Genij Ortopedii. 2023;29(5):546-551.

Original article

https://doi.org/10.18019/1028-4427-2023-29-5-546-551

Revision total hip arthroplasty with custom-made hip implant for Paprosky type IV femoral bone loss

K.A. Kovaldov, E. A. Morozova✉, E.A. Gerasimov, S.A. Gerasimov

Privolzhsky Research Medical University, Nizhny Novgorod, Russian Federation

Corresponding author: Ekaterina A. Morozova, ekaterina.m.96@mail.ru

Abstract

Introduction Replacement of extensive Paprosky type IIIB and type IV bone loss is a challenge in revision total hip arthroplasty (THA). **The purpose** was to demonstrate the possibility of femoral reconstruction in proximal femur bone loss using a custom-made implant for revision THA. **Material and methods** We report a case of a 72-year-old patient with an extensive Paprosky type IV femoral defect, which was replaced using a custom-made modular component. **Results** The femoral defect was successfully augmented with a custom-made modular component, and the hip function was restored. The locking mechanism of the constrained system failed at 6 months with the joint remained stable. The patient could ambulate with additional support. VAS, HHS and HOOS scores measured before and after 2 years showed positive dynamics. **Discussion** Paprosky type IIIB and type IV defects are a challenge for revision hip arthroplasty. There is a variety of surgical options with outcomes being ambiguous. Modular and monoblock tapered stems, the technique of impacted bone graft have been reported to have excellent results in revision THA with Paprosky type III and IV defects. A custom-made femoral component was developed based on the principle of modular stems. Joint stability is a concomitant problem with a severe bone defect that can be addressed with a double mobility or constrained system. Both methods are associated with a sufficient number of complications. **Conclusion** Replacement of a Paprosky type IV femoral defect with a custom-made modular component demonstrated satisfactory outcomes at a two-year follow-up. The patient had no complaints, could ambulate unassisted using an elbow crutch and positively evaluated the result of treatment.

Keywords: revision arthroplasty, hip joint, femoral defect, Paprosky type IV

For citation: Kovaldov K.A., Morozova E. A., Gerasimov E.A., Gerasimov S.A. Revision total hip arthroplasty with custom-made hip implant for Paprosky type IV femoral bone loss. *Genij Ortopedii*. 2023;29(5):546-551. doi: 10.18019/1028-4427-2023-29-5-546-551

INTRODUCTION

The number of revision THAs is projected to grow at a higher rate [1]. Bone deficiency is often observed with repeated operations and removal of endoprosthetic components can lead to a greater bone defect [2]. Femoral bone loss can occur secondary to osteolysis, infection and periprosthetic fractures [3, 4], stress shielding, and iatrogenic damage during surgery. One commonly used classification is the Paprosky classification for femoral bone loss, which is a categorization based on bone loss location and degree of severity, and proposes a treatment algorithm for surgical reconstruction based on these measures [5]. Paprosky type IIIB and IV extensive femoral bone defects are very difficult to reconstruct [4, 6, 7]. Options for Reconstruction of defects is based on the remaining healthy bone [2]. The objective was to demonstrate the possibility of femoral reconstruction in proximal femur bone loss using a custom-made implant for revision THA.

MATERIAL AND METHODS

A 72-year-old patient underwent total replacement of the left hip joint in 2013, followed by revision surgery in 2015 due to loosening of the implant. She presented with pain and limited ROM in the left hip, inability to walk without without assistance or use of a walker and was seen at the Institute of Trauma and Orthopaedics of the University Clinic the Volga Research Medical University in January 2016. Radiological examination showed displaced construct and severe osteolysis and revision THA was recommended for the patient. The patient was seen again in the clinic in January 2019 and was diagnosed with a deep periprosthetic joint infection (PJI). The first stage of revision THA included removal of endoprosthetic components, debridement and placement of a spacer. The absence of the lateral cortical bone to the level of the lower third of the femur and partial absence of the cortical bone posteriorly and anteriorly to the level of the lower third of the femur were revealed intraoperatively. To treat periprosthetic infection and replace a bone defect, a spacer was manufactured using a femoral rod 380 mm long with a diameter of 12 mm to address PJI and the bone defect. The femoral rod was fixed with bone cement and 2 cerclages placed at the border of the lower and middle third, middle and upper third of the femur (Fig. 1). A course of antibiotics was administered postoperatively, partial weight-bearing and isometric exercises recommended. Five months later, the patient was hospitalized for the second stage of revision THA. She could ambulate using a wheelchair due to lack of support and the lower limb length discrepancy of 5 cm. Laboratory tests indicated no infection. Subjective assessment of the functionality showed HHS of 39; HOOS of 24.4; VAS of 5. Standard components could not be used for Paprosky type IV extensive femoral bone defect of the femur and the absence of a "total hip" system required manufacturing and placement of a custom-made implant for the proximal femur. The patient was discharged from the hospital to allow time for manufacturing of a custom-made implant. The second stage of revision THA with placement of a custom-made implant was produced at the beginning of 2021. The patient's condition was consistent with that she had had during the previous hospitalization in 2019, without negative dynamics.

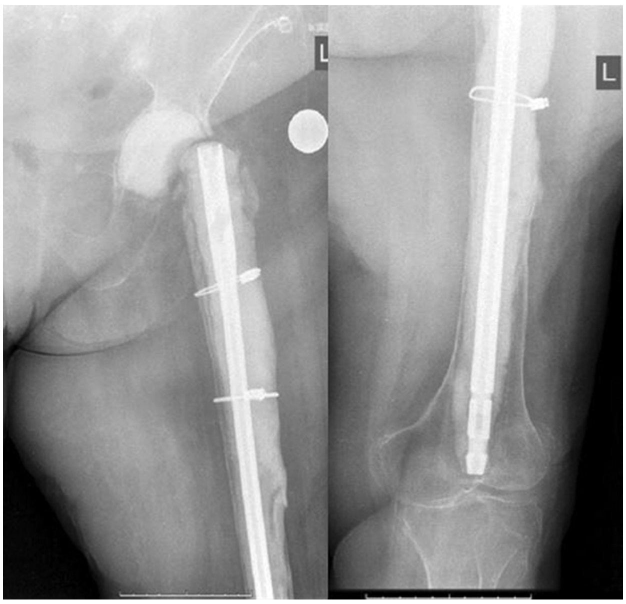

Fig. 1 AP and lateral views of the left femur with a spacer placed

Preoperative planning, implant manufacturing

Multislice computed tomography of the affected and contralateral femur was performed to create a three-dimensional digital model of the femur using Toshiba Aquilion 32 (Japan). On the created model of the affected joint, Metal constructs and cement were removed from 3D model to assess the length of the bone bed suitable for implant fixation. A model of the healthy femur was then mirrored to recreate the geometric parameters of the affected femur. A cylindrical component of the proximal femur with a neck was developed according to anatomical data. The custom-made femoral component consisted of a proximal and distal module. The proximal module of the cylindrical device with a neck was designed with the height being equal to the distance between the lesser trochanter to the great trochanter and the diameter being equal to the diameter of the healthy bone at the level of the lesser trochanter, and the neck ensured the adequate geometry (offset, neck-to-shaft angle, cervical length). The proximal module had a hole for the sleeve, and a comb with holes was formed on the side opposite the neck for suturing muscles and ligaments. A hirth coupling was designed to prevent rotation of the diaphyseal and proximal modules and to ensure fixation of the placement angle at the ends of the proximal and diaphyseal modules in the place where they were adjacent to each other. The distal module was made of two components: (1) a cylindrical diaphyseal component was equal to the diameter of the proximal module and had a hirth coupling in the proximal part, a sleeve recess and an axial fastening screw, the distal part of the diaphyseal component was represented by one of the parts of the Z-shaped connection; (2) the leg of the distal module in the proximal part had a geometry of the distal part of the diaphyseal component in inversed manner; it formed a Z-shaped connection with the diaphyseal component through intermediate fixing bushings and two transverse fastening screws. The rounded end of the custom-made stem was above the Blumenzaat line by at least 1 mm, the proximal end was designed in accordance with the level of immersion into the bone and the formation of a cement mantle of at least 2 mm with the stem placed. The length of the assembled custom-made femoral component ensured bone length equalization. With adjustment of the custom-made model of the implant, it was printed using a DMLS 3D printer. Heat treatment was carried out, step-by-step ultrasonic cleaning in distilled water, neutral, alkaline and acidic media and repeated washing in an ultrasonic bath with distilled water. The product underwent a standard disinfection and sterilization procedure by autoclaving.

Surgical technique

An extended Kocher-Langebeck approach was used for access to the joint with removal of the postoperative scar. The femoral component of the block spacer was removed en bloc and the acetabular cement was removed (Fig. 2).

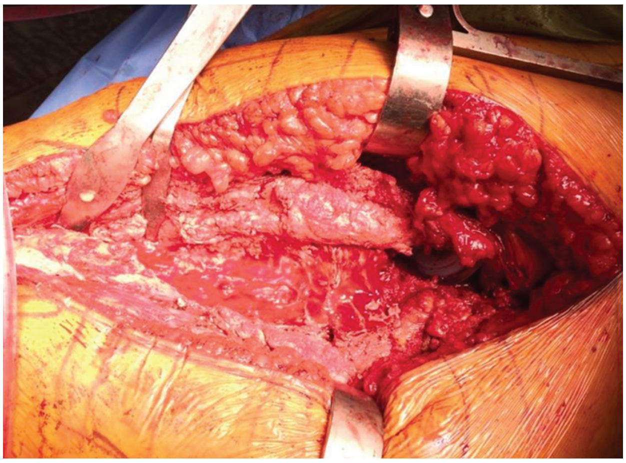

Fig. 2 Intraoperative appearance of the proximal femur defect

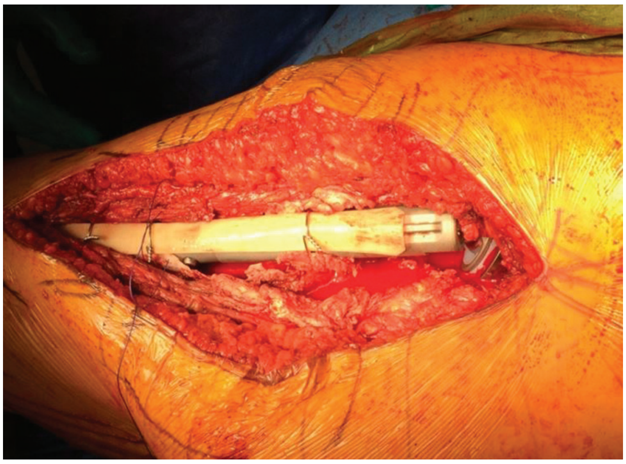

Fig. 3 Modular femoral component assembled

A Paprosky type IV femoral defect and a Paprosky IIA segmental and cavitary defect of the acetabulum were discovered after removal of the components, which conformed with the preoperative planning. Then curettage of the acetabulum and femoral canal was performed. Treatment of the acetabulum and implantation of a standard hemispheric acetabular component (Continuum, Zimmer, Warsaw, USA) fixed with five screws, was produced and an Longevity constrained liner (Zimmer, Warsaw, USA) placed. The custome-made implant was assembled and placed with bone cement into the treated bone canal (Fig. 3). A cortical tibial allograft of about 35 cm long was used to improve stability of the femoral component and fixed to the implant with cerclages extending onto the preserved lateral surface of the distal femur (Fig. 4).

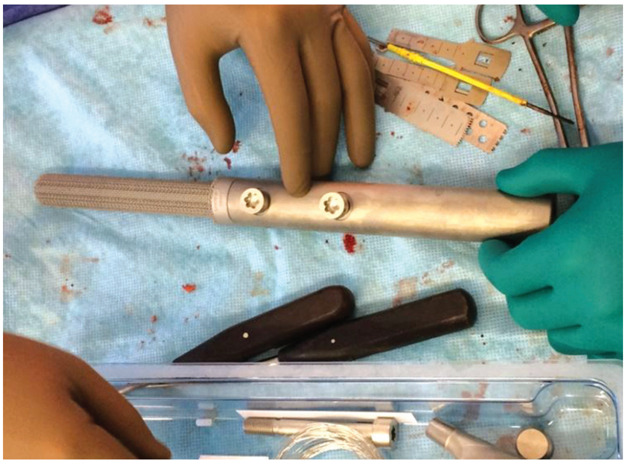

Fig. 4 Intraoperative appearance of the modular femoral component and constrained system placed

RESULTS

The postoperative period was uneventful. The patient was discharged from the hospital after 9 days of surgical treatment. The patient was recommended to walk using crutches for 31/2 months with the lower limb touching the floor and gradually increasing weight-bearing. Dabigatran etexilate was administered for 35 days and compression stockings recommended to prevent thrombosis added by non-steroidal anti-inflammatory drugs to relieve pain. The patient was seen at follow-up visits at 2 (Fig. 5) and 6 months. There were no negative dynamics early post surgery.

The constrained system failed by type III according to the classification developed by S.S. Cooke [8] with femoral head locking mechanism at 6 months with no signs of implant instability. Radiological examination showed signs of slight distal migration of the component, which did not progress throughout the observation period.

The patient could ambulate with the help of elbow crutches maintaining full weight on the operated limb at 12 months. She had no complaints of pain at the surgical site. ROM in the hip and knee joints was slightly limited. The patient could ambulate using an elbow crutch at two years sparing the operated limb (Fig. 7). The reported pain in the ipsilateral ankle joint and both knee joints. The subjective assessment of the function showed 48 HHS scores, 65.0 HOOS and 1VAS score.

Fig. 5 A full-length standing AP radiograph of the patient's lower limbs at 2 months following revision THA with use of the custom-made femoral component

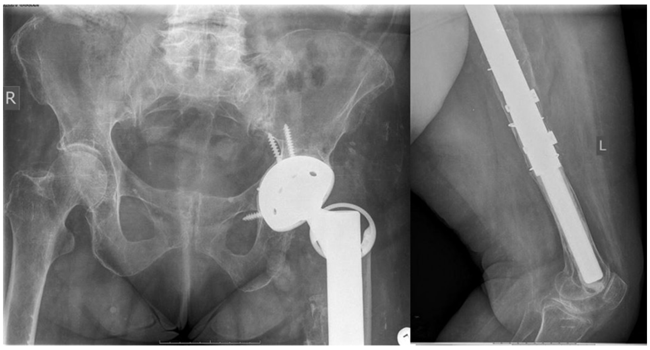

Fig. 6 AP view of the pelvis and lateral view of the shaft of the left femur at 6 months following implantation of a custom-made femoral component

Fig. 7 A full-length standing AP radiograph of the patient's lower limbs at 2 years following revision THA with use of the custom-made femoral component

DISCUSSION

The case report is of particular interest, demonstrating reconstruction of the femur with a severe Paprosky type IV bone defect, which is rare in surgical practice, with joint stabilization achieved. It is difficult to achieve stable fixation of the femoral component with this type of defect. The techniques currently used include femoral impaction bone grafting using a cemented stem, proximally coated stems, fully porous-coated cylindrical stems, allograft prosthesis composite, proximal femoral replacement. Femoral impaction bone grafting using a cemented stem is the method of choice for the reconstruction of large bone defects of the femur. The available level of evidence is primarily derived from case series, which shows a mean survivorship of 90.4 %, with revision or re-operation as the end-point, with an average follow-up of 11 years [9]. The rate of femoral fracture requiring re-operation or revision of the component varies between several large case series, with an average of 5.4 % [9]. The disadvantages include the technical complexity and the need for a large volume of bone mass to repair a Paprosky type IV defect.

Cementless proximally coated stems were defined as poor because required sufficient metaphyseal fixation, which was impossible with extensive bone defects [10]. Despite good survival results, the use of fully covered revision stems was inappropriate for Paprosky type IV defect due to inability to achieve durable primary fixation because of the absent isthmus [11, 12]. However, cortical allografts could create additional conditions for better fixation of the stem and serve as the basis for restoration of the bone defect [13, 14, 15]. Kim et al. reported the results of revision arthroplasty in 120 patients with severe femoral bone defects treated with fully coated stems and cortical allografts with the survival rate of 91 % at a 16-year follow-up [15].

Other options include proximal femoral replacement or the use of a "megaprosthesis" for primary fixation in the setting of a severe femoral defect. These methods are associated with a risk of complications in the form of dislocations, aseptic loosening and bone loss [16]. I.D. Martino et al. conducted a retrospective study evaluating outcomes of 30 patients with Paprosky type IIIB and type IV defects, with a mean follow-up of 5 years [17]. The patients underwent proximal hip replacement. Nine patients required reoperation for aseptic loosening, periprosthetic fracture, etc. Modular and nonmodular tapered fluted titanium stems provide satisfactory midterm results in revision THA in Paprosky III-IV defects [18]. It is generally accepted that modular stems provide better functional results and allow more accurate restoration of limb length, offset and setting the anteversion of the component. However, there are doubts about the mechanical reliability of the constructs with modular stems [19, 20]. The use of allograft-endoprosthesis composite shows good outcomes of femoral reconstruction with long-term follow-up [21].

Prototyping and 3D printing technologies were used to produce a custom-made modular femoral component to obtain satisfactory primary stability and restore limb offset and length in our case. A cortical allograft was used to provide additional stability to the stem. The choice of fixation method may seem controversial due to unpredictable long-term results. The size of the bone defect and the quality of the cortical bone of the distal portion of the affected femur were considered in preoperative planning. The lack of other options, insufficient amount of bone allograft for impaction bone grafting led to increase the contact area between the distal part of the implant and the cement mantle for a composite beam effect. In addition to reconstruction of the significant bone defect stabilization of the joint could be addressed with dual mobility or a constrained system.

V. Eecke et al. reported an evaluation of 5,617 cases of revision THA with higher survival rates (94.7 %) for dual mobility compared with the designs with constrained acetabular liners (81 %) [22]. The dislocation rates was lower with dual mobility (2.6 % vs. 11 %) and lower acetabular loosening rates (1.0 % vs. 2.0 %). No differences in functional outcomes were identified. Similar results were obtained in the study reported by N.N. Efimova et al. [23]. The dual mobility group showed less complications associated with component instability and periprosthetic joint infection. The difference in dislocation rates was statistically significant in the two groups. A greater risk of dislocation was found in the group of constrained acetabular liners with the system placed into the preserved acetabular component as compared with replacement, and with use of inserts for heads of smaller diameter. Some authors report a greater risk of dislocation with unconstrained acetabular liners in revision surgery and the presence of hip abductor deficiency. G.M. Alberton et al report a significantly greater risk of dislocation in patients with nonunion of the greater trochanter at revision surgery obsrved in 7 of 9 patients [26]. G. Zywiel et al. reported no association between abductor muscle quality and the incidence of failure using constrained systems in a group of 43 patients [25]. Survival of the constrained acetabular liners was 91 % at a mean follow-up of 51 months. Of the four hips that experienced failure of the acetabular liner/and or cup, there were two type I failures (at the cup/bone interface), one type II failure (at the liner/cup interface), and one type III failure (at the locking mechanism) as classified by S.S. Cooke. None of the four patients had abductor deficiency, which may indicate the ability of the systems to compensate for deficient hip stabilizers. There is a greater risk of dislocation with use of constrained systems in the presence of recurrent dislocations [26], inadequate placement of a constrained liner in a fixed cup [26, 27], and the inability to properly fix the cup with screws [28, 29].

A constrained system was used for our patient to stabilize the joint considering several factors: good fixation of the cup, both primary and with screws; total deficiency of the hip abductors and inability to perform a plastic surgery without additional injury to the soft tissues. The defect was classified as a type IV Paprosky femoral bone loss and treatment suggested avoidance of factors that could cause stress on the bone/cement/implant interfaces and recurrent dislocation. Type 3 constrained system (locking mechanism) failed, but the failure had no effect on the stability of the joint. The case report has limitations in presenting data for drawing unambiguous conclusions. Given the rarity of this type of femoral defect, demonstration of difficulties during treatment and the ways the issues were solved had a role.

CONCLUSION

Reconstruction of a Paprosky type IV femoral defect with a custom-made modular component demonstrated a satisfactory outcome over a two-year follow-up period. The patient presented no complaints, could ambulate unassisted using an elbow crutch and positively assessed the result of treatment.

Conflict of interest *The authors declared no potential conflicts of interest with respect to the authorship and/or publication of this article.*

Ethical review *Not required.*

Informed Consent *The patient gave voluntary written informed consent for the publication of the clinical observation.*

REFERENCES

1. Bozic KJ, Kurtz SM, Lau E, et al. The epidemiology of revision total hip arthroplasty in the United States. *J Bone Joint Surg Am*. 2009;91(1):128-133. doi: 10.2106/JBJS.H.00155
2. Wang X, Xu H, Zhang J. Using personalized 3D printed Titanium sleeve-prosthetic composite for reconstruction of severe segmental bone loss of proximal femur in revision total hip arthroplasty: A case report. *Medicine* (Baltimore). 2020;99(3):e18784. doi: 10.1097/MD.0000000000018784
3. Sakellariou VI, Babis GC. Management bone loss of the proximal femur in revision hip arthroplasty: Update on reconstructive options. *World J Orthop*. 2014;5(5):614-622. doi: 10.5312/wjo.v5.i5.614

4. Mayle RE Jr, Paprosky WG. Massive bone loss: allograft-prosthetic composites and beyond. *J Bone Joint Surg Br*. 2012;94(11 Suppl A):61-64. doi: 10.1302/0301-620X.94B11.30791
5. Paprosky WG, Lawrence J, Cameron H. Femoral defect classification: clinical application. *Orthop Rev*. 1990;19(suppl 9):9-17.
6. Amanatullah DF, Howard JL, Siman H, et al. Revision total hip arthroplasty in patients with extensive proximal femoral bone loss using a fluted tapered modular femoral component. *Bone Joint J*. 2015;97-B(3):312-317. doi: 10.1302/0301-620X.97B3.34684
7. Viste A, Perry KI, Taunton MJ, et al. Proximal femoral replacement in contemporary revision total hip arthroplasty for severe femoral bone loss: a review of outcomes. *Bone Joint J*. 2017;99-B(3):325-329. doi: 10.1302/0301-620X.99B3.BJJ-2016-0822.R1
8. Cooke CC, Hozack W, Lavernia C, et al. Early failure mechanisms of constrained tripolar acetabular sockets used in revision total hip arthroplasty. *J Arthroplasty*. 2003;18(7):827-833. doi: 10.1016/s0883-5403(03)00325-5
9. Scanelli JA, Brown TE. Femoral impaction grafting. World J Orthop. 2013;4(1):7-11. doi: 10.5312/wjo.v4.i1.7
10. Sheth NP, Melnic CM, Rozell JC, Paprosky WG. Management of severe femoral bone loss in revision total hip arthroplasty. *Orthop Clin North Am*. 2015;46(3):329-342, ix. doi: 10.1016/j.ocl.2015.02.002
11. McAuley JP, Engh CA Jr. Femoral fixation in the face of considerable bone loss: cylindrical and extensively coated femoral components. *Clin Orthop Relat Res*. 2004;(429):215-221. doi: 10.1097/01.blo.0000150274.21573.f4
12. Sporer SM, Paprosky WG. Revision total hip arthroplasty: the limits of fully coated stems. *Clin Orthop Relat Res*. 2003;(417):203-209. doi: 10.1097/01.blo.0000096803.78689.0c
13. Mokka J, Keemu H, Koivisto M, et al. Experience of structural onlay allografts for the treatment of bone deficiency in revi-sion total hip arthroplasty. *Scand J Surg*. 2013;102(4):265-270. doi: 10.1177/1457496913491208
14. Barden B, Fitzek JG, Huttegger C, Löer F. Supportive strut grafts for diaphyseal bone defects in revision hip arthroplasty. *Clin Orthop Relat Res*. 2001;(387):148-155. doi: 10.1097/00003086-200106000-00020
15. Kim YH, Park JW, Kim JS, Rastogi D. High Survivorship With Cementless Stems and Cortical Strut Allografts for Large Femoral Bone Defects in Revision THA. *Clin Orthop Relat Res*. 2015;473(9):2990-3000. doi: 10.1007/s11999-015-4358-y
16. Tomford WW. Transmission of disease through transplantation of musculoskeletal allografts. *J Bone Joint Surg Am*. 1995;77(11):1742-1754. doi: 10.2106/00004623-199511000-00017
17. Parvizi J, Tarity TD, Slenker N, et al. Proximal femoral replacement in patients with non-neoplastic conditions. *J Bone Joint Surg Am*. 2007;89(5):1036-1043. doi: 10.2106/JBJS.F.00241
18. Huang Y, Zhou Y, Shao H, et al. What Is the Difference Between Modular and Nonmodular Tapered Fluted Titanium Stems in Revision Total Hip Arthroplasty. *J Arthroplasty*. 2017;32(10):3108-3113. doi: 10.1016/j.arth.2017.05.021
19. Klauser W, Bangert Y, Lubinus P, Kendoff D. Medium-term follow-up of a modular tapered noncemented titanium stem in revision total hip arthroplasty: a single-surgeon experience. *J Arthroplasty*. 2013;28(1):84-89. doi: 10.1016/j.arth.2012.07.001
20. Richards CJ, Duncan CP, Masri BA, Garbuz DS. Femoral revision hip arthroplasty: a comparison of two stem designs. *Clin Orthop Relat Res*. 2010;468(2):491-496. doi: 10.1007/s11999-009-1145-7
21. Babis GC, Sakellariou VI, O'Connor MI, et al. Proximal femoral allograft-prosthesis composites in revision hip replacement: a 12-year follow-up study. *J Bone Joint Surg Br*. 2010;92(3):349-355. doi: 10.1302/0301-620X.92B3.23112
22. Van Eecke E, Vanbiervliet J, Dauwe J, Mulier M. Comparison of Constrained Acetabular Components and Dual Mobility Cups in Revision Total Hip Arthroplasty: A Literature Review. *Hip Pelvis*. 2020;32(2):59-69. doi: 10.5371/hp.2020.32.2.59
23. Efimov NN, Stafeev DV, Lasunskii SA, et al. Constrained Liners and Dual Mobility Systems for Prevention of Instability in Revision Hip Arthroplasty. *Travmatologiya i ortopediya Rossii*. 2018;24(3):22-33. doi: 10.21823/2311-2905-2018-24-3-22-33
24. Alberton GM, High WA, Morrey BF. Dislocation after revision total hip arthroplasty : an analysis of risk factors and treat-ment options. *J Bone Joint Surg Am*. 2002;84(10):1788-92.
25. Zywiel MG, Mustafa LH, Bonutti PM, Mont MA. Are abductor muscle quality and previous revision surgery predictors of constrained liner failure in hip arthroplasty? *Int Orthop*. 2011;35(6):797-802. doi: 10.1007/s00264-010-0962-3
26. Berend KR, Lombardi AV Jr, Mallory TH, et al. The long-term outcome of 755 consecutive constrained acetabular compo-nents in total hip arthroplasty examining the successes and failures. *J Arthroplasty*. 2005;20(7 Suppl 3):93-102. doi: 10.1016/j.arth.2005.06.001
27. Della Valle CJ, Chang D, Sporer S, et al. High failure rate of a constrained acetabular liner in revision total hip arthroplasty. *J Arthroplasty*. 2005;20(7 Suppl 3):103-7. doi: 10.1016/j.arth.2005.05.005
28. Goetz DD, Bremner BR, Callaghan JJ, et al. Salvage of a recurrently dislocating total hip prosthesis with use of a constrained acetabular component. A concise follow-up of a previous report. *J Bone Joint Surg Am*. 2004;86(11):2419-23. doi: 10.2106/00004 623-200411000-00009
29. Khan RJ, Fick D, Alakeson R, et al. The constrained acetabular component for hip instability. *J Arthroplasty*. 2007;22(3):377-82. doi: 10.1016/j.arth.2006.04.020

The article was submitted 19.06.2023; approved after reviewing 29.06.2023; accepted for publication 25.08.2023.

Information about the authors:

1. Kirill A. Kovaldov – Orthopedic Surgeon, kovaldovc@gmail.com, https://orcid.org/0000-0001-9314-2881;
2. Ekaterina A. Morozova – Laboratory assistant-researcher, ekaterina.m.96@mail.ru, https://orcid.org/0000-0001-7548-9398;
3. Evgeny A. Gerasimov – Orthopedic Surgeon, egerasimov2016@gmail.com, https://orcid.org/0000-0002-7026-5843;
4. Sergey A. Gerasimov – Candidate of Medical Sciences, Head of department, gerasimoff@list.ru, https://orcid.org/0000-0002-3179-9770.

Contribution of the authors:

Kovaldov K.A. – conceptualization, writing the original text of the article.
Morozova E. A. – conducting research, writing the original text of the article.
Gerasimov E.A. – writing the original text of the article.
Gerasimov S.A. – control, reviewing and editing the text of the article.