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Compensation of acetabular defects in primary and revision hip arthroplasty

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Abstract

Introduction Total hip arthroplasty in defects of the acetabulum is a complex type of surgical intervention, and the search for optimal implants and bone substituting materials to restore the integrity of the acetabulum is one of the current problems.

The **aim** of the work was to analyze the results of primary and revision hip arthroplasty with compensation of acetabulum defects.

Materials and methods The study material consisted of 93 patients with primary (65) and revision (28) total hip arthroplasty in the presence of bone defects of the acetabulum of varying severity. To systematize primary defects, the classification of the American Association of Orthopedic Surgeons (AAOS, 2017) was used; for defects in revision surgeries, the classification of W.G. Paprosky (1994) was used. Clinical, radiological, and statistical study methods were used. The results of managing bone defects of the acetabulum with various methods of compensation were studied. The Harris Hip Score (HHS), 1969, was used to assess the function of the involved joints.

Results Depending on the type of acetabular defects, an algorithm was developed for choosing a bone grafting method for acetabular defects and implanting the cup. The best results were observed for cases of a combination of resorbable and non-resorbable bone graft materials and cementless fixation of the pelvic component. A clinical example of three consecutive revision interventions on one hip joint in a patient with bilateral dysplastic coxarthrosis is presented.

Discussion The most widely used method of bone grafting in primary arthroplasty is plastic surgery with autologous chips from the femoral head. In significant bone tissue loss, one of the plastic surgery options is a structural auto- or allograft, the use of which allows restoring the rotation center and forming a bone support for possible future revisions; poor results with this method are caused by allograft lysis. In revision arthroplasty on the hip joint in large defects, plastic surgery of the defect is performed with crushed or structural allograft bone. An antiprotrusion constructs or cups made of trabecular metal are installed; in instability of the pelvic ring, osteosynthesis of the posterior column is required. Trabecular metal structures feachuring high porosity and adhesion to bone and the elastic modulus close to bone tissue provide conditions for optimal primary and secondary fixation of the component.

Conclusion Long-term and painless functioning of the hip joint after arthroplasty performed for acetabular defects is possible with restoration of the spherical shape of the acetabulum and the center of joint rotation in the true acetabulum, adequate elimination of bone tissue loss, reliable primary fixation of the cup with provision of conditions due to restoration and osteointegration. Acetabular defects are diverse in their anatomical manifestations, which create difficulties in choosing pelvic components, augments, and the method of their fixation to the pelvic bone. Based on the type of the acetabular defect, an algorithm has been developed for choosing a method for acetabular bone defect filling and implanting a cup.

Keywords: hip joint arthroplasty, bone defect of the acetabulum, osteosubstitution material, bone grafting

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INTRODUCTION

Hip joint arthroplasty in the presence of acetabular defects is a complex type of surgical intervention. The search for optimal designs and bone substituting materials to restore the integrity of the acetabulum has been currently one of the pressing issues in traumatology and orthopaedics. Defects in the acetabulum are typical of congenital dysplasia, systemic connective tissue diseases, and pelvic bone fractures. Bone defects may be formed due to implant instability, after resection of bone tumors, and also may result from previous periacetabular osteotomies [1].

The choice of methods for filling acetabular defects is determined by the quantity and quality of the bone tissue in the site, the integrity of the acetabular columns, and the stability of the pelvic ring. In primary arthroplasty, small defects are filled with non-structural autografts from the resected femoral head or allograft chips. Large defects require massive supporting grafts, for which structural allograft bone, xenograft bone, or artificial bone substituting materials (calcium phosphate ceramics, metal and titanium augments) are suitable [2, 3]. In some cases, bone cement is used to fill defects; however, most researchers describe the negative effect of cement on bone tissue, provide data on a large number of late complications and arthroplasty failures [4].

The main goal of filling an extensive defect of the acetabulum is to restore the integrity of the bone structure of the acetabulum, its hemispherical shape and the center of rotation of the hip joint to ensure primary stable implantation of the acetabular component [5].

Since the end of the last century, reinforcing and antiprotrusion rings with support on the lateral edges of the acetabulum (Müller, Ochsner, Gans, Burch-Schneider, Beznosko and other rings) have been used to manage defects of the acetabulum in both primary and revision arthroplasty. The most known is the reinforcing support ring, which was developed by M. Müller in 1977. Regularly, the size of the rings corresponds to the acetabulum; they are made of sheet metal, have bent edges for support and multiple holes for screws for attachment to the pelvic bone. To improve the osteointegrative qualities, the acetabular part of the ring can have a porous coating. The Burch – Schneider support ring is intended for defects that cannot be covered by the Müller ring. The use of Müller and Burch – Schneider support rings involves the initial filling of the defect with autogenous bone or allograft bone, and a support structure is installed press-fit on top of the bone graft. A standard cement cup is cemented into the support ring [6].

According to Schatzker et al., satisfactory results were obtained over a follow-up period of one to three years after twenty-five hip replacement surgeries (20 with Müller support ring, 5 with Burch – Schneider). It confirms the logic of their use in the treatment of patients with acetabular defects [7]. Currently, trabecular metal augments are increasingly used, as well as customized three-flange support structures, which are manufactured using computer modeling in cases of extensive defects and discontinuity of the acetabulum [8]. The results obtained by Kovalenko et al. show that acetabular reconstruction using the above-described techniques requires considering the individual anatomical features of the patient in providing surgical approach and implantation technology, otherwise the implant cannot be installed. Moreover, the first experience of customized implants was not always successful, and the rates of poor results remained high [9].

Purpose To analyze the results of primary and revision hip arthroplasty with compensation of acetabulum defects.

MATERIALS AND METHODS

The work was carried out within the framework of the state assignment 124020700095-4 FGBOU Ural State Medical University of the Ministry of Health of the Russian Federation for 2024–2026. The study was conducted in compliance with the ethical principles of the Helsinki Declaration and approved by the institutional ethics committee of the Ural State Medical University (protocol of 10.22.21 No. 9). All patients gave informed voluntary consent to participate in the study. The study design is presented in Figure 1.

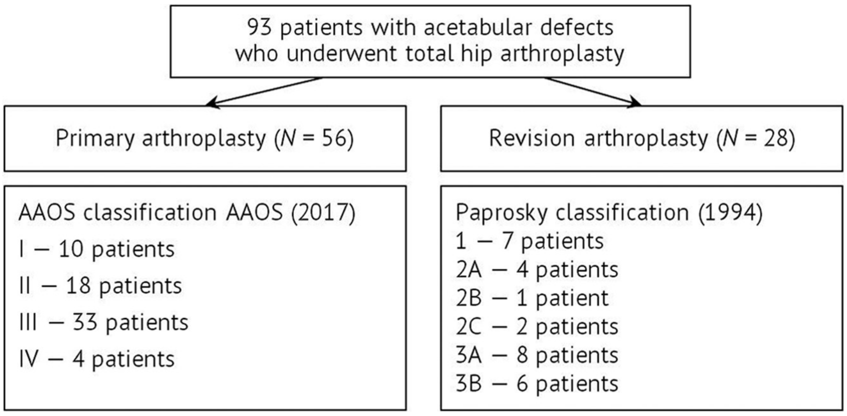

Fig. 1 Study design

The study material was 93 patients with primary and revision total hip arthroplasty in the presence of bone defects of the acetabulum of varying severity.

Primary arthroplasty was performed in 65 patients (21 men, 44 women), of which 26 patients were treated at the State Autonomous Healthcare Institution of the Sverdlovsk Region Regional Clinical Hospital No. 1, Yekaterinburg (Regional Clinical Hospital No. 1); 39 patients at the Ilizarov National Medical Research Center of Traumatology and Orthopaedics, Kurgan (Ilizarov Center). The average age of patients at primary arthroplasty was (56 ± 1.4) years.

Cementless arthroplasty was performed in 49 patients; cemented prostheses were installed in 16 patients. The following implant systems were used: Aesculap (*n* = 19), Smith&Nephew (*n* = 13), De Puy (*n* = 21), Zimmer (*n* = 12).

Revision arthroplasty was performed in 28 patients (2 men, 26 women), of which 19 patients were treated at the Regional Clinical Hospital No. 1; 9 at the Ilizarov Center. The average age of patients was (61.0 ± 2.4) years.

Cementless revision arthroplasty was performed in 12 patients, and cemented one in 16 patients. The ollowing systems were installed: Aesculap (*n* = 6), Smith&Nephew (*n* = 5), De Puy (*n* = 11), Zimmer (*n* = 6).

Age, social status and disability grade are presented in Table 1.

Table 1

Patients' age and social status

Категории		Primary arthroplasty (*n* = 65)		Revision arthroplasty (*n* = 28)	
		Number of patients	%	Number of patients	%
Age, years	18–44	11	17	3	10
	45–59	28	43	10	36
	60–74	23	35	11	40
	over 74	3	5	4	14
Social status	working	27	42	7	25
	Not working	10	15	2	7
	Not working pensioners	28	43	19	68
Disability	None	42	64	17	61
	Grade 3	14	22	6	21
	Grade 2	8	12	4	14
	Grade 1	1	2	1	4

Primary arthroplasty in the revision group of patients had been previously performed at the Regional Clinical Hospital No. 1 in four cases; at the Ilizarov Center in one case. The remaining 23 patients were initially treated at trauma hospitals of the Sverdlovsk and Kurgan regions.

To systematize primary defects, the classification of the American Association of Orthopedic Surgeons (AAOS, 2017) [10] was used due to its simplicity and the possibility of preoperative planning of bone grafting options. According to the AAOS classification, four types of acetabular defects are distinguished: type I is a segmental bone defect in the superior, anterior, or posterior part of the acetabulum; type II is a cavitary defect (bone cavity) in the superior, anterior, or posterior part of the acetabulum; type III is a combined segmental-cavitary defect; type IV is an obvious or hidden rupture of the pelvic ring [10].

The types of defects in patients with primary hip arthroplasty depending on the etiology of osteoarthritis (OA) according to the AAOS classification (2017) are presented in Table 2. The leading cause of acetabular defects in cases of primary arthroplasty was hip dysplasia. In 36 patients, dysplasia corresponded to Crow type II–III, in two cases to type IV [11, 12, 13]. The developing neoarthrosis at the level of the upper edge of the acetabulum and cranial displacement of the femoral head in Crow dysplasia II–III [11] led to the formation of defects in the roof of the acetabulum, corresponding to types II and III according to the AAOS classification (2017).

In systemic diseases of connective tissue (RA, systemic lupus erythematosus), due to porous bone tissue, a protrusive deformation of the acetabulum was formed with a medial displacement of the center of rotation of the joint, which led to the a defect in the bone tissue of the acetabulum in its central parts [14, 15].

Table 2

Types of defects in patients with primary THA depending on the etiology of OA according to the AAOS classification (2017)

Type of defects	I		II		III		IV		Total	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
Hip dysplasia	–		12	67	24	73	2	50	38	58
Systemic diseases of the connective tissue	9	90	6	33	7	21	–		22	34
Trauma	1	10	–		2	6	2	50	5	8
Total	10	100	18	100	33	33	4	100	65	100

Post-traumatic deformities of the acetabulum result from of injuries — fracture-dislocations of the hip joint. Tikhilov et al. divide post-traumatic deformities of the acetabulum into three groups of patients: 1) patients with fractures of the acetabulum bottom with a slight displacement of fragments or after osteosynthesis of the posterior parts; 2) patients after a fracture of the posterior part of the acetabulum with a defect in the area of the posterior wall and / or roof of the acetabulum of varying length; 3) patients with a complete violation of the anatomy of the acetabulum resulting from a defect in the posterior wall, roof, or from malunion of bone fragments [16]. In the first group it is possible to perform primary standard implantation of a cementless cup, while in the second and third groups, bone grafting, augments and revision support rings are required for implantation of the pelvic component. The most common post-traumatic defects of the acetabulum are in the posterior-superior part and are combined with subluxation of the hip and persistent flexion-adduction contracture. The acetabulum looks oval and elongated, the posterior wall is destroyed, and the head of the femur is displaced backwards and upwards.

To systematize revision defects, the Paprosky classification [17] was used. This classification reflects in detail the anatomical location of the defect and allows choosing the optimal method for replenishing bone tissue deficiency during preoperative planning, and considers technical difficulties during the intervention. According to the classification of W.G. Paprosky, there are

3 types of acetabular defects. Type 1 defect involves the presence of single or multiple bone cysts, the total volume of which does not exceed 10 mm^3. Subtype 2A is a superomedial cavitary defect; 2B defects are segmental superolateral defects, when bone loss does not exceed 1/3 of the acetabulum circumference; 2C is a defect of the medial wall of the acetabulum; 3A defect is a superolateral migration of the acetabulum or "up and out", intact medial support (lateral to the Kohler line) and lysis is observed in the ischial bone area; 3B defect is a superomedial migration or “up and in”, there is no medial and superior support (rupture of the Kohler line), pronounced lysis of the ischium (less than 15 mm above the superior obturator line), complete destruction of the “teardrop figure”; type 4 defect is an obvious or hidden rupture of the pelvic ring.

The types of defects according to the classification of W.G. Paprosky in patients with revision hip replacement depending on the initial disease/injury before primary arthroplasty are presented in Table 3.

Table 3

Types of defects according to the classification of W.G. Paprosky in patients with revision hip replacement depending on the underlying disease/injury before primary arthroplasty

Types of defects	1		2A		2B		2C		3A		3B		Total	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Trauma	4	57	1	25	1	100	1	50	4	50	1	20	12	43
Systemic diseases of the connective tissue	1	14	2	50	–		1	50	2	25	3	50	9	32
Hip dysplasia	2	29	1	25	–		–		2	25	2	30	7	25
Total	7	100	4	100	1	100	2	100	8	100	6	100	28	100

In patients with revision arthroplasty, the leading reason for performing primary arthroplasty was previous trauma. Of 28 cases of revision arthroplasty, early instability (up to 5 years after primary arthroplasty) developed in 15 patients (54%), late instability (after more than 5 years) in 13 (46%).

Study methods

Clinical The mid-term values of hip joint function were assessed using the Harris scale [16]: 90 points or more were considered an excellent result; 80–89 points — a good result; 70–79 points — a fair result; 69 points or less — a poor result.

Radiological The plain radiograph of the pelvis was assessed in a direct view, and the affected hip joint with the femur in direct and lateral views.

The computed tomography method was used to clarify the grade of acetabulum bone loss according to the AAOS classification for primary arthroplasty, and Paprosky classification was used for revision arthroplasty.

Statistical method The Statistica 8.0 analysis package was used in the study. Descriptive statistics data are presented as M ± SD; where M is the mean value, SD is the standard deviation.

RESULTS

Information on the methods of bone grafting and midterm results are presented in Table 4.

Based on the analysis of Table 4, it can be noted that in primary arthroplasty, type I defects were filled with bone cement in two cases, which is quite acceptable for cemented arthroplasty which was performed in these two cases; in eight cases (three cementless prostheses and five cemented ones), the defects were filled with bone chips from the resected femoral head.

Table 4

Methods of bone defect management in primary arthroplasty based on the type of defect according to the AAOS classification and HHS results

Method of defect compensation / functional outcome		Excellent		Good		Fair		Poor		Total	
		⩾ 90 points		80–89 points		70–79 points		⩽ 69 points			
		n	%	*n*	%	*n*	%	*n*	%	*n*	%
I type (4 ± 2)*	Bone autograft from femoral head	1	10.0	3	11.0	2	10.0	2	25.0	8	12.3
	Bone cement	1	10.0	1	4.0	–		–		2	3.1
II type (7 ± 2)*	Non-structural femoral head autograft	–		2	7.0	2	10.0	1	12.5	5	7.7
	Structural autograft from the femoral head, fixed with screws	2	20.0	6	21.0	3	15.0	2	25.0	13	20.0
III type (4 ± 3)*	Non-structural femoral head autograft	2	20.0	3	11.0	4	20.0	–		9	13.8
	Structural autograft from the femoral head, fixed with screws	2	20.0	8	30.0	7	35.0	2	25.0	19	29.2
	Big size cup	1	10.0	–		1	5.0	–		2	3.1
	Titanium mesh	–		1	4.0	–		–		1	1.5
	Metal support structure (Muller ring)	–		–		–		1	12.5	1	1.5
	Autograft from the femoral head + titanium mesh	–		1	4.0	–		–		1	1.5
IV type (6 ± 1)*	Structural autograft from the femoral head, fixed with screws	1	10.0	1	4.0	1	5.0	–		3	4.6
	Muller ring	–		1	4.0	–		–		1	1.5
Total		10	100	27	100	20	100	8	100	65	100

Note: *— average term after the intervention (years)

In type II, structural and non-structural autografts were used, which yielded good functional results. Of those, three implants were cemented and 15 were cementless. In this type of defect, only three poor results were noted, associated with premature lysis of the graft; in one of those cases, a cementless technique was used and two implants were cemented.

The greatest variety of defect compensation techniques was used for type III. For this type of defect, five were cemented fixation implants: two in combination with a structural autograft were fixed with screws, with good and fair results; one had a titanium mesh as a supporting structure with autoplasty of the defect; one cemented implant was installed with defect plasty with autobone chips and resulted in fair outcome; a failure was observed in the case of installing a cemented implant with a Muller supporting ring. In the remaining 28 cases of type III defect, cementless implants were installed. The best results were onserved with the use of structural autografts additionally fixed with screws.

Defects of type IV in primary arthroplasty were encountered in three cases and were compensated by massive structural autografts fixed with several screws to the pelvic bone, which provided good results; all three were cementless. A cemented implant was installed in one case together with a Muller ring, a fair result was obtained.

Methods of bone defect compensation in revision arthroplasty and assessment of hip joint function with HHS are presented in Table 5.

Table 5

Methods of bone defect management in revision arthroplasty based on the type of defect according to Paprosky classification and HHS results

Method of defect compensation / functional outcome		Excellent ⩾ 90 points		Good 80–89 points		Fair 70–79 points		Poor ⩽ 69 points		Total	
		n	%	*n*	%	*n*	%	*n*	%	*n*	%
1 type (3 ± 2)*	Bone cement	–		1	16.7	2	14.3	1	20.0	4	14.3
	Big size cup	–		–		3	21.4	–		3	10.7
2A type (4 ± 1)*	Impaction with allograft	–		–		2	14.3	–		2	7.1
	Bone cement	–		–		–		2	40.0	2	7.1
2B type 2*	Bone cement	–		–		1	7.1	–		1	3.6
2C type (6 ± 3)*	Bone cement	–		–		1	7.1	1	20.0	2	7.1
3A type (3 ± 3)*	Allograft	–		–		1	7.1	–		1	3.6
	Muller ring	–		1	16.7	1	7.1			2	7.1
	Iliac wing autograft	–		–		1	7.1	–		1	3.6
	Iliac wing autograft + mesh + screws	1	33.3	–		–		–		1	3.6
	Allograft+screws	1	33.3	1	16.7	–		–		2	7.1
	Allograft + mesh + screws	1	33.3	–		–		–		1	3.6
3B type (4 ± 2)*	Allograft	–		1	16.7	–		–		1	3.6
	Bone cement	–		–		1	7.1	–		1	3.6
	Iliac wing autograft + Muller ring	–		–		1	7.1	–		1	3.6
	Tantalum augment + autograft	–		1	16.7	–		–		1	3.6
	Big size cup	–		–		–		1	20.0	1	3.6
	Muller ring	–		1	16.7	–		–		1	3.6
Total		10	100	27	100	20	100	8	100	65	100

Note: *— average term after the intervention (years)

According to the data presented in Table 5, in revision operations to fill type 1 defects, from a total of seven patients four cases (57%) had cemented arthroplasty and the defects were filled with bone cement. If bigger diameter cups was used, cementless fixation was performed.

In four patients with defect type 2A, cemented technique was used in two cases, the defects were filled with cement. In two cases, impaction bone grafting with subsequent cementless fixation of the cup was used. In 2B (one patient) and 2C (two patients) defects, cemented fixation of the cup was used in all cases. No other bone substituting materials except cement were used. One defect type 2C compensation was a failure.

In Type 3A defects (eight patients), the cementless technique was used together with auto- and allografts fixed with press-fit, as well as with auto- and allografts fixed with screws. In the remaining cases, the cemented technique was used.

Cementless arthroplasty for type 3B defects (six patients in total) was used in three patients: together with autogenous bone, fixed press-fit, big-diameter cup and metal supporting structure. Cemented fixation was used in three patients: with a Muller ring, with a supporting structure made of tantalum and in one case the defect was filled only with cement with a fair result.

Based on the type of acetabular defect according to Paprosky classification (for revision) and AAOS (for primary AP), we developed an algorithm for choosing the method of managing the bone defect of the acetabulum and implanting the cup (Table 6) [18].

Table 6

Method of cup implantation based on the type of bone defect of the acetabulum

Type of defects (AAOS, Paprosky)	Method of cup implantation
Defects type I and II AAOS Type I and IIA Paprosky	It is possible to perform reimplantation of a hemispherical cup with a cementless press-fit fixation into the true acetabular region, bone grafting with auto- or allochips in osteolysis foci
Type III AAOS Defects IIB, IIC, IIIA Paprosky	It is possible to reimplant a hemispherical cup with a cementless press-fit fixation into the true acetabular region. To compensate for the segmental defect of the coating in the area of the roof of the acetabulum over 30% of the cup area and the medial defect in the bottom area, bone auto- and allografts, porous metal augments are used. It is possible to use acetabular components of a special oval shape. In case of pronounced medial defects, it is possible to use reinforcement of the defect with a titanium mesh fixed to the rim of the acetabulum with 2-3 screws, before this the defect is necessarily filled with autobone, allobone or artificial bone osubstituting material; a hemispherical cup with a cement type of fixation is implanted into the titanium mesh. It is possible to use big-sized Jumbo-cups with auto- or alloplasty of the defect
Defects IV AAOS Defects III B Paprosky	It is necessary to use Müller reinforcing rings or Bursch-Schneider antiprotrusion rings with defect repair in the true acetabulum with massive structural auto- or allografts, titanium augments; hemispherical cups with cement fixation are implanted into the support ring. It is possible to use bilobed or oblong cups with additional fixation with screws (distraction method for achieving stability), defect repair using modular titanium/ceramic inserts or a massive structural allograft. It is possible to use customized pelvic components manufactured with 3D model data.
Defects IV, V AAOS Defects with disrupted pelvic ring	Osteosynthesis of the anterior and posterior columns using reconstructive plates in combination with the Bursch-Schneider antiprotrusion ring (flanges for the ischial and ilium bones), plastic surgery of defects using massive structural allografts, a cup with cement fixation is implanted into the ring. It is possible to use bilobed or oblong cups with additional fixation with screws (distraction method for achieving stability). Arthrodesis, pelvic support osteotomy

We present the following case report as a clinical example of performing three consecutive revisions of the pelvic component within five years after the primary arthroplasty.

Patient A. with bilateral dysplastic coxarthrosis stage III, Crow IV subluxations of the hips referred to the clinic at the age of 55 years with complaints of persistent pain in the hip joints (more on the left), limited movement, and lameness (Fig. 2).

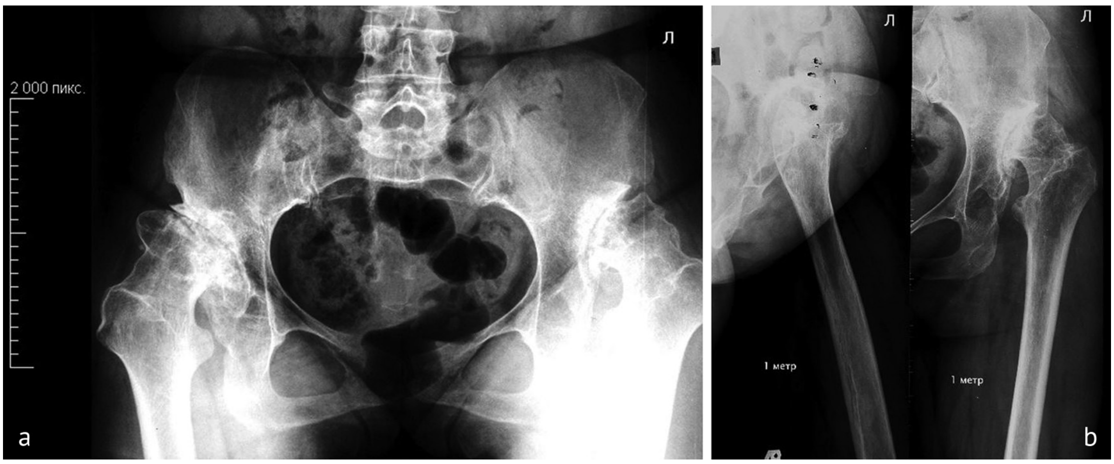

Fig. 2 Plain radiograph of the pelvis in a direct projection (*a*) and the left hip joint (*b*) in lateral and direct views before surgery. Bilateral dysplastic coxarthrosis stage III, Crow IV subluxations of the hips: the heads are displaced cranially, are located above the acetabular region, a deficiency of bone tissue is visualized in the area of the anterior, posterior edge and roof of the true acetabulum of the right and left hip joints. Defects of the bone tissue of the acetabulum correspond to type III AAOS

Case history Congenital bilateral hip dislocation was detected at the age of 3.5 years, for which she was treated conservatively using traction and staged plaster casts, but the dislocations were not reduced. At the age of 30 years, she started feeling pain in the hip joints. After visiting the clinic and undergoing a comprehensive examination, hip joint arthroplasty was indicated (Fig. 2).

In November 2009, the left hip joint was replaced with a cementless Smith&Nephew system with acetabular roof plasty using an autograft from the resected femoral head. The acetabular bone tissue defect III AAOS was adequately compensated. The early postoperative period was uneventful. However, four months later, pain in the area of the joint reappeared, and radiographs revealed probable signs of pelvic component instability: pronounced areas of bone tissue enlightenment (lysis) at the border of the cup and the pelvic bone in the II and III acetabular zones De Lee and Charnley (Fig. 3 a). Six months after the primary implantation on 05.05.2010, revision arthroplasty of the left hip joint was performed due to early instability of the cementless cup. A cement fixation cup was installed, signs of instability of which appeared 16 months after the repeated revision: an enlarged oval-shaped cavity with a crescent-shaped enlightenment in its lower sections was visualized, the pelvic component was located in its cranial section, a 3A Paprosky defect was diagnosed (Fig. 3 b).

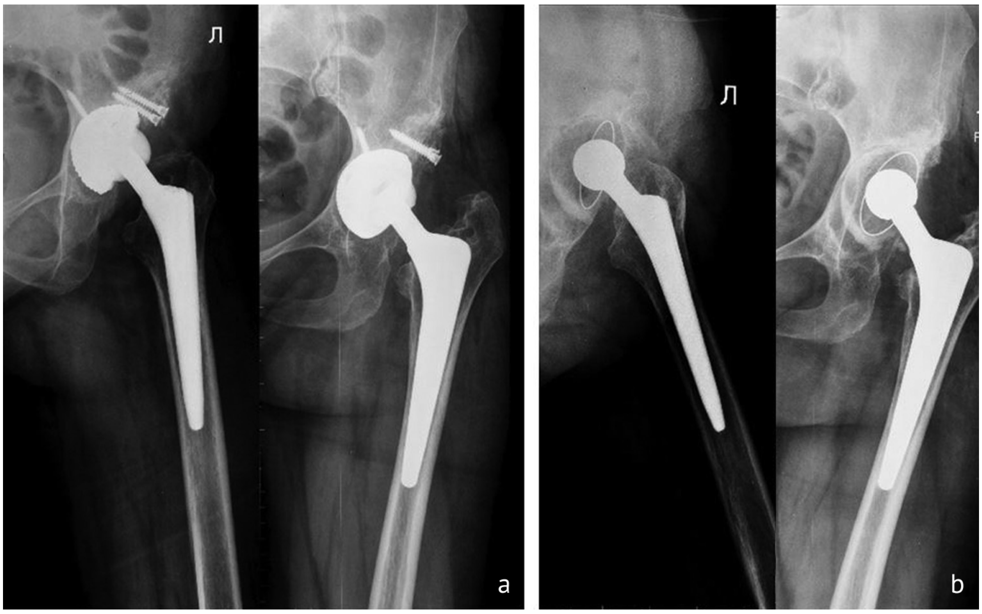

Fig. 3 Radiographs of the left hip joint in lateral and frontal views: *a* 6 months after primary arthroplasty (signs of instability of the cementless pelvic component); *b* 6 months after revision arthroplasty with replacement of the cup with a cemented system (instability of the cemented pelvic component)

On 19.05.2010, between repeated revisions of the left hip joint (before the development of repeated instability of the already cemented pelvic component), primary cementless arthroplasty of the right hip joint was performed using the Smith&Nephew system with impaction grafting using bone chips from the resected femoral head (Fig. 4 a). In September 2011, the second revision intervention was performed to replace the unstable cemented pelvic component: bone grafting using allochips was performed and a Müller support ring was installed with the pelvic component implanted into it using cement; the femoral component remained stable (Fig. 4).

Three years after the second revision, the patient felt pain in the left hip joint and groin, with irradiation to the thigh and knee joint. In February 2015, the third revision of the left hip joint was performed. Intra-operatively, instability of the Müller support structure was detected, which was removed along with the remnants of the cement. Some technical difficulties arose when releasing the screw head grooves from the bone cement. A defect of the anterior wall and a significant defect of the acetabular dome (3B Paprosky) were detected.

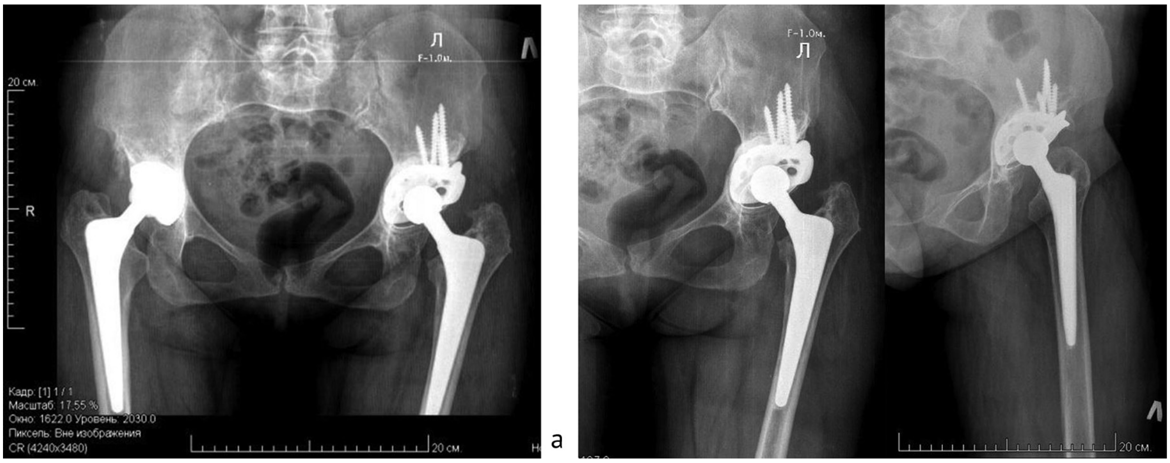

Fig. 4 Radiographs of the pelvis (*a*) and left hip joint in lateral and frontal views (*b*) after primary arthroplasty of the right hip joint and the second revision intervention on the left hip joint to replace the unstable cemented pelvic component and install a Muller support ring

The acetabulum was processed in turn with 40- to 50-mm cutters and bone spoons until bleeding occurred. A 50-mm Zimmer tantalum augment, 15 mm high, was installed in the area of the acetabular dome defect and fixed with two 6.5 × 35 mm and 6.5 × 30 mm screws. Next, the acetabulum was processed with 51- and 52-mm cutters centering in the true acetabular region, and the thinned bottom of the acetabulum was covered with bone chips (from the cutters after processing). A 52-mm Zimmer Trabecular Metal press-fit cup was stably installed. The cup was fixed with three 6.5 × 35 mm (1) and 6.5 × 20 mm (2) cancellous screws. The stem remained stable. A metal head + 4 mm (L) Smith&Nephew was installed. After reduction, the joint was stable, and the length of the legs was equal. In the radiographs, the position of all implant components is biomechanically correct (Fig. 5).

Fig. 5 Radiographs of the pelvis (a) and left hip joint in the direct and lateral views (b) after the third revision intervention on the left hip joint to replace the unstable Mueller support ring, fill the bone defect in the area of the acetabular dome with a tantalum augment from Zimmer and a cementless 52-mm cup Zimmer Trabecular Metal press-fit. The defect of the acetabulum, 3B Paprosky, was filled

At the time of this study (2024), 9 years passed since the third revision surgery to replace the pelvic component. The patient walks with a cane, has no complaints, no lameness, and uses public transport. The need for painkillers is episodical, after prolonged physical activity. The limb is in the correct position. The range of motion in the hip joints is restored. The functional HHS result is good (85 points).

DISCUSSION

Analyzing the above clinical case as a series of revision failures, it should be noted that initially the patient had a complex bilateral pathology of the hip joints with the formation of neoarthrosis of both supra-acetabular areas and high Crow grade III–IV subluxation of the femurs due to pronounced degenerative changes in the joints and surrounding muscles. Despite the fact that during the primary arthroplasty of the left hip joint the method of compensation of the bone defect in the area of the dome with an autograft from the resected femoral head was correctly chosen and the cup was installed biomechanically correctly in the true acetabulum, its early instability developed after six months.

Obviously, the main role in the development of early instability of the pelvic component was played by overloading of the joint due to the fact that patients almost immediately and unconsciously load the replaced joint, which no longer hurts, compared to the non-operated one. Even such a short time of increased loading on the endoprosthesis in the early postoperative period resulted in pain syndrome and instability of the pelvic component as secondary stabilization of the component through osseointegration did not occur due to increased loading. In bilateral severe joint pathology, it is advisable to operate on both joints in one surgical session or with a time interval of no more than 2-4 weeks [19, 20].

During the first revision, the cementless cup was replaced with a cemented one. However, the acetabulum had already been altered (AAOS type III defect), enlarged in longitudinal size, and there was no adequate covering of the expanded acetabulum by the pelvic component. The cup was installed in the upper sections of the acetabulum above the true acetabulum, and the lower sector of the implantation site remained unfilled with the component itself, bone, or cement. Therefore, instability of the pelvic component developed already 16 months after the revision. A second revision intervention was required with the installation of a Müller support ring and bone grafting with allochips. The Müller ring was also installed in the upper sections of the acetabulum, above the true acetabulum. This fact led to asymmetric loading on the pelvic bones (overload of the left hip joint) and the development of instability of the supporting structure. Both in the first and in the second revision, when bone deficiency was still moderate (Type 3A Paprosky), it was possible to use a large-diameter pelvic component, a Jumbo-cup. The use of a bigger cup provides lateralization and a slight caudal displacement of the rotation center of the hip joint. The biomechanics of the joint, therefore, approaches the normal one, while the contact area of the Jumbo-cup with the bone bed is large enough, which allows us to hope for successful secondary stabilization due to osseointegration and a good outcome.

Removal of the unstable Müller support ring, its fixing screws, and bone cement during the third revision further enlarged the bone deficit in the acetabulum area to the point of an extensive defect in the acetabular dome and its anterior rim (Paprosky type 3B defect).

During the third revision, the Paprosky type 3B bone defect in the acetabular dome area was compensated for with a Zimmer tantalum augment, a 52-mm Zimmer Trabecular Metal cementless cup, implanted press-fit into the true acetabular area. Adequate compensation of the defect, the correct choice of the augment and cup size, and its biomechanically correct positioning in the true acetabulum achieved its stable position and a good long-term result. Thus, it should be noted that it is important to fully compensate for the defects of the acetabulum to ensure the stability of the prosthesis and the ability to implant the cup into the true acetabulum to restore the correct anatomical relationships in the joint.

Currently, there are various options for implanting a pelvic component in case of acetabular bone tissue loss: installation of a standard full-profile cup with cementless fixation in the true acetabulum with bone grafting of the defect; installation of a cup in the true acetabulum with its partial non-coverage and grafting with bone chips; installation of the cup in a more vertical position; installation of a cup with a shift in the rotation center above the true acetabulum region in the preserved bone in the dome region; installation of a cemented cup into supporting and antiprotrusion structures. In all these options, it is possible to use structural autobone from the resected femoral head, massive structural allografts, bone auto- and allochips, artificial bone substituting materials made of titanium and ceramics, as well as their combinations.

The analysis of data reported by domestic and foreign researchers shows that the most widely used method of filling defects in primary arthroplasty remains plastic surgery with bone chips from the autologous femoral head. Such plastic surgery recreates the sphericity of the socket well and, if osseointegration is successful, provides mechanical support for the cup along its entire length and long-term functioning of the endoprosthesis. However, the volume of bone material is very limited and does not allow for filling an extensive defect. If revascularization fails, the autobone can lyse over time leading to loss of stability [21]. Crushed bone allografts are also widely used for plastic surgery of small defects, complementing any technique. Sometimes they are used as an independent augmentation method, impaction bone plastic surgery. Usually, a cementless press-fit cup is used, less often a cemented cup. The surface of the pelvic component in this case has little contact with the patient's bone, while contact with the donor allograft bone can approach 100% [2].

In large bone tissue defects (Paprosky type 2B, 3A, 3B), one of the options for plastic surgery is the use of structural auto- or allografts, which allow restoring the rotation center and bone support for possible future revisions. Poor results with this method are due to the lysis of the allograft bone, if its revascularization does not occur over time [20]. The long-term viability of the allograft bone with the preservation of its support characteristics remains controversial [22, 23].

The cemented cup was widely used in the first hip arthroplasty operations, especially in revision interventions. However, the results in the medium and long terms turned out to be poor. Therefore, at present, preference is given to pelvic components of cementless fixation in primary arthroplasty. If cement fixation is necessary, the thickness of the cement mantle should be minimal. The deficiency in the thickness of the medial wall under the cement mantle should be compensated by impaction bone grafting [4, 24, 25].

In revision interventions on the hip joint, one should consider severe osteoporosis, cicatricial changes in the capsule, and weakness of the surrounding muscles. Removal of the implant requires additional physical effort and is associated with the risk of periprosthetic fractures, as well as an increase in the length and depth of bone tissue defects in the area of the implantation bed [26]. One of the options for revision replacement of the pelvic component in moderate bone loss is the use of large-sized Jumbo-cups. However, if the acetabulum rims are insufficient, this method is unacceptable. A negative aspect of Jumbo-cup implantation is that the large component, being at the same time a supporting structure covering the defect, limits the possibilities of pelvic bone regeneration [15].

In large Paprosky 2B, 2C, 3A, 3B defects, plastic surgery with crushed or structural allobone is performed, an antiprotrusion ring or cups made of trabecular metal with press-fit fixation and screws are implanted. Then a plastic cup is installed in the metal cup or ring with cement; in pelvic ring instability, osteosynthesis of the posterior column is required. According to the studies of Tikhilov et al., the use of an antiprotrusion support ring allows creating support for the pelvic component, transferring the load to the remaining areas of the ilium and ischium. Implantation of the support ring is supplemented by bone alloplasty with a structural or crushed graft, implantation of a cup made of trabecular metal, osteosynthesis of the posterior column [27, 28].

In recent years, components made of highly porous materials, in particular trabecular metal, have become increasingly widespread. They can be used for both simple revisions and more complex cases, including osteoporosis, severe bone defects and pelvic ring disruption [29]. High porosity and adhesion to bone, elastic modulus close to bone tissue in trabecular metal structures provide conditions for optimal primary and secondary fixation of the component, while additional holes can be made with a high-speed drill in any area of such a component for fixation with screws to the pelvic bone. To achieve acceptable primary stability, bone coverage of the structure can be less than 50% [30, 31].

Positive treatment outcomes and long-term functioning of the prosthesis is possible to achieve only with a comprehensive approach to defect plastic surgery. AAOS defects I and II and Paprosky type 1 and 2A defects allow impaction bone grafting with resorbable non-structural grafts. AAOS defects

III and IV and Paprosky defects 2B, 2C, 3A, 3B require the use of structural grafts with additional fixation. It is preferable to use combined bone grafting, including non-resorbable and resorbable materials.

Pelvic components with cementless fixation, which demonstrate good survival after many years of functioning, are certainly promising for both primary and revision arthroplasty [32].

CONCLUSION

Hip joint arthroplasty (primary or revision) performed in the presence of a bone defect of the acetabulum is a complex surgical intervention, the technical aspects of which have not been finally resolved. Anatomical manifestations of acetabular defects are diverse and create certain difficulties in choosing pelvic components, augments, and methods of their fixation to the pelvic bone. Long-term and painless functioning of the hip joint implants used for acetabulum defects is ensured if the spherical shape of the acetabulum is restored and the center of the joint rotation is in the true acetabulum, bone tissue deficiency is adequately replenished, and reliable primary fixation of the cup provides conditions for secondary stabilization of the component due to its osseointegration.

The algorithm developed for choosing a method of filling a bone defect of the acetabulum and implanting a cup allows a practicing physician to adequately assess his experience, surgical skills and the capacity of the clinical institution in providing complex reconstructive surgeries on the hip joint.

Significant difficulties in surgical treatment of patients with acetabulum defects are due to the insufficient legislative base in the field of using customized designs, new materials and techniques for replenishing bone deficiency.

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