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Rationale for choosing a spacer at the first treatment stage for late deep periprosthetic knee joint infection

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Abstract

Background Periprosthetic infection develops in 0.5 to 5.0 % of cases after knee replacement, which is a social and economic problem. The most common causes of periprosthetic infection are methicillin-resistant staphylococcus aureus (MRSA) (36 %), gram-negative bacteria, and microbial associations. **The study was aimed** at improving the results of the sanitizing stage of revision arthroplasty in patients with periprosthetic infection of the knee joint by a developed long-acting antimicrobial composition and improving the designs of articulating spacers of the knee joint. **Materials and Methods** The treatment results of 121 patients with knee joint periprosthetic infection were analyzed. Nine patients had an early periprosthetic infection and 112 had a late one. Patients in satisfactory condition with stable implant components who had early periprosthetic infection underwent surgical treatment of the purulent focuses, replacement of a polyethylene tibial insert, thorough surgical wound washing using pulse lavage, drainage, and VAC-therapy. Patients with late periprosthetic infection were divided into 3 groups on the basis of the spacer used. An articulating spacer based on the developed antimicrobial composition of prolonged action (RU 191236 patent) was used in 59 patients of the first group. Preformed spacers were implanted in 29 patients of the second group, and 18 patients of the third group got a block-shaped spacer. **Results** An antibacterial anti-adhesive non-toxic composition with a prolonged action based on bone cement with gentamicin and such antiseptics as poviargol, dioxydine, and high-molecular polyvinylpyrrolidone has been developed. All the patients underwent the sanitizing stage of revision arthroplasty, implant removal, and spacer installation. Periprosthetic infection recurrence developed in 3 patients of the first group, 9 patients of the second group and 7 patients of the third one. The average time from the sanitizing stage to the second final stage of revision was 3-6 (4.8 ± 1.9) months. **Discussion** According to scientific data, the impregnation of new antibiotics into bone cement with gentamicin does not improve the antimicrobial effect of a spacer, especially in case of antibiotic-resistant strains. Block-shaped and preformed spacers lead to infection recurrence and complications. Antiseptic impregnation with different mechanisms of action is able to affect antibiotic-resistant bacteria, and the polymer is able to prolong the effect. **Conclusion** The use of articulating spacers for the knee joint, which include an antimicrobial composition, allows preserving the function of the joint and reducing the number of infectious complications, which facilitates the final stage of revision arthroplasty.

Keywords: knee joint, two-stage revision arthroplasty, periprosthetic infection, antimicrobial composition, spacer

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INTRODUCTION

The main indications for knee arthroplasty are idiopathic gonarthrosis and secondary gonarthrosis developed after osteosynthesis of intra-articular fractures. The widespread introduction of total knee arthroplasty (TKA) into orthopedic practice improves joint function and the patient's quality of life [1–5]. However, despite the fact that a significant improvement in the patient's condition is observed after TKA, there is a risk of complications such as periprosthetic joint infection (PJI), which occurs in 0.5 to 5.0 % of cases [6-8].

At the same time, the cost of treating patients who undergo revision interventions due to infectious complications increases by 8 times compared to primary arthroplasty. This is due to the complexity of treatment and the significant costs of the implants used.

The formation of microbial biofilms on the implant surface by weeks 3 to 4 prevents the penetration of antibacterial drugs into the infected joint [7, 9-11]. Frequent PJI recurrence after the first sanitizing stage (SS) of revision arthroplasty are associated with the short-time action of antibiotics (gentamicin and vancomycin) in the composition of the preformed spacer used without taking into account the type of isolated microorganisms and their sensitivity to antimicrobial drugs, as well as the design of the spacer and its installation without considering anatomical changes in the knee area [12-15]. To enhance the antimicrobial effect, compositions containing antibiotics (vancomycin, gentamicin) and antiseptics of different range of action (dioxidin, poviargol) have been used, which allow achieving positive outcomes during the sanitizing stage of revision arthroplasty [1].

Purpose: to evaluate the effectiveness of the sanitizing stage of revision arthroplasty in patients with PJI of the knee joint by developing an antimicrobial composition of prolonged action and improving the designs of articulating spacers of the knee joint.

MATERIALS AND METHODS

In the clinic of purulent osteology of the Mechnikov North-Western State Medical University, 121 patients aged 31 to 78 years were treated for knee PJI; women accounted for 68 % and men for 32 %. The mean age of patients was 64 years (95 %, CI: 38-77).

Among our patients, PJI developed after primary KJ arthroplasty within up to 3 months in 44 cases; from 3 to 8 months in 57 and after 8 months in 20. Inclusion criteria were: PJI of the knee joint after primary and revision arthroplasty with bone defects of the metaepiphyses (AORI types 1–2A). Exclusion criteria: sepsis, patients with significant bone defects of the metaepiphyses (AORI types 2B, 2C, 3A-3C).

Early knee PJI (Tsukayama classification) was observed in 9 patients (7.4 %) [16]. The remaining 112 patients with late PJI were divided into 3 comparison groups. The first group included 59 (52.7 %) patients who received an articulating spacer proposed by us (Patent RU 206668) [17] (Fig. 1.) based on the developed antimicrobial composition (Patent RU 2707734) [1]; the second group included 29 (25.9 %) patients who received a preformed spacer and 18 (16.1 %) patients were included in the third group who received a block-shaped mold spacer due to the presence of bone defects.

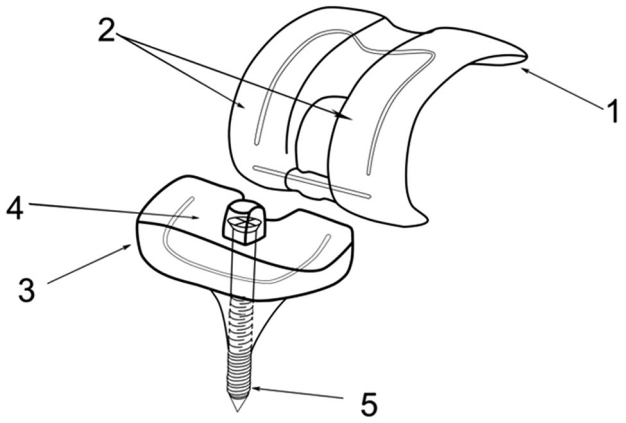

Fig. 1 Articulating spacer of the knee joint: 1 – femoral component; 2 – two conjugated hemispheres; 3 – tibial component; 4 – plateau of the tibial component; 5 – threaded axial rod, made in the form of a screw

Instability of implant components was observed in 23 (19.0 %) patients, including 11 (18.6 %) of the first, 8 (27.6 %) of the second and 4 (22.2 %) of the third groups.

According to the bone defect size in the first group, 26 (44.1 %) patients corresponded to type 1 and 33 (55.9 %) to type 2A; in the second group – 18 (62.1 %) and 11 (37.9 %), and in the third – 6 (33.3 %) and 12 (66.7 %), respectively.

Among our patients, 95 (78.5 %) patients had idiopathic gonarthrosis as an indication for primary arthroplasty; secondary gonarthrosis after intra-articular fractures of the knee joint developed in 26 (21.5 %). In patients of this group, type 2A defect was more common due to the development of necrosis of the distal part of the femur or proximal part of the tibia after intra-articular fractures.

The groups were comparable by the nature of concomitant pathology and the size of bone defects. However, more than half of patients with idiopathic gonarthrosis had a high average body mass index that corresponded to grade II of obesity. Diagnosis of PJI was based on clinical, laboratory, radiological and bacteriological study methods.

Most patients (85 %) complained of knee dysfunction and pain of varying intensity from 9 to 4.5 on the VAS scale. Additional means of support (crutches, canes) were used by 62 % of patients. Signs of local wound infection were edema, hyperemia, hyperthermia in 53 % of patients. Fistulas with purulent discharge were present in 59 (48.7 %) patients: in patients of the first group in 31 (52.6 %) cases, in the second one in 19 (32.2 %), in the third group in 9 (15.2 %) patients.

In all patients, the dynamics of blood parameters (leukocytosis, LII, CRP and ESR) was assessed before and after SS surgery, which were characteristic of the inflammatory process.

One of the most important diagnostic methods for studying PJI is microbiological [15, 18, 19]. Cultures from sinuses were seeded in all patients if any; or the joint was punctured at least three times under ultrasound control. Identification of microorganisms and sensitivity to antibacterial drugs was performed on a VITEK® 2 Compact bacteriological analyzer and a Triple Quad 6500+ LC-MS mass spectrometer.

Gram-positive pathogens (*S. aureus* and *S. epidermidis*) were detected in more than half of the patients, 77 (63.7 %) before SS stage of revision: in the first group in 38 (65.1 %) cases, in the second group in 18 (62.8 %), in the third one in 13 (69.7 %) patients. Methicillin-resistant strains were found in 8 (7.2 %) patients. Microbial associations (*S. aureus, S. epidermidis, P. aeruginosa, E. coli*) were second to be detected in 20 (16.5 %) patients, and gram-negative microorganisms were isolated in 8 (6.6 %) patients.

During a sanitizing operation, 5 tissue biopsies and removed implant components of each patient were taken to identify the type of microflora and for histological examination.

Radiological methods for diagnosing knee joint PJI such as plain radiography, fistulography (in the presence of fistulas) were performed in all patients, and, according to indications; computed tomography to detect bone destruction was used in 38 cases. Plain radiography revealed instability of implant components, bone resorption, especially at the bone-cement interface. Fistulography with double contrast (Verografin and hydrogen peroxide) revealed purulent influxes and transcortical fistulas.

The treatment option was chosen depending on the etiology, the size of bone destruction and soft tissue involvement of the knee joint, the type of microorganisms and the general condition of the patients. In the treatment of patients in a satisfactory condition with early PJI and stable implant components, surgical treatment of the purulent focus, replacement of the liner, thorough washing of the surgical wound using pulse lavage, wound closure and drainage were used.

Among 112 patients with late PJI, 106 (94.6 %) patients underwent two-stage revision arthroplasty. The first step was to remove the implant components, bone cement and other foreign bodies.

We have developed an articulating spacer of the knee joint (Patent RU 206668), which produced customized according to silicone molds and using the antimicrobial composition developed by us that consisted of gentamicin, poviargol, dioxidine, and high molecular weight polyvinylpyrrolidone, which has a prolonged antimicrobial effect (Fig. 1) [17]. In significant destruction of the articular ends of the knee bones and a relatively serious condition of patients, a block-shaped spacer made of bone cement with gentamicin was installed in 16.1 % of cases in order to eliminate the purulent process. Six (5.3 %) patients rejected the second stage of revision arthroplasty and after surgical treatment of the purulent focus underwent arthrodesis of the knee joint with the help of external fixation devices. The nature of the operation in the treatment of deep PJI of the knee joint depended on the type of bone defects, extension of the purulent process, and the condition of the patients. The main methods of surgical treatment are presented in Table 1.

In the postoperative period, a drainage system was installed. Draining term was individual, it was 3-6 days, depending on the amount of discharge. In addition, during this period, all patients underwent treatment of concomitant therapeutic pathology and correction of the immune status and, according to indications, with the use of immunomodulators. Patients with block-shaped spacers were recommended to wear an orthosis and walk with a dosed load on the operated limb. For patients with articulating spacers, wearing an orthosis was recommended only if there were signs of instability in the operated joint, for 4-6 weeks. During this period, they were advised to use crutches, and later a cane. In cases of the absent laxity of the ligamentous apparatus of the knee joint, the patients ambulated without additional support. In cases of preformed spacers, patients were recommended to walk for up to 6 weeks with a dosed load on the operated limb, using a walker or crutches, and then with a cane until the final stage of revision.

Table 1

Surgical interventions at the sanitizing stage of treatment of patients with deep periprosthetic infection of the knee joint

Surgical intervention	Number of cases	
	No	%
Surgical debridement and installation of an articulating spacer	59	48.7
Surgical debridement and installation of a preformed spacer	29	24.0
Surgical debridement and installation of a bock-shaped static spacer	18	14.9
Surgical debridement and insert change and VAC therapy	9	7.4
Knee arthrodesis	6	5.0

Targeted antibiotic therapy was carried out in the postoperative period for up to 6-8 weeks. In gram-positive microflora, Vancomycin and Daptomycin were prescribed. In gram-negative microorganisms, Ceftazidime / Cefoperazone and Ciprofloxacin / Levofloxacin, and for microbial associations Vancomycin and 3rd generation Cephalosporins were prescribed.

In all patients, the function of the knee joint and quality of life were assessed using the WOMAC, VAS, and KOOS scales before the second (final) stage of revision [18, 20, 21].

Statistical processing of the study results was performed using the STATISTICA program for Windows (version 10.0). Descriptive statistics indicators were used, including median (Me) and quartiles (Q_{25}-Q_{75}), Wilcoxon test. Differences between the groups were considered significant at $p < 0.05$.

RESULTS

Out of 106 patients with late PJI of the KJ who underwent two-stage revision, infection recurrence occurred in 19 (17.9 %) cases. Among them, there were 3 patients (15.7 %) of the first, 9 (47.4 %) of the second and 7 (36.9 %) of the third group. Consequently, out of 59 patients of the first group who received an articulating spacer, PJI recurrence was observed only in 3 (5.0 %) patients. In the second group of 29 patients in 9 (31.0 %), and in the third group of 18 patients PJI relapsed in 7 (38.8 %). Thus, the number of recurrences of infection in the first group of patients was statistically significantly less than the number of recurrence in the second and third groups ($p < 0.05$); at the same time, these indicators between the second and third groups were not significant ($p > 0.05$).

Out of 19 cases of recurrence, eradication of the infection was achieved in 12 after repeated debridement operations, and the final stage of revision was performed. Six patients (1 from the first, 2 from the second and 3 from the third groups) after repeated failure underwent arthrodesis of the knee joint with external fixation devices. One patient of the first group with a satisfactory function of the joint, a supportable limb and a stable spacer, and a fistula with a scanty discharge rejected further surgical treatment.

In the postoperative period, patients with recurrent PJI of the knee joint underwent bacteriological examination of the punctats from the joint cavity. In most cases, gram-positive strains were detected in all three groups, which averaged 61.3 %. Methicillin-resistant strains were on average in 9.5 % of cases. Microbial associations averaged 19.3 %, and gram-negative microorganisms were identified in 8 % of cases (Fig. 2).

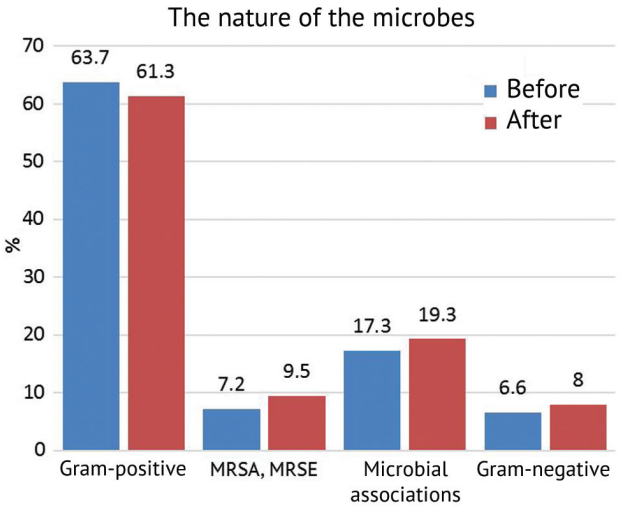

Fig. 2 The nature of the microbes before and after the debridement stage of revision in patients with recurrent PJI

The data presented in Figure 2 indicate that one of the possible causes of PJI recurrence is methicillin-resistant isolates, as well as associations of microbial cells and gram-negative microorganisms.

The effectiveness of the first SS treatment was achieved in 99 (93.4 %) patients: in the first group in 57 (96.6 %), in the second – in 27 (93.1 %), and in the third – in 15 (83.3 %) patients. At the same time, this indicator in the third group is significantly less than in patients of the first and second groups ($p < 0.05$). This difference is explained by the fact that block-shaped spacers were more frequently implanted in patients with PJI after knee bone fractures who underwent osteosynthesis and often in cases after the elimination of osteomyelitis.

The spacer was reinstalled in 2 cases in the first group, in 7 cases in the second group, and in 4 cases in patients of the third group. In one case, the block-shaped spacer was replaced with an articulating one, and, conversely, in 1 patient, the articulating spacer was replaced with a block-shaped one. In all 9 patients with preformed spacers, the latter were replaced by articulating ones, which we proposed on the basis of the developed long-acting antimicrobial composition. Stable remission was achieved in 57 patients in the first group, 27 in the second and 15 in the third group.

The average bed-day after SS revision in the first group was 18 ± 2.6 days, in the second group – 23 ± 8.7 days, in the third – 31 ± 6.2 days. The increase in the rate of bed-day in patients of the second and third groups is associated with the treatment of complications in the postoperative period, which were more common in patients of those groups.

Prior to SS revision, hematological parameters (leukocytosis, LII, ESR, CRP) in patients of all three groups were higher than the reference values. On the 10th day after SS revision, their significant decrease was observed ($p < 0.05$) in the first group, and by the 21st day, the indicators were close to normal. On the contrary, in patients of the second and third groups, they remained elevated, mostly in patients of the third group, where a block-shaped spacer was used. That indirectly could indicate the preservation of the inflammatory process. Three patients of that group had a history of postoperative osteomyelitis of the knee bones that occurred after osteosynthesis of intra-articular fractures of this localization (Table 3).

In the postoperative period, three to six months (mean 4.8 ± 1.9) after antibiotic therapy, 99 (89.3 %) patients underwent definitive knee replacement. Indications for final revision arthroplasty stage were

three negative results of cultures of KJ punctate.

In 97 out of 99 (97.9 %) cases, no signs of recurrence of the infectious process were detected after a year. The effectiveness of the first stage of treatment after one year was 96.6 % in the first group, 89.6 % in the second, and 77.8 % in the third. Non-infectious complications such as spacer instability and its dislocation/subluxation were observed in 3 patients with preformed spacers, in 2 patients with block molds, and in 1 patient with an articulating spacer.

Table 2

Character of surgical interventions in PJI recurrence

Intervention	Patients groups						Total	
	1		2		3			
	No	%	No	%	No	%	No	%
Repeated surgery with reinstallation of spacer	2	15.4	7	53.8	4	30.8	13	100
Spacer removal, arthrodesis	1	16.6	2	33.4	3	50	6	100
Total	3	15.9	9	47.3	7	36.8	19	100

Table 3

Blood counts before and after the debridement stage

Group	Indices	Findings at a definite term, Me (Q_{25}-Q_{75})		
		Before surgery	Day 10 after surgery	Day 21 after surgery
Group 1 (n = 59)	Leukocytosis, 10^9/l	10.3 (6.9-10.8)	8.8 (7.1-9.7)	5.9 (5.3-6.7)
	LII, mm/h	1.9 (1.3-2.9)	1.4 (0.8-1.5)	1.2 (0.4-0.7)
	ESR, mm/h	29.2 (26.7-42.1)	24.1 (15.7-21.9)	10.9 (9.1-11.8)
	СРБ, mg/l	15.9 (13.6-25.1)	13.1 (10.3-18.2)	10.8 (9.4-11.2)
Group 2 (n = 29)	Leukocytosis,10^9/l	10.7 (7.6-11.8)	11.5 (8.9-13.6)	11.0 (9.2-12.0)
	LII, mm/h	2.4 (0.8-3.1)	2.1 (1.8-2.6)	1.7 (1.1-2.3)
	ESR, mm/h	31.2 (27.3-42.1)	24.1 (20.3-28.8)	16.1 (10.2-18.1)
	СРБ, mg/l	24.1 (15.8-28.7)	16.7 (12.9-24.5)	9.7 (8.8-13.1)
Group 3 (n = 18)	Leukocytosis, 10^9/l	12.1 (8.9-13.3)	11.0 (9.9-15.1)	9.9 (8.8-13.7)
	LII, mm/h	2.6 (1.3-2.9)	2.8 (1.7-3.1)	1.9 (1.3-2.2)
	ESR, mm/h	31.3 (24.5-43.2)	24.2 (20.6-26.4)	17.2 (11.9-18.0)
	СРБ, mg/l	23.1 (17.8-28.8)	18.7 (15.5-24.9)	9.8 (8.1-19.8)

DISCUSSION

In recent years, two-stage knee replacement in patients with PJI has been the method of choice and depends on the SS quality in most cases [10, 11, 15, 20, 22]. Comparison of the results of the use of three types of spacers at the first stage of revision arthroplasty during the year revealed the advantage of articulating spacers, which include an antimicrobial composition, over preformed and block-shaped ones. The results of the staged treatment of patients with PJI indicate the effectiveness of the use of all three types of spacers: articulating structures (efficiency was 96.6 %), preformed (89.6 %) and block-shaped (77.8 %).

The obtained indicators coincide with the results of publications by other authors, which demonstrate the advantage of the articulating spacers over the static ones. Articulating spacers allow maintaining mobility in the joint between the two stages. Moreover, the number of infectious and non-infectious complications decreases [9, 10, 11]. The use of articulating spacers simplifies the final revision arthroplasty and improves the function of the replaced joint [11, 10].

The use of the antimicrobial composition developed by us provides an increase in the action of gentamicin or vancomycin, which are impregnated in the bone cement, against isolates of microorganisms resistant to it, while the use of preformed and block-shaped spacers causes an increase in the number of recurrence, lengthens the treatment time due to a short antimicrobial effect of the spacers made from bone cement with gentamicin [1, 18, 26].

CONCLUSIONS

A personalized approach to the implementation of the sanitizing stage of revision knee arthroplasty due to PJI can achieve positive outcomes in 97.9 % of cases with a satisfactory restoration of limb function if the microbial landscape, bone defects, spacer choice and the patient's condition are considered.

In PJI recurrence, the use of spacers, which include the proposed antimicrobial composition, is indicated, and in the case of the second or third failure, arthrodesis of the knee joint is indicated.

The use of articulating spacers impregnated with the proposed antimicrobial composition enables to eliminate the infection and maintain limb mobility and support, which increases efficiency and facilitates the final revision stage.

REFERENCES

1. Afinogenova A.G., Afinogenov G.E., Linnik S.A., [et al.]. *Antimicrobial composition for spacer formation*. Patent of the Russian Federation No. 2707734; 2019. (In Russ.)
2. Minasov B.S., Yakupov R.R., Hairov T.E., Gafarov I.R., Sirodzhov K.K., Karimov K.K., Filimonov G., Trubin A.R. features hip arthroplasty after reductionreconstructive interventions of proximal femur. *Research and Practical Medicine Journal*. 2015;2(3):10-18. (In Russ.) doi: 10.17709/2409-2231-2015-2-3-10-18
3. Kornilov N.N., Kuliaba T.A. *Arthroplasty of the knee*. SPb.: RNIITO im. R.R. Vredena; 2012:168-169.
4. Preobrazhensky P.M., Bozhkova S.A., Kazemirsky A.V., Goncharov M.Yu. [Results of Two-Stage Reimplantation in Patients with Periprosthetic Joint Infection after Total knee Arthroplast]. *Travmatologiya i ortopediya Rossii* [Traumatology and Orthopedics of Russia]. 2017;23(1):98-107. (in Russ.). doi: 10.21823/2311-2905-2017-23-1-98-10
5. Revisionary total arthroplasty of knee joint: general review. In: Revisionary arthroplasty of knee joint: guidance for doctors. Ed. by D.G. Gakofsky, E.K. Hedley; transl. by N.V. Zagorodniy. Moscow: GEOTAR-Media, 2015. 320 p.
6. Zagorodniy N. V., Dzhalilov S. O., Skipenko T. O., Voroshilov A. S. The problem of complications after knee replacement. *Modern Science: actual problems of theory and practice. Series: Natural & Technical Sciences*. 2019;(1):88-91. (In Russ.)
7. Proceedings of the Second International Consensus Meeting on Musculockeletal Infection. Translation by R.M. Tikhilov et al. St. Petersburg, 2019. 314 p. (In Russ.)
8. Preobrazhenskii P.M., Kazemirskii A.V., Goncharov M.Iu. Current views on diagnosing and treatment of patients with periprosthetic infection after the knee arthroplasty. *Genij Ortopedii*. 2016;(3):94-104. (In Russ.) doi: 10.18019/1028-4427-2016-3-94-104
9. Bozhkova S.A., Kasimova A.R., Tikhilov R.M., Polyakova E.M., Rukina A.N., Shabanova V.V., Liventsov V.N. Adverse trends in the etiology of orthopedic infection: results of 6-year monitoring of the structure and resistance of leading pathogens. *Travmatologiya i ortopediya Rossii* [Traumatology and orthopedics of Russia]. 2018;24(4):20-31. doi: 10.21823/2311-2905-2018-24-4-20-31
10. Romanò C.L., Bozhkova S., Artyukh V., Romanò D., Tsuchiya H., Drago L. Local Antibacterial Implant Protection in Orthopedics and Trauma: What's New? *Travmatologiya i ortopediya Rossii* [Traumatology and orthopedics of Russia]. 2019;25(4):64-74. doi: 10.21823/2311-2905-2019-25-4-64-74
11. Bozhkova A., Bogdanova T.Ya., Krasnova M.V., Anisimova L.O., Netyl'ko G.I., Rukina A.N., Bo Lyu. Experimental and clinical study of phenotypic features of S. Epidermidis strains and their role in theemergenceand development of implant-associated infection after orthopaedic surgerys. *Travmatologiya i ortopediya Rossii* [Traumatology and orthopedics of Russia]. 2014;20(2):68-77. (In Russ.)
12. Kornilov N.N., Kulyaba T.A., Fil A.S., Muravyeva Y.V. Data of knee arthroplasty register of Vreden Russian Research Institute of Traumatology and Orthopedics for period 2011-2013. *Travmatologiya i ortopediya Rossii* [Traumatology and orthopedics of Russia]. 2015;21(1):136-151. (In Russ.)
13. Parvizi J, Gehrke T, Chen AF. Proceedings of the International Consensus on Periprosthetic Joint Infection. *Bone Joint J*. 2013;95-B(11):1450-1452. doi: 10.1302/0301-620X.95B11.33135
14. Patel A, Calfee RP, Plante M, Fischer SA, Arcand N, Born C. Methicillin-resistant Staphylococcus aureus in orthopaedic surgery. *J Bone Joint Surg Br*. 2008;90(11):1401-1406. doi: 10.1302/0301-620X.90B11.20771
15. Parvizi J, Pawasarat IM, Azzam KA, Joshi A, Hansen EN, Bozic KJ. Periprosthetic joint infection: the economic impact of methicillin-resistant infections. *J Arthroplasty*. 2010;25(6 Suppl):103-7. doi: 10.1016/j.arth.2010.04.011
16. Tsukayama DT, Goldberg VM, Kyle R. Diagnosis and management of infection after total knee arthroplasty. *J Bone Joint Surg Am*. 2003;85-A Suppl 1:S75-80. doi: 10.2106/00004623-200300001-00014
17. Linnik S.A., Gruzinskaya T.R., Tsololo Ya.B., Karagezov G., Kravtsov D.V., Khaidarov V.M., Kucheev I.O., Zakharchenko A.I., Ismael A. Knee joint spacer. Patent of the Russian Federation No. 206668; 2021. (In Russ.)
18. Linnik S.A., Afinogenov G.E., Afinogenova A.G., Kvinikadze G.E., Kravtsov D.V., Klushin N.M., Maday D.Yu., Khaidarov V.M., Karagezov G., Vorokov A.A. The choice of a spacer at the first stage of treatment for late deep periprosthetic hip joint infection. *Genij Ortopedii*, 2021;27(5):548-554. doi: 10.18019/1028-4427-2021-27-5-548-554
19. Achievements of Russian traumatology and orthopedics. Materials of the XI All-Russian Congress of Traumatologists and Orthopedists: in 3 volumes. St. Petersburg. 2018. (In Russ.)
20. Murylev V.Yu., Kukovenko G.a., elizarov p.M., ivanenko l.R., Sorokina G.l., Rukin Ya.a., alekseev S.S., Germanov V.G. The First-Stage Treatment Algorithm for Deep Infected Total Hip Arthroplasty. *Travmatologiya i ortopediya Rossii* [Traumatology and orthopedics of Russia]. 2018;24(4):95-104. doi: 10.21823/2311-2905-2018-24-4-95-104
21. Prokopiev N.Ya., Malchevsky V.A., Kozel N.P. Gonarthrosis: international systems for evaluating the results of rehabilitation measures (literature review). *Vestnik YUUrGU. Seriya Obrazovaniye, zdravookhraneniye, fizicheskaya kul'tura* [Bulletin of SUSU. Series Education, health care, physical culture]. 2007;(2):55-57. (In Russ.)
22. Ermakov A.M., Kliushin N.M., Ababkov Iu.V., Triapichnikov A.S., Koiushkov A.N. Efficiency of two-stage revision arthroplasty in management of periprosthetic knee and hip joint infection. *Genij Ortopedii*. 2018;24(3):321-326. doi: 10.18019/1028-4427-2018-24-3-321-326
23. Liventsov V.N., Bozhkova S.A., Kochish A.Yu., Artyukh V.A., Razorenov V.L., Labutin D.V. Difficult-To-Treat Periprosthetic Hip Infection: Outcomes of Debridment. *Travmatologiya i ortopediya Rossii* [Traumatology and Orthopedics of Russia]. 2019;25(4):88-97. doi: 10.21823/2311-2905-2019-25-4-88-97
24. Mackinnon J, Young S, Baily RA. The St Georg sledge for unicompartmental replacement of the knee. A prospective study of 115 cases. *J Bone Joint Surg Br*. 1988;70(2):217-223. doi: 10.1302/0301-620X.70B2.3346291

25. Pavlov V.V., Petrova N.V., Sheraliev T.U. Two-Stage Treatment of Periprostetic Infection: Mid-Term Results. *Travmatologiya i ortopediya Rossii* [Traumatology and Orthopedics of Russia]. 2019;25(4):109-116. (In Russ.) doi: 10.21823/2311-2905-2019-25-4-109-116
26. Afinogenova A.G., Kvinikadze G.E., Spiridonova A.A., Afinogenov G.E., Linnik S.A., Maday D.Yu. Microbiological evaluation of the compositions based on bone cement with prolonged antimicrobial action against gentamicin-resistant Staphylococcus epidermidis. *Problemy meditsinskoi mikologii* [Problems in Medical Mycology]. 2018;20(4):49-54. (In Russ.)

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