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Exchange nailing with open bone grafting for aseptic femoral diaphyseal nonunion with implant failure: A study of 13 cases

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Abstract
Introduction: In spite of vast advances in implants and operative techniques in the management of femoral diaphyseal fracture, treating a case of aseptic nonunion still poses a great challenge to treating surgeon. In India, the illiteracy of the patient and the false security of stable fixation with intramedullary rods often leads to premature weight bearing causing implant failure and nonunion.
Material and methods: 13 patients aged 19 yrs - 52 yrs with aseptic femoral diaphyseal nonunion with implant failure were treated during Sept 2015 -Dec 2017. Twelve of them required opening nonunion site for implant removal, hence were treated by exchange nailing and auto genous bone grafts. One case treated by closed exchange nailing only.
Results: 11 cases achieved solid osseous union with single procedure in an average of 5.3 months. One patient required dynamization in 4th post-operative month. A case of closed exchange nailing without bone grafting healed in 6 months.
Conclusion: Exchange nailing with bone grafting is an excellent method for treating aseptic femoral diaphyseal nonunion with implant failure.

Keywords: Aseptic femoral diaphyseal nonunion, implant failure, exchange nailing, open bone grafting

Introduction
Fractures of pelvis and femur are increasingly seen with high velocity trauma. The management of fracture shaft femur has evolved from days of balanced skin traction to days of K nailing to present day of interlocking intramedullary nailing. Though the implants, operating facilities and techniques have advanced to a great extent still the treatment of aseptic nonunion remains a great challenge for the surgeon. Particularly in Indian scenario, illiteracy of the patient and the false security of stable fixation with intramedullary rods leading to premature weight bearing on fractured limb often results into implant failure and nonunion.
Nonunion could be due to biological failure or a mechanical failure. However, nonunion always leads to increased morbidity amongst the patients and ultimately increased cost of the treatment. The treatment of aseptic femoral nonunion without significant bone loss always remained a problem till the advent of interlocking nailing technique.
Now the exchange nailing with or without bone grafting is becoming a gold standard for treating aseptic nonunion of long bone fractures.
In our present series of thirteen patients almost in 12 patients aseptic femoral diaphyseal nonunion had resulted into implant failure. Our aim was to establish the utility of exchange nailing with or without the bone graft in the treatment of aseptic nonunion of femoral diaphyseal fractures.

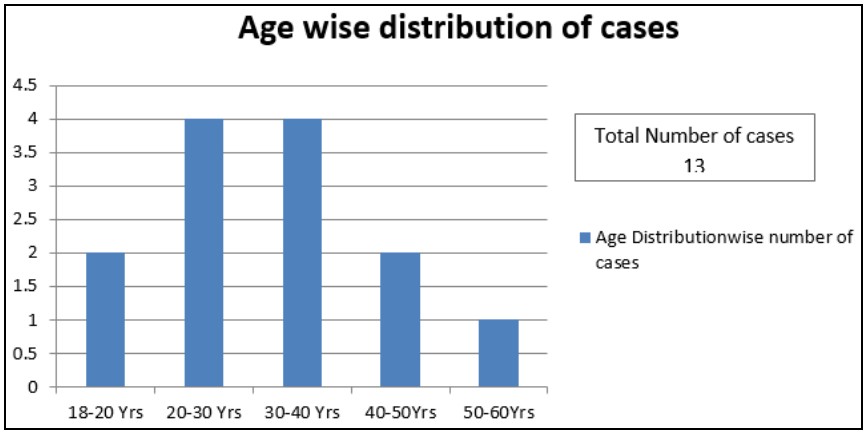
Material and methods
Total of 13 patients aged between 19 yrs to 52 yrs with aseptic femoral diaphyseal nonunion were included in the present study done at our Medical College at Andhra Pradesh during Sept 2015 till Dec 2017. All of them were primarily managed for their initial accidental trauma at other places with intramedullary rods using either Kuntscher K nail or interlocking femoral nails.

Inclusion Criteria
1. Aseptic nonunion
2. Less than 1 cm of shortening
3. No rotational or angular misalignment
4. No large bony defect
5. Presence of Mechanical instability (rotational instability with K nails)
6. Bent/ broken nails, screws (fatigue failure)

Exclusion criteria
1. Infected nonunion
2. Nonunion due to pathological fractures were excluded.
3. Gross soft tissue damage

Previous Treatment Received
1. Eight patients were treated outside by conventional Kuntscher nail.
2. Three were treated with interlocking nails.
3. One patient Cerclage wire was used in addition to K nail for fixing butterfly fragment.
4. In another patient Cerclage wire was used along with interlocking nail to fix the butterfly fragment.

Age distribution



Side involved: Right: Left = 8:5.
Sex Distribution: M: F ratio= 10:3.

Types of nonunion

Type of Nonunion	Number of patients
Oligotrophic	7
Hypertrophic	4
Mixed type	2
Total	13

Bone grafting
Out of thirteen cases, in 12 cases of implant failure due to nonunion, the nonunion site was opened for implant removal, after which open bone grafting was done. In one case bent K nail was successfully removed by closed technique, hence exchange nailing without bone grafting was done.

Observations and results
Cases were followed up postoperatively for average period of 12 months (ranging from 6 months to 24 months). The time interval between the first and second procedure varied considerably as shown in following table:

Time interval between first and second surgery	Number of cases done
4-12 months	8
1-2 years	4
More than 2 years	1

All cases the nonunion was fixed using exchange nailing technique after reaming 1-3mm more than the removed nail diameter with static interlocking.
In eleven fractures, single exchange nailing with bone grafting was sufficient to achieve osseous union. The fracture treated with only exchange nailing without bone grafting healed within 6 months postoperatively.
One patient required second procedure for dynamization in 4th post-operative month as the fracture line was clearly visible even then.
None of the patient suffered with any post-operative infections.
Average time taken for achieving solid osseous fusion was 5.3 months post operatively after the exchange nailing was done. Following table shows the time taken for the osseous union in various cases:

Solid Osseous union seen at	Number of cases
4 months	2
5 months	6
6 months	4
7 months	1

Only in two cases which came late and had knee stiffness preoperatively, in all remaining eleven cases the final functional recovery was good with minimal knee stiffness.

Discussion
Nonunion in the femoral diaphyseal fractures treated with intramedullary nailing is a major problem. The concept of use of exchange nailing for treating Aseptic femoral nonunion due to fracture being primarily treated inadequately by intramedullary nailing (IM Nailing) has following considerations
1. The cause of nonunion may be mechanical failure due to inadequate fixation using small diameter nails, inadequate interlocking and premature weight bearing due to false sense of security.
2. It could also be due to biological failure due to inability to achieve 100% reduction of large butterfly fragments using closed interlocking IM Nailing.

Hence, in the procedure of 'closed exchange nailing' following facts/points have to be considered.
1. Extra reaming of medullary canal to widen and ultimately lengthen isthmus and to facilitate use of bigger diameter

nail to provide better three-point fixation and mechanical stability.
2. The intramedullary reaming first removes the fibrous layer over endosteum and further reaming causes accumulation of bony powder at the site of nonunion which acts as the bone graft.
3. However, when in presence of larger butterfly fragments, for implant failures, one needs to open the fracture site to remove the broken implants, then adding extra bone grafts may be considered.

If the procedure of Exchange nailing is done properly following above mentioned principles then usually one procedure suffices for achieving osseous union.
In August 2007 [4], Mark R. Brinker and Daniel P, O'Connor *et al* concluded in their study that exchange nailing is an excellent treatment choice for aseptic, non-comminuted femoral diaphyseal fractures.
In 2010 [1], A. Mofidi, S. Bajada *et al*. during their systematic review of literature on the treatment of femoral nonunion compared the exchange nailing to other described techniques. They found that the average union rate was 89% for exchange nailing, 93% for plating and external fixation and 62% for bone grafting.
In our series we had seven comminuted and six Simple femoral diaphyseal fractures and all of them united well within 5-7 months post operatively after first exchange nailing with bone grafting. A large butterfly fragment was present in most of the nonunion. This seems to indicate a significant role of a large butterfly fragment with possible concomitant muscle interposition in development of failed union.
Various technical aspects of the Exchange Nailing procedure in present study like (1) Reaming (2) Nail diameter (3) Bone grafting etc. were based on the various published studies as follows:

Reaming: Court-Brown CM *et al* (1990) [2], stated;" Successively larger bits, by 0.5 mm each time, are used to remove endosteal fibrous tissue until bone is seen on the end of the reamer bit, usually at about a diameter of 1mm above the original reaming. More reaming is required if the original nail had been of inappropriately small diameter."
In 2000, Smith RM *et al* [8]. have studied that interleukin -10 is released and monocyte human leukocyte antigen-DR expression occurs during femoral nailing which stimulates healing.
It is recommended by [4] Mark O Brinker and P O'Connor that over reaming by an amount of 1-2 mm greater than the diameter of the new nail being inserted should be done and further recommended the use of sharp reamers with slow and gradual reaming. We also appreciated the advantages of observing those suggestions intra operatively in our present series.

Nail diameter: In 1991, Russell TA *et al*. [6], in 1995 Eveleigh RJ *et al*. [3], and in 1996 Schandelmaier P *et al*. [7] stated that the torsional rigidity of a closed section nail is many times higher than that of a slotted nail. The torsional rigidity of the closed section nail increases proportionately with the 4th power of the inner and outer radii of the nail. Thus, a larger diameter closed section nail has higher torsional rigidity.
Schandelmaier P *et al*. (1996) [7], Eveleigh RJ *et al* (1995) [3], and Wilkey KD *et al*. (1998) [10] through their studies confirmed that a larger diameter nail provides higher bending rigidity and strength.
It is recommended that the exchanged nail should be at least 1 mm larger in diameter than the nail being removed and it has been recommended that it be up to 4 mm larger when the nail being removed was greatly undersized. In our series we had most 1 mm to 3mm larger nails but not 4 mm; may be because of smaller diameter of medullary canal in our patients as compared with the western patients.

Bone grafting or no bone grafting
In 2000, Weresh *et al*. [9] reported that four out of nineteen patients underwent bone-grafting at the time of exchange nailing of the femur. In 2002, Pihlajamaki *et al* [5] in series of 11 patients used open autogenous iliac crest bone grafting in three during exchange nailing for femoral nonunion. They reported that all the three patients in who autogenous bone graft had been placed had osseous union after a single procedure.
Wu CC and Lee (2004) [11] reported that exchange nailing with an open bone-grafting achieved osseous union with restoration of femoral length in ten out of eleven patients who had a femoral nonunion with 1.5 to 3.5 cm of shortening. Many of the series of papers showed that those which have gone for nonunion even after exchange nailing, healed well after autogenous open bone grafting.

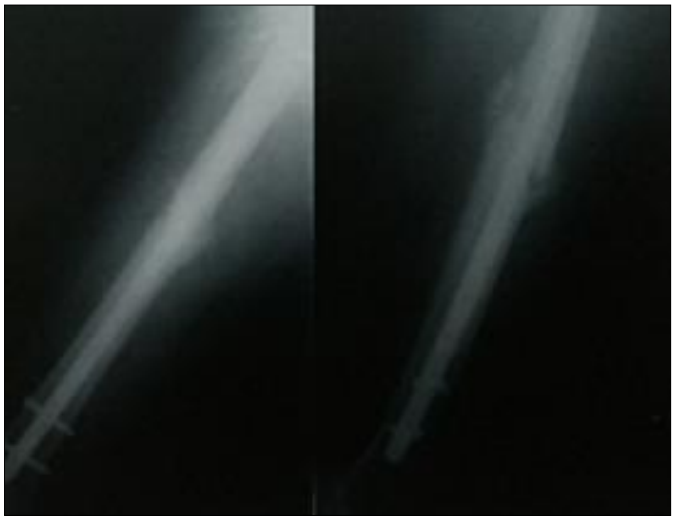
Conclusion
Exchange nailing with bone grafting is an excellent method for treating aseptic femoral diaphyseal nonunion. If even after six months postoperatively there is no convincing signs of consolidation in progress, the patient and his relatives must be counselled carefully for need of Exchange Nailing with Bone Grafting and operation should be performed at earliest lest implant failure may occur.
Exchange nailing with bone grafting should be done in cases with
1. Comminuted fracture nonunion with presence of large butterfly fragment
2. Oligotrophic nonunion
3. Whenever the fracture site is opened due to broken / bent nails as in all but one case in our present study.

In our series all thirteen patients with aseptic nonunion of femoral diaphysis were treated with exchange nailing and bone grafting except in one. All the cases achieved solid bony union. Hence, we conclude that exchange nailing with bone grafting can be the treatment of choice for the aseptic femoral diaphyseal nonunion.

Example cases

Patient - K. Sivakumar 32 Yrs/M Right knee flexion.

Pre-op x-ray right femur functional results clinical photo



Case 2: Final consolidation

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