JOURNAL OF CLINICAL MEDICINE OF KAZAKHSTAN (E-ISSN 2313-1519)
Original Article DOI: https://doi.org/10.23950/jcmk/14682

Comparative Evaluation of the Use of the Double Cementation Method and Modular Metal Augments for the Replacement of Bone Defects in Revision Knee Arthroplasty

Serik Balgazarov[1], Aleksey Belokobylov[2], Arman Batpen[3], Zhanatay Ramazanov[1], Denis Rimashevskiy[4], Ruslan Abilov[1], Alexey Dolgov[5], Artyom Moroshan[1], Aliya Atepileva[6], Yersultan Alzhanov[5], Alexandr Kriklivyy[6]

[1]Department of Trauma Consequences and Combustiology, National Scientific Center of Traumatology and Orthopedics named after Academician N.D. Batpenov, Astana, Republic of Kazakhstan
[2]Republican Center for Endoprosthetics, National Scientific Center of Traumatology and Orthopedics named after Academician N.D. Batpenov, Astana, Republic of Kazakhstan
[3]Scientific Center for Applied Research, National Scientific Center of Traumatology and Orthopedics named after Academician N.D. Batpenov, Astana, Republic of Kazakhstan
[4]Peoples Friendship University of Russia, Trauma and Orthopedic department, Moscow, Russia.
[5]Postgraduate Education Department, National Scientific Center of Traumatology and Orthopedics named after Academician N.D. Batpenov, Astana, Republic of Kazakhstan
[6]Institute of Life Sciences, Karaganda Medical University, Karaganda, Republic of Kazakhstan

Received: 2024-02-28.
Accepted: 2024-06-06

J Clin Med Kaz 2024; 21(3): 43-48

Corresponding author:
Alexandr Kriklivyy.
E-mail: kriklivyialexandr@gmail.com.
ORCID: 0000-0002-5675-0471.

Abstract

Background: During revision arthroplasty of the knee joint, defects of the femur and tibia may occur. One common method to replace these defects is the use of modular metal augments, but this method has certain disadvantages. Therefore, we suggest using the double cementation method.

Objective: This study aims to compare the effectiveness of the double cementation method and modular metal augments in replacing bone defects during revision knee replacement.

Material and Methods: We examined 150 patients diagnosed with periprosthetic infection who were treated at the National Scientific Center of Traumatology and Orthopedics named after Academician N.D.Batpenov from 2021 to 2024. For a randomized study, 36 patients were selected, divided into 2 groups of 18 people. In the main group, the double cementing method was used to replace defects of the femur and tibia during revision knee arthroplasty; in the control group, metal augments were used. A follow-up examination was conducted on all patients one year after the surgery.

Results: No significant differences were found between the groups in terms of the number of hospital beds spent (p = 0.11), bed days spent in the intensive care unit after surgery (p = 0.44), duration of surgery (p = 0.18), amount of intraoperative blood loss (p = 0.18), knee joint function according to the Knee Society Score (p = 0.23) and Oxford Knee Score (p = 0.09). In the main group, signs of radiographic instability were detected in 1 case (5.6%), in the control group, there were revealed 5 (27.8%) cases. The number of cases of periprosthetic infection in the main group was 1 case (5.6%), in the control group were 3 cases (16.7%).

Conclusion: The double cementation method is less likely to cause radiography lines of illumination at the cement/bone boundary and may be recommended for high-risk postoperative infections. Additionally, it may be more cost-effective than using metal augments.

Keywords: double cementation method, modular metal augments, revision arthroplasty, knee joint, bone defects.

Introduction

The issue of revision interventions in patients with knee replacement remains highly relevant due to the annual increase in their number [1,2]. Statistical collections indicate a rise in the number of revision endoprostheses of the knee joint in the Republic of Kazakhstan. In 2013, there were 26 cases of revision arthroplasty, while in 2020, the number increased to

175 people [3]. Audit operations are observed in many countries worldwide. In Germany, 13,961 revision arthroplasties of the knee joint were performed in 2021, with infectious complications accounting for 14.5% to 15.0% of all revisions between 2019 and 2021, according to the German Registry of Endoprosthetics [4-7]. In Australia, Ackerman et al. reported 43,188 revision knee replacement surgeries between 2007 and 2017 [8].

During knee joint revision arthroplasty, defects in the femur and tibia are common [9]. Proper positioning and stability of the endoprosthesis depend on the replacement of these defects [10]. Currently, various methods are used to replace bone defects during revision knee replacement, including cementing, cementing with reinforced screws, factory cement spacers with augments, modular metal augments, metaphysical bushings with pressed coating of porous titanium and structural cones of porous tantalum, autologous bone grafting, allogeneic bone grafting, impact bone grafting, structural bone allografts, mega-endoprostheses, or individual endoprostheses [9, 11-13].

The most common method for replacing defects is through modular metal augmentation. However, this method has certain disadvantages, such as metal abrasion and corrosion, as well as loosening of endoprosthesis components [11-16]. Additionally, noncement-based methods for replacing bone defects in the knee have the main problem of being unable to locally deliver antibacterial drugs to the infected joint or to those at high risk of postoperative infection [17]. The developed method of double cementation can serve as an alternative to the use of metal augments, avoiding their disadvantages.

The purpose of this study was to compare the use of the developed double cementation method with the traditional method of replacing defects with modular metal augments during revision arthroplasty of the knee joint.

Hypotheses of the study: the use of the double cementating method for replacing defects of the femur and tibia during revision knee joint replacement is equally effective with the traditional method using metal augments.

Materials And Methods

Ethics

The study was conducted in accordance with international ethical standards and principles of the Helsinki Declaration and was approved by the Local Ethics Commission of our hospital (Protocol No. 4 of October 19, 2021). All patients participating in the study signed an informed consent to be included in the study.

Main characteristics of the compared groups

The total number of examined patients was 150 people. A randomized clinical trial selected 36 patients who were treated at the of our center, according to the criteria for inclusion in the study. The criteria for inclusion in the study were: Patients with aseptic instability of the knee arthroplasty, a history of surgery for knee replacement, the patient's age between 40 and 79, the patient's consent to the treatment, the absence of severe concomitant diseases affecting the results of treatment. The exclusion criteria were: The age of patients under 40 and over 79, periprosthetic infection, hemiparesis on the side of the proposed operation, neoplasms of other localizations with or without metastases, as well as the patient's' refusal of surgery.

Patients were included in the study after prior consultation with related specialists.

A main group and a control group of 18 patients each were formed. The distribution into groups was carried out using the sealed envelope method.

In the main group, patients underwent revision knee arthroplasty using the double cementation method. In the control group, patients underwent revision knee arthroplasty using the standard method of defect replacement – the use of modular metal augments.

Comparison and comparability in the two formed groups were carried out according to the following criteria: gender, age, size of defects, the number of revision operations performed on this joint, including the revision performed as part of the study.

A follow-up examination of all patients was performed 1 year after surgery. The following indicators were evaluated: the number of hospital beds; the number of bed days spent in the intensive care unit; the duration of the operation; the amount of intraoperative blood loss; assessment of knee joint function, radiographic stability, the number of cases of periprosthetic infection. Knee joint function was assessed using the Knee Society Score scale (KSS) and the Oxford Knee Score questionnaire (OKS). The evaluation of the radiological stability of the knee joint was carried out using the Modern Knee Society Radiographic Evaluation System.

Surgical techniques

Main group – the double cementation method. The double cementation method is a method of revision knee arthroplasty, in which polymerized bone cement acts as Augments to replace defects in the femur and tibia. During revision knee arthroplasty, after removal of unstable components of the knee arthroplasty and careful debridement of tissues, the size of defects in the femur and tibia is assessed. Next, an endoprosthesis of the required size is selected and the first layer of bone cement is applied to the components of the endoprosthesis, acting as augments. Upon completion of polymerization of the first layer of bone cement, a second layer of bone cement is applied on top of the endoprosthesis and bone cement augments and the components of the endoprosthesis are installed. After the postoperative wound is sutured in layers [18]. The process of applying the double cementation method is also shown in Figure 1. An example of preoperative and postoperative knee radiographs is shown in Figure 2.

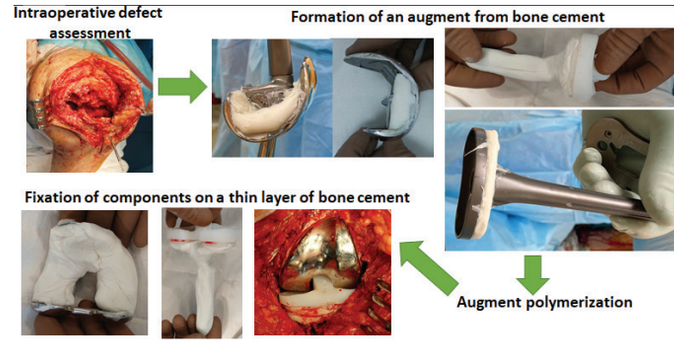

Figure 1 - The process of forming cement augments on endoprosthesis components and their subsequent fixation on a thin layer of bone cement (the order of the process is indicated by arrows)

Control group – Modular metal augments. Modular metal augments for this period of time are presented in the form of metal blocks and wedges [11]. After removal of unstable components of the knee arthroplasty and careful debridement of tissues, the size of the defect of the femur and tibia is assessed. After selecting the required size of the endoprosthesis, the necessary metal augments are fitted (Figure 3).

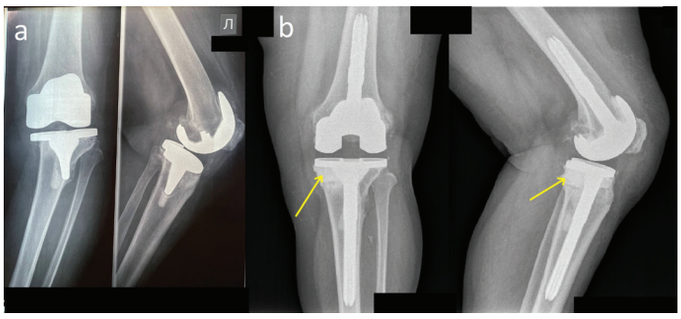

Figure 2 - Radiographs of the knee joint (a) - preoperatively, instability of both endoprosthesis components and migration of the tibial component are identified; (b) - postoperatively, the fitted endoprosthesis and cement augmentation are identified (indicated by arrows)

Next, the components of the endoprosthesis, together with augments, are installed in the bone on a thin layer of bone cement. After the postoperative wound is sutured in layers.

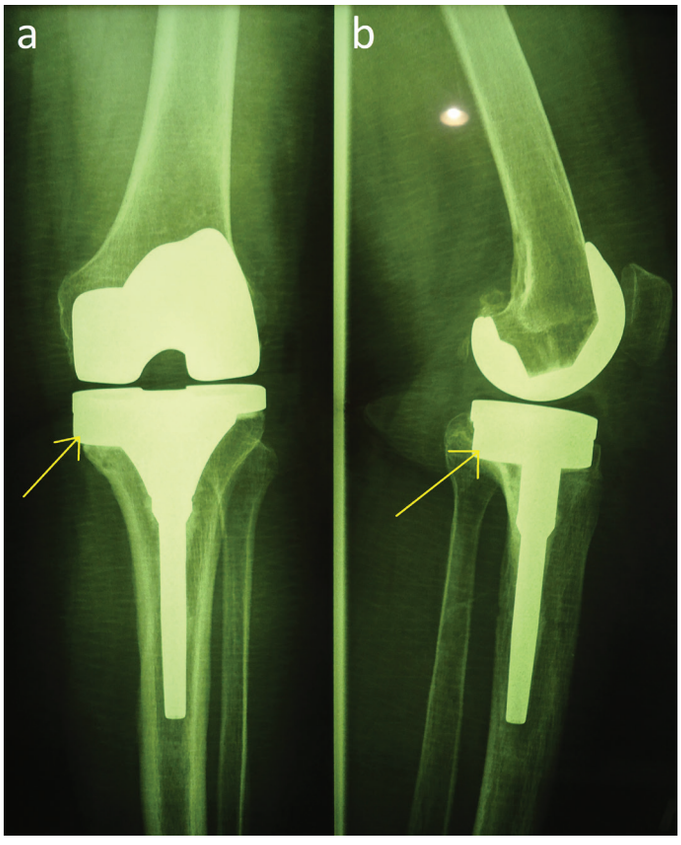

Figure 3 - Radiographs of the knee joint in frontal (a) and lateral (b) projections after revision endoprosthesis with the standard technique - use of modular metal augmentation (indicated by arrows)

Statistical analysis

Descriptive statistical methods were used for processing the statistical data. The nonparametric Mann-Whitney criterion was used to determine the significance of quantitative differences between the groups. To assess the significance of qualitative parameters when comparing treatment results in both groups, we used a nonparametric method of calculating Pearson's criterion $\chi 2$ (chi-squared). Differences between the groups were considered significant at $p<0.05$.

The statistical data was processed using Microsoft Excel from the Microsoft Office 2016 package and Statistica 12.0 software for statistical analysis developed by Statsoft [19].

Results

In the both groups, there were 4 men (22.2%) and 14 women (77.8%).

The average age of patients in the main group was 63.6 years ($\sigma = 9.7$; CI = 58.68 – 68.32), and in the comparison group 61.4 years ($\sigma = 5.4$; CI = 58.71 – 64.09).

The sizes of defects in the articular surfaces of the femur and tibia were estimated according to the Anderson Orthopaedic Research Institute (1997) scale [20]. In the main group, bone defects were distributed as follows: F1 – 4 (22.2%), F2A – 6 (33.3%), F2B – 8 (44.4%), T2A – 7 (38.9%), T2B – 11 (61.1%). In the control group, bone defects were distributed as follows: F1 – 5 (27.8%), F2A – 5 (27.8%), F2B – 8 (44.4%), T2A – 5 (27.8%), T2B – 13 (72.2%).

The average number of revision operations performed on the knee joint, including the revision performed as part of the study, in the main group was 1.5 ($\sigma = 0.6$; CI = 1.19 – 1.81) while in the control group – 2.2 ($\sigma = 0.7$; CI = 1.82 – 2.52).

Despite the presence of a small difference in age and size of defects between the two groups, no statistically significant differences were found. Statistically significant differences were revealed in the number of revision operations performed on the knee joint, including the revision performed as part of the study. In the group of metal modular augments, there were on average 0.7 more revisions than in the double cementation group ($p = 0.02$).

A comparison of the formed groups is also shown in Table 1.

The average number of hospital bed days in the main group was 14.7 days ($\sigma = 3.2$; CI = 13.13 – 16.31), and in the comparison group 18.1 days ($\sigma = 6.3$; CI = 14.95 – 21.17).The average number of bed days spent in the intensive care unit in the main group was 0.8 days ($\sigma=0.4$; CI = 0.57 – 0.99), in the comparison group also 0.8 days ($\sigma=0.9$ CI = 0.37 – 1.29).There was no statistically significant difference in the average number of bed days spent in the hospital ($p = 0.11$) or in the intensive care unit ($p = 0.44$) in the groups.

When comparing the time spent on the operation, the following results were obtained: in the main group, the average operation time was 97 minutes ($\sigma= 18.6$; CI = 87.75 – 106.25), in the comparison group 97.8 minutes ($\sigma= 19.4$; CI = 87.75 – 106.25). There was no statistically significant difference in the duration of the operation in these groups ($p = 0.18$). Also, when comparing the number of blood loss in the general group, there was no statistically significant difference ($p = 0.18$). The total increase in the main group averaged 339.5 ml ($\sigma= 205.9$; CI = 237.09 – 441.86), and in the control group 512.5 ml ($\sigma= 364.1$; CI = 331.40 – 693.60).

Comparative results of knee and functional scores in the both groups on the Knee Society Score and Oxford Knee Score scale 1 year after surgery are presented in Table 2. The average number of knee scores on the Knee Society Score scale in the main group was 85.6 ($\sigma= 10.3$; CI = 80.47 – 90.69), in the control group 81.3 ($\sigma= 12$; CI = 75.33 – 87.30).The average number of functional scores on the Knee Society Score scale in the main group was 80.6 ($\sigma= 14.4$; CI = 73.37 – 87.74), and in the control group 73.7 ($\sigma= 17.4$; CI = 65,04 – 82,33).The average number of points on the Oxford Knee Score scale in the main group was 17.8 ($\sigma= 8.6$; CI = 13.50 – 22.08), in the control group 22.3 ($\sigma=11.7$; CI = 16.43 – 28.07).The assessment showed that there were no statistically significant differences in scores on the presented scales between the group of the double cementation method and the group of modular metal augments.

An assessment of the radiographic stability of the endoprosthesis components at the bone/cement boundary

Table 1 Comparison of the formed groups

Groups	Knee Society Score Knee Scores	Knee Society Score Functional Scores	Oxford Knee Score
Main group	85.6 ±10.3 (CI = 80.47 – 90.69)	**80.6** ±14.4 (CI = 73.37 – 87.74)	**18.1** ±8.8 (CI = 13.75 – 22.47)
Control group	**81,2** ±12,4 **(CI = 75.07 – 87.38)**	**73.7** ±17.4 (CI = 65.04 – 82.33)	**22.7** ±11.8 (CI = 16.79 – 28.58)
p-value	**0.23**	**0.18**	**0.09**
Mann-Whitney U-test	**U = 123.5**	**U = 119.5**	**U = 108.5**

Table 2 Comparative results of evaluation of knee joint function 1 year after surgery

Comparison criteria	Double cementation method	Modular metal augments
Number of men	4 (22.2%)	4 (22.2%)
Number of women	14 (77.8%)	14 (77.8%)
Patients' average age	63.6 years (σ = 9,7; CI = 58.68 – 68.32)	61.4 years (σ = 5.4; CI = 58.71 – 64.09).
The size of femur defects	F1 – 4 (22.2%), F2A – 6 (33.3%), F2B – 8 (44.4%)	F1 – 5 (27.8%), F2A – 5 (27.8%), F2B – 8 (44.4%)
The size of tibial defects	T2A – 7 (38.9%), T2B – 11 (61.1%)	T2A – 5 (27.8%), T2B – 13 (72.2%)
The average number of postponed revision operations	1.5 (σ = 0.6; CI = 1.19 – 1.81)	2,2 (σ = 0.7; CI = 1.82 – 2.52)

showed that in the main group, signs of radiographic instability were detected in 1 case (5.6%). In the control group, there were revealed 5 (27.8%) cases of radiographic instability of the endoprosthesis components in the area of installation of metal augments.

The number of cases of periprosthetic infection in the main group was 1 case (5.6%), in the control group were 3 cases (16.7%) (Figure 4). The Mann-Whitney U-test score showed that there were no statistically significant differences between the groups in the number of cases of periprosthetic infection (p = 0.29).

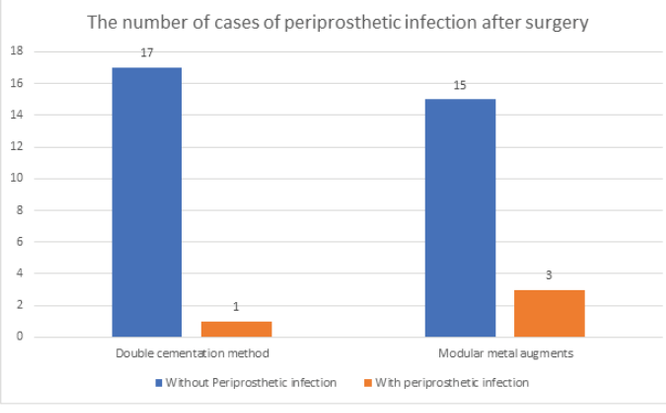

Figure 4 - Graph of the number of cases of periprosthetic infection in both groups

Discussion

According to several authors, modular metal augments can provide a more durable revision for bone defects up to 20 mm or type 2 and 3 according to AORI [9,11,21,22]. Huten et al. concluded that the use of metal augments is advisable for elderly patients and those with low motor activity [9,23].

Patel et al. also described the use of metal augments for AORI type 2 defects in their study. The study analyzed 102 patients who underwent revision knee replacement over an 11-year follow-up period. According to researchers, endoprostheses had a 92% survival rate without significant complications [11].

However, some studies have shown the drawbacks of using metal augments. Similarly, Innocenti et al. noted that the use of solid metal augments can increase the load on the adjacent bone, potentially decreasing the endoprosthesis characteristics [15]. In a study by Lee et al. on 37 patients (39 knee joints), it was concluded that the use of metal augments can lead to instability of the endoprosthesis components, which may result in the need for revision [14]. Panegrossi and co-authors conducted a study which found that the use of metal fragments can cause corrosion and abrasion of metal [16].

Studies by Cnudde et al. and Kumar et al. describe the application of a new layer to an old layer of bone cement using the 'cement-in-cement' technique. This involves removing the femoral component of the hip arthroplasty from a well-fixed femoral cement mantle. Afterwards, a new cement foot is installed in the original mantle. According to the assessment conducted by the authors, there was no significant difference in the survival of the leg and the risk of repeated revision for all reasons. The authors also noted that this technique shows promising results and has several advantages: reduced surgical intervention time, less blood loss during surgery, less bone loss, and reduced financial costs for the treated case [24, 25].

The fixation of factory cement augments of the tibia, in conjunction with factory cement spacers of the knee joint, implies the fixation of these components on bone cement. This procedure is prescribed in the operating instructions. The presented type of augment is approved for use by the Food and Drug Administration (FDA) [13].

The described report of the case of Balgazarov and co-authors showed successful long-term results (4.5 years) the use of the double cementation method to replace femoral and tibial defects against the background of recurrent periprosthetic knee infection shows the possibility of using this method during the treatment of periprosthetic infection and at high risk of postoperative infection [26].

A similar method was also described in the report of the Gililland and co-authors' case. The authors used an additional layer of bone cement in order to adjust the rotation of the femoral component of the endoprosthesis and achieve the correct positioning of both components of the endoprosthesis [27].

The main advantage of bone cement is that it can act as a means of delivering an antibacterial drug for local antibiotic

therapy. In their study, Lawrie and co-authors showed that the optimal method of local exposure to microorganisms is the addition of tobramycin and vancomycin to bone cement containing gentamicin [28].

A separate point in revision arthroplasty is to highlight the economic burden of these surgical interventions. According to a study by Fang and co-authors, revision knee arthroplasty requires more hospital resources and costs compared to primary arthroplasty [29]. Steele and co-authors described in their study that the cost of revision arthroplasty depends on the number and type of replacement components of the endoprosthesis [30]. Reducing the use of modular metal augments and the use of bone cement augments can significantly reduce the cost of revision knee replacement.

The negative aspects of our study are an insufficiently long follow-up period to confirm positive long-term treatment results and assess the risk of periprosthetic knee infection, the need to expand the sample of patients and the need to evaluate the use of the method for type 3 AORI defects.

Conclusion

A comparative assessment of the use of the double cementation method and modular metal augments during revision knee replacement revealed no significant differences in the number of hospital beds spent, bed days spent in the intensive care unit after surgery, in the duration of surgery, in the amount of intraoperative blood loss, in knee joint function according to the Knee Society Score and Oxford Knee Score. The developed method of double cementation can be used for revision knee replacement along with modular metal augments. The use of the double cementation method may be recommended at a high risk of postoperative infection, since bone cement can act as a method of delivering an antibacterial drug for local infection prevention. Also, the use of bone cement may be more economically advantageous than the use of modular metal augments.

Author Contributions: Conceptualization, S.B.; methodology, D.R.; validation, A.B; formal analysis, A.K.; investigation, R.A.; resources, A.B.; data curation, A.A.; writing – original draft preparation, Ye.A. and A.M.; writing – review and editing, Zh.R., A.D., A.K.; visualization, S.B.; supervision, A.B.; project administration, A.B. All authors have read and agreed to the published version of the manuscript.

Disclosures: There is no conflict of interest for all authors.

Acknowledgements: None.

Funding: The double cementation method was investigated within the framework of the scientific and technical program of program-targeted financing of the Ministry of Health of the Republic of Kazakhstan (№BR11065157).

References

1. Cram P, Lu X, Kates SL, Singh JA, Li Y, Wolf BR. Total knee arthroplasty volume, utilization, and outcomes among Medicare beneficiaries, 1991-2010. *JAMA*. 2012 Sep 26;308(12):1227-36. https://doi.org/10.1001/2012.jama.11153
2. Nham FH, Patel I, Zalikha AK, El-Othmani MM. Epidemiology of primary and revision total knee arthroplasty: analysis of demographics, comorbidities and outcomes from the national inpatient sample. *Arthroplasty*. 2023 Apr 2;5(1):18. https://doi.org/10.1186/s42836-023-00175-6
3. Bermagambetova G.N., Dzhaksybekova G.K. Osnovnye pokazateli travmatologo-ortopedicheskoj pomoshhi naseleniju Respubliki Kazahstan v 2020 godu. 20 let Nacional'nomu nauchnomu centru travmatologii i ortopedii imeni akademika Batpenova N.D. [in Russian]. Nur -Sultan: tipografija «Print Centr Julija», Kostanaj, 2021 – 85 p.
4. Grimberg A, Lützner J, Melsheimer O, Morlock M, Steinbrück A. German Arthroplasty Registry (Endoprothesenregister Deutschland - EPRD) - Annual Report 2022. Berlin: EPRD Deutsche Endoprothesenregister gGmbH; 2023. 172 p.
5. Grimberg A, Jansson V., Lützner J, Melsheimer O, Morlock M, Steinbrück A. German Arthroplasty Registry (Endoprothesenregister Deutschland - EPRD) - Annual Report 2021. Berlin: EPRD Deutsche Endoprothesenregister gGmbH; 2022. 189 p.
6. Grimberg A, Jansson V., Lützner J, Melsheimer O, Morlock M, Steinbrück A. German Arthroplasty Registry (Endoprothesenregister Deutschland - EPRD) - Annual Report 2020. Berlin: EPRD Deutsche Endoprothesenregister gGmbH; 2021. 127 p.
7. Grimberg A, Jansson V., Lützner J, Melsheimer O, Steinbrück A. German Arthroplasty Registry (Endoprothesenregister Deutschland - EPRD) - Annual Report 2019. Berlin: EPRD Deutsche Endoprothesenregister gGmbH; 2020. 118 p.
8. Ackerman IN, Busija L, Lorimer M, de Steiger R, Graves SE. Monitoring the lifetime risk of revision knee arthroplasty over a decade : a population-level analysis of Australian national registry data. *Bone Joint J*. 2022 May;104-B(5):613-619. https://doi.org/10.1302/0301-620X.104B5.BJJ-2021-1219.R1
9. Qiu YY, Yan CH, Chiu KY, Ng FY. Review article: Treatments for bone loss in revision total knee arthroplasty. *J Orthop Surg (Hong Kong)*. 2012 Apr;20(1):78-86. https://doi.org/10.1177/230949901202000116
10. Mozella AP, Cobra HAAB. Bone Defects in Revision Total Knee Arthroplasty. *Rev Bras Ortop (Sao Paulo)*. 2021 Apr;56(2):138-146. https://doi.org/10.1055/s-0040-1713392
11. Lei PF, Hu RY, Hu YH. Bone Defects in Revision Total Knee Arthroplasty and Management. *Orthop Surg*. 2019 Feb;11(1):15-24. https://doi.org/10.1111/os.12425
12. Ponzio DY, Austin MS. Metaphyseal bone loss in revision knee arthroplasty. *Curr Rev Musculoskelet Med*. 2015 Dec;8(4):361-7. https://doi.org/10.1007/s12178-015-9291-x
13. Lachiewicz PF, Wellman SS, Peterson JR. Antibiotic Cement Spacers for Infected Total Knee Arthroplasties. *J Am Acad Orthop Surg*. 2020 Mar 1;28(5):180-188. https://doi.org/10.5435/JAAOS-D-19-00332
14. Lee KJ, Bae KC, Cho CH, Son ES, Jung JW. Radiological Stability after Revision of Infected Total Knee Arthroplasty Using Modular Metal Augments. *Knee Surg Relat Res*. 2016 Mar;28(1):55-61. https://doi.org/10.5792/ksrr.2016.28.1.55
15. Innocenti B, Fekete G, Pianigiani S. Biomechanical Analysis of Augments in Revision Total Knee Arthroplasty. *J Biomech Eng*. 2018 Nov 1;140(11):111006. https://doi.org/10.1115/1.4040966
16. Panegrossi G, Ceretti M, Papalia M, Casella F, Favetti F, Falez F. Bone loss management in total knee revision surgery. *Int Orthop*. 2014 Feb;38(2):419-27. https://doi.org/10.1007/s00264-013-2262-1

17. Berger C, Parai C, Tillander J, Bergh P, Wennergren D, Brisby H. High Risk for Persistent Peri-Prosthetic Infection and Amputation in Mega-Prosthesis Reconstruction. *J Clin Med.* 2023 May 20;12(10):3575. https://doi.org/10.3390/jcm12103575
18. Batpen A.N., Balgazarov S.S., Belokobylov A.A., Ramazanov Zh.K., Rimashevsky D.V., Serikbayev V.D., Abilov R.S., Dolgov A.A., Moroshan A.V., Balgazarov A.S., Kriklivyi A.A., Kurmangaliyev Ye.-D. T., Aubakirov M.G., Ali A.E., Ustazov K.A. Patent for invention "Method of revision endoprosthetics of the knee joint by double cementation". «Academician N.J. Batpenov National Scientific Center of Traumatology and Orthopedics» Republican state enterprise on the right of economic management of the Ministry of Health of the Republic of Kazakhstan. 2023.
19. Koychubekov B.K. Biostatistika: ucheb. posobiye. – Almaty: Izdatel'stvo «Evero», 2015. –152 p.
20. Engh GA, Parks NL. The management of bone defects in revision total knee arthroplasty. *Instr Course Lect*. 1997;46:227-36.
21. Vasso M, Beaufils P, Cerciello S, Schiavone Panni A. Bone loss following knee arthroplasty: potential treatment options. *Arch Orthop Trauma Surg.* 2014 Apr;134(4):543-53. https://doi.org/10.1007/s00402-014-1941-8
22. Kang KS, Tien TN, Lee MC, Lee KY, Kim B, Lim D. Suitability of Metal Block Augmentation for Large Uncontained Bone Defect in Revision Total Knee Arthroplasty (TKA). *J Clin Med*. 2019 Mar 19;8(3):384. https://doi.org/10.3390/jcm8030384
23. Huten D. Femorotibial bone loss during revision total knee arthroplasty. *Orthop Traumatol Surg Res*. 2013 Feb;99(1 Suppl):S22-33. https://doi.org/10.1016/j.otsr.2012.11.009.
24. Cnudde PH, Kärrholm J, Rolfson O, Timperley AJ, Mohaddes M. Cement-in-cement revision of the femoral stem: analysis of 1179 first-time revisions in the Swedish Hip Arthroplasty Register. *Bone Joint J.* 2017 Apr;99-B(4 Supple B):27-32. https://doi.org/10.1302/0301-620X.99B4.BJJ-2016-1222.R1
25. Kumar A, Porter M, Shah N, Gaba C, Siney P. Outcomes of Cement in Cement Revision, in Revision Total Hip Arthroplasty. *Open Access Maced J Med Sci.* 2019 Dec 12;7(23):4059-4065. https://doi.org/10.3889/oamjms.2019.710
26. Balgazarov S, Belokobylov A, Batpen A, Ramazanov Z, Dolgov A, Rimashevskiy D, et al. The First Stage of Knee Revision Arthroplasty in Periprosthetic Infection with Replacement of a Large Defect Double Cementing Method: A Case Report. *Int Med Case Rep J*. 2023 Sep 6;16:513-520. https://doi.org/10.2147/IMCRJ.S420109
27. Gililland JM, Carlson VR, Fehring K, Springer BD, Griffin WL, Anderson LA. Balanced, Stemmed, and Augmented Articulating Total Knee Spacer Technique. *Arthroplast Today.* 2020 Oct 1;6(4):981-986. https://doi.org/10.1016/j.artd.2020.08.006
28. Lawrie CM, Jo S, Barrack T, Roper S, Wright RW, Nunley RM, et al. Local delivery of tobramycin and vancomycin in primary total knee arthroplasty achieves minimum inhibitory concentrations for common bacteria causing acute prosthetic joint infection. *Bone Joint J.* 2020 Jun;102-B(6_Supple_A):163-169. https://doi.org/10.1302/0301-620X.102B6.BJJ-2019-1639.R1
29. Fang CJ, Shaker JM, Ward DM, Jawa A, Mattingly DA, Smith EL. Financial Burden of Revision Hip and Knee Arthroplasty at an Orthopedic Specialty Hospital: Higher Costs and Unequal Reimbursements. *J Arthroplasty*. 2021 Aug;36(8):2680-2684. https://doi.org/10.1016/j.arth.2021.03.044
30. Steele JR, Ryan SP, Jiranek WA, Wellman SS, Bolognesi MP, Seyler TM. Cost of Aseptic Revision Total Knee Arthroplasty at a Tertiary Medical Center. *J Arthroplasty.* 2021 May;36(5):1729-1733. https://doi.org/10.1016/j.arth.2020.11.028