Nail over nail technique for distal locking of femoral intramedullary nails

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Abstract The free hand technique remains the most popular method for distal locking; however, radiation exposure is a major concern. In an endeavour to overcome this concern, distal locking with the nail over nail technique is evaluated. Seventy patients with femoral diaphyseal fractures treated by intramedullary nailing were divided in two groups for distal locking: either using the free hand technique (group I) or with the nail over nail technique (group II). The average number of images taken to achieve nail insertion without locking, for distal locking, and for the complete procedure in group I was 25.8, 24.2, and 50.08, respectively, compared with 24.8, 4.1, and 28.9, respectively, in group II (statistically extremely significant decrease in radiation). The nail over nail technique appears to be a reliable solution for decreasing radiation exposure during closed femoral intramedullary nailing. However, over-reaming of 1.5 mm is the key to the success of the technique.

Résumé Le verrouillage à main levée est une technique populaire cependant, le problème de l'irradiation demeure important. Nous avons voulu l'évaluer lors du verrouillage des clous centro-médullaires. 70 patients présentant une fracture de la diaphyse fémorale ont été traités par enclouage centro-médullaire divisés en deux groupes, verrouillage distal à main levée (groupe I) et verrouillage selon la technique « nail over nail » (groupe II). le nombre d'image moyen nécessaire pour mettre en place le clou avec un verrouillage distal où lors de la procédure complète a été

respectivement, pour le groupe I de 25,8, 24,2 et 50,08 comparé à 24,8, 4,1 et 28,9 pour le groupe II (différence extrêmement significative en ce qui concerne la diminution de l'irradiation). la technique « nail over nail » apparaît comme une technique fiable et permet une diminution de l'exposition aux rayons X lors de l'enclouage fémoral. Cependant, il est nécessaire de rappeler qu'un alésage supérieur à 1,5 mm est la clef du succès de cette technique.

Introduction

Intramedullary interlocked nailing of the femur, although well established and widely accepted as the standard of treatment for diaphyseal femoral fractures, is a technically demanding procedure. Experience is required on the part of both the surgeon and the radiographer to achieve distal locking accurately, in the least possible time, and with the least possible exposure to radiation. Numerous techniques and devices have been proposed to aid distal targeting in attempts to overcome some of the associated problems. These include free hand techniques and hand-held guides [10, 12, 20], image intensifier mounted targeting devices [3], and nail-mounted guides [11, 13]. Computer-assisted methods are under development and offer an alternative approach [14, 21]. Each technique has its own advantages and disadvantages, and as a result the free hand technique remains the most popular method for distal interlocking screws [11, 17]. However, operating room personnel within 12 inches of the fluoroscopy beam (such as when performing the free hand technique for interlocking screw insertion using a radiolucent drill) receive significant amounts of radiation exposure, particularly to the unprotected eyes, neck, and hands [8]. Radiation exposure should be decreased when possible [6]. The purpose of this study

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was to compare prospectively the duration of the nailing procedure, number of radiation exposures or images required for distal locking, and the accuracy of interlocking screw placement with the nail over nail technique versus using the free hand technique for femoral intramedullary nails.

Materials and methods

In a prospective study, 70 patients (40 males and 30 females) with femoral diaphyseal fractures were operated upon with closed interlocked nailing using the free hand and nail over nail techniques after stratified randomisation from March 2004 to July 2007. To maintain uniformity, we tried to perform all procedures under identical operating conditions. All patients were operated upon by the same surgeons (first and second authors). Anteroposterior and lateral radiographs including full extent of femur from hip joint to knee joint were obtained. This helped in fracture classification and preoperative planning. As per AO classification 20, 24, and 26 fractures were type 32 A, B, and C, respectively. After fracture classification, the patients were assigned randomly to one of the two treatment groups using the lottery method. Patients in group I had distal locking with the free hand technique. In group II distal locking was performed with the nail over nail technique. Operations were performed on ordinary operation tables under image intensifier control in lateral decubitus with the fractured leg uppermost. Nailing was performed as the standard procedure [18], except the distal interlocking.

Techniques for distal interlocking of the nail

Group I: the free hand technique Distal locking of the nail was performed as the described standard procedure [18].

Group II: the nail over nail technique This technique is based on the standard procedure of nailing [18]; however, the nail over nail technique requires 1.5 mm of over-reaming of the medullary canal to avoid nail deformation during insertion. Figure 1 shows the instruments used for the technique. Figure 2 shows the schematic assembly of the instruments. Another nail of the same size is placed over the thigh. Two trocars and cannulae are inserted through the holes of the proximal guide into the proximal holes of the second nail (Fig. 3). This stabilises the second nail placed along the longitudinal axis of the femur. A 2-cm incision is made down to the bone at the site corresponding to the distal most screw of the second nail. The second nail is aligned along the longitudinal axis of the femur. A 4.0 mm drill (the same drill bit which is recommended for

Fig. 1 Instruments used in the nail over nail technique. **a** 4-mm drill bit. **b** 4-mm Steinmann pin. **c** Trocar. **d** Cannula. **e** Trocar. **f** Cannula

the interlocking screws) is passed through the distal most hole of the second nail and drilled into the lateral cortex (Fig. 4). Then the second nail is withdrawn and light is focussed over the hole in the lateral cortex. A fine suction tip is used to aid visualization of the nail hole through the hole in the lateral cortex. It is usually possible to insert the drill bit through the nail hole. The nail can be manipulated axially and rotationally by 1–2 mm if required for inserting the drill bit through the nail hole. The drill bit in the distal most hole of the nail is confirmed with a metallic touch generated as the guide wire introduced from the proximal end of the nail hits the drill bit distally. After confirming the drill bit in the distal most hole, the opposite cortex is drilled and an appropriate size locking screw is placed in the distal most interlocking hole. Again a guide wire is used to

Fig. 2 Assembly of the instruments

Fig. 3 An externally placed nail is used as a guide for distal locking. The two trocars and two cannulas passing through the proximal interlocking guide stabilise the nail

confirm the position of the screw with the help of a ‘sounding technique’, and the length of the guide wire reaching up to the screw confirms the placement of the screw by comparison from outside. Next, the second nail is again placed over the thigh and two trocars and two cannulas are inserted through the holes of the proximal interlocking guide into the proximal holes of the second nail. A Steinman pin is passed through the distal most hole of the nail to the distal most screw just inserted. This stabilizes the second nail placed along the longitudinal axis of the femur. A 2-cm incision is made down to the bone at the site corresponding to the second distal screw of the second nail. A 4.0-mm drill is passed through the second distal hole of the second nail and drilled into the lateral cortex (Fig. 5). The rest of the procedure to lock the second distal screw is the same as for the distal screw.

Fig. 4 A 2-cm incision is made at the site corresponding to the distal most screw of the second nail and a 4-mm drill bit is used to drill the lateral cortex

Fig. 5 Technique for placement of the second distal interlocking screw

Proximal locking is performed using a proximal interlocking guide. The following parameters were recorded for each procedure:

1. Nail insertion time without locking. This was defined as the period beginning with the skin incision and ending with confirmation under the image intensifier of insertion of the proper size nail without locking.
2. The radiation exposure during nail insertion without locking. This was defined as the number of images required until confirmation under the image intensifier of insertion of the proper size nail without locking.
3. Distal locking time. This was defined as the period between successful nail insertion without locking and the confirmation of accurate insertion of both distal screws.
4. Radiation exposure during distal locking. This was defined as the number of images required for interlocking of both distal screws.
5. Total operative time. This was defined as the period beginning with the skin incision and ending with completion of skin closure.
6. The total radiation exposure. This was defined as the total number of images required during the operation.
7. Total fluoroscopic time. This was defined as the total radiation exposure time during the complete procedure as depicted on the image intensifier screen.
8. The success or failure of the technique. The precision of passing the drill through the interlocking holes in the nail was assessed as follows. Precision was considered *successful* if only one lateral cortical hole was made for single interlocking and *successful with difficulty* if up to two lateral cortical holes were made for single interlocking. A *failure* of each technique was recorded when more than two holes were drilled in the lateral cortex during single distal interlocking. All failures of the nail over nail technique were converted to the free hand

technique. In these cases, the time taken for distal locking and the radiation exposure during distal locking included not only the time and radiation incurred during the attempt with the nail over nail technique, but also the time and radiation required for the subsequent free hand technique.

Statistical analysis

Data were analysed by chi-square test with Yates' correction and Student's *t* test. For all tests, probability less than 0.05 was considered significant.

Results

Group I was composed of 35 patients (21 males and 14 females) with an average age of 44.14 years (range, 25–65 years). Group II was composed of 35 patients (19 males and 16 females) with an average age of 45.7 years (range, 21–66 years). The average diameter of the nails used in the free hand technique was 11.3 mm and 10.7 mm in the nail over nail technique. A total of 70 distal interlocking screws (4.9 mm) were inserted in each group. Sixty-one screws were inserted *successfully* and five screws were inserted *successfully with difficulty* in group I compared with 59 and 6 in group II, respectively. The technique *failed* in four screws (three in the distal and one in the second distal hole) in group I and in five distal screws in group II. All second distal (more proximal) holes were inserted successfully in group II. Values of other parameters are depicted in Tables 1 and 2. Radiation exposures during distal locking were required either for confirmation of successful locking or for interlocking in failures of the technique in group II. No patient had fracture at screw sites after implant removal.

Comparison of groups I and II

No significant difference could be detected between groups I and II with respect to gender ($P=0.8$), bent distal locking screws ($P=0.55$), type of fracture ($P=1.0$), and precision problems ($P=0.8$) (Table 1). However, there was a statistically significant difference with respect to the diameter of intramedullary nails used ($P=0.026$). An unpaired *t* test did not reveal significant differences between groups I and II with respect to the patient's age ($P=0.72$), average nail insertion time without locking ($P=0.88$), average distal locking time ($P=0.54$), average total operative time ($P=0.31$), and average number of images taken to achieve nail insertion without locking ($P=0.5$) (Table 2). The average number of images taken to achieve

Table 1 Comparison of the two groups with respect to gender, type of fracture, nail diameter, bent distal screws, and precision problems

	Free hand technique	Nail over nail technique	<i>P</i> value
Males	21	19	NS
Females	14	16	
Type of fracture			
A	10	10	NS
B	12	12	
C	13	13	
Nail diameter			Significant ($P=0.026$)
10 mm	4	15	
11 mm	16	16	
12 mm	15	4	
Bent distal screws	1	2	NS
Precision problems	9	11	NS

NS Not significant

distal locking was less in the nail over nail technique versus the free hand technique. This 86% decrease in radiation when using the nail over nail technique is statistically extremely significant at $P<0.0001$. The average total number of images required during the complete procedure and average total fluoroscopic time were less in the nail over nail technique versus the free hand technique. This decrease in radiation by 44% when using the nail over nail technique is statistically extremely significant at $P<0.0001$.

Discussion

Ionizing radiation has no safe threshold of exposure below which it ceases to have adverse effects [9, 14]. Moreover, long-term effects of this radiation exposure are unknown [7]. Therefore, every effort must be made to keep radiation exposure to a minimum [9]. The free hand technique is chosen for comparison because it remains the predominant method used by orthopaedic surgeons for distal locking [17]. The average number of images taken to achieve distal locking with the free hand technique in our series was within the range (11.5–43.7) reported in the literature [11, 16, 20]. Using the nail over nail technique we were able to perform distal locking with 44% decreased exposure to radiation as compared to the popular 'free hand technique'. This decrease is extremely significant statistically ($P<0.0001$). The technique is not time consuming as reflected by a statistically insignificant difference of the average distal locking time and the average total operative time between the two groups. This technique uses readily

Table 2 Comparison of the two groups

	Free hand technique		Nail over nail technique		<i>P</i> value
	Mean	Standard deviation	Mean	Standard deviation	
Nail insertion time without locking (min) (range)	35.74 (24–44)	5.56	35.54 (23–49)	6.33	NS
Distal locking time (min) (range)	23.34 (15–55)	7.51	24.34 (15–41)	6.04	NS
Total operative time (min) (range)	70.97 (50–97)	9.91	73.4 (54–92)	9.97	NS
Exposures in nail insertion without locking (range)	25.86 (13–38)	5.64	24.86 (13–38)	6.85	NS
Exposures in distal locking (range)	24.23 (11–81)	13.07	4.11 (1–21)	6.0	Extremely significant ($P<0.0001$)
Total exposures in procedure (range)	50.08 (26–104)	15.54	28.97 (14–52)	8.72	Extremely significant ($P<0.0001$)
Total fluoroscopic time (minutes) (range)	0.25 (0.13–0.52)	0.08	0.14 (0.07–0.26)	0.04	Extremely significant ($P<0.0001$)

NS Not significant

available instruments and is not technically demanding. The second nail can be reused after autoclaving.

No forcible insertion or hammering is done to avoid nail deformation. The canal has to be reamed 1.5 mm more than the diameter of the nail to prevent deformation of the nail. Over-reaming is the key to success of this technique. Although reaming can have an early deleterious effect on endosteal and cortical blood flow, canal reaming appears to have several positive effects on the fracture site, such as increasing extraosseous circulation, which is important for fracture healing [2]. Union at the fracture site was not affected in this series nor in another series of closed antegrade interlocked nailing of femoral shaft fractures in 200 patients where the canal was reamed 2 mm more than the diameter of the nail to prevent deformation of the nail [1]. Over-reaming results in the insertion of a smaller diameter nail, which has been implicated as a biomechanical cause of nail failure [19]. A larger distal skin incision is made with this technique than with the percutaneous method of screw insertion in the free hand technique. Multiple cortical holes in case of precision failures are another disadvantage of the technique. The placement of two holes in close proximity produces an area of stress concentration and the repeated drilling may lead to screw loosening [17]. The presence of multiple cortical holes is another known complication of the free hand technique [17]. Kanellopoulos et al. reported a technique of distal locking under direct vision through a small window in the anterior femoral cortex [5]. No postoperative fractures occurred through the cortical defect [5]. We also did not observe any fracture at screw sites in our study. Hajek et al. reported that only one distal screw could provide adequate distal fixation [4]. The locking of a second distal hole was adequately performed in every case

in group II in our series. This confirms statistically insignificant bending of screws between the two groups in the series.

Techniques of distal locking similar to the nail over nail technique are described in literature. Rao et al. used the nail as a guide for locking more proximal of the distal holes [12]. Following the placement of a Kirschner wire into the distal hole, a second nail is positioned external to the limb with the wire passing through the corresponding hole. Using the nail as a guide, a wire is passed through the more proximal of the distal holes [12]. Steriopoulos et al. described an H-shaped device, which aided distal locking in femoral nailing by holding two similar intramedullary nails parallel to one another [13]. Tanna described an image intensifier independent technique of distal locking for tibial nailing [15]. A Kirschner wire is drilled through the hole in the distal jig, which corresponds to the site of the distal locking holes in the interlocking nail. Plain radiographs are taken to confirm that the location of the wire is at the level of the interlocking hole. A 4.5-mm drill hole is made at the judged entry site after wire removal. A fine suction tip and good light allow the nail and locking hole to be seen through the drill hole. The far cortex can now be drilled and the screw inserted [15]. Aiyer et al. reported successful use of Dr. Tanna's technique in the instance when the jig did not work [1]. All these techniques [12, 13, 15] still need radiographic images for distal locking whereas the nail over nail technique of distal locking is almost radiation independent as radiographic images were taken only to confirm screw placement or when some intra-operative difficulty occurred. The limitations of our study include the small number of patients in the series and potential for user bias because the surgeon could not be blinded with respect to the method used for distal locking.

Conclusion and recommendations

This prospective study on distal locking of femoral intramedullary nails shows that radiation exposures to achieve equivalent precision are reduced with the nail over nail technique compared with the free hand technique. The nail over nail technique can also be used when an image intensifier is unavailable or goes out of order peroperatively. Success of the nail over nail technique lies in prevention of nail deformation during insertion. Over-reaming of the medullary canal by 1.5 mm serves this purpose.

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