Exchange nailing and percutaneous bone grafting for management of aseptic non-union of the femur

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Abstract

Introduction
Non-union of femur fracture is a known complication, managed by various methods, including exchange nailing. Additional bone grafting is known to enhance fracture healing. Percutaneous bone grafting has been reported for tibia and humerus in the literature. The authors report a series of aseptic non-union of the femoral shaft managed by exchange nailing, supplemented with percutaneous reamer debris grafting.

Materials and methods
Our purpose was to deliver more vital osteoblasts to the fracture gap through a percutaneous route. The reamer debris, which accumulated at the proximal entry point and collected from the reamer flutes, was percutaneously delivered into the non-union site, after disturbing the fibrous tissue around the fracture. This study analysed the management of aseptic non-union of five cases of aseptic non-union of the femur in adults.

Results
The fracture was found healed when there was bony continuity in at least three cortices and the patient was able to bear weight without pain.

Conclusion
We achieved sound union in all five cases of aseptic non-union of the femur with our technique of exchange nailing with percutaneous bone grafting.

Introduction
Intra-medullary nailing of the femur diaphyseal fracture has become the gold standard, and extending the indications to the metaphyseal region has resulted in complications as per various reports1. Closed intramedullary nailing has the advantage of small surgical incision and stable reduction without breach of soft tissue envelope around the fracture. Moreover, the load is carried physiologically down the mechanical axis of the bone1. Incidence of nail failure is between 1.7% and 5.6%2. In severe comminuted fractures, there is a 10% non-union rate after closed reamed femoral nailing. Intra-medullary nails fail by fatigue fracture secondary to cyclical loading, leading to cracking which propagates to nail breakage. This happens due to non-union of the fracture, implant quality or improper surgical techniques1.

Non-union occurs due to insufficient mechanical stabilisation or due to failure of biological processes of fracture healing. If the fixation is mechanically stable, addition of vital osteogenic cells, such as bone graft, is all that is required3. Exchange with a nail that is 2–4 mm larger in diameter increases the strength of the construct4. The aim is to report exchange nailing and percutaneous bone grafting for management of aseptic non-union of the femur.

Materials and methods
This work conforms to the values laid down in the Declaration of Helsinki (1964). The protocol of this study has been approved by the relevant ethical committee related to our institution in which it was performed. All subjects gave full informed consent to participate in this study.

A total of five cases of aseptic non-union of the femur were managed in this secondary-care trauma centre from 2007 till 2010. The femoral fractures are managed in this centre with closed intra-medullary nailing with Arbeitsgemeinschaft für Osteosynthesefragen (AO) universal femoral nail, and locked proximally and distally. Union of the fracture was confirmed when the patient was able to bear weight on the extremity without pain and there is union in three cortices when plain films are done in two planes. We had five non-unions during this study period.

Age of patients ranged from 28 to 33 years. Out of the five cases, four non-unions were in male patients. One patient, in addition to the fracture distal shaft femur, also had fracture of the inferior pole of patella, which was repaired with transosseous suture of the patellar tendon reinforced with stainless steel wire augmentation (Table 1).

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Table 1. Patient demographics.

<table>
<thead>
<tr>
<th>No</th>
<th>Age</th>
<th>Sex</th>
<th>Side</th>
<th>Location of fracture</th>
<th>Size of initial nail</th>
<th>Size of final nail</th>
<th>Time to union (weeks)</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>33</td>
<td>Female</td>
<td>Right</td>
<td>Distal shaft</td>
<td>10 × 360</td>
<td>13 × 360</td>
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<td>Right</td>
<td>Mid-shaft</td>
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<td>13 × 380</td>
<td>15</td>
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<td>3</td>
<td>28</td>
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<td>Right</td>
<td>Proximal shaft</td>
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<td>21</td>
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<tr>
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<td>Distal shaft</td>
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<td>36</td>
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<tr>
<td>5</td>
<td>29</td>
<td>Male</td>
<td>Right</td>
<td>Proximal shaft</td>
<td>11 × 360</td>
<td>13 × 360</td>
<td>24</td>
</tr>
</tbody>
</table>

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Technique
The original nail was removed after passing a guide wire. Using the image intensifier, the fracture site was localised. Through a stab incision, the drill sleeve of the proximal locking set was passed into the fracture site, and the fibrous tissue was drilled all around the non-union. A fine curette was then used to freshen the non-union site. The drill sleeve was removed and reaming was done, over reaming the canal at least 3 mm more than the previous surgery. The reamer debris was collected from the reamer flutes and the proximal incision into a bowl. The fracture was then nailed with a nail of diameter 2 mm more than what was used for the primary surgery. After nailing, the sleeve was reintroduced into the non-union site. Grafts were then placed into the sleeve and implanted into the non-union site with help of the trocar. Placement of the grafts was then confirmed with an image intensifier. If possible, the fracture was retro-impacted after locking distally. If retro-impaction was possible, the nail was locked statically and dynamically. Otherwise, only dynamic locking was done for impaction of the fracture with weight bearing. All patients were advised weight bearing as per their pain tolerance (Figures 1 and 2).

Results
Three out of the five cases had implant failure. In one patient the implant broke at the level of the distal locking screw, when the patient was doing quadriceps exercise in a static cycle. In this case, the broken distal part of the nail was removed by the technique reported by Kerdalani. The proximal part of the nail was removed from the piriformis fossa. A plastic exchange tube was passed into the medullary canal, and the ball of the ball tip guide wire was negotiated into the distal nail, and the ball was passed beyond the nail tip. A 12-mm 3.5 cortical screw...
was passed into the distal hole, and tightened till it got jammed with the guide wire. The distal nail was then removed. The canal was then over reamed and nailed with static and dynamic locking (Figures 3–5).

The distal locking screws were broken in a case where the patient was weight bearing with a non-healed fracture. He had bilateral femur fracture, with the right femur going for aseptic non-union (Figures 6 and 7).

In one case, the nail was broken at the level of the proximal static locking screw and was detected only after extraction of the full nail.

Radiographs were done at 3-week intervals, and assessed for healing. Mean time of healing was 21.6 weeks. In all cases, solid union was seen and the patient was able to bear weight without pain.

Discussion

Expanding the indications of intramedullary nailing has resulted in more complications, one of which is aseptic non-union with implant failure. Although considering the gold standard for management of femoral fractures, intra-medullary nailing of femoral fractures is known to result in non-unions and implant failure. If there are no convincing signs of healing, reoperation should be performed within 6 months to prevent nail breakage. Non-union rate has been reported to be from 1% to 10%. There are many options available for the management of femoral shaft non-union after interlocking nailing. These include exchange nailing, dynamisation, bone grafting and plate augmentation. Augmentation plating with open grafting has also been advocated by many authors. In distal third fractures, exchange nailing may not be able to resist rotational movement, and hence many authors tried to improve the rotational stability by supplementary fixation with a six-or eight-holed plate and open bone grafting.

Plate augmentation retaining the original nail provides stability at the fracture site and prevents excessive motion that leads to hypertrophic non-union. Augmentation plating, however, is more invasive than exchange nailing, and bicortical screw purchase may always be a problem due to the intramedullary nail.

Fractures are known to heal faster with a reamed nail. Exchange nailing has been reported as the preferred method of treatment of non-union after femoral nailing with success rate varying from 100%, 78.3%, to 53%. Exchange nailing has a lower complication rate and most of the time obviates the need for supplementary bone grafting. Though exchange nailing has been found successful in both atrophic and hypertrophic non-unions, a failure rate of 47% was observed by Weresch et al. requiring additional procedures for healing.

Recently, Kim et al. classified non-unions into type I (presence of bone defect of less than 5 mm or callus formation) and type II (presence of bone defect of over 5 mm or no callus formation). They were further subclassified into A and B based on presence or absence of implant stability. Authors recommend exchange nailing in type I B non-unions and exchange nailing with bone grafting in type IIB. Wu recommended invasive bone grafting if there is a bone defect or if bone formation ability is required.

Furlong et al. reported that union was earlier when additional bone grafts were used along with bone grafting with non-grafted cases healing in 36.2 weeks and grafted cases healing in 24 weeks and 6 days. It has been proved that intramedullary reaming significantly improves the healing of aseptic non-union. The larger diameter nail due to the biological effects of reaming and mechanical stability, ensures healing of the fracture. The increased healing potential is due to increase periosteal blood supply, which occurs with reaming. Studies have proved that there is six-fold increase in periosteal blood flow after reaming. In the series by Court-Brown et al. (33 aseptic non-unions, four of which required bone grafting after second exchange nailing) and Templeman et al. (27 tibial non-unions, two required bone grafting after exchange nailing), bone grafting was used after the non-unions failed to heal after repeated exchange nailing.

In the series by Furlong et al., all 12 patients in whom autogenous bone grafting has been used resulted in osseous union. In the series of Pihlajamaki et al., all three patients in whom the fixation was supplemented with autogenous bone grafting resulted in healing. However, in the series by Weresch et al., healing failed to occur in three out of four patients when a combination of exchange nailing was used with bone grafting. In the series by Weresch et al., open bone grafting was used. Many techniques have been described for bone grafting along with exchange nailing. This includes open autogenous iliac crest grafting, percutaneous bone grafting, and percutaneous bone marrow implantation.

Over reaming of the canal produces between 60 and 80 ml of graft with a one-time passage of a large
diameter reamer tip, as proved with a reamer–irrigator–aspirator system. Further reaming produced more useful grafts. One concept of exchange nailing is that the reamer debris reaches the non-union site during reaming, accelerating fracture healing. The intact fibrous tissue around the non-union could prevent graft extrusion into the periosteal region. Hence, many authors resorted to open bone grafting, after disrupting the fibrous union.

Kuntscher did the first but unsuccessful attempt of closed autogenous bone grafting through a needle at the non-union site, which he called closed bone transportation. Percutaneous bone grafting was used for the first time by Ebrahim et al. in a case of fracture tibia with vascular injury. Here, the iliac crest graft was passed through a 2-cm portal through a rigid plastic tube after making it into a paste. The technique of harvesting the reamer debris from the flutes of the reamer tip and using it as an intramedullary graft has been described by Chapman as early as 1980.

In an animal study on sheep, Fronkle et al. found that 24% of the reaming debris collected at the fracture site and 76% extruded from the proximal entry point. Hoegel et al. who found 20.5% debris accumulation in A2 fractures and 21% in A3 fractures have reported this. Many authors found the reamer debris containing a rich source of growth factors such as osteoblasts, multipotent stem cells comparable to iliac crest grafts. In the study on sheep tibia, Frolke et al. proved that the reamer debris from sheep femur stimulated callus formation and they also found that the bone healing with reamer debris occurs in the early phase of healing. Compared with open techniques of grafting closed techniques resulted in earlier healing.

The reamer debris is unlikely to penetrate the fibrous tissue in the non-union site and act as periosteal bone graft. If direct surgical implantation of graft is possible, this considerably improves the volume stiffness and strength of the callus. To surgically implant the reamer debris, the fracture site has to be opened resulting in further complications. The fact that fibrous union and pseudoarthrosis can be made to ossify has been documented by Pemister, who encouraged onlay grafting without disturbing the fibrous union. But by disturbing the fibrous tissue, the reaming debris inside the canal is also expected to reach the fracture site.

Endoscopy has been used by Kim et al. to remove the fibrous tissue and sclerotic bone, with endoscopic burr and curette. Authors used cancellous graft from the iliac crest, implanted through Corb’s bone biopsy needle, and recommend rigid internal fixation before grafting. Johnson et al. managed eight cases including tubial and humeral non-unions with transcutaneous onlay grafting though an arthroscope; however, the procedure described by both Kim et al. and Johnson et al. requires the services of an experienced arthroscopic surgeon.

The technique we used was the same as Maneerjit et al.’s, using the proximal locking sleeve and the trocar. In the technique described by Maneerjit et al., the fibrous tissue was debrided at the non-union site using an 8-mm drill bit. They found shorter operating time, less blood loss, with comparable rates of union, and postoperative pain.

Three of our cases resulted in aseptic non-union with implant failure. All the implants were removed closed, and exchange nailing was done with percutaneous reamer debris grafting.

Unlocked and dynamically locked nails allow gradual compression of the fracture with weight bearing and aid in fracture healing. Acute compression of the fracture can also be attained by retro-impaction of the fracture at the time of exchange nailing. In cases where we could not achieve bony contact, only dynamic locking was used. Though reamer irrigator aspirator system is a better way to collect the reamer debris, it is not cost effective and is not available at most of the centres.

Conclusion
Authors report a series of aseptic non-unions of the femur, managed with exchange nailing and percutaneous grafting using the reamer debris. We found that the reamer debris, which goes wasted during exchange nailing, contains many osteoinductive cells that are not wasted, resulting in early and guaranteed healing. However, whether the healing is due to the effects of reaming and stabilisation with bigger diameter nail or from the graft implanted is beyond the scope of this article.

References

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