Distal Intramedullary Nail Interlocking

The Flag and Grid Technique

Christos K. Yiannakopoulos, MD,† Anastassios D. Kanellopoulos, MD,† Constantinos Apostolou, MD,† Emmanuel Antonogiannakis, MD,* and Dimitrios S. Korres, MD‡*

Summary: Distal interlocking in intramedullary nailing of long bone fractures accounts for a significant proportion of the total fluoroscopy and operative time. We describe a modification of the "perfect circles" freehand technique employing a metallic grid temporarily attached to the skin of the lateral surface of the femur or to the medial surface of the tibia that acts as a fixed "navigational" aid. The position of the distal nail holes in relation to the grid is fluoroscopically ascertained. Subsequently, under fluoroscopic control, a modified Steinmann pin with a metallic handle attached to its blunt end ("flag") is used to accomplish targeting and to create the screw holes, affording improved visualization. This technique was compared with the traditional freehand technique in 2 groups of patients. Use of the modified technique led to reduction of radiation exposure and total distal interlocking time, and there were no significant complications related to the technique.

Key Words: distal interlocking, fracture, intramedullary nailing, radiation

(*J Orthop Trauma* 2005;19:410–414)

Several simplified techniques, tips and pearls, jigs, laser-assisted and mechanical guiding instruments, self-guiding and bundle-type nails, and surgical navigation systems have been used to perform distal interlocking of intramedullary nails, but none has found widespread acceptance.[1–13] Mechanical aiming systems had been introduced for radiation-independent tibial and femoral nail interlocking, but they were not successful because of failure to take into account the deformation the nail undergoes during insertion into the medullary cavity.[14–16] More recently developed aiming devices, which take nail deformation into account, facilitate distal interlocking with limited exposure to radiation.[17–22] Despite the development of sophisticated techniques and devices, the freehand method remains the most commonly used distal interlocking technique.[2,3,20,21]

We describe a modification of the "perfect circles" technique for distal interlocking of femoral and tibial nails using a metallic grid and a "flag." The technique evolved secondary to the desire to minimize radiation exposure and to accelerate distal interlocking insertion.

TECHNIQUE

The patient is positioned supine on the fracture table, and the fracture is reduced and nailed under fluoroscopic control. As soon as the nail has been inserted, 2 not commercially available devices are used to perform distal interlocking (Fig. 1). The first device, the "flag," consists of a 20-cm-long and 3.0- or 4.0-mm-thick Steinmann pin, depending on the core diameter of the locking screws, with a quadrilateral 1-mm-thick stainless steel plate permanently attached to its blunt, proximal end at a 45° angle using standard arc welding. The dimensions of the metallic plate are 6 cm × 2.5 cm × 1 mm. The preparation of the "flag" is fast and easy. This modification was undertaken to provide a handle that would facilitate holding of the Steinmann pin during targeting. At the same time, the surgeon's hand is kept further away from the primary radiation beam. A flag can be used for 30 times before it needs to be replaced, and it should be changed only when the tip becomes blunt. The second device used is a stainless steel grid with external dimensions of 20 × 10 cm, whereas the internal dimensions of the grid's quadrants are 10 × 10 mm. Prior to distal interlocking, the grid is temporarily attached to the skin of the lateral surface of the femur or the medial surface of the tibia using a plastic adhesive drape (Fig. 2). After the intramedullary nail has been inserted, the distal nail holes are fluoroscopically viewed as perfect circles. The radiation beam is directed from medial to lateral to minimize exposure to scattered radiation.[23] On the screen, the external metallic grid is superimposed on the distal nail holes (Fig. 3). The exact position of the distal nail holes in relation to the metallic grid is ascertained by referring to the grid's quadrants. A hemostatic clamp is attached to the grid to provide reference. A 0.5- to 1-cm-long skin incision is performed at the appropriate quadrant, the fascia lata, and the vastus lateralis fibers or the medial tibial subcutaneous tissue are bluntly dissected and unobstructed access to the lateral femoral or the medial tibial surface is obtained. Through the skin incision, a modified Steinmann pin is positioned in contact with the bone cortex at a 30° angle in a proximal to

Accepted for publication November 13, 2004.
From the *2nd Orthopaedic Department, 401 General Army Hospital, Athens, Greece, †Pediatric Orthopaedics Department, KAT Accident Hospital, Athens, Greece, and ‡1st Orthopaedic Department, University of Athens, Athens, Greece.
No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.
The materials used in this study are FDA approved.
Reprints: C. K. Yiannakopoulos, MD, Byzantiou 2, Nea Smyrni 171 21, Athens, Greece (e-mail: cky@ath.forthnet.gr).

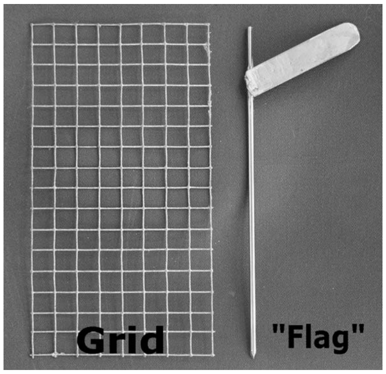

FIGURE 1. The devices, the ''flag'' and the grid, used in this study to facilitate distal nail interlocking.

distal direction to avoid obscuring the view. The sharp, long tip of the Steinmann pin is used to locate the center of the more distal of the distal nail holes, and this is verified fluoroscopically. The surgeon may start the procedure choosing any other nail hole, i.e., it is not mandatory to start with the most distal nail hole. The most proximal or any other hole can be chosen because the technique is flexible. A distal to proximal screw insertion is preferred, although the reverse screw insertion order can also be chosen. Rarely is deviation more than 2 mm in relation to the screw hole center encountered. In cases of significant deviation, the Steinmann pin is repositioned, sliding it on the cortex without loosing contact. Slight deviation is acceptable, i.e., it is not necessary for the Steinmann pin to point to the geometric center of the screw hole. Subsequently, with smooth rotational movements, the tip of the pin starts penetrating the cortex and is then positioned parallel to the radiation beam. The pin is advanced through the near cortex and the nail with hammer blows, and its tip can usually be felt protruding through the far cortex (Fig. 4A). The inclination of the flag can be easily changed, taking advantage of the skin elasticity and of the loose connection between the grid and the skin via an adhesive drape. A second pin is then inserted, preferably in the more proximal hole using the same

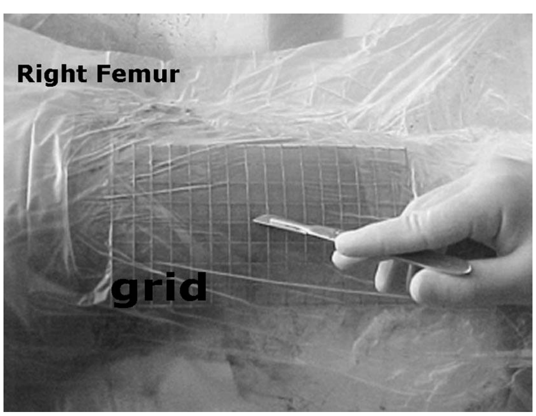

FIGURE 2. The metallic grid is attached to the lateral surface of the femur (or the medial surface of the tibia) with an adhesive drape.

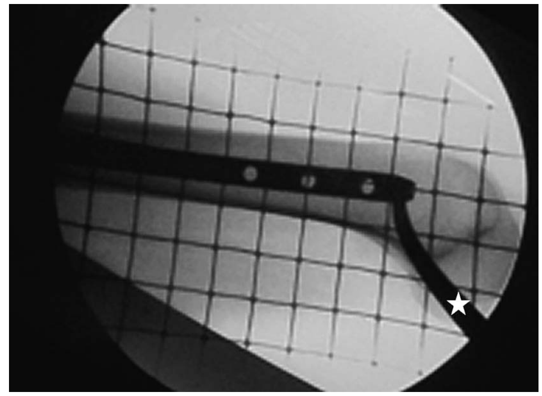

FIGURE 3. Lateral fluoroscopic imaging of the femur showing the relationship between the extramedullary metallic grid and the distal holes of the intramedullary nail. A hemostatic clamp (star) is gripping the grid indicating the position of the nail holes in relation to it.

technique (Fig. 4B, C), although any other nail hole can be selected. The first pin is removed and a screw of appropriate length is inserted followed by insertion of the second screw (Fig. 5). In summary, the technique involves following steps:

1. Insertion of the intramedullary nail.
2. Attachment of a metallic grid to the skin surface corresponding to the distal nail holes.
3. Viewing of the distal holes as perfect circles and determination of their position in relation to the metallic grid on the screen.
4. Skin incisions at the appropriate quadrants.
5. Targeting and opening of the screw hole with a modified Steinmann pin.
6. Insertion of the interlocking screws.

MATERIALS AND METHODS

To compare the modified with the classic freehand technique, 106 patients operated between October 1997 and January 1999 were allocated to 2 groups. The study was prospective, but not randomized. There were no demographic differences between the 2 groups, and adolescents were included in both groups. The first 2 authors, who are experienced trauma surgeons performing more than 70 nailings each annually, did most of the operations. All surgeons were skilled in both techniques. Group A included 62 patients with 24 femoral and 39 tibial fractures, and group B 44 patients with 15 femoral and 31 tibial fractures. In group A, the modified technique was used, whereas in group B, the classic freehand technique was used. The patients' age in group A ranged between 12 and 67 years (mean 31.5 years) and in group B between 11 and 29 years (mean 25.2 years). In adults, reamed nailing was performed, whereas in adolescents, unreamed nailing was done. The total time necessary to obtain a perfect circles view and to insert the distal screws was measured. The difference between the freehand and the flag and grid techniques regarding interlocking time, number of radiographs taken, and radiation time was statistically compared using the Student *t* test for independent samples. Differences were

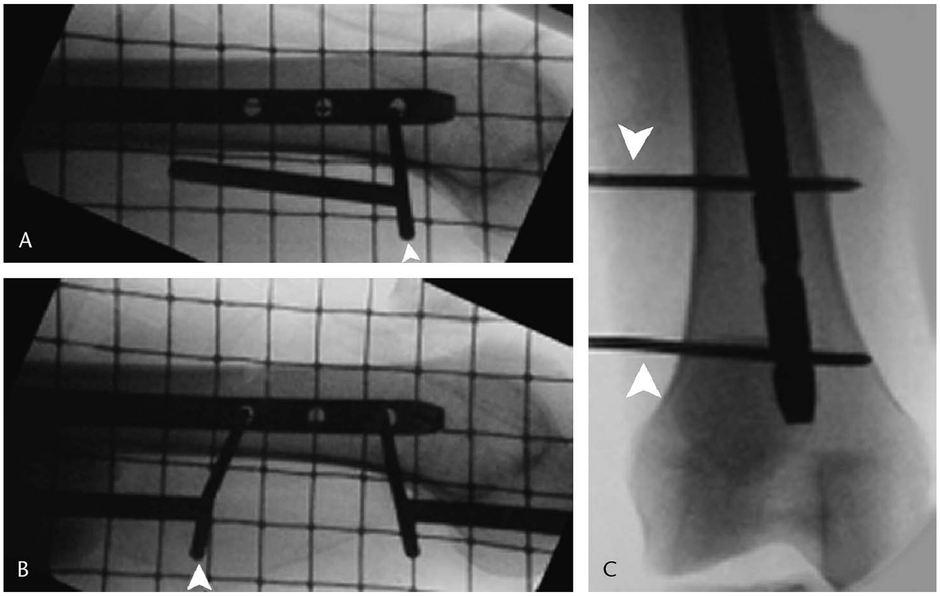

FIGURE 4. A, Lateral fluoroscopic view of the femur showing the ''flag'' (arrowhead) centered on the distal nail hole. The most proximal or any other hole can be chosen. The technique is flexible. In this case, 2-screw insertion was performed in a distal to proximal insertion. The reverse screw insertion order can also be chosen. B, A second ''flag'' (arrowhead) is inserted into the more proximal of the distal nail holes. C, Anteroposterior fluoroscopic view of the distal femur showing 2 ''flags'' (arrowheads) passing through the nail.

considered significant when P was less than 0.05. The number of radiographs taken and the radiation time numbers relate only to distal screw interlocking and no other part of the operation.

RESULTS

In group A, there was no difficulty with screw insertion, despite the lack of formal drilling and the fact that most patients were young and their bones were expected to be dense. Total distal interlocking time was 5.1 $\pm$ 2.7 minutes with the flag technique and 19 $\pm$ 7.1 minutes with the freehand technique. With the flag technique (group A), distal targeting required performance of 5 to 9 radiographs (mean 6.2), and the radiation time ranged between 0.05 and 0.09 minutes (mean 0.062 minutes). When the freehand technique was used (group B), distal targeting required 17 to 52 radiographs (mean 28.4), and the radiation time ranged between 0.17 and 0.52 minutes (mean 0.284 minutes). The difference regarding interlocking time, number of radiographs, and radiation time were statistically significant ($P < 0.001$, for all comparisons). There were no failures in inserting the distal screws with the modified technique. However, in 2 cases, limited blowout of the far distal femoral cortex was observed probably because of dullness of the pin's tip. This complication had no impact on the postoperative course, did not compromise nail fixation, nor did these screws back out. Using the freehand technique, 4 screws missed the nail and 5 screws were not inserted due to enlargement of the proximal cortical hole secondary to repeated drilling. There were no complications from the missed noninserted screws.

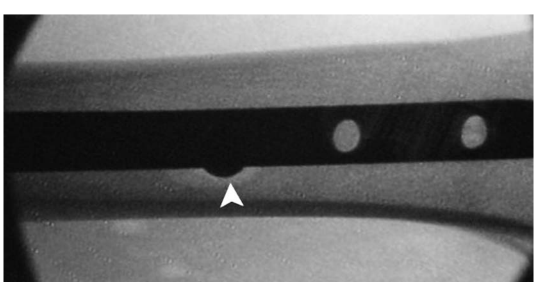

FIGURE 5. Final lateral fluoroscopic view of the femur showing insertion of the most proximal of the distal interlocking screws (arrowhead).

DISCUSSION

A modification of the freehand technique for distal interlocking has been described using a modified Steinmann pin and a metallic grid, with which radiation exposure and interlocking time have been significantly reduced.

Several techniques have been devised and many devices have been designed to facilitate distal interlocking, but currently the freehand technique is the most successful and most widely used method.[2,3,20–25] The freehand, perfect circles technique is the gold standard to which all other techniques are compared but it has 3 disadvantages: the learning curve of the technique is steep, the amount of radiation exposure may be significant, and the technique may be time consuming.[1,4,12,17,19,21,25,26] Additionally, minimal position errors may result in drill hole misplacement and screw malpositioning, whereas overdrilling or repeated drilling of the proximal cortex may jeopardize screw purchase.[2,24]

The contribution of distal interlocking radiation to the total radiation has been reported in several studies.[4,19,27–30] Distal interlocking radiation time with the freehand technique, presented as a percentage of the total radiation time, has been reported to be 29%,[4] 31%,[27] 40%,[28] and 57%.[29] In one study, despite the use of a radiolucent drill, distal targeting radiation accounted for 50% of the total radiation.[19] Use of a radiolucent drill may reduce but certainly does not eliminate exposure to ionizing radiation. Furthermore, this drill is expensive and not readily available in all operating theaters.

Distal interlocking is time consuming. Sanders et al,[30] using the freehand technique to perform distal interlocking in the femur and the tibia, reported the mean time for screw insertion was 30.2 and 13.25 minutes, respectively. In a further relevant study, distal interlocking time with and without a targeting device was 17.06 and 19.08 minutes, respectively, whereas the total surgical time was 81 versus 85 minutes, respectively.[17] In other words, distal interlocking consumed approximately 20% of the total operation time. Distally based targeting devices reduce screw insertion time. In a study comparing a fluoroscopy-free mechanical targeting system to the freehand technique, distal locking time was 16.7 ± 8.6 and 21.9 ± 10.5 minutes, respectively, whereas the screw insertion failure rate was 1.6% in both groups.[25] The freehand technique has been compared to the AO distal aiming system in the femur.[31] The average distal locking time was 35.8 ± 18.6 and 19.3 ± 9.8 minutes, respectively, whereas the average number of images taken to achieve distal locking was 11.5 ± 3.4 and 3.8 ± 3.5, respectively. The average distal locking time using the distal aiming device decreased by 46.1% and the total radiation by 70%.[31]

Distal locking time in reamed and unreamed tibial nailing is similar.[1] In a comparative study, the total operation time in reamed and unreamed nailing was 70 and 59 minutes, respectively, whereas distal locking time was 13 and 14 minutes, respectively.[1] Distal interlocking using the freehand technique required 18.57% and 23.7% of the total operating time, respectively.

The technique described in this paper is completely different than the Grosse-Kempf C-arm–based targeting technique, the radiolucent handle, and other devices that have been used.[4,6,7,9,11] The metallic grid used acts as a fixed "navigational" aid, minimizing primary beam exposure and facilitating location of the distal nail holes. It can be used universally with success without relying on expensive tools or guides, the devices used are easy to manufacture, the required materials are readily available, and their cost is approximately $15. The location of the nail hole can be also accomplished using the handle of a clamp. However, this maneuver directly exposes the surgeon's hand to the radiation beam, and the position of the clamp is frequently adjusted more than once. In contrast, only 1 radiograph is necessary to precisely locate the distal nail holes when using the grid.

Drilling of the screw hole is performed using a pointed Steinmann pin, with a diameter corresponding to the core diameter of the locking screws. The pressure at the tip of the pointed Steinmann pin is high, due to the concentration of the mechanical energy of the hammer blow at a very small area, i.e., its tip. Additionally, distal locking takes place at the expanding distal part of the femur, where the cortical bone is thin and the metaphysis contains mainly cancellous bone. Inserting a Steinmann pin has never been troublesome in our experience, despite the young age of our patients. The use of a longer, tapered tip of a pin facilitates also fluoroscopic visualization of the distal nail hole, whereas the wider, beveled tip of a drill bit may impede targeting by obscuring visualization.[24] Use of a drill bit is not absolutely necessary to drill the screw hole, and use of a Steinmann pin has been recommended by other authors.[24] Many locking screws used in modern nailing systems are self-tapping and may create their own exit hole, especially in the distal femur. Furthermore, the smooth pin avoids wrapping of soft tissue, so loss of direction due to impaired visualization is less likely. If a drill bit is used and a drill hole has been opened in a wrong position, subsequent redrilling and screw insertion may be difficult. A Steinmann pin is used instead of a drill bit because the former is stronger and breaks less easy than the side-cutting drill bit. Furthermore, the sharp tip of the pin obstructs the fluoroscopic view less when compared with the more cylindrical drill bit.

The technique described is suitable for reamed and unreamed nails, but the size of the pin should correspond to the core diameter of the locking screws. This technique may be modified to allow multidirectional placement of screws, i.e., mediolaterally or anteroposteriorly by placing the metallic grid at the medial or the anterior surface of the distal femur or tibia, respectively.

Although not yet used in our practice, the described technique can hypothetically be employed for humeral nail interlocking. In that situation, a thinner Steinmann pin and a smaller grid should be used, attached to the distal lateral or anterior surface of the humerus.

In our experience, errors with this technique are rare. The most common error is blowout of the far cortex secondary to the use of an oversized or blunt Steinmann pin. This complication was encountered twice in our experience and did not endanger the fixation. The technique is easy to master, flexible, straightforward, and successful.

As with most interlocking techniques, this technique requires fluoroscopic guidance but radiation exposure is kept to a minimum, consequently reducing the total operating time. It is a universal, reproducible, and inexpensive technique that does not necessitate the use of external guides or expensive navigation systems.

REFERENCES

1. Blachut PA, O'Brien PJ, Meek RN, et al. Interlocking intramedullary nailing with and without reaming for the treatment of closed fractures of the tibial shaft. A prospective, randomized study. *J Bone Joint Surg Am*. 1997;79:640–646.
2. Brumback RJ. The rationales of interlocking nailing of the femur, tibia, and humerus. *Clin Orthop*. 1996;324:292–320.
3. Gregory P, Sanders R. The treatment of closed, unstable tibial shaft fractures with unreamed interlocking nails. *Clin Orthop*. 1995;315:48–55.
4. Kempf I, Grosse A, Beck G. Closed locked intramedullary nailing. Its application to comminuted fractures of the femur. *J Bone Joint Surg Am*. 1985;67:709–720.
5. Goulet JA, Londy F, Saltzman CL, et al. Interlocking intramedullary nails. An improved method of screw placement combining image intensification and laser light. *Clin Orthop*. 1992;281:199–203.

6. Hashemi-Nejad A, Garlick N, Goddard NJ. A simple jig to ease the insertion of distal screws in intramedullary locking nails. *Injury.* 1994;25: 407–478.
7. Kelley SS, Bonar S, Hussamy OD, et al. A simple technique for insertion of distal screws into interlocking nails. *J Orthop Trauma*. 1995;9: 227–230.
8. Knothe U, Knothe Tate ML, Klaue K, et al. Development and testing of a new self-locking intramedullary nail system: testing of handling aspects and mechanical properties. *Injury.* 2000;31:617–626.
9. MacMillan M, Gross RH. A simplified technique of distal femoral screw insertion for the Grosse-Kempf interlocking nail. *Clin Orthop*. 1988; 226:252–259.
10. Ohe T, Nakamura K, Matsushita T, et al. Stereo fluoroscopy-assisted distal interlocking of intramedullary nails. *J Orthop Trauma*. 1997;11: 300–303.
11. Rao JP, Allegra MP, Benevenia J, et al. Distal screw targeting of interlocking nails. *Clin Orthop*. 1989;238:245–248.
12. Suhm N, Jacob AL, Nolte LP, et al. Surgical navigation based on fluoroscopy—clinical application for computer-assisted distal locking of intramedullary implants. *Comput Aided Surg*. 2000;5:391–400.
13. Kanellopoulos AD, Yiannakopoulos CK, Vossinakis I, et al. Distal locking of femoral nails under direct vision through a cortical window. *J Orthop Trauma*. 2003;17:574–577.
14. Lin J, Lin SJ, Chen PQ, et al. Stress analysis of the distal locking screws for femoral interlocking nailing. *J Orthop Res*. 2001;19:57–63.
15. Hutson JJ, Zych GA, Cole JD, et al. Mechanical failures of intramedullary tibial nails applied without reaming. *Clin Orthop*. 1995;315:129–137.
16. Krettek C, Konemann B, Miclau T, et al. in vitro and in vivo radiomorphometric analyses of distal screw hole position of the solid tibial nail following insertion. *Clin Biomech (Bristol, Avon)*. 1997;12:198–200.
17. Gugala Z, Nana A, Lindsey RW. Tibial intramedullary nail distal interlocking screw placement: comparison of the free-hand versus distally-based targeting device techniques. *Injury.* 2001;32(suppl 4): 21–25.
18. Krettek C, Konemann B, Farouk O, et al. Experimental study of distal interlocking of a solid tibial nail: radiation-independent distal aiming device (DAD) versus freehand technique (FHT). *J Orthop Trauma*. 1998;12:373–378.
19. Krettek C, Konemann B, Miclau T, et al. A mechanical distal aiming device for distal locking in femoral nails. *Clin Orthop*. 1999;364: 267–275.
20. Kneifel T, Buckley R. A comparison of one versus two distal locking screws in tibial fractures treated with unreamed tibial nails: a prospective randomized clinical trial. *Injury.* 1996;27:271–273.
21. Noordeen HH, Sala MJ, Belham GJ. Insertion of distal screws in interlocking intramedullary nails. *Injury.* 1993;24:357–358.
22. Rabin SI, Naeni F, Robledo SL, et al. Inserting distal screws into interlocking IM nails-revisited. Methods to make it easier. *Orthop Rev.* 1993;22:1059–1063.
23. Giachino AA, Cheng M. Irradiation of the surgeon during pinning of femoral fractures. *J Bone Joint Surg Br.* 1980;62:227–229.
24. Brumback RJ. Interlocking screw insertion. *Tech Orthop*. 2001;16: 342–348.
25. Krettek C, Konemann B, Farouk O, et al. A comparison of a fluoroscopy-free mechanical targeting system and a free-hand technique for the placement of distal interlocking screws of tibial nails. *Chirurg*. 1997;68: 1194–1201.
26. Wolinsky PR, McCarty EC, Shyr Y, et al. Length of operative procedures: reamed femoral intramedullary nailing performed with and without a fracture table. *J Orthop Trauma*. 1998;12:485–495.
27. Sugarman ID, Adam I, Bunker TD. Radiation dosage during AO locking femoral nailing. *Injury.* 1988;19:336–338.
28. Levin PE, Schoen RW Jr, Browner BD. Radiation exposure to the surgeon during closed interlocking intramedullary nailing. *J Bone Joint Surg Am*. 1987;69:761–766.
29. Coetzee JC, van der Merwe EJ. Exposure of surgeons-in-training to radiation during intramedullary fixation of femoral shaft fractures. S Afr Med J. 1992;81:312–314.
30. Sanders R, Koval KJ, DiPasquale T, et al. Exposure of the orthopaedic surgeon to radiation. *J Bone Joint Surg Am*. 1993;75:326–330.
31. Pardiwala D, Prabhu V, Dudhniwala G, et al. The AO distal locking aiming device: an evaluation of efficacy and learning curve. *Injury.* 2001;32: 713–718.

