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What Characteristics of the Acetabular Defect Influence the Choice of the Acetabular Component During Revision Hip Arthroplasty?

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Abstract

The purposes of the retrospective cohort study were: 1) to determine the severity of defects in the acetabulum and the probable causes of their formation in patients who underwent revision hip arthroplasty (RHA), as well as an assessment of factors that exacerbate the severity of the defects; 2) identifying the proportion of severe defects in the overall structure of acetabular revisions and determining the effectiveness of using serial implants in comparison with individual constructions made by 3D printing; 3) the rationale for rational indications for the use of individual constructions. ***Materials and Methods.*** The structure and reasons for the formation of bone defects in the acetabulum were evaluated in 726 cases of revisions performed from 2004 to 2018. In addition, the results of revision operations in a group of patients with severe defects (type 3 according to Paprosky and pelvic discontinuity) were evaluated. ***Results.*** The most frequent cause of defect formation was iatrogenic (53.2%), and the share of severe defects was 39.5% (287 observations). A factor aggravating the severity of the defect is the lack of its limitation by the support bone. The results of RHA in patients with severe defects were assessed in 186 cases out of 287 (64.8%). In 73 (39.2%) cases, individual constructions were used, the average follow-up was 26 months. (from 12 to 50), and in 113 (60.8%) cases, serial implants were used, the average follow-up period was 62 months. (12 to 186). Individual constructions were more often implanted in patients with 3B acetabular defects ($p<0.05$) and its uncontained defects ($p<0.001$). The number of cases of aseptic loosening in the group of patients undergoing endoprosthetics using serial implants was greater than in the group of patients with individual constructions for the entire period ($p<0.05$) and in the early stages of observation ($p<0.05$). ***Conclusion.*** In case of RHA in patients with severe acetabular defects, individual implants, in comparison with serials, demonstrate better survival with an average follow-up of 26 months and due to design features, they can count on great long-term effectiveness. This study needs to be continued to increase follow-up.

Keywords: revision hip arthroplasty, acetabular bone defects, individual implants, serial implants.

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Introduction

Worldwide, more than 1 million of primary total hip arthroplasties (THA) are performed annually [1, 2]. An increase in the number of primary THA leads to an inevitable increase in the number of revisions [3, 4, 5]. The revisions are a difficult reconstructive task, required careful preparation and wide material and technical support. Although, even with all the necessary conditions the revisions are characterized by a high level of complications [6, 7, 8]. One of the causes of the high rate of revisions failures is bone defects of varying severity [9, 10, 11]. For the evaluation of the periacetabular bone loss in revision THA, various classifications have been developed. The most used of them is the Paprosky classification [12], proposed in 1993 [13, 14]. But despite its popularity, the classification does not take into account some important characteristics of the defects, namely whether the defect is contained or uncontained, as well as whether the pelvic ring continuity preserved or not [12, 15, 16]. These two important parameters are provided in the Saleh/Gross [17, 18] and AAOS [19] classifications. But it is not always possible to determine these indices based on the standard X-rays without additional CT and intraoperative imaging [12, 20, 21, 22].

Today, there exist various surgical options for providing primary reliable fixation and optimization of biomechanics relationship in the hip: large hemispherical acetabular components (Jumbo cup) using multiple screws [23, 24], including increased porosity [25], impaction bone grafting in combination with cement cups [26, 27], structural allo-and autografts combined with various constructions [28, 29], anti-protrusion cages [30, 31], highly porous acetabular components with metal augments [32, 33] and cup-cage constructions [34, 35]. The results of revision with various standard components are largely contradictory and depend on the specific revision conditions: the size of the defect, bone quality, the compliance of the components with the task to be solved, and the surgeon's skill. The literature describes various algorithms for choosing the acetabular construction based on the defect severity [36, 37], but the significant bone defects heterogeneity within one classification category makes it difficult to select surgical tactics and to compare the treatment results [12]. In practice, the standard components provide adequate initial stability and further osseointegration in conditions of sufficient contact with the underlying viable bone. However, in the conditions of limited contact, the results of arthroplasties significantly worsen [38]. In this regard, in the last decade, interest in individual constructions (ICs) has significantly increased. The ICs provide primary implant stability, even in the condition of catastrophic defects in the acetabulum region [44, 45, 46].

Conducting this study, we tried to solve several issues:

1) To assess the degree of acetabular defect severity and the probable causes of defects formation in the patients undergone revision THA, as well as to identify factors aggravated the defects severity.

2) To identify the proportion of severe defects in the overall structure of the acetabular revision and determine the effectiveness of serial constructions (SCs) in comparison with made by 3D printing ICs.

3) To justify the rational indications for the use of ICs.

Materials and Methods

The study design: retrospective cohort study.

At the first stage, the study included 726 cases of revision THA performed by one surgical team from 2004 to 2018.

Analysis of the bone defects structure in this group of patients was carried out on the basis of the Paprosky classification with an additional feature of defect containment in accordance with the Saleh/Gross classification. The group of patients with pelvic discontinuity was considered separately. The inclusion criterion in this study at the 1st stage was the information on the revision THA with acetabular component replacement and the availability of pre- and post-operative X-rays.

The reasons for defects formation were divided into the following groups:

"Osteolysis and loosening" — the formation of a defect under the influence of polyethylene or metal wear products, as well as the mechanical bone destruction due to acetabular component loosening.

"Iatrogenic effect" — the formation of a defect as a result of the removal of well-fixed acetabular components, for example, in a spacer placement or revision for recurrent dislocations and persistent pain, destruction of the acetabulum by a unipolar or bipolar endoprosthesis, or by a prefabricated spacer, and also the acetabular component placement in a non-anatomical position in the patients with dysplasia and acetabular fractures consequences.

"Post-traumatic changes" — the consequences of acetabulum fractures or destruction of the bones that form the acetabulum after migration of the constructions for the proximal femur osteosynthesis.

For the second stage, a group of patients with severe acetabulum defects was selected. The criterion for inclusion into the study at stage 2 was the availability of information at the time of the study conduction about patient's condition, artificial hip function and performed revisions. In total, 186 cases of revision THA were subjected to in-depth analysis. All of them had severe defects (Paprosky 3 and pelvic discontinuity). The analysis of this group was conducted on the basis of medical records and X-rays. The following indicators were determined:

In this group, on the basis of medical records and X-ray studies, the following factors were determined: gender; age; body mass index; the number of hip surgeries; diagnosis for primary THA; reason for the revision; volume of the revision; surgical approach (extended hip osteotomy); bone grafting; operative time; the number of fixing elements in the acetabular construction placed.

The evaluation of surgical treatment results when the comparative effectiveness of ICs and SCs employment was carried out on the basis of complications (aseptic loosening, periprosthetic infection, recurrent dislocations). The functional status of the patients was assessed by the Harris Hip Score (HHS) and Oxford Hip Score (OHS).

Statistical analysis

Statistical processing was performed using the software package Past 3.14. For quantitative indicators, after checking for normal distribution, the Student's parametric criterion was used, for the non-parametric — the Mann-Whitney criterion. For qualitative indicators, a set of nonparametric criteria was employed: χ^2, χ^2 with Yates's correction and Fisher's criterion. A risk ratio and odds ratio were also calculated with a confidence interval of 95%.

Results

The most common cause of defect formation was iatrogenic (53.2%). In 61.4% it was due to the endoprosthesis removal because of infection and spacer placement (Tabl. 1). Revisions for severe defects were performed in 287 cases (39.5%), the proportion of uncontained defects was 30.7% (223 cases). In osteolysis and loosening, the uncontained defects were observed 2.3 times less than contained, in iatrogenic origin — 2.6 times less, and in the consequences of injury — 4.3 times more often. The most numerous groups were groups with Paprosky 2A, 2B and 3A defect.

Table 1

Characterization of the defects depending on the cause of their formation, *n* (%)

Type of defect by Paprosky	Defect containment	Cause of defect formation, n (%)			Total
		Osteolysis/ loosening	Iatrogenic	Post-traumatic	
1	Contained	4 (0.6)	27 (3.7)	0	31 (4.3)
2A	Contained	54 (7.4)	128 (17.6)	1 (0.1)	183 (25.2)
2B	Contained	75 (10.3)	83 (11.4)	0	158 (21.8)
	Uncontained	4 (0.6)	8 (1.1)	0	12 (1.7)
2C	Contained	28 (3.9)	10 (1.4)	2 (0.3)	40 (5.5)
	Uncontained	8 (1.1)	7 (1.0)	0	15 (2.1)
3A	Contained	37 (5.1)	24 (3.3)	2 (0.3)	63 (8.7)
	Uncontained	28 (3.9)	64 (8.8)	10 (1.4)	102 (14.0)
3B	Contained	21 (2.9)	7 (1.0)	0	28 (3.9)
	Uncontained	39 (5.4)	21 (2.9)	7 (1.0)	67 (9.2)
Pelvic discontinuity	Uncontained	15 (2.1)	7 (1.0)	5 (0.7)	27 (3.7)
Contained		219 (30.2)	279 (38.4)	5 (0.7)	503 (69.3)
Uncontained		94 (12.9)	107 (14.7)	22 (3.0)	223 (30.7)
Sum		313 (43.1)	386 (53.2)	27 (3.7)	726 (100)

At the second stage, the results of the surgery were evaluated in 186 of 287 severe defects (64.8%). In 73 cases (39.2%), the ICs were used, the average follow-up was 26 months (12 to 50 months). In 113 cases (60.8%), the SCs were used, the average follow-up was 62 months (12 to 186 months). The comparative analysis of the groups with SCs and ICs revealed the statistically significant differences in the average age of the patients (p<0.01). ICs were placed in younger patients.

Also, the patients from ICs group were superior to the patients with SCs in the number of joint surgeries (p<0.05), duration of surgery (p<0.001), and the number of fixing elements (p<0.001).In addition, there were observed differences in primary diagnoses (p<0.05), approach used (p<0.05), and body mass index (p<0.05) (Tabl. 2, 3).

ICs were more often placed in the patients with of Paprosky 3B defects (p<0.05) and uncontained Saleh/Gross defects (p<0.001) (Tabl. 4).

Analyzing by the four radiological signs on which the Paprosky classification is based, statistically significant differences were found within the framework of one defect category, namely: migration of rotation center of femoral component types 3A and 3B acetabulum defects (p<0.05), ischial lysis (p<0.01) and migration beyond the Kohler's line (p<0.05) with 3B acetabulum defects (Tabl. 5).

The following options were most often used in the group of SCs: a) hemispherical acetabular component — 43.4% (49 cases out of 113); b) a hemispherical acetabular component in combination with one augment — 39.8% (45 cases out of 113). In the group of ICs, the tri-flange constructions were the most commonly used — 64.5% (45 cases out of 75) (Fig. 1, 2).

Table 2

Comparative characteristics of the patients in both groups

Indicator		Group		Total
		Serial constructions (*n* = 113)	Individual constructions (*n* = 73)	
Gender	Male	30 (26.6%)	16 (21.9%)	46 (24.7%)
	Female	83 (73.4%)	57 (78.1%)	140 (75.3%)
Average age, years		62.8 (sd 12.9) (min-max 31–91) (med 62) **	56.6 (sd 13,5) (min-max 27–84) (med 58)	60.4 (sd 13.4) (min-max 27–91) (med 61)
Body mass index		27.0 (sd 4.3) (min-max 17.7–39.3) (med 27.0)	28.6 (sd 4.7) * (min-max 18,7–42.6) (med 28.3)	27.6 (sd 4.5) (min-max 17.7–42.6) (med 27.4)
Average number of hip surgeries		2.2 (1–6)	2.9 (1–8)*	2.2 (1–8)
Cause of revision	Aseptic loosening	69 (61.1%)	51 (69.9%)	120 (64.5%)
	Infection	39 (34.5%)	22 (30.1%)	61 (32.8%)
	Dislocation	2 (1.8%)	–	2 (1.1%)
	Others	3 (2.6%)	–	3 (1.6%)
Primary diagnosis	Idiopathic arthrosis	31 (27.4%)	18 (24.6%)	49 (26.3%)
	Dysplastic arthrosis	43 (38.1%)	32 (43.8%)	75 (40.3%)
	Post-traumatic arthrosis	21 (18.6%)	17 (23.1%)	38 (20.4%)
	Rheumatoid arthritis	7 (6.2%)	5 (6.8%)	12 (6.5%)
	Proximal femur fracture or pseudoarthrosis	10 (8.8%)*	–	10 (5.4%)
	Others	1 (0.9%)	1 (1.3%)	2 (1.1%)

* *p*<0,05; ** *p*<0,01; *** *p*<0,001.

Table 3

Peculiarites of surgeries employed the serial or individual constructions

Indicator		Group		Total
		Serial constructions (*n* = 113)	Individual constructions (*n* = 73)	
Revision volume	Total revision	73 (64.6%)	48 (65.8%)	121 (65.1%)
	Acetabular component revision	40 (35.4%)	25 (34.2%)	65 (34.9%)
Approach	Anterior lateral	93 (82.3%)*	44 (60.3%)	137 (73.7%)
	Posterior	18 (15.9%)	20 (27.4%)	38 (20.4%)
	Combined	2 (1.7%)	9 (12.3%)*	11 (5.9%)
Extended hip osteotomy	Yes	27 (23.9%)	23 (31.5%)	50 (26.9%)
	No	86 (76.1%)	50 (68.5%)	136 (73.1%)
Acetabulum bone grafting	Yes	68(60.1%)	36(49.3%)	104 (55.9%)
	No	45(39.8%)	37(50.7%)	82 (44.1%)
Operative time, min		149 (65–300)	189 (60–310)***	164 (60–310)
Blood loss, ml		594 (100–2700)	662 (200-2450)	620 (100–2700)
Number of fixing elements		4.5 (0–11)	8.1 (2–13)***	5.8 (0–13)

* *p*<0,05; ** *p*<0,01; *** *p*<0,001.

Table 4

The use of serial and individual constructions depending on the defects severity

Indicator & cause of defect formation		Serial constructions	Individual constructions
Paprorsky	3A	71	28
	3B	35	36*
Saleh/Gross	Contained	48	11
	Uncontained	58	53**
Pelvic discontinuity		7	9

* *p*<0,05; ** *p*<0,01.

Table 5

X-ray characteristics of bone defects severity depending on the acetabulum defect type and constructions used

X-ray sign	Type of defect						Total
	3A		3B		Pelvic discontinuity		
	Serial	Individual	Serial	Individual	Serial	Individual	
"Teardrop" osteolysis, mm	1.8	1.6	2.4	2.3	2.4	2.6	2.2
Ischial lysis, mm	5.6	6.4	8.0	11.1**	9.4	11.5	8.8
Migration beyond the Kohler's line, mm	0	0	10.0	14.0*	10.5	10.6	11.2
Cranial migration of the rotation center before the surgery, mm	44.9	51.2*	59.3	67.6*	61.1	63.1	57.9

* *p*<0,05; ** *p*<0,01.

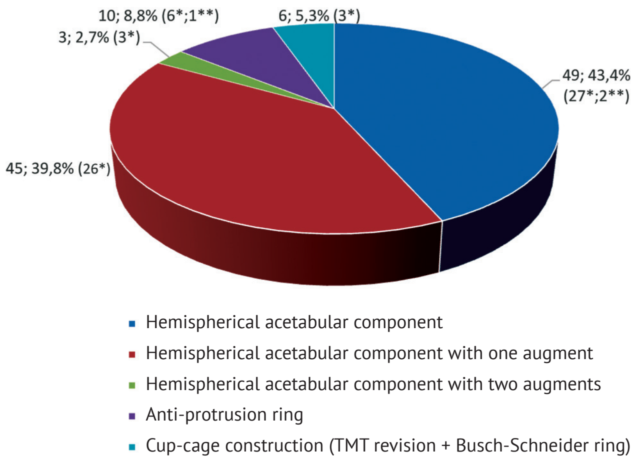


Fig. 1. Distribution of patients according to options of standard implants used
* — using morselized bone graft;
** — using structural bone graft.

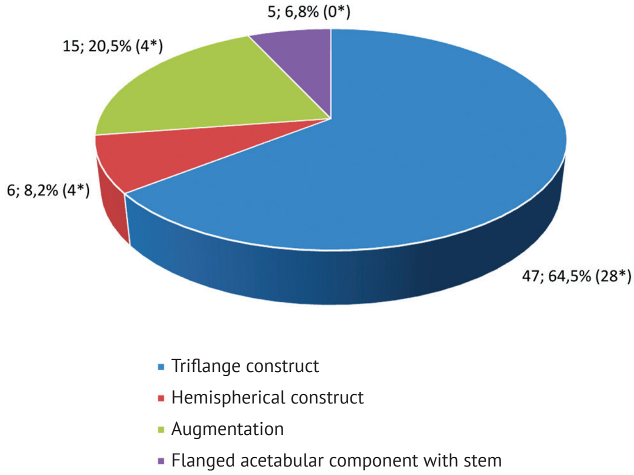


Fig. 2. Distribution of patients according to options of individual implants used
* — using morselized bone graft.

Over the entire follow-up period, 18 patients from the SCs group required re-revisions. In 12 cases, the aseptic loosening of the components was observed within the first 4 years after the previous surgery, in 6 cases — at a later time. In 12 cases out of 18, during the re-revision, the ICs were placed, and in 6 cases — SCs (Tabl. 6).

In the group of patients with ICs, the only case of aseptic loosening occurred within one year after the surgery. Later, the acetabular component migration was complicated by the lower flange fracture of the construction. To date, the patient has been invited to the clinic for the revision.

The number of cases of aseptic loosening in the group of patients undergone revision with SCs was significantly greater than in the group of patients who had ICs placed ($p<0.05$). It was observed for the entire follow-up period, as well as within the first 4 years of follow-up ($p<0.05$) (Tabl. 6).

All cases of periprosthetic infection were observed during the 1st year after the surgery and required debridement with the components removal. It should be noted that all patients who had infectious complications after of ICs placement had a history of periprosthetic infections.

In 2 cases of recurrent dislocations in the group of ICs, the revisions were performed with the dual mobility system and the acetabular component preservation. No further dislocations were observed in these patients.

In the group of 3B defects, the rate of aseptic loosening in the patients undergone revisions with SCs was greater than in the patients undergone ICs placement ($p<0.05$).

There was a statistically significant difference in the rate of aseptic loosening after SCs placement in the patients with uncontained defects in comparison with the same category of patients after ICs placement for the entire follow-up period ($p<0.05$), as well as within the first 4 years after surgery: 8 cases of loosening out of 58 in the group of SCs, one case out of 53 in the group of ICs ($p<0.05$) (Tabl. 6).

In the group of patients with uncontained defects undergone the SCs placement, a relationship between the loosening rate and the defect replacement method was found ($p<0.05$). Revisions with the employment of massive allografts in comparison with augments led to an increase in the likelihood of aseptic loosening (OR = 5.1 CI 95%: 2.6–9.9). In the Scs subgroup, 3 out of 3 patients required a re-revision, in the ICs — 7 out of 36.

The evaluation of the results with additional characteristics of 3A and 3B defects (contained vs. uncontained), the rate of aseptic loosening in the patients with of SCs placement was as follows ($p<0.01$): 3A contained defects — 3.3% of aseptic loosening (1/30), 3B contained defects — 5.5% (1/18), 3A uncontained defects — 9.8% (4/41), 3B uncontained defects — 41.2% (7/17). In case of ICs, aseptic loosening was observed only in one patient (Tabl. 6).

The SCs placement in the patients with an unstable pelvic ring resulted in a greater number of aseptic loosening cases than the placement of ICs for the entire follow-up period, as well as within the first 4 years of follow-up ($p<0.05$). There were 4 cases of loosening out of 7 in the group of SCs vs. 0 out of 9 cases in the group of ICs ($p<0.05$) (Tabl. 6).

Functional results

The functional results of SCs vs. ICs employment did not reveal any statistical differences by both scales, OHS HHS, considering each group of the patients as a whole. However, in the subgroup of the patients with pelvic discontinuity, the patients with ICs placement had the functional results significantly higher than the patients with SCs ($p<0.05$) (Tabl. 7).

Table 6

The rate of complications in the patients after the placement of serial or individual constructions taking into account two classifications and pelvic discontinuity

Complications	Serial constructions (*n* = 113)						Individual constructions (*n* = 73)						Serial and individual constructions in sum					Total (*n* = 186)
	Type of defect					Total	Type of defect					Total	Type of defect					
	3A		3B				3A		3B				3A		3B			
	Cont (*n* = 30)	Uncont (*n* = 41)	Cont (*n* = 18)	Uncont (*n* = 17)	PD (*n* = 7)		Cont (*n* = 7)	Uncont (*n* = 20)	Cont (*n* = 4)	Uncont (*n* = 33)	PD (*n* = 9)		Cont (*n* = 37)	Uncont (*n* = 61)	Cont (*n* = 22)	Uncont (*n* = 50)	PD (*n* = 16)	
Aseptic loosening	1 (3.3%)	4 (9.8%)	1 (5.5%)	7 (41.2%)*	5 (71.4%)*	18 (15.9%)*	–	–	–	1 (3.1%)	–	1 (1.4%)	1 (2.7%)	4 (6.0%)	1 (4.5%)	8 (16.0%)	5 (31.3%)	19 (10.2%)
Infection	–	–	–	–	–	–	–	–	–	3 (9.1%)	–	3 (9.1%)	–	–	–	3 (6.0%)	–	3 (1.6%)
Dislocation	2 (6.7%)	1 (2.4%)	–	2 (11.8%)	–	5 (4.4%)	–	–	–	2 (6.1%)	–	2 (2.7%)	2 (5.4%)	1 (1.6%)	–	4 (8.0%)	–	7 (3.8%)
SUM	3 (10.0%)	5 (12.2%)	1 (5.5%)	9 (53.0%)	–	23 (20.3%)	–	–	–	6 (18.3%)	–	6 (8.2%)	3 (8.1%)	5 (8.2%)	1 (4.5%)	15 (30.0%)	5 (31.3%)	29 (15.6%)

* $p<0,05$. Table 6 abbreviations: Cont – contained defects; Uncont – uncontained defects; PD – pelvic discontinuity.

Table 7

The comparison of functional results after serial and individual constructions placement

Classifications	Serial constructions (n = 113)					Individual constructions (n = 73)				
	Type of defect					Type of defect				
	3A		3B		PD (n = 7)	3A		3B	3B	PD (n = 9)
	Cont (n = 30)	Uncont (n = 41)	Cont (n = 18)	Uncont (n = 17)		Cont (n = 7)	Uncont (n = 20)	Cont (n = 4)	Uncont (n = 33)	
Oxford Hip Score	35.9 (sd 10.2)	33.5 (sd 10.3)	34.6 (sd 10.6)	34.4 (sd 9.9)	23.3(sd 8.7) (min-max 13–38) (med 23)	36.0 (sd 7.8) (min-max 16–48) (med 35)	35.3 (sd 9.0)	40.0 (sd 7.3) (min-max 23–48) (med 43)	36.6 (sd 8,4)	34.6 (sd 7.6)* (min-max 25–45) (med 35)
Harris Hip Score	74.8 (sd 22.5)	66,4 (sd 28.2)	72.5 (sd 24.9)	71.7 (sd 24.7)	42.0 (sd 26.2) (min-max 16–83) (med 49)	74,6 (sd 12.2) (min-max 50–96) (med 74)	68.6 (sd 18.4)	73.8 (sd 15.7) (min-max 49–94) (med 76)	72.8 (sd 16.2)	69.5 (sd 16.7)* (min-max 52–89) (med 71)

* p<0,05. Table 7 abbreviations: Cont – contained defects, Uncont – uncontained defects, PD – pelvic discontinuity.

Discussion

The choice of a method for acetabular revision is based on the understanding of the bone defect type. Until now, the most commonly used classification has been Paprosky, which is based on the assessment of four X-ray signs which characterize the change in various parts of the acetabulum [13]. However, in clinical practice, we often encounter situations where the interpretation of these signs does not correlate with the real severity of the acetabular defect. Such situations are most often observed in iatrogenic defects and the consequences of acetabulum fractures. According to our data, the rate of such defects is 45.7%. It turns out that the classification created in the early 1990s to describe the osteolytic acetabular defects is not enough for a detailed assessment of the acetabular bone tissue condition, especially in view of the modern imaging technologies. On the other hand, the analysis of the long-term results of the complex acetabular defects treatment in terms of Saleh/Gross "contained/uncontained defect" revealed that the greatest number of aseptic loosenings after SCs placement occurred in the patients with 3A and 3B uncontained defects. In this regard, in the era of the widespread 3D visualization technology, it is advisable to further characterize the main types of defects (according to the Paprosky classification), based on their "contained/uncontained" characteristic. Undoubtedly, a more detailed quantitative assessment of the "uncontained defect" type is necessary, since the surgical technique of transition such a defect into a contained largely depends on such detalization. It is also true for the assessment of the acetabulum fragments mobility and degree of displacement in pelvic discontinuity.

The long-term results of severe, but contained, acetabular defects are quite favorable, even employing various standard surgical technologies, from the porous multi-hole hemispherical cups to the impaction bone grafting [26, 47]. In our observations, the rate of aseptic loosening was 3.3% within an average follow-up of 60 months. The good results are based on several following principles. Gentle but, at the same time, thorough treatment of bone tissue until a viable bone appears. The maximum possible contact of the implant with the bone. For that purpose the bone grafting is used only to fill cavitary defects. The maximum possible use of screws for additional fixation of the implant, mandatory fixation of the Charnly-DeLee 3rd zone. Undoubtedly, the presence of acetabulum and construction plastic models in the operating room is useful for determining the optimal location of the screws. Good long-term results of SCs in the patients with contained acetabulum defects narrow the indications for using ICs. In our opinion, the latter are suitable for use in the form of complex augments, especially for iatrogenic and post-traumatic defects, or in the form of hemispherical cups with a given holes location in the cases of limited preservation of acetabular bone tissue.

Much worse are the results of treatment of 3B uncontained acetabulum defects. The rate of loosening with the SCs employment reaches almost 41%. An analysis of the complications made it possible to formulate several principles, which could reduce the number of unsatisfactory results.

In 3A uncontained acetabulum defects, the main cause of the failure is the limited contact of serial augment with the bone bed. The absence of a good mechanical support in conditions of complex acetabulum anatomical disturbance does not provide the possibility for secondary osseointegration and leads to a displacement (usually rotational) of the entire construction. An example of loosening after replacing an uncontained 3A defect with a serial augment and a hemispherical cup is a 27-year-old patient (Fig. 3).

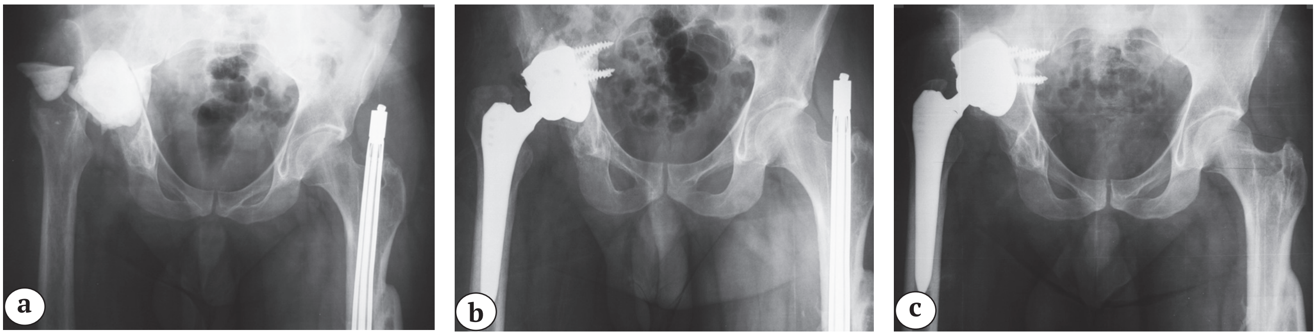
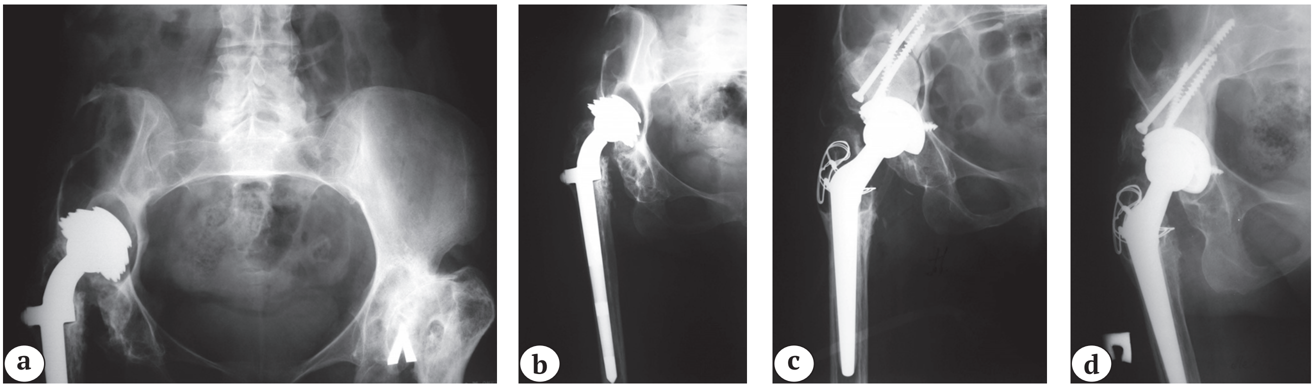


Fig. 3. X-rays of male patient 27 y.o.:
a — at admission: there is a block-shaped spacer of the right hip joint, established about a periprosthetic infection 4 months ago;
b — during the revision, uncontained defect 3A is blocked by an augment set on the flat side to the ilium;
c — the lack of sufficient osseointegration of serial augment due to limited contact and severe sclerosis of the underlying bone, as well as the lack of good fixation in the projection 3 of the Charnley-DeLee zone, resulted in the migration of standard implants 4 years after endoprosthetics, which required the installation of an individual construction.

For the same reason, we refused to use massive allografts to replace large acetabulum defects (and not only of 3A type). The limited fusion along the edge of the bone and the absence of complete bone substitution ultimately lead to loosening of the construction (Fig. 4). Therefore, the use of complex individual augments, produced considering the acetabulum anatomy, is quite justified for these types of defects.



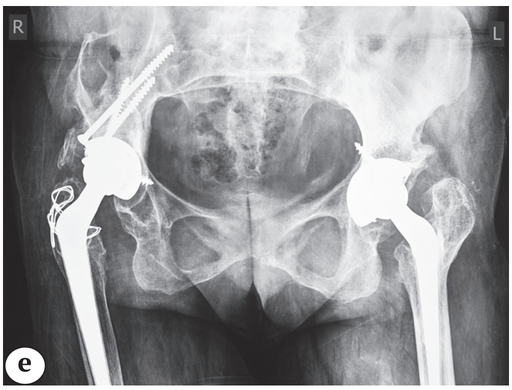


Fig. 4. X-rays of female patient 50 y.o.:
a, b — at admission: loosening of acetabular component;
c — for reconstruction of the defect area a massive allograft was used, then a hemispherical acetabular component was installed with a distal reduction of the rotation center from the previous level by 15 mm;
d — 7 years after revision;
e — 12 years after revision, displacement of the acetabular component is determined — the line of X-ray enlightenment in the 3rd zone of Charnley-DeLee increases.

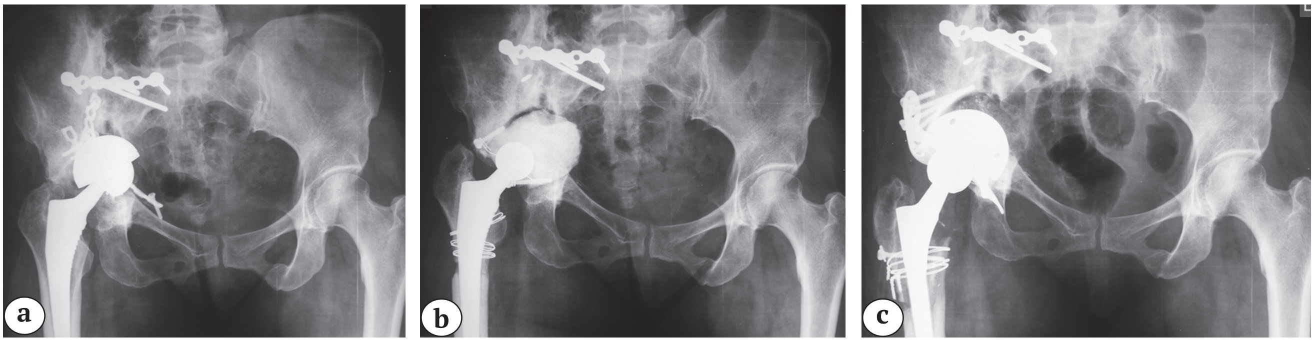
Over the course of 5 years, the graft provided stable fixation. But at the 7th year of follow-up, the patient began to suffer from pain in the area of the hip surgery. In the control X-ray, the migration of the cup was revealed. In the 12th year of the follow-up, in view of the increased pain and further acetabular component migration, re-revision was performed. In this case, we observed the absence of the massive allograft rearrangement and its replacement with bone tissue. As a result, the allograft did not provide adequate support for the acetabular component.

In uncontained 3B defects, one of the key moments is the replacement of a defect in the inner acetabulum wall to transfer the uncontained defect into a contained. This will provide the sufficient contact of the implant with the bone, required for secondary osseointegration, the stable primary fixation of the implant, especially in the lower sections, the so-called Charnley-DeLee 3rd zone. We illustrate the above mentioned with three clinical examples.

Case 1. A 43-year-old female patient undergone a right THA a year earlier in another medical institution. She was admitted with post-traumatic coxarthrosis and acetabular component loosening (Fig. 5).

The placement of two augments connected together in the patients with large post-traumatic acetabular uncontained defect did not provide the conditions for their reliable fixation because of limited contact with the sclerosed bone. The absence of secondary osseointegration and the mobility of the entire construction ultimately led to a fracture of the Burch-Shneider anti-protrusion ring. This example is very indicative from the point of view of the need to quantify an acetabular uncontained defect.

Another clinical example of the difficulty to ensure a reliable fixation with a SC in the patients with 3B uncontained defect is a 70-year-old female patient (Fig. 6).



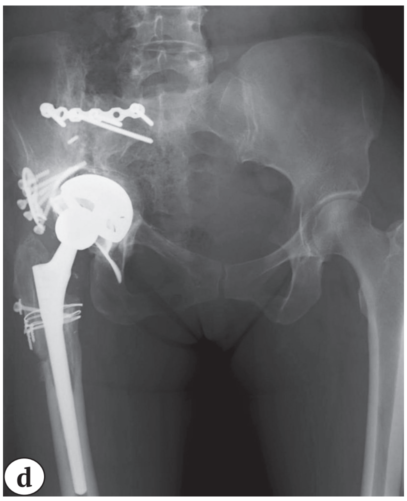


Fig. 5. X-rays of female patient 43 y.o.:
a — significant migration of the acetabular component beyond the Kohler line, uncontained defect 3B;
b — a spacer was installed in the first stage of treatment;
c — during revision: implant bone grafting of cavitary defects and the creation of a medial support from two trabecular metal augments connected by bone cement, then an antiprotrusion ring was installed;
d — 2 years after revision: aseptic loosening was revealed as a result of the lack of osseointegration of the medial support under cyclic loads, a fracture of the antiprotrusion construction occurred.

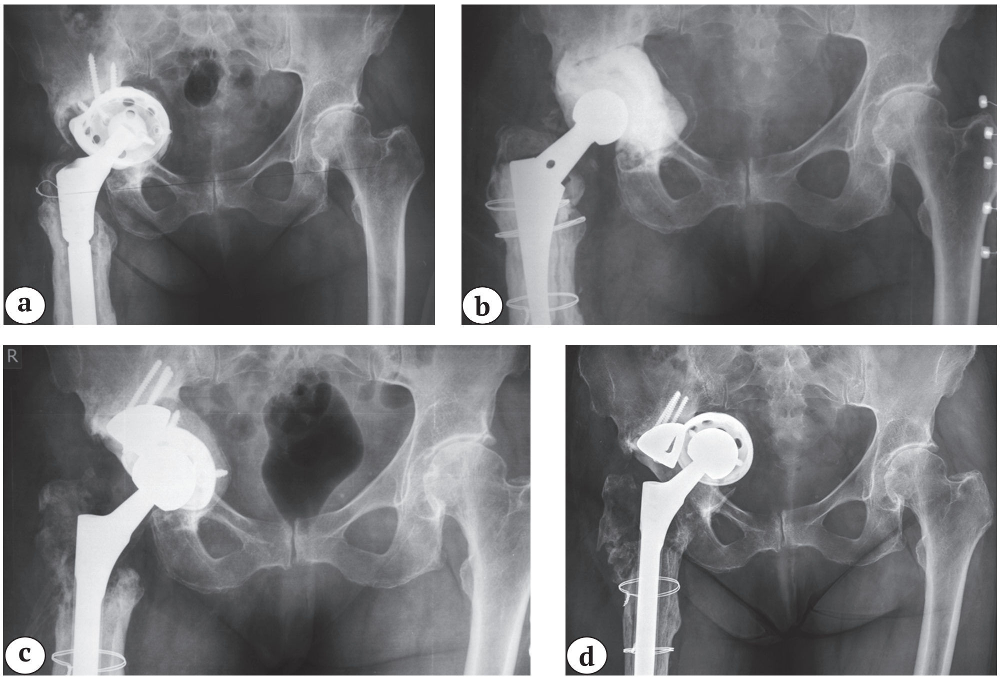


Fig. 6. X-rays of female patient 70 y.o.:
a — at admission: there is significant medial migration of the acetabular component beyond the Kohler line;
b — due to infection, in the first stage of treatment a spacer was installed;
c — after 10 months revision surgery was performed: bone grafting of cavitary defects, the defect superior and anterior wall was replaced with an augment, then a multi-hole cup was implanted;
d — the lack of good medial support and insufficient contact of the acetabular component with the ishium bone, as well as poor fixation in the projection of the zone 3 Charnley-DeLee, led to loosening and medial migration of the construction for 2 years.

The use of SC with such large medial defects does not provide mechanical strength. The latter can be achieved either by using cup-cage structures, or by ICs.

In yet another clinical example, we see a multifactorial cause of the poor result: the use of a massive allograft in the treatment of 3B uncontained defect, limited contact of the TMT component with acetabular bone tissue and the absence of the 3rd zone fixation (Fig. 7).

It is likely that in such clinical situations the use of ICs provides potential advantages, but according to the literature, the rate of unsatisfactory results was quite high (Tabl. 8).

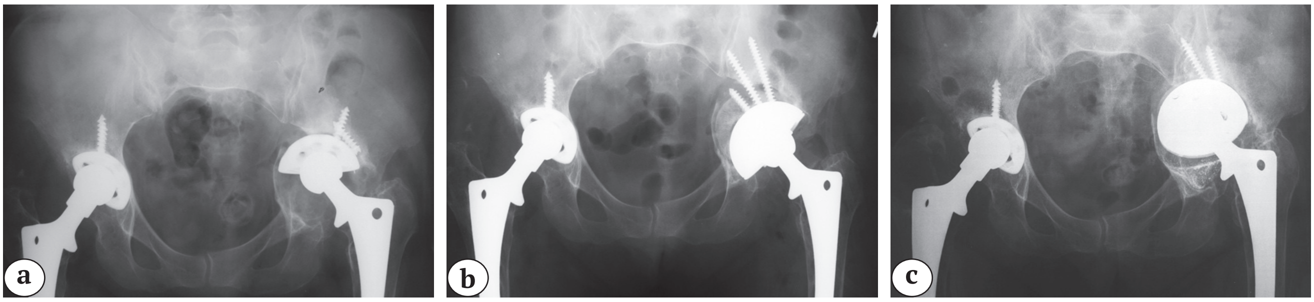


Fig. 7. X-rays of female patient 57 y.o.:
a — at admission: significant upper medial migration of the acetabular component beyond the Kohler line;
b — during revision was performed with the replacement of the defect of the medial wall with a structural allograft and the installation of a standard highly porous hemispherical acetabular component;
c — as a result of the lack of sufficient mechanical support on the part of the allograft and the fixation of the 3 Charnley-DeLee zone, after 4 years, repeated migration of the acetabular component was observed.

Table 8

The rate of complications after revisions with individual constructions (data from literature) [44]

Authors, year	Number of observations	Follow-up duration	Type of defect (n)	Number of complications
Wind et al., (2013)	19	31 (16–59)	AAOS III (16), IV (3)	6 (31.5%)
Friedrich с соавт. (2014)	18	30 (17–62)	Paprosky 3B or AAOS III and IV (18)	5 (27.8%)
Berasi et al., (2015)	24	57 (28–108)	Paprosky 3B (24)	2 (8.3%)
Barlow et al., (2016)	63	52 (17–87)	Paprosky 3 (63)	17 (27%)
Baauw et al., (2017)	12	25 (19–39)	Paprosky 3A (4), 3B (8)	0 (0%)
Gladnick et al., (2018)	73	90 (60–144)	Paprosky 3B (73)	14 (19.1%)
Myncke et al., (2017)	22	25	Paprosky 3A and 3B (22)	0 (0%)
Moore et al., (2018)	35	Not less than 120	The absence of support of one or both acetabular columns or defect of the medial wall of more than 4 cm in combination with an uncontained defect affecting the acetabulum roof (35)	3 (8.6%)
Kieser et al., (2018)	18	62 (34–108)	Paprosky 3A and 3B (18)	1 (5.5%)

At the same time, the overall rate of complications after ICs placement (14.2%) is not so much higher than the rate of complications after revision HAs with Scs. It should be noted that ICs were placed for more complex defects according to various classifications (Tabl. 9).

ICs are used, as a rule, for the most complex acetabular defects, in cases where the use of SCs does not provide the reliable stable fixation.

In our study, with the same type of Paprosky defect, ICs were placed with a more pronounced cranial-lateral (51.2 mm) and cranial-medial (67.6 mm) migration of the femoral component rotation center, in comparison with SCs (44.9 mm and 59.3 mm). The migration determines the degree of destruction of the acetabulum upper lateral part in 3A defects and the upper medial walls, as well as the anterior column with 3B defects, respectively. It was also revealed that ICs were more often placed in the patients with uncontained acetabulum bone defects (82.8%).

The rate of aseptic loosening after revision THA with ICs, observed in our study, was 1.6%. It is comparable to that of other authors (according to a systematic review by F. Chiarlone et al. [48], 2.6%, SD 4.0%, 634 observations). A small number of aseptic loosenings did not allow revealing a statistically significant relationship with any risk factor. However, it is worth noting that the only case of loosening in the patients with ICs placement occurred as a result of a fracture of the metal construction flange. The likely cause of the fracture, in our opinion, was the resorption of the osteoplastic material, which was used in the reconstruction of an uncontained acetabulum defect. Perhaps, this led to a fracture of the flange under cyclic loads.

Table 9

The rate of complications after revisions with serial constructions (data from literature) [44]

Options used	Number of observations	Follow-up duration	Type of defect (*n*)	Rate of complications
Hemispherical Jumbo cup acetabular component	518	117 (65–240)	Paprosky 3A (86), 3B (29), AAOS III (114) and IV (2)	12.1%
Reconstructive cages and rings	831	81 (41–175)	Paprosky 3A (156), 3B (178), AAOS III (228) and IV (43), SOFCOT stage 3 (62) and 4 (43)	11%
Trabecular metal augments	1021	49 (21–175)	Paprosky 3A (291), 3B (107), AAOS III (14) and IV (2)	7.3%
Impaction bone grafting combined with metal mesh	204	63 (32–89)	Paprosky 3A (98), 3B (83), AAOS III (23)	7.3%

The most common cause of complications in the group of patients undergone the ICs placement was periprosthetic infection. According to the literature, one of the risk factors for periprosthetic infection during revision arthroplasty was the duration of surgery and the presence of infection after previous hip surgeries in the anamnesis. The average duration of surgery in our patients with ICs exceeded the duration of surgery in the patients with SCs and amounted to 189 minutes. However, this indicator was much lower than presented in the literature. Myncke [49] and DeBoer [43] in their studies reported an average duration of surgery of 241 and 300 minutes, respectively. At the same time, there was a correlation between the rate of infection after ICs placement and the history of surgeries for infection, which reached the value of a statistical trend (11% vs 0%, $p = 0.07$). Thus, the high rate of infectious complications (8.3%), in our opinion, is associated with the initial severity of the patients due to a history of infection.

Another problem that we encountered in our study was dislocations. Unfortunately, even the optimal anteversion and acetabular component tilt, calculated on the basis of 3D visualization of the pelvis, do not prevent dislocations associated with gluteal muscle deficiency, deterioration of the soft tissues as a result of repeated surgeries, the presence of an acetabulum defect which interferes with the restoration of the center of rotation, and the femoral apparatus tension.

Conclusion

Based on the above mentioned, the most justified indications for the use of ICs are uncontained 3A and 3B defects and pelvic discontinuity, since according to our research, the treatment of these defects using various surgical tactics with SCs was accompanied by an extremely high rate of unsatisfactory outcomes and the need for re-revisions. The use of ICs provides reliable primary fixation due to the multiple screws. The porous surfaces of the flanges significantly expand the contact with the bone and make it possible to rely on secondary osseointegration.

The study limitations. Of course, the limitation of this study is the difference in the follow-up duration. However, the ability to provide primary reliable stability due to additional screw fixation of ICs, the potential of secondary biological fixation, as well as the possibility to increase the structural supportability of the constructions in the patients with massive defects, including those outside the acetabular region, make it possible to to expect the long-term survival of these constructions.

Publication Ethics

All the patient gave an informed consent for participation in this clinical study.

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Authors' contribution

R.M. Tikhilov — research concept and design, data interpretation and analysis, text editing.

A.A. Dzhavadov — material collection and processing, research conduction, data statistical processing, text preparation.

A.N. Kovalenko — data analysis and interpretation, text editing.

A.O. Denisov — data analysis and interpretation, text editing.

A.S. Demin — material collection and processing.

A.G. Vahramyan — text preparation.

I.I. Shubnyakov — coordination of study participants, data analysis and interpretation, data statistical processing, text editing.

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