Section A-Research paper

ISSN 2063-5346

Antibiotic cement impregnated intramedullary nail for treatment of infected nonunion of long bones

[1]Dr. Harish Murthy, [2]Dr. Vinod Kumar Sajjan, [3]Dr. Mahalingam, [4]Dr. Kartik Sharma

[1]Associate Professor and HOD, Department of Orthopedics, Raichur Institute of Medical Sciences, Raichur, Karnataka, India
[2]Senior Resident, Department of Orthopedics, Raichur Institute of Medical Sciences, Raichur, Karnataka, India
[3]Junior Resident, Department of Orthopedics, Raichur Institute of Medical Sciences, Raichur, Karnataka, India
[4]Junior Resident, Department of Orthopedics, Raichur Institute of Medical Sciences, Raichur, Karnataka, India

Corresponding Author: Dr. Harish Murthy
Email: harikalp@gmail.com

Abstract

Aims and objective: The aim of this study is to study the fracture union and soft tissue healing of infected nonunion of long bones using antibiotic impregnated intramedullary nails.

Methodology: This is a retrospective study of 40 patients with infected nonunion treated with antibiotic cement coated intramedullary nail at Raichur institute of medical sciences, Raichur and Suraksha Hospital, Raichur from 2014 September to 2022 September. All the patients selected for the study were examined according to protocol, clinical examination and radiological investigations were done. Antibiotic cement impregnated intramedullary Kuntscher's K nail was used for femur and bent K nail and V nail was used for tibia. The outcome of procedure evaluated with respect to infection control, bony union, limb length discrepancy.

Results: Infection control and union was achieved successfully in 36 cases (90%) out of 40. Out of these, 14 patients (35%) had union without need for exchange interlocking nailing, 22 patients (55%) underwent exchange interlocking nailing after infection control to achieve union. 4 patients (10%) did not achieve union and had persistent infection in the form of discharge with 2 among them (Tibia) insisted for below knee amputation.

Conclusion: ACIIMN is a effective way to control infection and achieve union of fracture simultaneously. This procedure has good patient compliance, safe, cost

ISSN 2063-5346

effective, and easy way without need of expert hands when compared to traditional surgeries like ilizarov's external fixators for nonunion of tibia and femur.

Keywords: Infected non-union, antibiotic cement impregnated intramedullary nail (ACIIMN), K nail, V nail

Introduction

Background

Infected nonunion of long bones is very challenging situation for any orthopedic surgeon. Infected nonunion is defined as state of failure of union for 6 to 8 months with persistent infection at the fracture site [1].

Most of the infected nonunion develop due to open fracture due to high velocity trauma with other causes being previous open reduction and internal fixation (ORIF) and also due to chronic osteomyelitis due to haematogenous route[1]. Due to avascular environment at the fracture site due to cicatrisation of the soft tissue around the fracture site and necrosis of the bone near the nonunion site, the intravenous antibiotics do not reach the fracture site to eradicate the infection, so there is need for local antibiotics to be instilled in the fracture site simultaneously keeping the fracture under relatively stable reduction[1]. There is also need for the removal of the focus of the infections like sequestrum, necrotic tissues and sinus tract before instillation of the local antibiotics. This can be done by various methods like, conventional external fixators, ilizaro's ring external fixators and antibiotic coated intramedullary nails.

The antibiotic coated intramedullary nails keep the fracture stable with early weight bearing, preventing the problems related to prolonged immobilization and also deliver the antibiotics at local site with 200 times more concentrated than intravenous route without any systemic adverse effects[3]. With bone loss more than 4 cm Ilizarov's external fixator is best choice of treatment by distraction osteogenesis and bone transport [4]. Buchholz and Engelbrecht were the first to use antibiotic impregnated cement [2]. Paley and Herzenberg JE were first to use antibiotic coated intramedullary nails for infected non-union [5]. Traditionally complex non unions were managed by Ilizarov's external fixator, but the disadvantages of ilizarov's are poor patient compliance, inconvenience of frame, pin tract infection and difficult frame construction [11].

Aims and Objective

The aim of this study is to study the fracture union and soft tissue healing of infected nonunion of long bones using antibiotic impregnated intramedullary nails.

Materials and Methods

This is a retrospective study of 40 patients with infected nonunion treated with antibiotic cement impregnated intramedullary nail (ACIIMN) at Raichur institute of medical sciences, Raichur and Suraksha Hospital, Raichur from 2014 September to 2022 September. Informed written consent was taken from all patients. Ethical committee clearance was obtained.

ISSN 2063-5346

Culture and sensitivity of the pus was done from the discharging sinus and appropriate heat stable antibiotics were used to make the ACIIMN. Vancomycin to cover gram positive organisms and tobramycin to cover gram negative organisms was used along with cement in most of the cases. Kuntscher's K nail was used for femur and bent K nail and V nail for tibia. In 3 cases commercially available spiked interlocking nails were used.

In our study age distribution ranged from 20 to 70 years with mean age being 45 years. Out of 40 infected nonunion patients, 18 (45%) patients had intramedullary nail in situ, 14 (35%) patients had external fixators, remaining 8 (20%) patients had no implants. Out of 40 cases 28 cases were infected nonunion tibia with 1 bilateral infected nonunion tibia and 11 cases were infected nonunion femur.

The time duration between initial surgery (after fracture) and antibiotic coated nailing was 5 days to 1 year with mean duration of 6 months.

Inclusion criteria

1. Patients with established infected nonunion of femur and tibia
2. Bone loss or fracture gap less than 4 cm.

Exclusion criteri

1. Bone loss or fracture gap of more than 4 cm.
2. Patients with neurological and vascular deficits.
3. Patients allergic to vancomycin and tobramycin.
4. Non-union secondary to causes other than infection.

Surgical technique: It was carried out in 2 stages.

First Stage

1. Preoperative workup

a) Physical examination of wound, scar, sinus and discharge with ROM of adjacent joints.
b) Total WBC count, Differential count, Hb level.
c) ESR, CRP.
d) Culture/Sensitivity Reports.
e) Previous investigations and radiographs.
f) Present radiograph.

2. Removal of infected Implant, Debridement of the Infected wound and fracture

18 patients had interlocking nails, 14 patients had conventional external fixators. These implants were removed. All necrotic bone, skin and soft tissue were removed till viable tissue margins obtained. Sinus tract was excised. The debrided tissue and pus collected was sent for microbiological investigations. Reaming was done with higher diameter reamer than previous nail diameter. Medullary canal is curetted using

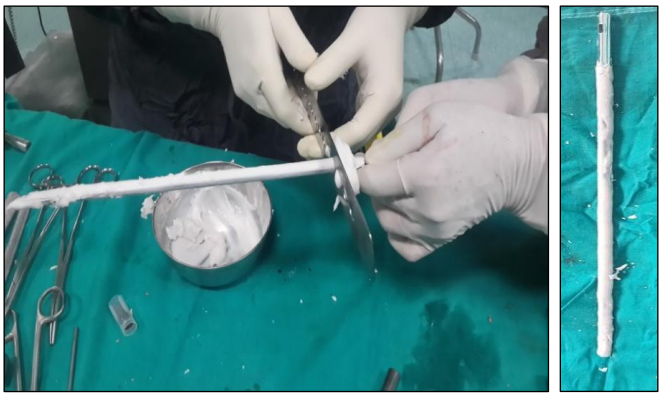
ISSN 2063-5346

long curette, followed by wound wash. 8 patients underwent primary nailing with antibiotic coated nail.

3. Preparation of antibiotic impregnated intramedullary nail and Nailing

Patient was re draped with fresh ones. Gloves changed. Another table was used for preparation of antibiotic coated nail. Nail length was measured preoperatively and confirmed under c-arm. The desired diameter was always bigger than previous nail diameter. 2-3 mm lesser diameter K nail for femur or bent K nail for tibia were chosen to be occupied by antibiotic cement coat to get the desired diameter. 40 gm of cement was mixed with 2 gm Vancomycin and 160 mg tobramycin. When this reached non-sticky stage, coating to the nail was done manually uniformly without creating any gap. Nail was passed through diameter gauge of the size 10 or 11 mm to get uniform diameter. Occasionally 12 mm nail was required for femur. Proximal eye was left uncovered with cement to allow removal of nail later. Cement is allowed to set for 15 minutes and nail inserted.

Images showing preparation of ACIIMN using K nail for Femur



4. Post-operative protocol

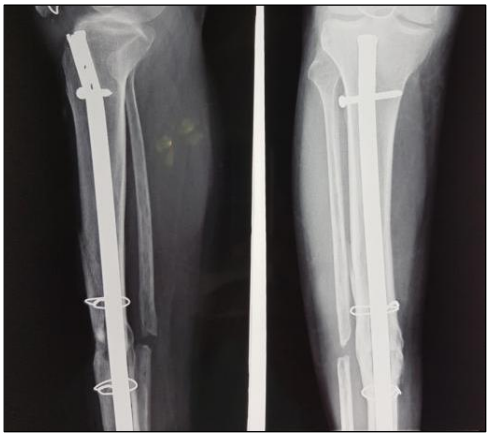
Appropriate IV antibiotics based on culture and sensitivity were given, and non-weight bearing or partial weight bearing walker assisted mobilization advised for 6 weeks. Physiotherapy for regaining adjacent joints mobility was advised, Regular examination to look for clinical improvement was done. CBC, ESR and CRP were tracked every 2 weeks to assess infection control. X-rays were obtained every 4 weeks to assess union by callus formation.

Second Stage: Exchange Nailing after infection control.

This procedure involved removal of antibiotic coated intramedullary nail and introducing standard intramedullary interlocking nail for those patients in which infection was controlled but the bone was yet to unite.

ISSN 2063-5346

Radiograph showing Infected union of Right tibia with IMIL tibia Nail for which implant removal was done in other hospital



Radiograph of above patient again had a history of trauma and sustained fracture with infection 1month post implant removal

Clinical intraoperative picture showing ACIIMN and debridement of the infected wound and postoperative radiograph after ACIIMN

ISSN 2063-5346

Radiograph after exchange nailing with interlocking nail for fracture union and radiograph showing successful union after 1year after the exchange nailing

Observation and Results

In our study age distribution ranged from 20 to 70 years with mean age being 45 years. Most of the cases are between 20 to 40 age group (42.5%), with least being >60 years age group (17.5%). 35 patients are males (87.5%), 5 (12.5%) are females.

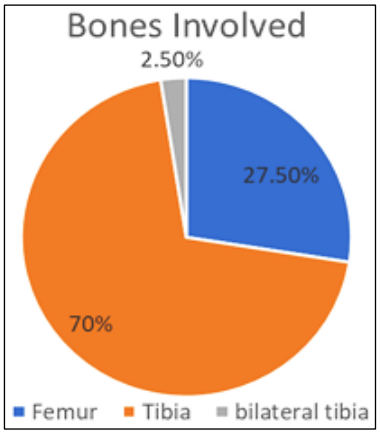
Age distribution in years	Number	Percentage
20- 40	17	42.5%
41-60	16	40%
> 60	7	17.5%
Total	40	100%

Out of 40 cases 28 cases of infected nonunion tibia with 1 bilateral infected nonunion tibia and 11 cases of infected nonunion femur

Bone involved	Number	Percentage
Femur	11	27.5%
Tibia	28	70%
Bilateral tibia	1	2.5%
Total	40	100%

Pie chart showing different bones involved in the study

ISSN 2063-5346



Out of 40 infected nonunion patients, 18 (45%) patients had Intramedullary nail in situ, 14 (35%) patients had external fixators, remaining 8 (20%) patients had no implants, so underwent antibiotic cement coated nailing primarily.

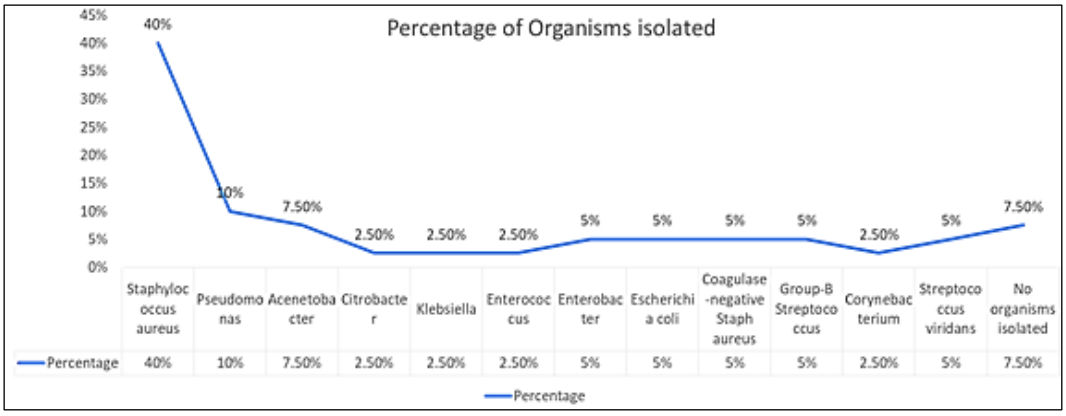
The time duration between initial surgery (after fracture) and antibiotic coated nailing was 5 days to 1 year with mean duration of 6 months.

Staphylococcus aureus was the most common organism isolated (40%), followed by pseudomonas as second most common organism. All these organisms were sensitive to Vancomycin and gentamycin.

Organisms isolated	**No of cases**	**Percentage**
Staphylococcus aureus	16	40%
Pseudomonas	4	10%
Acenetobacter	3	7.5%
Citrobacter	1	2.5%
Klebsiella	1	2.5%
Enterococcus	1	2.5%
Enterobacter	2	5%
Escherichia coli	2	5%
Coagulase-negative Staph aureus	2	5%
Group-B Streptococcus	2	5%
Corynebacterium	1	2.5%
Streptococcus viridans	2	5%
No organisms isolated	3	7.5%
Total	40	100%

Line chart showing the percentage of different microorganisms isolated from infected non-union cases

ISSN 2063-5346

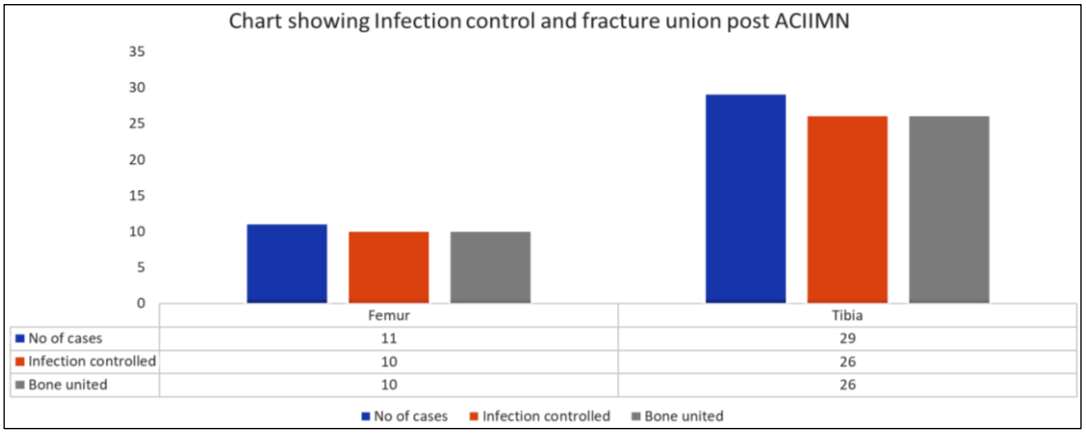


Infection control and union was achieved successfully in 36 cases (90%) out of 40. Out of these 14 patients (35%) had union without need for interlocking nailing, 22 patients (55%) underwent interlocking nailing to achieve union. 4 patients (10%) did not achieve union and had persistence infection in the form of discharge with 2 among them (Tibia) insisted for below knee amputation.

Infection control and fracture union

Bone involved	No of cases	Infection controlled	Bone united	Percentage
Femur	11	10	10	25%
Tibia	29	26	26	65%
Total	40	36	36	90%

Column chart showing infection control and fracture union post ACIIMN



Complications

In our study the most common complication was debonding of cement. We found debonding in first 4 cases of tibia with V nail 1 case with spiked nail. So we shifted to bent K nail for rest of tibia cases where none of the patients showed debonding. In two cases of tibia, there was difficulty in removing the nail as the eye of the nail broke in one case and nail was bent in another case. Knee stiffness was noted in 4 cases. 4

ISSN 2063-5346

cases had persistence of infection after the removal of antibiotic nail 2 among them underwent amputation.

Complications	**No of cases**	**Percentage**
Debonding	5	12.5%
Persistant infection	4	10%
Nail bending	1	2.5%
Nail Breakage	1	2.5%
Proximal nail migration	1	2.5%
Distal nail migration	1	2.5%
Broken eye	1	2.5%
Knee stiffness	4	10%

ISSN 2063-5346

Discussion

Eradication of infection in infected nonunion is a challenging situation faced by orthopedic surgeon. The implant inside act as an excellent substrate for bacterial proliferation and biofilm formation. Along with this infection can spread along the bone and soft tissue [9,10]. To overcome this problem, our two staged procedure is a very good method where in the first stage is aimed to control the infection and keeping the fracture stable followed by achieving union with standard locked intramedullary nail.

Osteomyelitis is commonly poly microbial in 75% of patients. The most common infecting organism in other studies and our study is Staphylococcus aureus with second most common being Pseudomonas. The first peak of local antibiotic release can be seen within the first 24 h after implantation and relevant local concentrations can be upheld for up to 6 weeks [6]. During the debridement the Reamer Aspirator Irrigator (RAI) can be used which irrigates the intramedullary content after wide reaming to aspirate it out of canal [7]. In our study we used conventional reamers to decrease the cost of procedure.

Implants can be custom made (our study) or commercially available antibiotic coated nails. *Garabano D* in 2021 did comparative study with custom made nails and commercially available nails. Commercially available implants have very less debonding rate, short duration of surgery with decrease need for auto-graft, early rehabilitation and less need for additional procedures compared with custom made nails owing to their rigid fixation with static locking system. But no significant difference in reoperation rates, infection control and failure [8]. There is also chance of union without needing second procedure with commercially available implants which decreases the duration of treatment making better quality of life of patient [13.]

Antibiotic coating of nail is done by various methods with some of them mentioned in literature are with reusable mould, silicon tubes with standard size of 12.5 mm and manual method [14, 12].

Debonding

By over-reaming the cavity by 1.5 to 2 size of previous nail, the debridement of medullary canal will be thorough removing all biofilm and necrotic and infected material and will also facilitate easier entry of nail during insertion preventing from delamination from nail that cause debonding while nail removal [14]. Uniform thickness of the coating, anatomical variation of the bone and its length are other factors to be considered to prevent debonding. While removing the nail the entry area is cleared from bone and soft tissue to prevent impingement of cement.

When debonding present literature gives various methods for retrieval of the cement. A non-absorbable suture secured at the end of nail and suturing it to subcutaneous tissue will have a hold on the cement to pull it out of cavity [13].

Use of reamer-irrigator-aspirator (RIA) technique, creating bone window on cortex and endoscopically assisted cement fragment retrieval [15-18] are also tried. Thonse and

ISSN 2063-5346

Conway use J hook used in revision total arthroplasty of hip to retrieve the cement in their study [19].

In our study for initial cases Antibiotic impregnated V nail and interlocking nails with sharp spikes were used for tibia, as debonding was encountered with V nails and spiked nails, we shifted to K nail for femur and bent K nail for tibia. We noticed that some time when we pass the prepared ACIIMN through diameter gauge cement peals off the nail. We tend to add cement in this portion, but this causes increased localised thickness and difficulty in passing the nail. This tendency to add bone cement after passing through diameter gauge should be avoided.

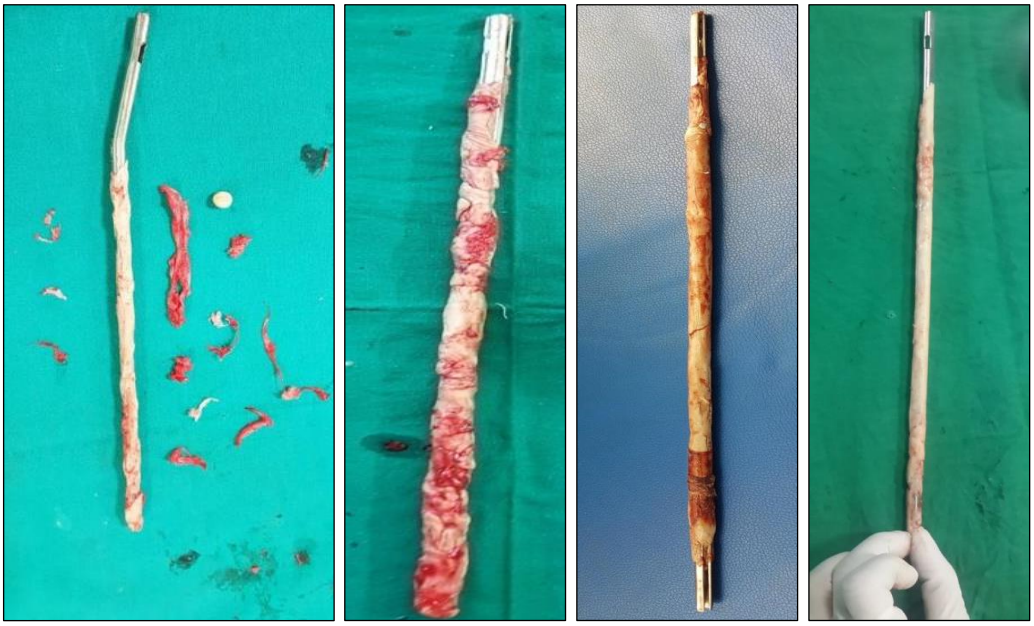
In our study removal of debonded cement was done using long K-wires, Steinman pin and instruments used for revision THR.

Debonding was encountered with V nails, but there was no debonding of cement with K nail due to its cross section.

Other problems encountered during this procedure were, implant removal that is due to cut K-nails, broken eye of nail, for which repeat holes had to be made with machine drill bits to remove the nail.

If there is comminution at the fracture site and if ACIIMN can not give length stability then our technique of antibiotic nailing has to be supplemented with additional temporary external fixation to provide length and rotational stability.

Images of post implant removal ACIIMN K-Nail: There is no debonding of cement post nail removal.



ISSN 2063-5346

Images showing implant breakage and Debonding of cement from V-nail

Requirements of a good ACIIMN

Antibiotic nail should be strong.
It should be easy to put in and remove-Implant removal should be easy.
It should hold good amount of antibiotic cement and elute antibiotic in the body.
It should not cause debonding at the time of implant removal.
It should be easy to make antibiotic nail.
It should have uniform diameter from top to bottom.
Locking options should be available.
Cannulated nail if possible is better.

Advantages of ACIIMN

High local concentration of antibiotics about 200 times greater than systemic drug administration.
Systemic toxicity of drugs are not observed.
Antibiotic levels are above the minimal inhibitory concentration of sensitive organisms.
Long stay in hospital is avoided.
Control of infection and stability is achieved by single procedure.
It is cost effective.
Easy compliance on the part of patient.
Planning of plastic reconstructive procedures if required can be done easily.
Wider surface area for elution will allow high concentration along entire length of bone treated.
There is high concentration of antibiotic even in presence of scarring and compromised vascularity.
Patients with renal compromise can be treated with effective concentrations of antibiotic without side effects.

ISSN 2063-5346

Conclusion

ACIIMN is a effective way of infection control with good fracture stability. Though this procedure demands time and additional surgeries to achieve union, it has good patient compliance, safe, cost effective, and easy way without need of expert hands when compared to traditional surgeries like ilizarov's external fixators for nonunion of tibia and femur. However, if infected gap nonunion of more than 4 cms is present then Ilizarov becomes the treatment procedure of choice.

Antibiotic cement impregnated intramedullary nail with bent K nail for tibia and straight K nail for femur is a good tool in management of infected non-union of tibia and femur.

Initial removal of infected foci and dead bone is important prerequisite to eradicate infection.

Debonding of cement with nail is complication with V nail and interlocking nails with sharp spikes.

The results of ACIIMN are good for femur than tibia.

There is a need to develop a good design of ACIIMN.

ACIIMN is not a good option for gap non-union of more than 4 cms.

References

1. Avinash B, Subramanian K. A Prospective Study of Analysis of the Treatment of Infected Nonunion of Long Bones Using Monolateral External Fixator, J Res Med Dent Sci. 2021;9(4):467-475.
2. Whaling H, Dingeldein E, Bergmann R, *et al*. The release of gentamycin from poly methyl methacrylate beads: an experimental and pharmacokinetic study. J Bone Joint Surg Br. 1978:60-B(2):270-275.
3. Thonse R, Conway J. Antibiotic cement-coated interlocking nail for the treatment of infected non-unions and segmental bone defects. J Orthop Trauma. 2007;21(4):258-268.
4. Maini L, Chadha M, Vishwanath J, *et al*. The Ilizarov method in infected non-union of fractures. Injury. 2000;31(7):509-517.
5. Paley D, Herzenberg JE. Intramedullary infections treated with antibiotic cement rods: preliminary results in nine cases. J Orthop Trauma. 2002;16(10):723-729.
6. Liu JZ, Crist BD. Coated nails: is their use supported by the literature? OTA Int. 2021;4(3S):e110. DOI: 10.1097/oi9. 0000000000000110
7. Dehghan N, Schemitsch EH. Extended applications of the reamer-irrigator-aspirator (RIA) system. Injury. 2017;48(1):S47-S51. Doi: 10.1016/j.injury.2017.04.025
8. Garabano G, Del Sel H, Rodriguez JA, *et al*. The effectiveness of antibiotic cement-coated nails in post-traumatic femoral and tibial osteomyelitis-comparative analysis of custom made versus commercially available nails.
9. Patzakis and Zalavras, 2005; Patzakis *et al*., 1986; Barger *et al*. 2017; Chadayam-muri *et al*. 2017; Beals and Bryant, 2005

ISSN 2063-5346

10. Barger *et al*. 2017; Koury *et al*. 2017; Paley and Herzenberg, 2002; Bhadra and Roberts, 2009.
11. Seenappa HK, Shukla MK, Narasimhaiah M. Management of complex long bone non-unions using limb reconstruction system. Indian J Orthop. 2013 Nov;47(6):602-7. Doi: 10.4103/0019-5413.121590. PMID: 24379467; PMCID: PMC3868143.
12. Thonse R, Conway JD. Antibiotic cement-coated nails for the treatment of infected non-unions and segmental bone defects. J Bone Joint Surg Am. 2008 Nov;90(4):163-74. Doi: 10.2106/JBJS.H.00753. PMID: 18984728.
13. Antoci V, Phillips MJ, Antoci V Jr, *et al*. Using an antibiotic-impregnated cement rod-spacer in the treatment of infected total knee arthroplasty. Am J Orthop. 2009;38:31-33.
14. Shyam AK, Sancheti PK, Patel SK, *et al*. Use of antibiotic cement impregnated intramedullary nail in treatment of infected non-union of long bones. Indian J Orthop. 2009;43(4):396-402.
15. Lowe JA, Vosburg C, Murtha YM, *et al*. A new technique for removing intramedullary cement. J Orthop Trauma. 2011;25(12):762-766.
16. Buehler KO, Walker RH. Polymethylmethacrylate removal from the femur using a crescentic window technique. Orthopedics. 1998;21(6):697-700.
17. Porsch M, Schmidt J. Cement removal with an endoscopically controlled ballistically driven chiselling system. A new device for cement removal and preliminary clinical results. Arch Orthop Trauma Surg. 2001;121(5):274-277.
18. Zweymüller KA, Steindl M, Melmer T. Anterior windowing of the femur diaphysis for cement removal in revision surgery. Clin Orthop Relat Res. 2005;441:227-236.
19. Abalkhail TB, Elhessy AH, Conway JD. Removal of Antibiotic Cement-Coated Interlocking Nails. J Orthop Trauma. 2022 Jun;36(6):317-320. Doi: 10.1097/BOT.0000000000002287. PMID: 34653105.