B. H. Ziran · A. D. Wasan · M. W. Chapman

Femoral nailing with transverse locking screws through the femoral neck

Accepted: 19 June 2001 / Published online: 1 November 2001
© Springer-Verlag 2001

Abstract We treated 55 patients with subtrochanteric or comminuted femoral fractures with a transverse locking femoral nail (Alta, Howmedica). This nail was positioned more cephalad than usual so that at least one fixation screw was located in the femoral neck or head. Forty-seven fractures (20 subtrochanteric and 27 diaphyseal) were available for follow-up averaging 12 months (3–35). The time to radiographic healing averaged 7 months (3–21). There was one delayed union, one non-union, two superficial infections, one broken proximal screw, one compartment syndrome of the thigh, and one peroneal nerve palsy. There were no femoral neck fractures, avascular changes of the femoral head, or gluteal irritation at the most recent follow up. The described technique appears safe and effective, is technically easy, and avoids intra-articular screws.

Résumé Nous avons traité 55 patients présentant une fracture fémorale sous-trochanterienne ou comminutive avec un clou à verrouillage transversal (Alta, Howmedica) qui a été placé de façon plus céphalique qu'habituellement afin qu'au moins une des vis de la fixation ait été localisée dans le col ou dans la tête. 47 fractures, 20 sous-trochanteriennes et 27 diaphysaires, étaient disponibles avec un suivi moyen de 12 mois (3–35). Le temps de consolidation radiographique était de 7.0 mois (3–21). Il y avait un cas de retard de consolidation, une non-consolidation, deux infections superficielles, une vis proximale cassée, un syndrome de compartiment de la cuisse, et un paralysie du sciatique poplité externe. Il n'y avait pas de fractures du col fémoral, ni de trouble vasculaire de la tête fémorale, ni de tendinite du fessier au plus récent examen. La technique décrite ne paraît pas dangereuse, efficace, techniquement facile, et évite le risque de vis intra-articulaires.

B.H. Ziran (✉)
University of Pittsburgh, Pittsburgh, PA, USA
e-mail: ziranbh@msx.upmc.edu
Tel.: +1-412-605-3327, Fax: +1-412-687-3724

A.D. Wasan · M.W. Chapman
University of California, Davis Medical Center, USA

Introduction

Most second-generation intramedullary nails with proximal and distal cross-locking are designed to be inserted so that the proximal end of the nail is flush with the tip of the greater trochanter. In this position, the proximal cross-locking screws may not provide adequate stability for fractures near or involving the lesser trochanter. To allow fixation into the femoral neck, the nail must be left proud above the greater trochanter. This is a common cause of postoperative pain and frequently requires nail removal. There are also concerns about placing cross-locking screws in the femoral neck and creating a stress riser. In this study, we looked at a transverse locking nail design (Alta, Howmedica Inc., Rutherford, N.J.) that places the proximal end of the nail at the top of the femoral neck at its junction with the greater trochanter and provides a smaller distance between the top of the nail and the proximal interlocking holes. In this position, the transverse cross-locking screws are usually inserted near or through the lesser trochanter (Fig. 1). With this particular implant we found that, when indicated, the nail can be seated more proximally without excessively protruding above the tip of the greater trochanter, thus allowing for more proximal screw placement into the femoral neck without the discomfort of a proud nail (Fig. 2). The authors have been using this method of transverse cross locking through the femoral neck for the treatment of stable and unstable subtrochanteric fractures at their institutions since 1991. The purpose of this study was to evaluate our clinical experience with proximal cross locking through the femoral neck and head in subtrochanteric and diaphyseal fractures of the femur.

Materials and methods

We performed a retrospective review of the medical records and radiographs for all patients with fractures of the proximal femoral shaft treated between January 1991 and July 1997 in which at least one transverse cross locking screw was placed into the femoral

Fig. 1 Radiograph of standard position of interlocking nail with screws around the lesser trochanter

Fig. 2 Radiograph of proximally seated nail with interlocking screws into the femoral neck. The top of the rod is at the level of the center of the femoral head, which is anatomically also the level of the top of the greater trochanter

neck. The femoral neck was defined as that portion of the femur between the superior edge of the lesser trochanter and the inferior edge of the articular surface of the femoral head (Fig. 3). The parameters evaluated included patient demographics, mechanism of injury, type of fracture, type and location of internal fixation, intraoperative complications, return to function, and complications such as infection, nonunion, and any problems related to the fixation devices, in particular, the proximal cross locking. Radiographs were reviewed for the fracture type, parameters of internal fixation, and time to healing of the fracture, as well as complications related to the fixation and/or nonunion. Fractures were considered axially unstable if they were Winquist 3, 4, or 5 proximal third diaphyseal fractures [12], or Sensheimer 3A or 4 [9], or AO

Fig. 3 Illustration of the regions of the proximal femur used in the present study. The area where the tip of the screw is located defines its region. The head region is that portion of the femoral head whose cephalad boundary is the top of the femoral neck at the intertrochanteric line. *H* head, *N* neck, *LT* lesser trochanter

type B3 or C type subtrochanteric fractures [8]. Since the purpose of the study was not comparative, a statistical analysis was not performed.

Results

Out of a total of 55 patients with 88 screws (head 6, neck 53, and lesser trochanter 29), 47 (85%) with 79 screws (head 5, neck 46, and lesser trochanter 28) had complete medical records or sufficient length of follow up. In these 47 patients, we specifically evaluated the 51 screws inserted into the femoral neck and head as the focus of the current study. There were 39 males and eight females with an average age of 29 years and a follow-up time averaging 12 (3–35) months. The average time for clinical and radiographic healing was 7 (3–21) months. There were nine open fractures (three grade I, five grade II, and one grade IIIC) and 18 patients had multiple injuries (both orthopaedic and nonorthopaedic). There were 20 subtrochanteric fractures and 27 comminuted diaphyseal fractures.

Of the 47 patients in the study, one experienced nonunion, one delayed union, two superficial infections, four hardware irritation of an interlocking screw requiring screw removal, one a broken proximal screw, one thigh compartment syndrome, and one postoperative peroneal nerve palsy. There were no cases of pain at the top of the nail or of nail failures, no fractures of the femoral neck, and no cases of avascular necrosis of the femoral head. The two superficial infections occurred in a closed and an open grade II diaphyseal fracture. Both resolved with débridement and intravenous antibiotics. At final follow-up, neither patient had any evidence of osteomyelitis and both had healed. The patient experiencing nonunion had a subtrochanteric fracture (Sensheimer 3B, AO type B1) with a neck and lesser trochanter screw. He was effectively treated with exchange nailing and healed by 16 months. In the patient with a delayed union, the fracture was also subtrochanteric (Sensheimer 4, AO type

B2) with a neck and lesser trochanter screw. This patient was treated effectively with distal dynamization and healed by 21 months. Neither of these patients had any hardware-related problems; therefore, we feel other factors were the cause of the delayed unions in these two patients. In the patient with a broken screw, the fracture was an unstable subtrochanteric fracture with involvement of the lesser trochanter (Sensheimer 3A) and the most proximal screw was found to be broken at final follow-up. However, the fracture had healed and the patient had no symptoms. We surmise that the broken screw was indicative of either early instability or lack of fracture contact. After failure of the screw, the fracture settled into stable position and healed. Three patients with trochanteric pain from an interlocking screw had both neck and lesser trochanteric screws and, in all three, the pain resolved after screw removal. We could not determine which screw was causing the pain. There was one patient with pain related to the distal screw, which required removal of the screw. Four patients requested removal of the nail for reasons unrelated to interlocking screw placement.

Discussion

To date, clinical experience with transverse interlocking screws through the femoral neck has not been reported. The bone on the medial femoral neck is one of the strongest struts of cortical bone in the body, providing excellent purchase for screws and offering excellent fixation for unstable fractures. While there are concerns that the integrity of the femoral neck might be compromised, there were no femoral neck fractures or clinically significant screw failures in our series. Biomechanical tests have demonstrated that cortical defects less than 20% of the diameter of a long bone do not incur a significant stress riser or weaken the bone, predisposing it to fracture [6, 7]. The average femoral neck diameter is 40–50 mm and insertion of 4-mm cancellous cross-locking screws is well within the 20% margin of safety. Studies have also shown that when a hole in the bone is filled with a screw, the strength of the bone is equivalent to that of the screw's control value. Only when screws are removed acutely are the stress patterns significantly altered. When late removal is performed, the bone has had a chance to develop adaptive strain patterns, and the strength reduction is less than that of acute removal. Furthermore, within 6 weeks of screw removal, the strength approaches that of normal bone [6]. Recently, the biomechanical performance of cephalad-positioned intramedullary nails with screws placed into the medial femoral neck was reported to be equal to that of reconstruction-type nails under both axial and torsional loads. In static tests of failure in both synthetic and cadaveric bone specimens, axial failure loads were similar for both reconstruction-type nails and high-seated transverse locking nails. The mechanism and pattern of failure were nearly identical in both implant constructs [14].

Although the situation in our clinical series is different than static *in vitro* loading, the loads that would be experienced by both methods of fixation would be similar to those reported in the model of Ziran et al. [14]. Also, unless weight bearing was initiated too early (e.g., before callous formation), fatigue failure – as reported by Bucholz for the distal femur – is less of a concern [5]. Another recent study by Aboulafia et al. compared screws placed into the femoral neck to an oblique screw placed from the greater trochanter into the lesser trochanter. They found that both methods failed with similar mechanisms and loads [1]. Interpretation of these studies would indicate that, *in vitro*, the three methods of proximal femoral fixation (reconstruction screw, transverse screws into the neck, and standard oblique screws) do not differ biomechanically. For practical purposes then, the decision on which method of proximal fixation is used may depend more on the bone available than on the fixation method. We would caution that these are *in vitro* studies and that in the clinical setting other factors and the clinician's judgments play a greater role.

Fixation into the femoral neck with two transverse cross-locking screws through a standard second-generation nail offers many potential advantages. These nails are much easier to insert and cross lock as there is no need to place screws within the femoral neck into the head, with the risk of either missing the femoral neck or head or accidentally penetrating the articular surface of the hip joint. The nail can be inserted in whatever rotation suits the fracture without the need to orient the nail for the anteversion angle of the femoral neck. Since the extraosseous blood supply to the femoral head comes primarily from the medial circumflex artery and courses along the posterior-superior aspect of the femoral neck, it is irrelevant whether the screws penetrate the anterior, medial, or posterior neck, as long as the superior neck is avoided. Although avascular necrosis has been reported with standard femoral nailing, its etiology has been unclear. It is possible that we do not have adequate follow-up to determine the occurrence of avascular necrosis; however, based on the existing literature and the anatomic considerations, we do not feel its occurrence is likely.

Recognizing that we do not have long-term follow-up, the primary goal of the study was to evaluate the clinical performance of the described technique in the postoperative period up to healing. We could not identify any complications that preclude the use of this technique. The rates of nonunion and infection were comparable to that reported in the existing literature [2, 3, 4, 10, 11, 13]. We had no significant hardware failures or femoral neck fractures; however, since none of the nails were removed and only three proximal screws required removal, we do not know the long-term outcomes of patients with screws removed from the femoral neck. We feel that in carefully selected cases the use of transverse cross-locking screws into the femoral neck offers a viable alternative to condylocephalic reconstruction nails in the treatment of difficult proximal femoral fractures.

References

1. Aboulaflia AJ, Price MM, Kennon RE, Hutton WC (1997) A comparison of mechanical strength of the femoral neck following locked intramedullary nailing using oblique versus transverse proximal screws. *Clin Orthop* 339: 82–91
2. Brien WW, Wiss DA, Becker V, Lehman T (1991) Subtrochanteric femur fractures: a comparison of the zickel nail, 95 blade plate, and interlocking nail. *J Ortho Trauma* 5:458–464
3. Brumback RJ, Reilly JP, Poka A, Lakatos RP, Bathon GH, Burgess AR (1988) Intramedullary nailing of femoral shaft fractures. *J Bone Joint Surg [Am]* 70: 1453–1462
4. Bergman GD, Winkquist RA, Mayo KA, Hansen ST (1987) Subtrochanteric fracture of the femur. Fixation using the Zickel nail. *J Bone Joint Surg [Am]* 69: 1032–1040
5. Bucholz RW, Ross SE, Lawrence KL (1987) Fatigue fracture of the interlocking nail in the treatment of fractures of the distal part of the femoral. *J Bone Joint Surg [Am]* 69: 1391–1399
6. Edgerton BC, An K, Morrey BF (1990) Torsional strength reduction due to cortical defects in bone. *J Orthop Res* 8: 851–855
7. McBroom RJ, Cheal EJ, Hayes WC (1988) Strength reductions from metastatic cortical defects in long bones. *J Orthop Res* 6: 369–378
8. Müller ME, Allgower M, Schneider R (1990) *Manual of internal fixation*. Springer, Berlin Heidelberg New York
9. Seinsheimer F (1978) Subtrochanteric fractures of the femur. *J Bone Joint Surg [Am]* 60: 300–306
10. Smith J, Goodman SB, Tischenko G (1991) Treatment of comminuted femoral subtrochanteric fractures using the Russell-Taylor reconstruction intramedullary nail. *Orthopaedics* 14: 125–129
11. Tencer AF, Johnson KD, Johnston WC, Gill K (1984) A biomechanical comparison of various methods of stabilization of subtrochanteric fractures of the femur. *J Orthop Res* 2: 297–305
12. Winkquist RA, Hansen ST Jr, Clawson DK (1984) Closed intramedullary nailing of femoral fractures. A report of five hundred and twenty cases. *J Bone Joint Surg [Am]* 66: 529–39
13. Wiss DA, Brien WW (1992) Subtrochanteric fractures of the femur: Results of treatment by interlocking nails. *Clin Orthop* 283: 231–236
14. Ziran BH, Sharkey NS, Smith TS, Wang G, Chapman MW (1997) Intramedullary fixation of proximal femoral fractures: a biomechanical comparison of transverse versus cephalomedullary interlocking screws. *Clin Orthop* 339: 82–91