

ANTIBIOTIC IMPREGNATED BONE CEMENT NAILS TO TREAT INFECTIONS IN LONG BONES AT A VERY LOW COST - A CASE SERIES

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Abstract

Infections in long bones is very common in orthopedic practice. Especially if the long bones involved had an open fracture nature or were fixed with implants. Treating this infection however is a long and protracted process. .

Due to biofilm production or intramedullary extension of the infection a prolonged antibiotic coverage is needed. Bone cement impregnated with specific antibiotic sensitive to the infection may be used as beads strung on stainless steel wires or coated on intramedullary nails. Traditionally a k-nail or a v-nail is used to coat the antibiotic laden cement. But the resultant bone cement surface area is either too small and narrow if cement was poured into the nails or have a very thin layer if coated on such nails. Patients were initially evaluated with radiographs and blood investigations as base line once they were identified as infected. Routine blood tests like complete blood counts with ESR and C reactive proteins along with pro-calcitonin values were undertaken. The specific antibiotic for the infection is ascertained after getting the culture and biopsy reports. After preparing the medullary canal of the bone by sequential reaming and continuous suction to dislodge and remove all possible infective sources in the canal, a small size TENS nail (2mm) is used. The chest tube or suction tubing for the required length of the nail was cut. Slow setting Bone cement is slowly mixed along with the 'specific' antibiotic. Usually the nail (2mm TENS nail) with bone cement would make a core diameter of 8 to 10mm in diameter once the curing process is complete. The final nail with antibiotic impregnated bone cement was inserted into the canal of the long bone. These intramedullary cement nails are usually maintained for 6 to 8 weeks. Patient are followed up with serial blood investigations post operatively including CBC, ESR, CRP and procalcitonin. If no signs of infection are noted at 8 to 12 weeks, then the nail may be removed. Fresh cultures are taken from the intramedullary area of the bone. If cultures are sterile then a definitive fixation if needed may be planned later for the fracture, if fracture is not yet united. All ten patient's cases presented here healed within the generally described time taken for infections to settle as per literature. All patients are back to normal activities of daily living with healed scars and united fractures but mildly reduced range of motion of nearby joints. With our series we like to present a very cheap method of creating antibiotic leaching bone cement coated intramedullary device in the treatment of infections of the long bones.

INTRODUCTION

Infections in long bones is very common in orthopedic practice. Especially if the long bones involved had an open fracture nature or were fixed with implants. Treating this infection however is a long and protracted process.^[1,2] Usual treatment protocol involves initial oral/intravenous antibiotics with blood and radiological evaluations, including

complete blood counts and esr, c reactive protein, other co-morbidity parameters, ultrasound, x rays and Mri, or bone scans or even biopsy of the affected bone.^[3,4] If the infection doesn't settle then a thorough debridement and implant removal are indicated.^[5] Intra op cultures and soft tissue biopsy is taken. Due to biofilm production or intramedullary extension of the infection a prolonged antibiotic coverage is needed.^[6] Giving

only parenteral antibiotic is not enough in most of the infection cases.^[7] After implant removal, debridement and stabilization of the general parameters of the patient, the secondary procedure may be planned.^[8] Cultures taken per op by now would have given results. Bone cement impregnated with specific antibiotic sensitive to the infection may be used as beads strung on stainless steel wires or coated on intramedullary nails.^[9] This includes an antibiotic coated intramedullary nail which will support the fracture also.^[10] Intramedullary nails with antibiotic coating are available in the market. However, they are costly.^[11] Adding to the hospital financial burden to the patient.^[12] Traditionally a k-nail or a v-nail is used to coat the antibiotic laden cement.^[13] But the resultant bone cement surface area is either too small and narrow if cement was poured into the nails or have a very thin layer if coated on such nails.^[14] We present here a cost-effective method of making antibiotic coated bone cement nails which have a larger surface area to leach the antibiotic and are of thicker core diameter to withstand stresses with things available in the operation theatre.

CASE 1

69yrs. male presented to us in the outpatient department with chronic discharging sinus in left middle thigh region for more than 6 months now. He had been operated more than 20 yrs. back with a Kuntcher's nail. On examination and investigations, it was found to be infected with organism isolated from the pus cultures and osteomyelitis changes noted on x rays. Patient underwent surgical decompression with removal of nail and debridement. Antibiotic specific bone cement nail was prepared and inserted into the femur. Patient was mobilised with thigh corset protection at 2 months post-surgery. Antibiotic coated cement nail was removed at 4 months interval and patient was put on thigh corset assisted independent bipedal ambulation.

CASE 2

29yrs male presented to causality with discharging sinus from the leg. He was operated upon for an open fracture tibia with an intramedullary nailing elsewhere. However, he started to have a discharge from the wound one-month, post-surgery. He was advised to continue with dressing, antibiotics and maintaining the intramedullary nail inside as the fracture was not united at the primary hospital. Patient was weight bearing at 6 months post-surgery when he presented to the causality with the discharge and non-healing wound for second opinion. He was investigated radiological and clinicopathological and we removed the infected nail washed the tibia and inserted the antibiotic specific cement nail into the tibia. As the anterior cortex was showing some signs of union patient was gradually mobilised with a patellar tendon bearing

brace. Patient was full weight bearing in 2 months post antibiotic nail insertion. Patient was negative for features of infection with normalization of biochemical markers, absence of pus discharge and x ray features of union. The implant was removed. Patient is an independent ambulator now without discharge from wound.

CASE 3

72yrs presented to us with an open fracture of the tibia with exposed bone. Patient was taken up for immediate debridement and stabilisation of the fracture with external fixator. However, over the course of 6 weeks patient started developing a discharge from the wound. Cultures from the wound were taken and appropriate antibiotics started. In spite of three weeks of parenteral antibiotics which were sensitive to the pus culture reports the wound kept discharging purulent pus. It was decided to open up the fracture site and debride the soft tissue and curette the dead bone. About 1.5 cm of dead non-viable bone was removed from the fracture ends. At this stage the antibiotic covered tens nail was used to stabilise the fracture along with providing high concentrations of the antibiotics directly to the fracture site. After 2 months once the discharge subsided and some callus formation was noted, the patient underwent a definitive procedure of removing the antibiotic nail and substitution with an interlocking tibial nail. He has a 2cm shortening of the affected lower limb. A one cm shoe raise was given and patient is bipedal ambulant with the foot wear modification without any discharge from any wounds.

CASE 4

49yrs was brought to the outpatient department with a discharging wound in the right arm following an operation for fracture humerus after fall from height done at a different hospital. She had a compression spine fracture along with clavicle fracture. Both of these fractures were managed conservatively and patient had been bed ridden since surgery when she was brought to us. She was post-surgery 2 months and only the humerus wound was discharging pus. After investigations and x rays it was decided to remove the dynamic compression plate and debride the local area. After removal of plate fresh cultures were taken from the fracture site. She was on parenteral antibiotics and a 'U' slab for three weeks. Even after 4 weeks patient kept of having a discharge from the arm. Second procedure was done to remove the dead and damaged bone ends and immobilize the fracture with specific antibiotic covered tens nail along with an arm brace. Biochemical markers improved drastically over 2 weeks after second procedure and the discharge stopped. She went back to house hold activities by 3 months with motivation and physiotherapy. The patient even refused to remove the antibiotic nail after 6 months of union. She is under 6 monthly follow up and has been advised to remove the

fixation device. At present there is no discharge and there is ample callus formation on x rays. But patient is constraint for money and has refused a nail extraction.

CASE 5

45yrs sustained a both bone fracture of his left forearm after fall from a tree while pruning it. It was an open fracture with leaves and dirt stuck in the exposed bones. He was informed about the possibility of infection because of the foreign bodies. Initially managed with debridement of the damaged soft tissue and bone along with above elbow plaster slab. The wound healed with no discharge at 3 weeks. There were no signs of inflammation or infection at one and half months, no change in biochemical markers suggesting infection, patient underwent open reduction and internal fixation with plates and screws. Post op period was uneventful and patient was on 3 weekly follow ups. 2 months post-surgery patient developed redness at surgical site over the ulna. After 1 week a blister developed which ruptured and discharging pus. Cultures were taken and patient advised to get the implant removed and fracture site cleared of dead tissue. At surgery it was found that the radius was uniting with callus formation and no pus in the fracture site. However, the ulna had screw loosening with lysis of the bone. After plate removal for the ulna the ends of the bone were debrided and intramedullary fixation was done with antibiotic covered nail. Patient was given an above elbow slab post-surgery for three weeks. As the discharge stopped immediately following the nailing the slab was discarded at 3 weeks. Physiotherapy was initiated and elbow mobilisation started. Fracture united without further complications. At 1 yr. the plate and nail were removed and patient went back to tree climbing and pruning them.

CASE 6

22yrs old male presented with discharge from his left femur at medical college. He was investigated and found to have infection of the femur with features of osteomyelitis. Patient gives history of open fracture femur 5yrs back which was managed by bone setters. Patient was investigated with pus cultures and x rays, put on a slab and advised bed rest. However, patient walked and sustained a cortical break on the medial side. He was brought to us with the discharging wound and fracture of the femur. We decided to redo cultures from the wound and took him up for debridement and external fixation. Once the culture reports were collected a culture specific antibiotic cement nail insertion after reaming irrigation of the shaft. The wound and discharge healed after 6 weeks. Patient was mobilised with thigh corset and walker. Implant removal was done at 12 weeks when adequate callus was noted on the medial cortex. Patient is full weight bearing and driving his taxi around town.

CASE 7

44 yrs. old female sustained poly trauma with fracture both bones both leg and femur fracture on the right. Left side tibia was grade one open fracture. All three fractures were managed with intramedullary nailing after debriding the open wound. The open tibia on the left side went on to continue discharge from the fracture site even at 5 weeks. It was decided to remove the nail and debride the wound and bone and put in an antibiotic coated bone cement nail. The culture and soft tissue biopsy from the open site were collected prior to procedure. Culture specific antibiotics were mixed in cement. The wound healed 3 weeks post-surgery. The antibiotic nail was kept till 12 weeks and removed once x rays showed callus formation. Patient was mobilised with a patellar tendon bearing brace and walker. All three fractures united without further issues. All implants were removed at 2yrs time. Patient is ambulant and has gone back to collecting tickets in bus.

CASE 8

37yrs old female was a traveling to Kollam beach sustained an RTA. Open tibia with minimal contamination. She underwent a nailing for the leg. 5 weeks post-surgery patient started discharging pus from the open wound area. In spite of parenteral antibiotics as per culture sensitivity the discharge would not subside. Patient underwent an exchange nailing with antibiotic impregnated cement nailing. She was put on a patellar tendon brace and partial weight bearing was started at 2 months post exchange nailing. The discharge gradually stopped and at three months callus formation was noted. Implant was removed at 6 months period and she continued on walker ambulation with full weight bearing. Union was delayed, however at one and a half years post implant removal patient was weight bearing without a brace, independent.

CASE 9

60yrs old female with history of fall from stairs sustaining fracture surgical neck and spiral fracture of the shaft without radial nerve injury. She was diabetic with chronic renal disease and coronary artery disease on antiplatelets and dialysis. She underwent nailing of the humerus antegrade. One-month post-surgery patient presented with pain and swelling over the shoulder region. There was fullness anteriorly with a possible collection along with local rise of temperature. Aspiration from the collection along with ultrasound was suggestive of septic arthritis. She underwent an Mri of the arm which showed osteomyelitis in the shaft along with collection in the shoulder. Patient underwent exchange nailing with antibiotic cement nail. Arthroscopy of the shoulder and exchange nailing for the shaft was done. The symptoms and signs of inflammation subsided over time. At 6 weeks the biochemical markers reached baseline and patient

was asymptomatic on a humerus brace. 6 months post exchange the implant was removed. Patient was on a brace for one and half year. She continues to visit our nephrology department for dialysis, symptom free for the arm fracture.

CASE 10

50yrs old male sustained fall at home with subtrochanteric fracture femur. Patient had undergone a nailing done 2 months back in Saudi Arabia. He presented to the hospital with pain and gradually increasing swelling over the thigh. On investigation it was noted that x rays showed periosteal changes along the shaft. Multiple lytic lesions and cortical erosions were seen at multiple regions. Soft tissue swelling was noted corresponding to the superficial one with which the patient had presented. High ESR, CRP and Procalcitonin values were suggestive of osteomyelitis. Patient was taken up for surgery and the nail removed along with debridement of the collection. Shaft was reamed and vancomycin impregnated antibiotic nail was inserted. The signs of infection subsided and cortex started showing healing at 3month time. The thigh was supported with a corset and patient was mobilised by partial weight bearing. Antibiotic nail was removed at 4 months and the fracture fixed with a long proximal femoral nail. The canal was reamed and washed again prior to nailing. Patient was on oral antibiotics for three weeks post-surgery. Patient at present is full weight bearing with walker support. At present there are no signs of infection, swelling or any discharge. Blood parameters are within normal limits and patient is full weight bearing with a walking cane. X rays were taken showing callus formation.

Study Method

The study was initiated once approval is obtained from the IRB and Ethics committee. The data was collected from the hospital medical records. The procedure involves placing an antibiotic impregnated bone cement intramedullary nail in long bones that have infection.

Patients were initially evaluated with radiographs and blood investigations as base line once they were identified as infected. Routine blood tests like complete blood counts with ESR and C reactive proteins along with pro-calcitonin values were undertaken. The specific antibiotic for the infection is ascertained after getting the culture and biopsy reports. Inside the operation theatre the suction tubing/chest tube is used as an exoskeleton to construct the nail. After preparing the medullary canal of the bone by sequential reaming and continuous suction to dislodge and remove all possible infective sources in the canal, a small size TENS nail (2mm) is used to measure the canal length. A precautionary 4 cm was added to the required length so that the tens nail protrudes from the bone at the entry site (extramedullary) in order

to enable easy extraction later on. A routine chest tube or a suction tube is used. The diameter of these tubes varies from 10 to 8mm. The chest tube or suction tubing for the required length of the nail was cut. Slow setting Bone cement is slowly mixed along with the 'specific' antibiotic. In its liquid form the cement is poured into the suction tube. Once the cement starts coming out of the tubing at the other end, the small TENS nail is inserted into the tubing with the straight edge first. The nail is inserted till the curved end comes to rest on the edge of the tubing and the cement inside. The bent tip of the nail is kept free of cement. The extra length of the nail on the opposite side of the tube is kept free of cement. The suction tubing is held closed with fingers by the surgeon at both ends and gently rotated by assistant over the palms of the hand. This slowly displaces the cement uniformly over the TENS nail. Time is given for the bone cement to set completely. The outer tubing is cut with a 22-size surgical blade once the cement has cured. Usually the nail (2mm TENS nail) with bone cement would make a core diameter of 8 to 10mm in diameter once the curing process is complete. The final nail with antibiotic impregnated bone cement was inserted into the canal of the long bone. The wound is closed in layers and a protective brace is given with special instruction for non-weight bearing on the operated lower limb. These intramedullary cement nails are usually maintained for 6 to 8 weeks. Patients are followed up with serial blood investigations post operatively including CBC, ESR, CRP and procalcitonin. If no signs of infection are noted at 8 to 12 weeks, then the nail may be removed. Fresh cultures are taken from the intramedullary area of the bone. If cultures are sterile then a definitive fixation if needed may be planned later for the fracture, if fracture is not yet united.

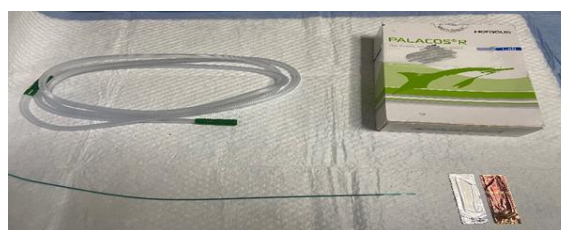


Figure 1: tubing, bone cement, tens nail and surgical blades



Figure 2: antibiotic impregnated bone cement nail after final curing of cement



Figure 3: Introduction of the antibiotic nail in fem



Figure 4: Anteroposterior and lateral views of infected femur with 'K' nail insitu



Figure 5: After removal of 'k' nail and insertion of antibiotic impregnated bone cement nail



Figure 6: X rays after removal of antibiotic nail at 4 months post operative



Figure 7: Infected tibia with intramedullary interlocking nail



Figure 8: X rays after placing antibiotic nail in tibia



Figure 9: X rays at 4 months post operative



Figure 10: 4 months after antibiotic nail removal

DISCUSSION

In case of infections of the bone an initial treatment of intravenous antibiotics followed by oral therapy is tried. The risk of chronic infections increases unacceptably when effective therapy is given for less than 3 weeks.^[15] In adults, parenteral antibiotic should be given for at least 6 weeks for uncomplicated cases in which no residual nidus of infection is suspected.^[16] If the infection doesn't subside then a thorough debridement of the area is required.^[17] However, with associated fractures intramedullary or extramedullary fixation devices may be needed or have already been put in prior to infective sequence. Presence of 'biofilm' (glycocalyx) and foreign body (fixation devices) make eradication of infection more difficult by systemic antibiotics.

When the infection doesn't subside or the fracture is not united, there a removal of primary device along with further debridement of the infected bone, removal of dead bone, filling of dead space with bone grafts, tissue flaps, and placement of locally aggressive antibiotics impregnated material is indicated.^[18] A one stage approach with debridement alone or immediate reimplantation of hardware is less likely to achieve cure.^[19]

This can be achieved by antibiotic coated or impregnated bone cement intramedullary devices.^[20] The use of such a cement nail provides advantages over other surgical options.^[21] The nail provides some stability across the fracture site, unlike cement beads.^[22] It has been well established that osseous stability is important in the management of infected non unions and intramedullary osteomyelitis.^[23] Second, this enables a prolonged time for the antibiotics to elute in high concentrations in and around the infected area of bone.^[24] Normally the antibiotic continues to disperse from the bone cement for up to 200 days or more. Peak local concentration of antibiotic is with in first 24hrs and may last up to 6 months peaking at 6 to 8 weeks.

Timely removal of the nail once infection subsides is advocated as live bacteria are known to persist on bone cement. The implant exit time varies among other hospitals but 90-day period is considered a standard at our hospital. This has shown to have a therapeutic effect on refractory infection and allow a higher concentration of antibiotic present locally with fewer associated side effects than is achievable with systemic antibiotics.^[23,25]

After preparation of the antibiotic laded cement nail, [Figure 1,2] the infected bone was once more debrided and sequentially reamed to remove any possible infective focus along the inside of the canal. If an intramedullary implant was present, it was removed at this stage. The canal was washed with at least 3 litres of normal saline. All the debris were removed from the canal with suctioning.

The "appropriate" antibiotic cement laden nail was introduced into the canal after curing of the cement. [Figure 3]

The wound closed in layers and protective slab or brace was given depending on the status of the native bone stock.

For the femur we give a thigh corset and for the tibia we used the patella tendon bearing brace to protect the nail and the damaged bone from fracturing with inadvertent weight bearing. The infected bones of the upper limb were usually protected by plaster of Paris immobilization or a functional brace.

Patients were kept under regular follow up with serial x rays at 2 to 3 weeks intervals. Patients were reviewed and x rays taken at 1-, 3- and 6-months periods. The blood parameters were also evaluated at the same time. The nails were kept in place for another 4 weeks after the parameters for active infections dropped to normal or near normal values.

The antibiotic cement nails were removed and a fresh tissue culture from the medullary canal was taken as a precautionary measure. Antibiotics specific to this culture can be started post removal if indicated.

In our series all the cultures after removal of the nail were negative and the patients were followed up at regular intervals.

None of the patient showed a flare up of reinfection or secondary fractures.

All the infections subsided and the fractures united. The range of motion of adjacent joints were compromised by 5 to 15 percent. However, the patients were happy with the healing and returned to normal activities of daily living.

Two of our patients had a secondary intramedullary fixation device put in after antibiotic nail extraction. Another one has refused to remove the humerus due to financial constraints.

Usually, antibiotic impregnated bone cement laden intramedullary nailing systems are usually very costly for the general population in India, especially Kerala.

In 2005 DePuy Synthes marketed the unreamed tibial nail with gentamycin. The cost of the nail was in excess of 600 dollars. This system was later

upgraded to the expert tibial reamed and interlocked nail. A French company came out with the “Synimed” nail. Argentina developed the “Subiton” nail. The imported variety of these systems cost about 50 to 60000 Rs.^[30] Indian company Matrix Meditec had the local variety of the nails. However, these local nails are usually not available in non-metropolitan cities in India. They would cost about 20 to 30000 Rs.^[29,30]

Most orthopedic surgeon then fall back on creating such a nail in house in the operation theatre. Normally the cavity of Kuntcher’s nail is filled with antibiotic bone cement or are manually coated onto the smallest diameter interlocking intramedullary nail.^[28] Conventionally the desired nail with coating of 1.5-2.5 mm layer of antibiotic cement mixture is made. (21) Even here the cost of these devices must be incurred by the patient which still amounts to more than 10 to 20000 Rs.^[30]

In our study the cost to the patient includes the cost of the TENS nail and bone cement, still cheaper than any system at present available in the local market.

The total cost or hospital expenditure was not included in the analysis as some patients preferred pay wards or a/c suits for treatment. Here we present the appropriate cost of TENS nail covered with antibiotic laden bone cement alone in comparison to available antibiotic laden bone cement intramedullary device in the market.

Approximate cost of the antibiotic nail in our series

a) Tens nail 2mm Rs 1500 to 2000

b) Bone cement 20gm Rs 1800 to 2500

Management and outcome

All the patients presented with infection in the long bones after surgical intervention with plate or a nail. After establishing the infection clinically, radiologically and with biochemical and blood parameters of infection they were explained about the procedure planned. (Implant removal/ debridement/ antibiotic nail insertion)

The implants were removed, cultures taken, organism identified and exchange nailing with antibiotic impregnated cement nail was done

All ten patient’s cases presented here healed within the generally described time taken for infections to settle as per literature.

All patients are back to normal activities of daily living with healed scars and united fractures but mildly reduced range of motion of nearby joints.

CONCLUSION

With our series we like to present a very cheap method of creating antibiotic leaching bone cement coated intramedullary device in the treatment of infections of the long bones.

We compared our series with other readily available systems to deliver antibiotics locally at the fracture site along with providing some stability to the fractured bone.

The approximate cost for the nail to the patient in our series was about Rs 5000, depending on the antibiotics used. We used gentamycin and vancomycin in 8 patients. Two patients were treated with colistin. The cost of the nails thus shot up to 8000 Rs.

Clinical message

A low-cost method of making antibiotic impregnated bone cement nail for treating infected long bones.

Learning points of the article

Cost effective antibiotic nail, infection control, stability to fracture site

REFERENCES

1. Jason H Calhoun, MD., FACS., M.M Manning PhD Osteomyelitis of long bones Semin Plast surgery. May 2009; 23(2): 59-72
2. Azar FM, et al. Osteomyelitis. In: Campbell’s Operative Orthopaedics. 13th ed. Philadelphia, Pa: Elsevier 2017
3. Kremers HM, et al. Trends in epidemiology of osteomyelitis: a population-based study 1969 to 2009. The Journal of Bone and Joint Surgery. 2015
4. Joseph M Fritz, MD and Jay R McDonald, MD osteomyelitis and diagnosis Phys Sports med. 2008; 36(1): nihpa 116823
5. John Hatzenbeuhler MD et al, diagnosis and management of Osteomyelitis, Am Fam Physician 2011;84 (9): 1027-1033
6. Luca Lazzarini, Benjamin A Lipsky, Jon T Mader, international journal of infectious diseases, volume 9, issue 3, may 2005 Antibiotic treatment of osteomyelitis: what have we learned from 30 yrs. of clinical trial
7. Brad Spellberg, Benjamin A systemic antibiotic therapy for chronic osteomyelitis in adult, clinical infectious diseases, volume 54, issue 3,1 2012
8. Ismat A, Walter N, Baertl S et al, antibiotic cement coating in orthopedic surgery, Journal of Orthopaedics and Traumatology, dec 2021, 22(1):56
9. C Bhatia, MS Orth et al, Role of antibiotic cement coated nail in infected non-union of tibia Malays Orthop J 2017 mar; 11(1): 6
10. Ashok K Shyam et al, use of antibiotic impregnated intramedullary nail in treatment of infected non-union Indian J Orthop 2009, oct-dec; 43(4):
11. G Wang et al, custom made antibiotic cement coated nail, Biomed Research International, vol 2021
12. Micheal J Steflik et al, antibiotic cement coated intramedullary nail cost, J. injury, 2022
13. Ajay Bharti et al, a simple method for fashioning antibiotic impregnated rod, J Clin Orthop Trauma 2016 oct-dec; 7 (suppl 2) 171-176
14. Janet Conway et al, antibiotic cement coated nail for infected non-union, The journal of Bone and Joint Surgery 2008
15. Dich VQ, Nelson JD, Haltalin KC et al, osteomyelitis in infants and children, a review of 163 cases. Am J Dis child 1975;129,1273-78
16. Mader JT, Calhoun J, osteomyelitis, principles and practice of infectious disease 5th ed Churchill Livingstone 2000; 1182-96
17. Joseph M Fritz, Jay R MacDonald, Phys sports med 2008;36(1): nihpa 116823
18. Widmer AF, Gaechter, Ochsner PE et al, antimicrobial treatment of orthopedic implant related infection, Clin Infect Dis 1992;14;1251-53
19. Meehan AM, Osman DR, Duffy MCT et al, outcome of streptococcal joint infection treated with debridement and retention of prosthesis, Clin Infect Dis, 2003;36;845-49
20. Qiang Z, Jun Po, Jie XJ, Hang L et al, use of antibiotic cement rod to treat intramedullary infections after nailing, Arch Orthop Trauma Surgery 2007;127;945-51
21. Paley D, Herzenberg JE, intramedullary infections treated with antibiotic cement rods, J Orthop Trauma, 2002;16;723-9

22. Sancineto CF, Basla JD, treatment of long bone osteomyelitis with mechanically stable intramedullary antibiotic dispenser, *J Trauma* 2008;65;1416-20
23. Madangopal SG, Seligson D, Roberts CS, the antibiotic cement nail for infection after tibial nailing, *Orthopedic* 2004;27;709-12
24. Thonse R, Conway J, antibiotic cement coated interlocking nail for treatment of infected non-union and segmental bone defects, *J Orthop Trauma* 2007;21;258-68
25. Nelson CK, Hichman Sg, Harrison BH, elution characteristic of gentamycin PMMA beads, *Orthopedic* 1994;17;415-6
26. Nizegorodcew T, Palmieria G, Marzetti E, antibiotic coated nails in orthopedic and trauma surgery, *Int J ImmunopatholPharmacol* 2011;24;125-8
27. Reil RU, Gladden PB, a simple method of fashioning an antibiotic cement coated intramedullary nail, *Am J Orthop* 2010, 39;18-21
28. C Bhatia, AK Tiwari, SB Sharma, role of antibiotic coated nailing in infected tibia, *Malays Orthop J* 2017,11(1);6-11
29. Kendal RW, Duncan CP, Smith JA, persistence of bacteria on antibiotic loaded acrylic depots, *Clin OrthopRetal Rs* 1996;329;272-80
30. Micheal J, B Gage, Dhana Patel, antibiotic cement intramedullary nail cost effectiveness, *Injury* 2022, 08;005