Open Intramedullary Nailing for Segmental Long Bone Fractures: An Effective Alternative in a Resource-restricted Environment

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Abstract

Background: Closed, locked intramedullary nailing has been accepted as the gold standard in the care of femoral fractures, with reported union rates as high as 98–100%. Closed, locked intramedullary nailing often requires expensive equipment which is a challenge in developing countries. Segmental long bone fractures are often a result of high-energy trauma and hence often associated with a lot of injuries to the surrounding soft tissues. This consequently results in higher rates of delayed or nonunion. This study was proposed to review the outcome of management of segmental fractures with locked intramedullary nails, using an open method of reduction. **Methods:** A retrospective analysis was made of data obtained from all segmental long bone fractures treated with intramedullary nailing over a 1-year period. Records were retrieved from the folders of patients operated on from January 2011 to December 2011. Patients were followed up for a minimum of 1 year after the surgery. **Results:** We managed a total of 12 segmental long bone fractures in 11 patients. Eight of the 12 fractures were femoral fractures and 10 of the fractures were closed fractures. All but one fracture (91.7%) achieved union within 4 months with no major complications. **Conclusions:** Open method of locked intramedullary nailing achieves satisfactory results when used for the management of long bone fractures. The method can be used for segmental fractures of the humerus, femur, and tibia, with high union rates. This is particularly useful in low-income societies where the use of intraoperative imaging may be unavailable or unaffordable. It gives patients in such societies, a chance for comparable outcomes in terms of union rates as well as avoidance of major complications. Larger prospective studies will be necessary to conclusively validate the efficacy of this fixation method in this environment.

Keywords: Locked intramedullary nailing, open reduction, segmental fractures

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Introduction

Long bone fractures are often a result of high-energy trauma which may result into comminuted or segmental fractures. Fractures following high-energy trauma are often associated with extensive soft tissue injuries. The state of the surrounding soft tissues and the local blood supply to the bone are the most important factors determining the tendency of the fracture to heal.[1] This is usually compromised in segmental fractures because of injury to the surrounding soft tissues in addition to the compromised blood supply to the middle segment. This often leads to nonunion or delayed union.[2]

Epidemiological reports have shown that a large number of trauma patients, especially following road traffic crashes, are from developing countries.[3-8] In such environments, challenges of inadequate trauma care lead to higher rates of morbidity and mortality. Since the majority of trauma patients are young male adults, a good outcome will reduce the vicious cycle of poverty and disease and ultimately the burden of the disease in these countries.

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Antegrade closed, locked intramedullary nailing has been accepted as the gold standard in the care of femoral shaft fractures, with high union rates reported.[9,10] Locked intramedullary nails could be solid or hollow. Hollow nails have the advantage of permitting the use of a guide wire. This makes closed nailing easier to achieve.[11] Solid nails, on the other hand, have been shown to have a lower infection rate.[12,13] This makes them especially useful in contaminated Type I and II open fractures. Closed, locked intramedullary nailing often requires expensive equipment such as image intensifiers, in addition to appropriate surgical training. All these are challenges in developing countries. These problems have led to the development of various intramedullary nail instrument sets with external target arms to allow for distal locking of the nails without the need for an image intensifier.

Surgical Implant Generation Network (SIGN®) is a not-for-profit organization committed to equity in fracture management worldwide. SIGN® nails are solid intramedullary locked nails inserted with a rigidly attached targeting side arm which allows the placement of locking screws distally, without the need for an image intensifier. SIGN® nails are manufactured such that the same nails and instrumentation can be used for femoral, tibial, and humeral fractures. The nails are distributed free or at an affordable cost so that the average patients in these countries have an opportunity to receive modern, effective orthopedic treatment.

Fracture reduction can be achieved by open or closed methods, depending on the facilities available. SIGN® intramedullary nailing system has been shown to promote predictable healing of fractures in resource-poor environments.[14] Use of SIGN® nails for long bone fractures has also been shown to be associated with low infection rates.[15]

Various studies have documented good outcomes after the usage of locked intramedullary nailing for segmental long bone fractures following closed reduction.[9,16,17] There is some controversy in the literature about the possible side effects of open reduction compared with standard closed reduction prior to intramedullary nailing. Early reports by Rokkanen *et al*. showed slightly superior results with closed nailing compared with open nailing of femoral fractures.[18] Some studies have suggested higher infection rates and slower rate of union following open intramedullary nailing of long bone fractures.[19-22] On the other hand, open reduction has the advantages of being easily learned, producing better reduction and having shorter operation times.[23,24] Kimmatker *et al*. also showed a significantly higher rate of rotational deformity following closed reduction of femoral shaft fractures as compared with open nailing.[19] Other studies have shown no statistical differences in the infection and union rates between the two methods of reduction.[25,26]

With the higher rates of nonunion in segmental fractures generally, it is, therefore, essential to establish whether an open method of intramedullary nailing has any deleterious effect on the rate of union compared with the standard closed intramedullary nailing. This information will be particularly useful in our environment where availability of resources for closed intramedullary nailing is limited. The study objective is, therefore, to review the outcome of segmental fractures, using an open method of reduction, with SIGN®-locked intramedullary nails.

Methods

A retrospective analysis of prospectively collected data on all segmental fractures treated over a 1-year period was done from our patient records from January 2011 to December 2011. The study was carried out in a university teaching hospital which serves as the only public tertiary care center for a population of over 2 million people. Three orthopedic surgeons in the institution operated on the segmental fractures during the 1-year period of this study using SIGN® nails. SIGN®-locked intramedullary nails are second-generation solid intramedullary nails designed with two oval holes at the distal end of the nail while the proximal end has one oval and one round hole each. The oval holes allow dynamic locking while the round hole is used for static locking as desired. All patients with long bone fractures who have SIGN® intramedullary-locked nailing are routinely entered into our SIGN® database. Data retrieved include the patients' bio data, nature of the fracture, surgical access, antibiotics used, time to painless full weight-bearing, time to radiological union, and the presence of complications.

For the purpose of this study, a segmental fracture was defined as a two-level long bone fracture with at least one intermediate free segment. Segmental fractures are classified by the Orthopaedic Trauma Association System, as complex fractures Type C.[27]

Fracture union was taken as the absence of tenderness at the fracture site during weight bearing with callus bridging at least three cortices on two different views of the fracture radiologically.[28] Nonunion in the femur and tibia was defined as a fracture that has failed to unite within 9 months and that has no radiographic sign of healing for 3 consecutive months.[29] In the humerus, it was taken as a fracture that fails to unite in 4 months with no radiologic evidence of additional callus formation for 2 consecutive months.

At presentation, all patients had some form of immobilization of the fractures prior to the surgery. Those with femoral fractures had skin traction applied, while those with tibial and humeral fractures were immobilized with posterior splints. Patients were then worked up for surgery and had definitive fracture fixation as soon as possible.

An antegrade approach was made for all humeral and tibial fractures and some of the femoral fractures. However, where the femoral fractures were located closer to the distal femur, a retrograde approach was used instead. Reaming was done without the use of a guide wire, for the proximal and distal segments of the bone only, except in cases where there was a long and narrow middle segment. In such cases, a small bone clamp was used to stabilize one end of the middle segment while it was reamed. Reduction was achieved through 3–5 cm incisions made at the fracture sites. The nails were then digitally guided into the fracture segments without direct visualization. These were all aimed at preserving soft tissue attachment and therefore blood supply to the bone, especially to the middle segments which were most at risk. All nails were locked proximally and distally with one or two screws at each end of the nail to achieve dynamic compression.

Patients without other confounding comorbidities were commenced on the range of motion exercises by the 1st postoperative day and nonweight-bearing ambulation by the 3rd postoperative day under the supervision of physiotherapists. Nonweight-bearing or toe-touch ambulation was maintained for the first 6 weeks because of the unstable nature of segmental fractures. Partial weight bearing was commenced 6 weeks after the surgery, provided some callus formation was present on the follow-up X-rays. Patients were graduated to full weight-bearing ambulation following the union of their fractures. For the humeral fracture, range of motion exercises were commenced on the 2nd postoperative day, and progressive muscle strengthening exercises were carried out until fracture union. All patients were followed up in the outpatient clinic for at least 1 year (range 12–18 months). Follow-up X-rays were done at 6 and 12 weeks postoperatively. Monthly X-rays were then done until the fractures had united satisfactorily.

Results

We managed a total of 12 segmental fractures in 11 patients. They constituted 15% of all the various types of fractures (80). We managed using SIGN® nails during the period under review. The age range was from 20 to 59 years with an average age of 35 years. Seven of the patients were male and four were female. Eight (75%) of the fractures were femoral, three were tibial, and one was a humeral fracture. Ten cases were closed fractures (83%), with one Type 1 open fracture each occurring in the humerus and tibia. Seven patients (64%) were multiply injured with other injuries ranging from multiple limb fractures (five patients) to head injuries (two patients) and incomplete spinal cord injury (one patient).

The mean duration between injury and surgery was 8.5 days with a median of 7 days (range 3–22 days). Antegrade and retrograde approaches were done equally (4 each) for the femoral fractures whereas the humeral fracture was fixed using the antegrade approach. Nine millimeter nails were used for the femoral fractures and 8 mm nails for the tibial and humeral fractures. All but one had rigid fixation with 3–4 locking screws, with the exception having only one locking screw fixed proximally and one locking screw distally due to a missed distal locking. We neither had the records of surgery time nor the blood loss during the surgery. None of the patients had any additional external immobilization of the limb after the surgery.

Most patients were on admission for longer than 4 weeks mainly due to delayed mobilization as a result of associated injuries as shown in Table 1. However, by 4 months postinjury, all except one had achieved union with painless full weight-bearing ambulation (91.7%). The remaining patients eventually had a nonunion of a closed tibial fracture, for which he had exchange nailing and bone grafting which thereafter united. There were two cases of superficial wound infection and a case of prominent locking screw which was removed. The wound infections occurred in one closed femoral fracture and one Type 1 open tibial fracture. The wound infections were managed with wound dressing and antibiotics and they resolved within a few days. There were no observed pulmonary problems associated with the management of the patients. All patients had preoperative pharmacological prophylaxis against deep vein thrombosis. Two patients had subcutaneous enoxaparin continued postoperatively. One had an associated incomplete spinal cord injury, while the other had multiple lower limb fractures which prolonged his period of immobilization. Other patients had postoperative mechanical prophylaxis in the form of compressive stockings and early physiotherapy as appropriate. None of the patients had any further complications at the end of the follow-up period.

Table 1: Relationship between associated injuries and duration of hospital stay

Additional injuries	Number of patients	Average number of days before surgery	Average number of postoperative days on admission	Average total days of admission
None	3	5.7	21.3	27
Head injury	2	8.5	26.5	35
Other long bone fractures	5	9.6	35.8	45.4
Spinal cord injury	1	13	52	65

Discussion

It is well established that injury is a major burden worldwide.[3-8] Road traffic crashes account for 25% of all injuries.[5-7] It is estimated that for every road traffic injuries (RTIs)-related death, there are up to 50 times more survivors with some type of disability.[30-33] Majority of these injuries occur in low- and medium-income countries.[34-36]

Segmental fractures are often a result of high-energy trauma. The incidence of segmental fractures varies from one long bone to the other. The average on the SIGN® online database is 7% with the highest incidence in the tibia.[37] A multicenter study on the outcome of segmental humeral fractures in the UK gave an incidence of 8.1%.[38] However, Burgess reported an incidence of 30% in tibial fractures following pedestrian accidents.[39] This is not too far away from our incidence of 15%.

Male patients in the first four decades of life have often been shown to be largely affected by trauma worldwide. A previous study on trauma in our center also revealed a preponderance of male patients in the first four decades of life.[40] This trend has not changed.

Segmental fractures have always been associated with high-energy trauma. It is, therefore, not surprising that most studies have documented other associated injuries.[16,38,39] The UK study on recorded injury severity scores as high as 23 with 45% of the patients having associated injuries ranging from head, chest, pelvic, and other long bone fractures.[38] The study by Burgess shows multisystem injury of 33% and significant pelvic and head injuries in 43% of the patients.[39] Seven (64%) of our patients had associated injuries ranging from other long bone fractures to head injuries. This accounted for the prolonged hospital stay, since there are no support facilities for proper hospice care outside the hospital. Other studies on segmental fractures also report prolonged hospital stay due to the associated injuries.[16]

Various methods of management of segmental long bone fractures have been documented. These range from conservative or nonoperative management to locked intramedullary nailing, locked plating, dynamic compression plates, rush nail, ender nails, and external fixation.[38] Nonoperative management has been found to be associated with nonunion rates as high as 27.2%.[38] Even when union does occur, it is often delayed and malunited with a significant loss of muscle bulk and consequent difficulty in rehabilitating the patient. A multicenter study in the UK compared the outcome of segmental fractures managed with compression plating, intramedullary nails, and external fixators. The study showed that the use of intramedullary nailing had the best outcome. Intramedullary nailing has the benefit of soft tissue protection, load-sharing capacity of the implant, closed method of application, and preservation of extramedullary blood supply.[10,41,42] We have no records of management outcomes using other methods of fixation of segmental fractures in our center.

Though antegrade nailing is usually favored for femoral fractures, we were guided by the standard indication for the retrograde approach, which in our study were mainly fractures located close to the distal femoral condyles.

Separate studies by Utva *et al*. and Reichert *et al*. studied the controversy on reaming in segmental fractures using animal models. It was observed that there is no difference in healing rates as well as blood supply to the middle segment, as the reduced endosteal blood supply led to an increased periosteal blood flow from the muscles.[43,44] It was also observed that the use of either rigid or loose fitting nails did not significantly affect the blood flow later.[45] Their study, however, considered closed reaming and nailing of the fractures. It is, therefore, important in open nailing to ensure that soft tissue exposure and dissection are minimal to ensure the preservation of periosteal blood flow to the middle segment which we tried to achieve in this study.

Closed nailing ensures that the original fracture hematoma is preserved at the fracture site, thereby promoting union. Closed reaming of the intramedullary canal also deposits useful graft material around the fracture site.[22,46] On the other hand, open nailing technique often results in extensive soft tissue damage and increased blood loss, raising concerns about nonunion and infection. Nonetheless, because it requires no special equipment and achieves quick stabilization, some authors advocate open nailing for polytrauma patients.[20,23,24] The technique is also particularly useful in resource-poor environments because it requires less training and minimally expensive equipment. Liao *et al*. described a mini-open method of reduction and nailing for femoral fractures,[47] a variation of which was used in our study, where a small incision was made at the fracture site and reduction was achieved using one or two fingers passed through the incision. Their study demonstrated a comparable union rate (97.3%) to that of closed nailing. However, their study was performed on simple or minimally comminuted fractures. All our segmental fractures were done using open method of reduction. The proximal and distal segments were reamed leaving the middle segment except when there was a long middle segment. This helped us to avoid devitalizing the blood supply to the middle segment while attempting to stabilize it for reaming.

A major advantage of locked intramedullary nailing is the prevention of shortening and maintenance of rotational alignment. To achieve these, all except one of our fractures were statically locked using 3 or 4 interlocking screws.

Despite the open method of reduction, our overall union rate of 91.7% at 4 months is comparable to other reports of closed nailing of simple, as well as segmental fractures,[9,16,38] although our sample size is smaller.

Delayed union and nonunion are the known complications of segmental fractures.[4] Among the patients studied, there was only one case of nonunion which involved the fracture between the middle and proximal segments of one of the tibial fractures. The middle and distal segments had united within 4 months. Exchange nailing with cancellous bone grafting was done at the site of nonunion. This was later followed with dynamization, and union was eventually achieved. However, various studies have reported inconsistent results with dynamization, preferring only bone grafting for delayed union.[17,48]

The other complications recorded were two superficial wound infections which were managed with antibiotics and wound dressings, and they resolved in a few days.

The prolonged hospital stay was mainly due to delayed mobilization as a result of the multiple injuries sustained by the patients. Table 1 shows the associated injuries that the patients had with the duration of stay. It shows that the patients with more severe additional injuries had longer periods of admission compared with those with the segmental fractures alone.

These made mobilization difficult and sometimes necessitated procurement of wheelchairs before discharge to home. Some others had multiple surgeries for the various injuries sustained.

Conclusion

The incidence of segmental long bone fracture is increasing as a result of increasing high-energy trauma, especially in low- and medium-income countries. The consequent disability from nonunion can be reduced by the open method of intramedullary nailing using SIGN® nails. This is especially beneficial in the developing countries with inadequate or inaccessible infrastructure for closed intramedullary nailing. Patients in such low-income societies have a chance of good outcomes in terms of rates of union as well as avoidance of major complications.

The limitation to this study is the small patient load and the retrospective analysis. A multicenter prospective study is proposed to look at a larger volume of patients to validate the findings.

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Conflicts of interest

There are no conflicts of interest.

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