) and failure; 46% patients died within 12 months of surgery. The PFN is a satisfactory implant in the management of unstable proximal femoral fractures, however accurate reduction and implant position are essential to provide the best conditions for union and to prevent implant failure.

Key Words

Fractures of the proximal femur · Hip fracture · Intramedullary nailing of long bones

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Introduction

The management of the unstable proximal femoral fractures remains controversial. Many implants are available providing either intra or extra-medullary fracture stabilization. The reported results of extra medullary stabilization with the sliding hip screw (SHS) have shown failure rates as high as 21% [1]. The biomechanical principles of intra-medullary devices suggest that cut-out rates in unstable fracture configurations should decrease due to the reduction in lever arm moment [2] but current evidence is unable to support this common anecdotal perception [3].

The proximal femoral nail (PFN) was developed by AO/ASIF and introduced by Synthes in 1996 for the management of unstable proximal femoral fractures. Previous studies have highlighted technical failure and poor screw position as reasons for PFN failure but have failed to quantify this [2, 4, 5]. We have therefore examined the use of this device with particular reference to implant position and adequacy of reduction. Positioning of the lag screw in the SHS has been shown to accurately predict failure: a Tip-Apex distance of greater than 25 mm predicting cut-out [6]. To our knowledge this series is the first analysis to use this technique of radiological analysis with a cephalo-medullary implant.

Materials and Methods

Between May 2002 and October 2004, 61 consecutive patients were identified from theatre records, that had undergone fracture treatment using the PFN following low-energy injuries. High-energy injuries and pathological fractures were excluded. 45 patients were female and 16 were male. The mean age was 77.8 years (range 45–97). Fractures were classified using the AO/OTA system. All patients had unstable fracture patterns, 15 patients had sustained multi-fragmentary

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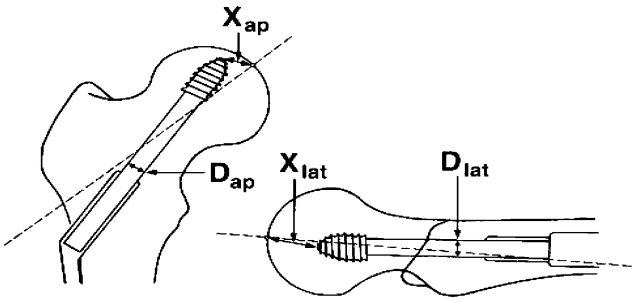

$$TAD = \left(X_{ap} \times \frac{D_{true}}{D_{ap}}\right) + \left(X_{lat} \times \frac{D_{true}}{D_{lat}}\right)$$

Figure 1. Measurement of Tip-Apex distance [6].

inter-trochanteric fractures (AO31.A2) and 43 had reverse obliquity fractures involving the sub-trochanteric region (AO31.A3). Three patients had radiographs of insufficient quality for accurate assessment of initial fracture configuration.

Surgery was performed at a mean 2.4 days (range 0–14) following admission. The procedure was performed by a specialist registrar in 42 cases and performed or supervised by a consultant in 19. The permitted post-operative weight bearing status varied with the preference of the operating surgeon. 44 patients were permitted to fully weight-bear, the remainder were allowed to partial weight-bear as able. This was determined by the operating surgeon's impression of fracture reduction and stability. 47 patients received a long PFN, 14 were treated with a short PFN. Patients required in-patient admission for an average of 29.7 days (range 3–105).

Intra-operative or immediate post-operative radiographs were assessed for adequacy of implant position using Tip-Apex distance [6] and adequacy of reduction using Medial Proximal Femoral Angle (normal range 80–89°, mean 84°) [7]. Tip-Apex distance is the combined distance, measured in millimeters, from the tip of the cannulated screw to the apex of the femoral head on both antero-posterior and lateral radiographs. The magnification is standardized by measuring the diameter of the cannulated screw (Figure 1).

A retrospective analysis of patients' records and subsequent radiographs was performed to assess operative details, clinical outcome and radiological evidence of fracture union. The elderly nature of the population involved prevented recalling patients for additional out-patient follow-up. 24 patients had incomplete out-patient follow-up. The general practitioner of each was therefore contacted for additional

Figure 2. Intra-operative radiograph of right hip showing treatment with long PFN following A3 fracture. Tip-Apex distance is 27.9 mm.

clinical outcome data. Those patients who were mobile and asymptomatic from their affected hip were deemed to have gone on to clinical union. Further information was available in 21 patients. None of the patients had required further revision surgery. All had achieved asymptomatic mobilization from the point of view of their operated hip. These patients were deemed to have developed clinical union. Three patients were lost to follow-up.

Results were analyzed using SPSS statistical software (Chicago, IL). Levene's test was used to establish equality of variance. Parametric two-tailed *t* tests were then used to test the hypotheses with the level significance demonstrated at $p < 0.05$.

Results

The mean Tip-Apex distance (TAD) was 24.6 mm (range 9.1–52.6 mm, SD 8.49). The mean MPFA was 83.3° (range 65°–106°, SD 7.58).

Four implants failed secondary to proximal cut out of the cannulated hip screw (Figures 2–4). All of these failures occurred early and within the in-patient stay. Two PFNs were revised directly to total hip arthroplasty (THA) and one to a fixed angle dynamic condylar screw. One PFN was revised to a long plate SHS; however, this also subsequently failed and required revision to THA.

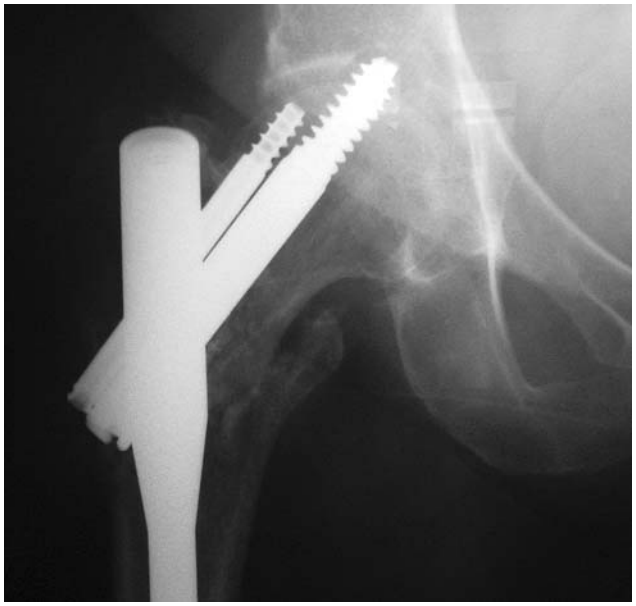

Figure 3. Post-operative radiograph of same hip showing superior migration of cannulated screw as PFN fails.

Four patients required further surgery prior to the development of radiological union. One patent required secondary stabilization with circlage wiring at 7 weeks following the initial operation, due to fracture displacement. One patient had backing out of the proximal de-rotation screw following radiological union, necessitating removal. Two patients had delayed union but united following dynamization by removal of distal locking bolts. There were no periprostheitic fractures. Three patients were lost to follow-up. The overall failure rate was therefore 6.9% (4/58) and the total re-operation rate 13.8% (8/58).

When analyzing the whole cohort of fractures, we found no statistically significant relationship between TAD and failure (two-tailed *t* test, p = 0.792). However, all of the A2 fractures developed clinical and radiological union and all of the failures occurred in patients who had sustained A3 configurations. All of these patients had received a long PFN. When looking at this A3 group in isolation (n = 38) we found a significant relationship between increasing TAD and failure (two-tailed *t* test p = 0.023). The mean TAD in the implant failure group was 28.3 mm and in the united group 20.5 mm. The mean MPFA in the failure group was 77° and in the united group 82.5°. Levene's test is on the borderline of significance (p = 0.062) for MPFA. If we therefore do not assume equality of variance, there is a significant trend between lower MPFA and failure (p = 0.038). Should we assume equal variance then p = 0.112. There was no association between level of surgeon grade or permitted weight-bearing status and failure.

Figure 4. Revision of failed PFN to fixed angle dynamic condylar screw.

17 patients with low-energy traumatic fracture (17/58, 29.3%) died within 3 months of surgery. A total of 27/58 patients died within 12 months (46.6%).

Discussion

Unstable fractures of the proximal femur are significant injuries and occur predominantly in an elderly population. Our study, in-line with previous series [4], has demonstrated a high mortality rate of 29% at 3 months, which rises to 46% at 1 year. Failure of primary fracture fixation will necessitate subsequent revision operations and is likely to increase this rate further. Maximizing the probability of success of the index procedure is therefore imperative.

We have demonstrated that poor screw position, as assessed by increasing Tip-Apex distance, is a significant predictor of failure in the very unstable A3 type sub-group of fracture configurations. We have also demonstrated a trend to suggest that varus mal-reduction, as shown by MPFA < 80°, also increases the chance of cut-out.

Accurate implant position and reduction is important to avoid implant failure in the management of all fractures; but in the unstable A3 type configuration this becomes critical. Simmermacher [8] reported that the majority of operations in their series were ''easy'' or ''usual''. Our experience is that with A3 fractures, accurate closed reduction is often difficult to achieve, even in experienced hands. The proximal fragment often remains flexed due to the unopposed pull of ilio-psoas and abductor muscles. Ramakrishnan et al. [9] advocates the use of open reduction and circlage wiring prior the insertion of the PFN if closed reduction is not possible. We performed this procedure on one patient in this series but as a second operation.

We acknowledge that follow-up is limited by the elderly nature of our population and by the high mortality rate. We have utilized clinical data from general practice for long-term follow-up in many of our patients. If early patient mobilization and pain relief determine a successful treatment outcome, then this data remains useful. We also acknowledge the difficulty in assessing proximal femoral angles due to the effect of hip rotation. All radiographs used for the assessment of MPFA were taken with the patient supine in an antero-posterior direction; further standardization would not be possible due to patient compliance.

Unstable subtrochanteric fractures of the proximal femur are difficult fractures to manage both from a technical point of view and the frail nature of the population who sustain them. The failure rate of the PFN demonstrated by this study is comparable to published series of PFN outcome [2, 4, 10] and favorable when compared to series of SHS when used in the treatment of unstable proximal femoral fractures [11]. The PFN is a satisfactory implant in the management of unstable proximal femoral fractures, however accurate reduction and implant position are essential to provide the best conditions for union. Care must be taken to avoid varus mal-reduction and to minimize Tip-Apex distance.

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