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Research Article

An Effective Method for Intramedullary Fixation of Long Bone Fractures Reducing the Operative Duration and Flouroscopy Time: Guide Wire Assisted Nail Locking

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Abstract

Objectives: Intramedullary nailing is still the gold standard surgical technique in treatment of long bone diaphyseal fractures. In this surcigal procedure, distal locking phase gives rise to increased operative durations and flouroscopy time. Various device and techniques has been developed to overcome this issue. In our study, we aimed to investigate a practical and inexpensive technique for insertion of distal locking screws in intramedullary nailing of long bone diaphyseal fractures.

Methods: 90 patients with diaphyseal fractures of tibia(48) and femur(42) who underwent intramedullary nailing were enrolled for this study. Classical Free Hand Locking (FHL) and Guidewire Assisted Locking (GAL) techniques were performed in distal locking phase of the procedure on 51 and 39 cases, respectively. These techniques were compared according to the influence on total operative duration and c-arm flouroscopy time.

Results: GAL technique compared to FHL technique was provided statistically significant reduction in operative duration of both femur fractre surgery (75 vs 93 min., p<0,05) and tibia fracture surgery (63,5 vs 83 min, p<0,05). Flouroscopy time was also significantly lower in both femur (9 vs42,5 sec., p<0,05) and tibia (11 vs 38 sec., p<0,05) cases when utilizing GAL technique.

Conclusion: GAL technique facilitates the distal locking phase of intarmedullary nailing surgery. It is an inexpensive and practical technique which reduces operative duration related complications and ionizing radiation exposure of surgical team.

Keywords: Distal locking, femur fractures, flouroscopy, intramedullary nailing, tibia fractures

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Intramedullary nailing is the gold standard surgical method for the treatment of long bone diaphysis fractures such as femur and tibia.[1] Previous studies has shown that intramedullary nailing of these fractures provides high union and low complication rates.[2] But, distal locking phase of nailing surgery maintains its importance among troublesome orthopaedic surgical procedures.[3] Standard external guides attached proximal part of the nail solved distal locking problem in a large extent, which aims to lock the nail from outside of the extremity. But these basic guides failed to achieve required success.[4] Even if locking guide is adjusted precisely after assembling with the nail; the deli-

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cate setting between nail and guide can be disturbed while inserting nail into intramedullary canal.[5] Nail is exposed to bending and torsional forces entering the intramedullary canal. This causes alteration of the distinctively curved nail design. Thus, the setting between rigid external guide and nail can be disturbed. Drilling to find nail holes through the external guide holes may deviate from the target.[4, 5] Many technological devices have been developed to overcome these problems, such as special nail designs reducing the need of flouroscopy, various computer assisted navigation systems, video augmented flouroscopy and electromagnetic targeting device. Besides of being expensive, success of these devices are also controversial.[2, 3, 6, 7] C-arm flouroscopy assisted free hand locking is still the most widely used method. Altough this technique is succesful with experienced surgeons; it can cause time loss and excessive radiation exposure.[4, 6, 8] There is a need for device/methods for increasing accuracy of external guides that is practical, cost-effective, time saving and establishing reduced radiation exposure. In this study, we aimed to investigate a practical and cost-effective technique which reduces the duration of distal locking phase of long bone diaphyseal fracture nailing surgery.

Methods

Necessary permissions for the study were obtained from the local Ethics Commitee (14.06.2019/1861). 90 patients were retrospectively enrolled for this study who admitted to our emergency department with femur fracture (n=42) and tibia fracture (n=48) treated with femoral intramedullary nai l(Tasarımmed, Istanbul, Turkey) and tibial intramedullary nail (Tasarımmed, Istanbul, Turkey), respectively. Patients were divided into four groups as Guidewire Assisted Locking-Femur (GAL-F), Guidewire Assisted Locking-Tibia (GAL-T), FreeHand Locking-Femur (FHL-F) Free Hand Locking-Tibia (FHL-T) according to the fractured bone and nail locking technique. The data about the duration of both the operation and fluoroscopy were retrospectively compared. NCSS (Number Cruncher Statistical System) 2007 (Kaysville, Utah, USA) program was used for statistical analysis. As we evaluate the study data, in addition to descriptive statistical methods (mean, standard deviation, median, frequency, ratio, minimum, maximum), we used Mann Whitney U test to compare the variables that did not met normal distribution criteria. Spearman correlation analysis was used to assess the relationships between quantitative variables. $P<0.05$ value was considered statistically significant.

Operative Technique:

Femur Group (GAL-F and FHL-F): The same surgical technique was used in both femur groups until the nail locking phase. Under spinal anesthesia, patient was positioned on fracture table. Proper povidon iodine application and sterile coverage was done. Major trochanter was palpated and a 3 to 5 cm longitudinal skin incision was made 10-15 cm proximal to majör trochanter in line with femoral anterior curvature. Subcutaneous tissues and fascia lata sharply dissected and piriform fossa was exposed. A guide K wire was interted from the piriform fossa. A cannulated reamer was used for reaching the medullary canal through the guide K wire. Then reamer and K wire were removed and a guidewire inserted into the medullary canal. Fracture was reduced in a closed manner with guidence of flouroscopy, then guidewire was advanced through the fracture line up to distal medulla. Another identical guidewire was used for measurement of nail length. Reamerisation was performed through guidewire starting from smaller diameter reamers up to the planned nail width which we prefer as thick as possible. The nail with proper length and width that attached to the simple external guide was inserted to the medullary canal and advanced. Then nail locking phase was initiated.

Tibia Group (GAL-T and FHL-T): The same surgical technique was used in the tibia groups until the nail locking phase. Under spinal anesthesia, patient was positioned supine, properly prepared and draped. Leg part of the operation table was inclined downwards to flex the knee as possible. 3 cm longitudinal skin incision was made over the patellar tendon. Patellar tendon was retracted medially. 3mm medial of the tibial crest in frontal plane and intersection of tibial metaphysis and pletau in saggital plane were marked as nail entry point. A guide k wire was insterted from this point. A cannulated reamer was advanced through this K wire to enter the medullary canal. After this, the k wire was removed and a guidewire was introduced to the medullary canal.Under flouroscopic guidence, the fracture was reduced in closed manner and the guidewire was passed through the fracture line and advanced up to the end of distal medllary canal. Another identical guidewire was used for measurement of nail length. Reamerisation was performed through guidewire starting from smaller diameter reamers up to the planned nail width which we prefer as thick as possible. The nail with proper length and width that attached to the simple external guide was inserted to the medullary canal and advanced. Then nail locking phase was initiated.

Nail Locking Technique:

Free Hand Locking Group (FHL-F and FHL-T): In this technique, distal locking part of the external guide attached to the nail was removed and distal locking screws were placed with the freehand method. First, the locking screw hole of the nail was determined to form a circle on lateral flouroscopic image (perfect circle technique). The drill bit was placed in this circle which corresponds to the screw hole under lateral flouroscopic guidence. The first bony cortex was drilled and the nail was reached. After getting through the screw hole, second cortex was drilled. Then, flouroscopy was adjusted for antero-posterior imaging to determine the screw length. After locking screws were placed, flouroscopy was positioned for lateral image again and the image was evaluated for the screw-screwhole overlap. If head of the screw was covered the hole, distal locking was considered as succesful. Same procedure was repeated for the second screw in distal part. Proximal locking screws were placed through the external guide holes.

Guidewire Assisted Locking Group (GAL-F ve GAL-T): "Guidewire assisted nail locking (GAL) technique" was used for placement of proximal (proximal lower-proximal upper) and distal(distal lower-distal upper) locking screws which based on determining whether the drill or screw was in locking screw hole or not. First, the guidewire was advanced through nail cannula as far as distal end of medullar canal. Proximal part of the guidewire that remains outside of the nail was marked with a clamp (A clamp). The guidewire attached with A clamp was pulled back slightly to prevent intersection with the drill bit which was going to be inserted through locking screw hole (Fig. 1). Drilling process was started with the assistance of external guide holes targeting locking screw holes. After the first bony cortex was drilled, drill bit was advanced slightly, then the guidewire was advanced through nail cannula to confirm that the drill was in the locking screw hole. If the drill is in the locking screw hole, a new distance will be formed on the guidewire between A clamp and entry hole of the nail cannula (distance x). If the drill is not in the screw hole, this distance will not be formed. In this case, the drill was pulled back up to the first cortex and attempted to insert into the possible points of cortex targeting the screw hole (more anterior-posterior-superior-inferior) with guidewire controls at every attempt. After succesfully targeting the screw hole, the second cortex was drilled and the drill was left in place (Fig. 2). By this way, in addition to the proximal attachment site, a new moment point was formed between the nail and external guide where the drill crosses the distal-lower locking screw hole. Thus, shortened lever arm provided minimization of movement of distal part of the nail. This process increased the chance of the second drill to succesfully engage into the distal upper screw hole at the first attempt. Proximal part of the guidewire that remains outside of the nail was marked with another clamp (B clamp) at cannula entrance. The guidewire attached with A and B clamps was pulled back slightly to prevent intersection with the drill bit which was going to be inserted through distal-upper locking screw hole (Fig. 3). Same steps were followed to succesfully place the distal upper locking screw of the nail. If the second drill is in the distal upper locking screw hole, a new distance will be formed on the guidewire between B clamp and entry hole of the nail cannula (distance y). Second drill was confirmed to be on target (Fig. 4). After that, secon cortex was drilled and the drill was left in place. Then the distal lower drill was removed and the locking screw was placed, but the screwdriver was left connected with the screw. Distal upper drill was removed and the guidewire was advanced. If the distance x was formed again between the A clamp and the entry hole of the nail cannula, it is considered as succesful placement of the distal lower locking screw (Fig. 5). The guidewire was slightly pulled back and distal upper screw was placed. If the distance y

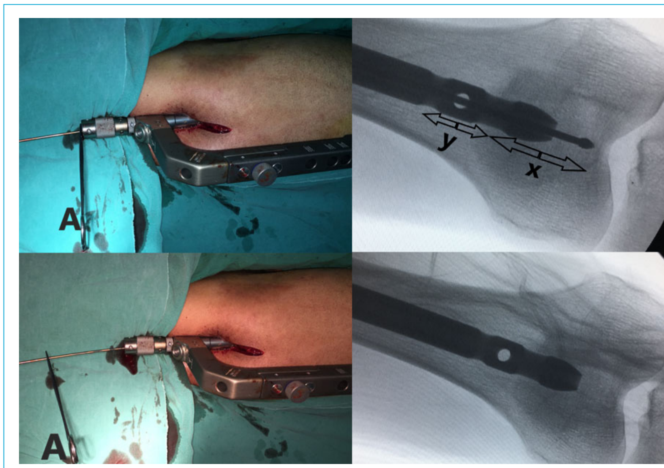

Figure 1. Guidewire being marked with A clamp, correspondings of x and y distances on bone medulla.

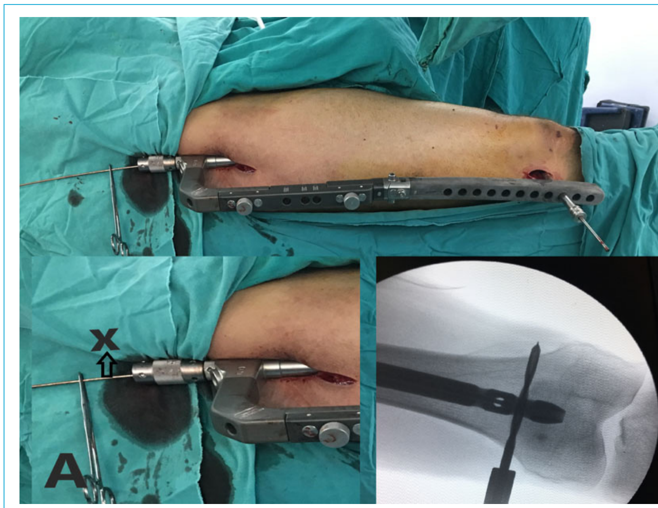

Figure 2. x distance formed after drill insertion to distal-lower locking screw hole.

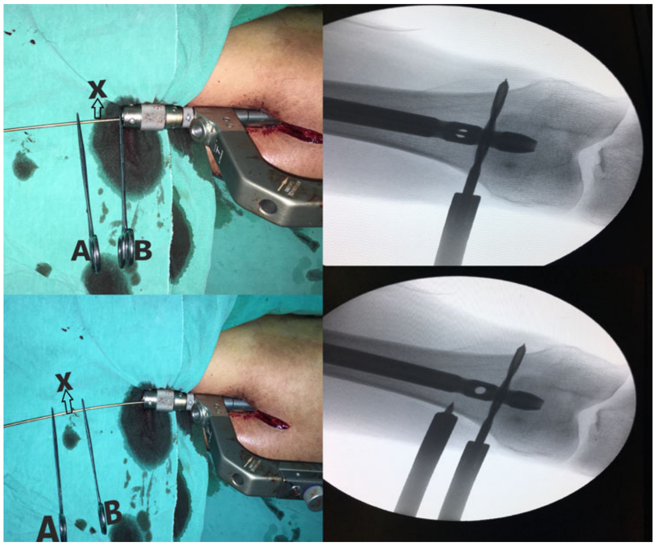

Figure 3. Insertion of the drill to distal-upper locking screw hole.

Figure 4. x and y distances formed after both distal locking holes were insterted with drills.

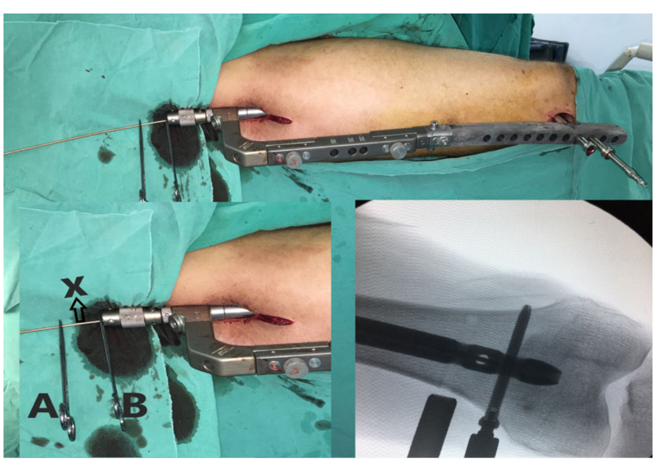

Figure 5. Distance y disappeared and distance x persisted on guidewire after distal-lower locking screw placement demonstrating confirmed distal-lower locking.

was formed again between the B clamp and the entry hole of the nail cannula, it is considered as succesful placement of the distal upper locking screw (Fig. 6). Thus, both distal locking screws were placed succesfully. Proximal locking

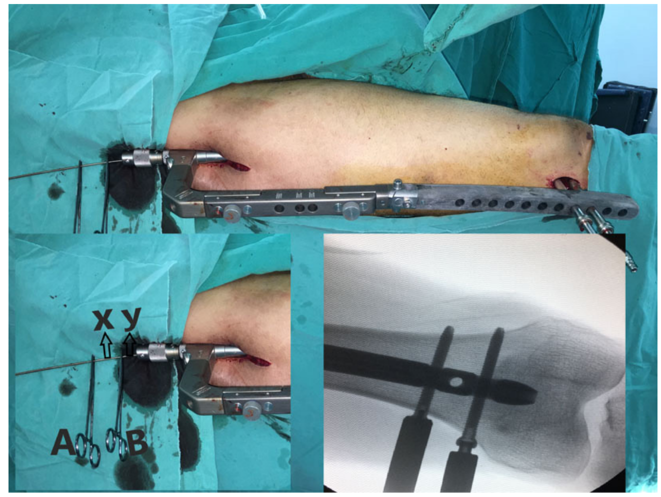

Figure 6. Distance y formed on guidewire afer placement of distal-upper locking screw demonstrating confirmed distal-upper locking.

screw through external guide holes is generally succesful because of the proximity to the extenal guide-nail attachment site. Nevertheless, same technique was used to improve the success rate of locking screw placement.

Results

This studies sample consisted of 42 patients (27 males and 15 females; mean age 44.7 years) who underwent intramedullary femoral nailing and 48 patients (22 males and 26 females; mean age 38.4 years) who underwent intramedullary tibial nailing. In femur cases, 18 cases fell into the GAL technique group and other 24 into the FHL group. In tibial nail locking, GAL technique was used in 21 cases and FHL technique was used in 27 cases. In general evaluation it was found to be a significant correlation between the operative duration and flouroscopy time ($r=0.783$; $p<0.01$). It was determined that the duration of surgery increased as the use of fluoroscope increases. Mean operative duration was 93 minutes (range:76-148) for the femur-FHL group, 75 minutes (range:48-124) for the femur-GAL group, 83 minutes (range:52-118) for the tibia-FHL group and 63,5 minutes (range:44-96) for the tibia-GAL group. Flouroscopy time and other parameters were summerized in table 1 according to the technique used for the placement of loncking screws. Data analysis has shown that GAL technique significantly reduced the operative duration and fluoroscopy time compared to the FHL technique among tibial and femoral nailing groups ($p<0.05$).

Discussion

Locked intramedullary nailing is the preferred surgical treatment of tibia and femur diaphysis fractures.[4] Nail must be locked from proximal and distal part to prevent

Table 1. The number of cases among the groups according to the nail locking technique, mean operative duration and flouroscopy time

Nail Locking Technique	Number of cases (n=90)	Operative duration (minutes)	Flouroscopy time (seconds)
GAL-F	18	75.48±37.72	9.33±22.63
GAL-T	21	63.53±28.48	11.37±17.83
FHL-F	24	93.28±43.62	42.53±24.55
FHL-T	27	82.71±34.52	38.43±14.78

possible shortening and rotation and being able to bear weight earlier.[5, 9] Especially distal locking phase is the most problematic part of the intramedullary fixation.[6] After the nail was insterted into the medullary canal, the surgeon could not see the locking hole site of the nail.[10] So the surgeon is obligated to lock the nail with indirect methods or the help of external guides. FHL is one of these methods.[11-13] In FHL technique, first of all, antero-posterior flouroscopic imaging is used to align and adapt the position of the screw to orientation of the screw hole. Then, vast number of lateral flouroscopic images are taken to see the perfect circle. Besides, repetitive flouroscopic images are needed to locate the incision, to drill and confirm that the screw is placed accurately.[4] It is reported that the ionizing radiation exposure is lower in flouroscopy than other medial imaging modalities, also the amount of radiation absorbed is reduced accordingly to the distance to the source. However, the surgeon can not place his hands in a radiation safe position.[4, 14, 15] Previous studies have shown that the nail locking phase causes additional 1,1 to 6,9 minutes of flouroscopy time and 12 mrem radiation exposure to surgeons hand.[16] The surgeon is exposed to cumulative ionizing radiation lifelong due to lacking of radiation protective equipment for hands.[4, 14, 15] Repetitive repositioning of the C-arm is reported to pose a risk of contaminating the surgical area besides of exposure to radiation. Previous studies have shown that the coverage of C-arm was easily contaminated during repositioning. Especially during lateral imaging, image intensifier of the c-arm is closely positioned to the surgical area. Additional sterile drape is used to prevent contamination causing increased operative duration and cost.[4, 17] Some authors have advocated that to use dual c-arm which makes it possible to get ap and lateral flouroscopic images without repositioning instead of single c-arm thus decreasing the complications due to increased duration of operation and anesthesia. But this method not only will cause increased flouroscopy costs, but also there will not be a significant decrease in ionizing radiation exposure.[12] Some nail locking techniques alternative to FHL technique were developed to overcome the complications related with overuse of the c-arm. Electromagnetic Targeting Device(ETD) assisted nail locking method is one of these techniques which is frequently used nowadays. Nail locking phase of 47 patients with long bone fractures who underwent intramedullary nailing was evaluated in a study investigating the ETD assisted nail locking method. In this study, it is reported that the mean time required to prepare the device was 5,1 minutes and to place the single locking screw was 5,8 minutes. It is demostrated that ETD technique reduces radiation exposure and operative duration compared to general literature.[6] A study comparing ETD and FHL technique demonstrated shorter operative duration (52 vs 70 min.), mean distal locking time (5 vs 16 min.) and less radiation exposure (8 vs 40 sec.) in ETD group. ETD method is reported to be as succesful as FHL method in terms of accuracy.[18] In another study investigating tibial fractures, ETD locking technique was used in half of the patients and FHL technique was used in the other half of total of 50 patients. It is demonstrated that the ETD technique was significantly reduced the mean distal locking time (10 vs 21 min.) and medan radiation exposure time (4,6 vs 19,4 sec.) compared to FHL technique.[19] In a study investigating both techniques on femur fracture surgery, ETD and FHL technique was utilized in 29 and 26 patients, respectively. As demonstrated in previously referenced studies, ETD group was found to be associated with less distal locking time (6,1 vs 19,5 min.) and radiation exposure time (2,2 vs 26,8 sec.).[2] In contrast with previously mentioned studies, another study has advocated that the ETD method was effective in reducing radiation exposure but not in the operative duration. Preparation and setup of the system was reported to be time wasting.[20] In general, the surgeon is reccommended to master the FHL technique due to locking the nail with the ETD system could fail despite its superiorities.[6] In addition, other metals in the operating room might reduce the accuracy of the system by creating an electromagnetic field.[6, 21]

In locking phase of intramedullary nails for surgical treatment of long bone diaphyseal fractures, simple and low-cost nail locking techniques which provides succesful nail locking by guidewire assistance and single plane imaging are also in use instead of device-dependent techniques. Finelli et al. have demonstrated mean operative duration of 55,6 minutes for tibia fractures and 78 minutes for femur fractures by means of guidewire assisted "dip-stick" technique in their study which included a vast number of femur and tibia fractur cases. For each of distal locking screws, it is reported that mean screw placement time was 3,8 minutes and radiation exposure was 7,65 seconds. They indicated that the "dip-stick" technique elicited significantly lower mean operative duration and radiation exposure compared to the literature.[4] In our study, GAL technique was used which resembles "dip-stick" technique. When the results were compared with the FHL technique, it was determined that GAL technique significantly reduces operative duration and flouroscopy time in both tibia and femur fracture surgery. Despite the fact that GAL technique resembles "dip-stick" technique in general terms, it has a few adcantages. Additional antero-posterior imaging is not required for localization, drilling and placing screw in our study but an external guide was used instead. Alignment between drill-bone-target can not be accurately achieved without external guide causing wrong holes in bone and drill fractures due to bending. Also more than one anterior-posterior flouroscopic image is needed to corrtectly align the drill. In GAL technique, a limited number of anterior-posterior image was used only to measure the screw length. Another advantage of this technique is being able to confirm succesful placement of locking screws at the end of the procedure by means of previously measured x and y distances. In our study, results with GAL technique have shown parralellism with results of ETD technique in literature. It may be advantegous in terms of cost-effectivity for GAL technique compared to ETD technique that it does not require any apparatus and monitor.

Conclusion

GAL technique reduces total operative duration and flouroscopy time by facilitating locking phase of intramedullary nailing surgery used in treatment of femur and tibia diaphyseal fractures. Thus, it may be beneficial in preventing possible complications related with longer durations of operation and anesthesia for the patient and also preventing cumulative side effects of radiation for the surgical team.

Disclosures

Ethics Committee Approval: Health Sciences University Istanbul Training and Research Hospital Clinical Research Ethics Committee 14.06.2019/1861.

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Conflict of Interest: None declared.

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