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Locked Plate Impregnated with Antibiotic-Loaded Bone Cement Application as a First Stage For Managing Long Bones Infected Nonunion: A Technical Note

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Abstract

Background. Infected nonunion of long bone fractures poses a dilemma for trauma surgeons, especially when accompanied by bone defects. The main goals for management are curing infection, reconstructing the bone defect, achieving union at the fracture site, and eventually obtaining acceptable functional outcomes. In these situations, the surgeon could manage the infected nonunion through single-stage surgery. However, some surgeons prefer two-stage surgical intervention, wherein in the first stage, all attention is paid to curing the infection and providing temporary stabilization till the second stage, which is the definitive fixation. Temporary fixation during the first stage after thorough debridement could be obtained by various methods, including intramedullary nails coated by bone cement or external fixators.

The aim — to describe a modification while using a locked plate impregnated with antibiotic-loaded bone cement during the first stage of two-stage revision for managing infected nonunited distal femoral fracture.

Technique description. The method described in the current technical note is a locking plate impregnated with antibiotic-loaded bone cement. This technique provides optimal local antibiotic delivery through the bone cement and proper stability owing to the fixation using the locking plate, which could be applied as close to the bone as possible due to its function as an internal-external fixator.

Conclusion. The technique is easy and efficient and can be applied using ordinary tools without needing complex instruments.

Keywords: infected nonunion, bone cement spacer, local antibiotic therapy, antibiotic cement-impregnated locking plate.

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Применение накостной пластины с цементной антимикробной мантией на первом этапе лечения инфицированных несращений длинных костей: техническая заметка

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Реферат

Актуальность. Инфицированное несращение переломов длинных костей может вызывать сложности у травматологов, особенно если оно сопровождается костными дефектами. Основными целями лечения являются купирование инфекции, замещение костного дефекта, сращение в месте перелома и, в конечном итоге, достижение удовлетворительных функциональных результатов. При выборе тактики лечения инфицированного несращения хирург может выбрать одноэтапную операцию, однако некоторые предпочитают двухэтапное хирургическое вмешательство, при котором на первом этапе все внимание уделяется лечению инфекции и обеспечению временной стабилизации до второго этапа, на котором осуществляется окончательная фиксация. Временная фиксация на первом этапе после тщательной санации может быть достигнута различными методами, включая интрамедуллярный стержень с цементным покрытием или внешние фиксаторы.

Цель — описать модификацию применения накостной пластины, покрытой цементной антимикробной мантией, на первом этапе двухэтапной ревизии при лечении инфицированного несросшегося перелома дистального отдела бедренной кости.

Описание техники. Метод, описанный в данной работе, заключается в использовании фиксирующей пластины, покрытой смесью костного цемента с антибиотиком. Эта техника обеспечивает местную доставку антибиотика через костный цемент и надлежащую стабильность благодаря фиксации с помощью пластины, которая может быть установлена как можно ближе к кости благодаря своей функции внутреннего фиксатора.

Заключение. Техника проста в использовании и эффективна, ее можно применять с помощью обычных инструментов, не прибегая к сложным приборам.

Ключевые слова: инфицированное несращение, спейсер из костного цемента, локальная антибактериальная терапия, накостная пластина, цементное антимикробное покрытие.

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INTRODUCTION

Infected nonunion of long bones is one of the complications occurring after surgical management of long bone fractures, either associated with open reduction and internal fixation (ORIF) using plates and screws or even with closed reduction and internal fixation using minimally invasive surgical (MIS) techniques or intramedullary nails (IMN) [1, 2, 3, 4, 5].

After establishing the diagnosis of long bone fractures infected nonunion, the surgeon could choose between single-stage surgery, which entails hardware removal (if present), debridement, and revision of internal fixation; or proceed with two-stage revision, where the first stage involves hardware removal, debridement (including obtaining samples for culture and sensitivity), and applying a temporary fracture fixation method and cement spacer loaded with antibiotics, then a second stage of ORIF after infection clearance with application of bone graft if required [2, 6, 7, 8, 9].

For the two-stage procedure, various options were introduced during the first stage, aiming to maintain the limb length, eradicate the infection, and induce a membrane for later bone graft application (Masquelet technique) [10, 11]. This could be achieved using IMN coated with antibiotics, the application of a cement spacer loaded with antibiotics, and an external fixator [12, 13, 14]. Recently, more surgeons started using locked plates coated with cement for local antibiotic delivery and obtaining more stability at the fracture site [15, 16, 17, 18, 19].

The aim — to describe a modification while using a locked plate impregnated with antibiotic-loaded bone cement during the first stage of two-stage revision for managing infected nonunited distal femoral fracture.

SURGICAL TECHNIQUE

In all cases, the management should start with the optimum diagnosis of infected nonunion, which could be achieved by applying the criteria recommended by an international expert group on fracture-related infection [2, 3, 20].

It is worth noting that proper patient selection cannot be overlooked, which includes: patient understanding and willingness to go through the possible lengthy management plan; medically fit patients (including controlled chronic medical conditions, no severe vascular insufficiency, and stop smoking); acceptable bone defect length ≤10 to 15 cm (as larger defects might require vascularized fibular grafts); enough distal and proximal bone after debridement for robust plate fixation; and adequate soft tissue coverage [2, 21, 22].

Once the diagnosis is confirmed and the decision is made to proceed with two-stage revision surgery, the first stage is mainly applied to get rid of the infection and is followed by a second stage, usually the definitive fixation (regardless of the device used).

We proceed with the following steps:

1. Debridement, tissue sampling, and irrigation

If possible, we incorporate the previous surgical approach; care is taken to develop proper tissue flaps for later closure. All hardware and dead tissues (soft tissues and bones) are removed, and tissue samples are obtained from at least five sites. Then, the wound is copiously irrigated with normal saline to decrease the bacterial load.

2. Dead space management

The defect resulted from debridement is evaluated and a cement spacer is loaded with antibiotics (preferably to be sensitive to the infecting organism; however, if the organism is not known, we empirically use vancomycin in a dose of 2 g for each 40 g pack of bone cement). We fabricate a bone cement tube using a 50cc syringe, which is adjusted to the length of the bone defect (from our experience, a 40 g pack of bone cement is enough to fabricate a cement tube using the 50cc syringe to fill a 25 mm size defect). Besides delivering antibiotics locally and maintaining bone length, this cement spacer will help in membrane formation and could be used for bone graft application during the second stage [23].

3. Temporary fixation using a locked plate impregnated with bone cement

Now, attention is being paid to the temporary fixation bridging the bone defect area. For distal femoral infected nonunion, we used a distal femoral locked plate impregnated with bone cement loaded with antibiotics. For plate preparation, we first filled all the plate combi-holes with plastic syringe caps so the hole would not be filled with bone cement. Then, the bone cement was mixed with antibiotics (the same as performed in the previous step), and while it was still in a doughy state, we applied the cement to the outer and inner surfaces of the plate, making sure that the layer is proper and not so thick. After the bone cement hardens, the plate is applied and fixed to the bone after gaining proper bridging at the fracture site, and the application of the screw should be enough proximally and distally to achieve optimal stability and proper bone alignment.

4. Postoperative protocol and second stage procedure

After completing the first stage, empirical antibiotic therapy is started immediately (broad spectrum, including agents against gram-negative bacilli) till the results of tissue sampling are obtained; then, an antibiotic treatment according to the culture and sensitivity results is begun [2]. The duration of the antibiotic therapy is from 6 to 12 weeks (where in the first two weeks, antibiotics were administered by intravenous route, then continued orally). After clearance of infection, the second stage could be performed, ensuring that samples are obtained after removing the cement-impregnated plate and the cement spacer, the bone graft is applied according to the size of the present defect, and final fixation is obtained using hardware according to the surgeon preference.

The described surgical technique is illustrated by the clinical case of a 32-year-old male patient who presented to us with an infected nonunited distal femoral fracture that was managed by a two-stage approach (Figures 1, 2, 3).

Figure 1. Admission X-rays of a 32-year-old male patient, who gave a history of a previous open distal femur fracture, which was treated initially with open reduction and internal fixation and got infected.
Over two years, he had five surgeries (all included a sort of debridement):
a — initial fixation and application of a cement spacer (red arrowheads), which failed;
b — hardware was removed, and external fixation was applied;
c — lastly, after reinfection, all hardware was removed, and the patient presented with an infected nonunited distal femoral fracture (yellow arrowheads) with an open sinus on the lateral aspect of the distal thigh

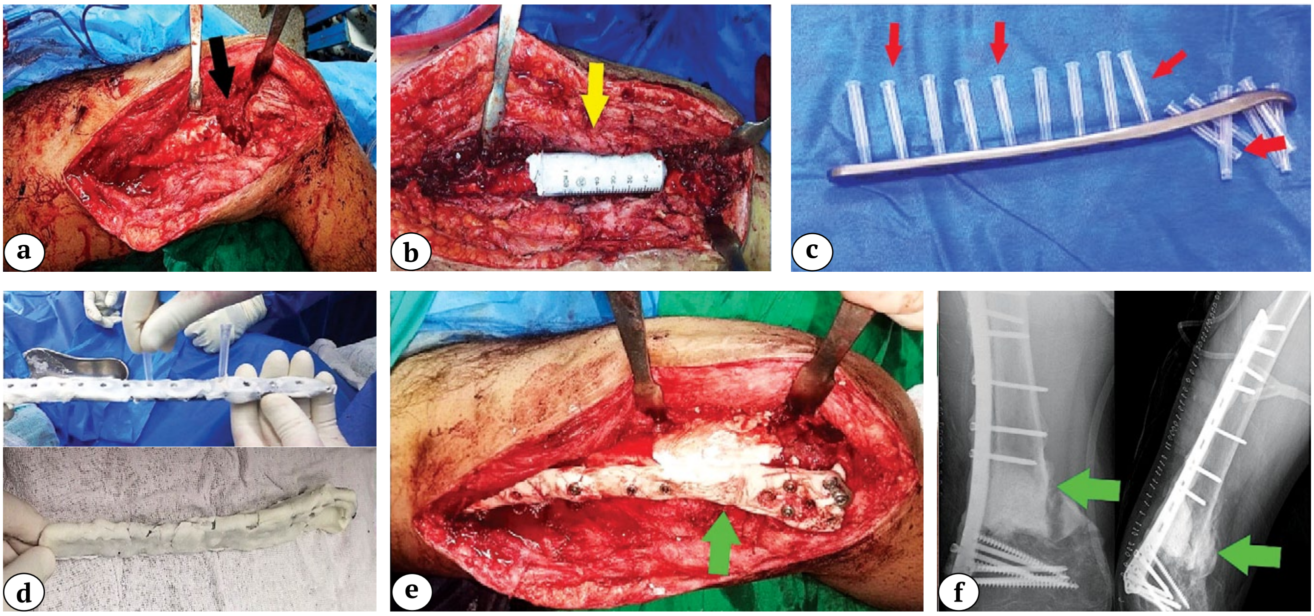

Figure 2. The first stage of revision surgery:
a — massive debridement with a resultant bone defect (black arrowhead), specimens retrieved showed infection with *Staphylococcus aureus* bacteria;
b — applying a bone cement spacer loaded with antibiotics (we applied vancomycin as an empirical antibiotic) at the site of the bone defect (a yellow arrowhead);
c — the locked plate with the plastic syringes and plastic caps inserted in the screw holes (red arrowheads);
d — after the locked plate is impregnated with bone cement (vancomycin);
e, f — intraoperative and postoperative X-rays showing the plate and cement spacers in position (green arrowheads)

N.B. *Antibiotics against the infective organism were prescribed by our microbiology team in the form of 2 weeks of IV, then oral for an extended 6 weeks.*

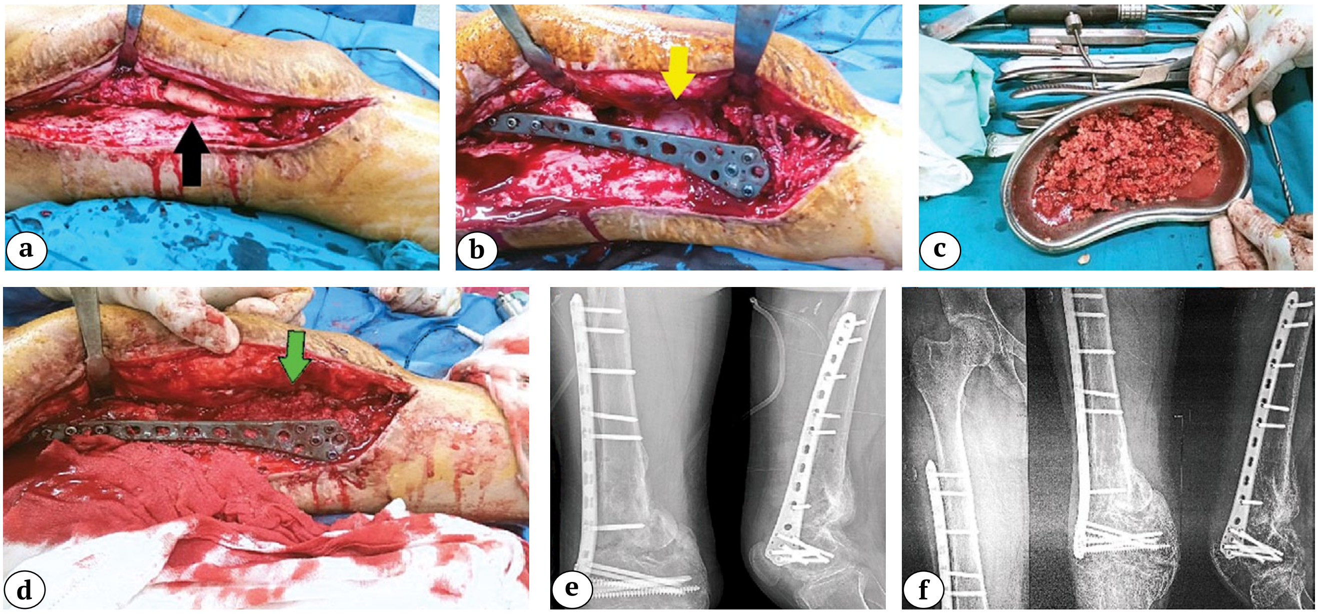

Figure 3. The second stage of revision surgery and final follow-up:
a — after the cement-impregnated locked plate was removed, the cement spacer is evident (black arrowhead);
b — the cement spacer was removed, and fixation using a distal femoral locked plate was performed, with the yellow arrowhead indicating the induced membrane;
c — bone graft preparation;
d — the bone graft was applied inside the induced membrane to fill the defect (a green arrowhead);
e — immediate postoperative X-rays;
f — one year follow-up X-rays showing union at the fracture site

DISCUSSION

Long bone fractures complicated with infected nonunion pose a burden on patients, surgeons, and the healthcare system [1, 3, 24]. The management protocols aim mainly to cure the infection and obtain fracture union to improve the patient's quality of life and functional outcomes [2, 23, 24].

Various management options were suggested, including debridement and acute implant retention (DAIR procedure), one or two-stage revisions, and suppressive antibiotic therapy [2]. Each management option relies on many factors, including the patient's general status, the surgical team's efficiency, and the infecting organism's virulence [2, 6, 7].

We describe a technique of using bone cement loaded with an antibiotic spacer to manage bone defects while treating infected nonunited long bone fractures with a supplementary fixation using a locked plate impregnated with antibiotic-loaded bone cement. Which we believe to be feasible and applicable to each surgeon's daily practice. However, for the technique to be successful, the surgeon should consider proper patient selection, ensuring that radical debridement is achieved and the infective organism is properly identified to prescribe antibiotics accordingly. It is also important to ensure that the surrounding soft tissues are respected as possible as these will provide blood supply. The antibiotic-loaded bone cement spacer should be of adequate length to provide initial stability, and the bone defect should be reconstructed using various options of bone grafts or synthetic bone substitutes. Stable fixation is a key for success, and finally the patients should be followed up at shorter intervals to detect any signs of infection recurrence.

The results have been well-established in the literature in many reports [15, 16, 17, 18, 19]. C. Jia et al. reported one of the largest series, including 183 patients with a mean follow-up of 32.0 months (ranging from 12 to 66) who were presented with infected nonunited long bone fractures (100 tibias, 81 femurs, and two fibulas). The authors reported that they achieved infection control in 91.3% of the patients during the first stage, and finally they achieved fracture union in 95.9% of the patients at a mean of 5.4 months (ranging from 4 to 12) [15]. We admit that the technique we described is not novel; however, we introduced detailed and simplified steps to accomplish this procedure and added a tip for plate preparation.

Besides the well-documented advantages of membrane-induced technique after applying a bone cement spacer to the bone defect site [5, 11, 22], using a locked plate impregnated with antibiotic-loaded bone cement serves the following functions: first, it provides more robust stability at the bone defect site compared to external fixators or IMN. Some authors have advocated stability across the fracture or bone defect site as a significant factor in curing infection [25, 26]. Second, being coated with bone cement on the inner and outer surfaces, the local antibiotic elution is increased. Third, owing to the principle of locking plates as internal-external fixators, there is no need to apply the plate directly to the bone surface [27], which might not be possible due to the bone cement layer on the inner surface. Although we do not have such experience, it is worth noting that some authors suggested a promising role of utilizing implants with antimicrobial coatings, which showed a significant effect in decreasing the peri-implant contamination and the bacteria concentration [28].

However, the surgeon should be very cautious while applying this technique, ensuring that a cement spacer and plate are used after completely curing the bone cement to avoid thermal injury to the surrounding soft tissue and bone structures. If the surgeon applied a bone cement layer that was too thick or did not approximate the plate to the bone surface as much as possible, this could impede the soft tissue closure and require a secondary closure or soft tissue reconstruction.

Moreover, we need to highlight some possible limitations or complications that might occur with the current technique. First, resistant infection (which is actually a significant issue regardless of the technique used), which might be attributed to inadequate debridement, failure to identify the causative organism, polymicrobial infection (where mono antimicrobial therapy will be unsuccessful), and failure to provide adequate initial skeletal stability to ease soft tissue healing. Second, some issues related to the locked plate and screws, which might include plate or screw breakage, so the surgeon should be prepared with a broken screw removal set if such complication occurs. Third, the inability to fill the bone defect with adequate bone graft might lead to defective union; furthermore, the surgeon should be prepared with allografts or synthetic bone substitutes in cases with larger defects. Last, patients should be counseled regarding the length management protocol and the need for extensive postoperative rehabilitation to obtain acceptable functional outcomes and satisfaction, especially as most of these patients are non-ambulatory of the affected limb for longer periods; they also went through multiple operations with the resultant soft tissue contracture, muscles atrophy, and nearby joints stiffness.

CONCLUSION

A locked plate impregnated with antibiotic-loaded bone cement is a viable option during first-stage management of infected nonunion of long bone fractures, which offers the advantage of local antibiotics delivery accompanied by robust internal fixation and stability at the fracture or bone defect site. The technique is easy and efficient and can be applied using ordinary tools without needing complex instruments.

DISCLAIMERS

Author contribution

Michael G. Tawfeek — data acquisition and interpretation, drafting the manuscript.

Ahmed A. Khalifa — data acquisition and interpretation, drafting the manuscript.

Hossam Abubeih — study concept and design, editing the manuscript.

Mahmoud Badran — data acquisition and interpretation, drafting the manuscript.

Osama Farouk — study concept and design, editing the manuscript.

All authors have read and approved the final version of the manuscript of the article. All authors agree to bear responsibility for all aspects of the study to ensure proper consideration and resolution of all possible issues related to the correctness and reliability of any part of the work.

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REFERENCES

1. Flores M.J., Brown K.E., O'Marr J.M., Adejuyigbe B., Rodarte P., Gomez-Alvarado F. et al. The economic impact of infection and/or nonunion on long-bone shaft fractures: a systematic review. *OTA Int*. 2024;7(3):e337. doi: 10.1097/OI9.0000000000000337.
2. Metsemakers W.J., Morgenstern M., Senneville E., Borens O., Govaert G.A.M., Onsea J. et al. General treatment principles for fracture-related infection: recommendations from an international expert group. *Arch Orthop Trauma Surg*. 2020;140(8):1013-1027. doi: 10.1007/s00402-019-03287-4.
3. Govaert G.A.M., Kuehl R., Atkins B.L., Trampuz A., Morgenstern M., Obremskey W.T. et al. Diagnosing Fracture-Related Infection: Current Concepts and Recommendations. *J Orthop Trauma*. 2020;34(1):8-17. doi: 10.1097/BOT.0000000000001614.
4. Bauer T., Klouche S., Grimaud O., Lortat-Jacob A., Hardy P. Treatment of infected non-unions of the femur and tibia in a French referral center for complex bone and joint infections: Outcomes of 55 patients after 2 to 11 years. *Orthop Traumatol Surg Res*. 2018;104(1):137-145. doi: 10.1016/j.otsr.2017.10.014.
5. Farouk O., Khalifa A.A. Tibial Bone Loss: How to Treat without Circular Fixation? *J Orthop Spine Trauma*. 2023;9(1):1-5. doi: 10.18502/jost.v9i1.12561.
6. Migliorini F., Schäfer L., Simeone F., Vaish A., Bhadani J.S., Vaishya R. Management of Distal Femoral Non-union: A Systematic Review. *Indian J Orthop*. 2024;58(12):1686-1723. doi: 10.1007/s43465-024-01205-4.
7. Somford M.P., van den Bekerom M.P., Kloen P. Operative treatment for femoral shaft nonunions, a systematic review of the literature. *Strategies Trauma Limb Reconstr*. 2013;8(2):77-88. doi: 10.1007/s11751-013-0168-5.
8. Khalifa A.A., Fadle A.A., Elsherif M.E., Said H.G., Elsherif E., Said G. et al. Concomitant intramedullary nailing and plate augmentation as a single-stage procedure in treating complicated nonunited femoral shaft fractures. *Trauma*. 2021;24(4):286-293. doi: 10.1177/14604086211007037.
9. Barabash A.P., Kesov L.A., Barabash Ju.A., Shpinyak S.P. Building of extensive diaphysis defects in long bones. *Traumatology and Orthopedics of Russia*. 2014;20(2):93-99. (In Russian). doi: 10.21823/2311-2905-67.
10. Yang X., Xu X., Li J., Song M., Sun H., Zhang H. et al. Management of infected bone defects of the femoral shaft by Masquelet technique: sequential internal fixation and nail with plate augmentation. *BMC Musculoskelet Disord*. 2024;25(1):552. doi: 10.1186/s12891-024-07681-x.
11. Bu Z.Y., Hu L.J., Li C., Li A.J. Clinical analysis of application of antibiotic bone cement spacer combined with membrane induction technology in treatment of osteomyelitis after femoral intramedullary nail operation – A case series. *J Pak Med Assoc*. 2020;70(2):360-362. doi: 10.5455/JPMA.9552.
12. Solanki T., Maurya M.K., Singh P.K. Results of Antibiotic-Impregnated Cement/Polymer-Coated Intramedullary Nails in the Management of Infected Nonunion and Open Fractures of Long Bones. *Cureus*. 2023;15(8):e43421. doi: 10.7759/cureus.43421.
13. Garabano G., Pereira S., Alamino L.P., Munera M.A., Ernst G., Bidolegui F. et al. Antibiotic cement-coated rigid locked nails in infected femoral and tibial nonunion. Reoperation rates of commercial versus custom-made nails. *Injury*. 2023;54(Suppl 6):110650. doi: 10.1016/j.injury.2023.02.033.
14. Romanò C.L., Bozhkova S.A., Artyukh V., Romanò D., Tsuchiya H., Drago L. Local Antibacterial Implant Protection in Orthopedics and Trauma: What's New? *Traumatology and Orthopedics of Russia*. 2019;25(4):64-74. doi: 10.21823/2311-2905-2019-25-4-64-74.
15. Jia C., Wang X., Yu S., Wu H., Shen J., Huang Q. et al. An antibiotic cement-coated locking plate as a temporary fixation for treatment of infected bone defects: a new method of stabilization. *J Orthop Surg Res*. 2020;15(1):44. doi: 10.1186/s13018-020-1574-2.
16. Qiu X.S., Cheng B., Chen Y.X., Qi X.Y., Sha W.P., Chen G.Z. Coating the plate with antibiotic cement to treat early infection after fracture fixation with retention of the implants: a technical note. *BMC Musculoskelet Disord*. 2018;19(1):360. doi: 10.1186/s12891-018-2285-2.
17. Wang X., Wang S., Xu J., Sun D., Shen J., Xie Z. Antibiotic cement plate composite structure internal fixation after debridement of bone infection. *Sci Rep*. 2021;11(1):16921. doi: 10.1038/s41598-021-96522-1.
18. Bidolegui F., Codesido M., Pereira S., Abraham A., Pires R.E., Giordano V. Antibiotic cement-coated plate is a viable and efficient technique for the definitive management of metaphyseal septic nonunions of the femur and tibia. *Rev Col Bras Cir*. 2023;49:e20223060. doi: 10.1590/0100-6991e-20223060-en.
19. Keller D.M., Pizzo R.A., Patel J.N., Viola A., Yoon R.S., Liporace F.A. Use of antibiotic-cement coated locking plates in the setting of periprosthetic infection and infected nonunion. *Injury*. 2022;53(7):2567-2572. doi: 10.1016/j.injury.2022.03.040.
20. Metsemakers W.J., Morgenstern M., McNally M.A., Moriarty T.F., McFadyen I., Scarborough M. et al. Fracture-related infection: A consensus on definition from an international expert group. *Injury*. 2018;49(3):505-510. doi: 10.1016/j.injury.2017.08.040.
21. Afanasyev A.V., Bozhkova S.A., Artyukh V.A. Predictors for Recurrence of Chronic Osteomyelitis Following Long Bones Cavity Defect Replacement with Synthetic Materials. *Traumatology and Orthopedics of Russia*. 2024;30(4):14-24. (In Russian). doi: 10.17816/2311-2905-17591.
22. Azi M.L., Teixeira A.A.A., Cotias R.B., Joeris A., Kfuri M. Induced-Membrane Technique in the Management of Posttraumatic Bone Defects. *JBJS Essent Surg Tech*. 2019;9(2):e22. doi: 10.2106/JBJS.ST.18.00099.
23. Kadhim M., Holmes L. Jr., Gesheff M.G., Conway J.D. Treatment Options for Nonunion With Segmental Bone Defects: Systematic Review and Quantitative Evidence Synthesis. *J Orthop Trauma*. 2017;31(2):111-119. doi: 10.1097/BOT.0000000000000700.
24. Rupp M., Kern S., Walter N., Anastasopoulou L., Schnettler R., Heiss C. et al. Surgical treatment outcome after serial debridement of infected nonunion – A retrospective cohort study. *Eur J Orthop Surg Traumatol*. 2022;32(1):183-189. doi: 10.1007/s00590-021-02930-4.
25. Schmidt A.H., Swiontkowski M.F. Pathophysiology of infections after internal fixation of fractures. *J Am Acad Orthop Surg*. 2000;8(5):285-291. doi: 10.5435/00124635-200009000-00002.
26. Berkes M., Obremskey W.T., Scannell B., Ellington J.K., Hymes R.A., Bosse M. et al. Maintenance of hardware after early postoperative infection following fracture internal fixation. *J Bone Joint Surg Am*. 2010;92(4):823-828. doi: 10.2106/JBJS.I.00470.

27. Zhu Y., Jiang P., He Z., Qian H. Non-contact locking plate: A useful alternative to external fixation in second-stage treatment of post-traumatic tibial osteomyelitis. *Exp Ther Med*. 2024;27(5):230. doi: 10.3892/etm.2024.12518.

28. Savchuk O.P., Tapalski D.V., Zinovkin D.A., Nikolaev V.I., Yarmolenko M.A., Rogachev A.A. Perifocal Soft Tissue Reactions in Response to Contaminated Implants With a Composite Antibacterial Coating: Experimental Study. *Traumatology and Orthopedics of Russia*. 2023;29(1): 36-45. doi: 10.17816/2311-2905-2000.

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