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Paprosky Type 3B Acetabular Defects: Uniform Pattern or Spectrum of Variants?

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Abstract

The aims of the study — to identify variants and combinations of acetabular structural damage in patients with Paprosky type 3B defects based on the three-dimensional reconstructions of the pelvis, as well as to determine the degree of heterogeneity among these variants within type 3B defects and the dependence of the formation of different damage variants on various factors.

Methods. The study included 132 patients with Paprosky type 3B acetabular defects who underwent revision total hip arthroplasty. Based on the computer tomography data, three-dimensional reconstructions of the pelvis were created. Acetabular supporting structures were assessed. Each structure was evaluated according to three levels of integrity: anatomically preserved, partially preserved/lytic destruction, and complete loss of support/full defect. The heterogeneity of defect variants was assessed using the Shannon index. The association between identified defect variants and patient-related factors was evaluated using multivariate ordinal logistic regression with calculation of odds ratios for each factor.

Results. Five main variants of acetabular damage within Paprosky type 3B defects were identified. The most common variant was the combination of a complete medial wall defect and an anterior column defect. The normalized Shannon index was 0.91 (H/Hmax), suggesting that, for the five identified variants, the heterogeneity of type 3B defects approaches the maximum possible level. A prior periprosthetic joint infection increased the odds ratios of developing a defect pattern with more extensive involvement of load-bearing structures by nearly 2.5 times, while each additional revision procedure increased the risk by 65%.

Conclusions. At least five distinct variants of acetabular load-bearing element damage within Paprosky type 3B defects can be identified. Among the five identified variants, the diversity approaches its maximal possible level. Significant factors influencing the variant of defect were a history of periprosthetic joint infection and the number of previous revision operations. Mandatory three-dimensional visualization for extensive acetabular defects gives the surgeon a more informative picture of the lost and preserved supporting elements. Mandatory three-dimensional modeling in cases of extensive acetabular defects provides the surgeon with a more informative understanding of the lost and preserved load-bearing structures.

Keywords: revision total hip arthroplasty; acetabular defects; Paprosky classification; three-dimensional reconstruction; Shannon index.

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Дефекты вертлужной области типа 3B по Paprosky: типичная картина или разнообразие вариантов?

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Реферат

Цели исследования — выделение вариантов повреждений анатомических структур вертлужной впадины и их комбинаций у пациентов с 3B типом дефектов по классификации Paprosky на основании данных трехмерной реконструкции таза, определение степени разнородности вариантов повреждений при дефектах типа 3B и зависимости формирования вариантов повреждений от различных факторов.

Материал и методы. В исследование были включены 132 пациента с дефектами вертлужной области типа 3B, которым было выполнено ревизионное эндопротезирование тазобедренного сустава. На основании компьютерной томографии выполнялась трехмерная реконструкция таза. Оценивалась сохранность опорных структур вертлужной области. Структуры вертлужной области оценивались по трем степеням целостности: анатомическая сохранность, частичная сохранность/литическое разрушение и полное отсутствие опорности/полный дефект. Анализ разнородности вариантов повреждений проводился с использованием индекса Шеннона. Взаимосвязь вариантов повреждений с различными факторами определялась при помощи многофакторной порядковой логистической регрессии с расчетом отношения шансов для каждого фактора.

Результаты. Были выделены пять основных вариантов повреждений вертлужной области типа 3B по классификации Paprosky. Наиболее часто встречаемым вариантом являлась комбинация полного дефекта медиальной стенки и передней колонны. Нормализованный индекс Шеннона составил 0,91 (H/Hmax). Это означает, что при пяти представленных вариантах повреждений мы имеем дело с разнообразием, близким к максимально возможному. Наличие перипротезной инфекции в анамнезе увеличивало отношение шансов варианта повреждения с большим поражением опорных структур почти в 2,5 раза, а количество предшествующих ревизионных операций в анамнезе — на 65%.

Заключение. Можно выделить не менее пяти вариантов повреждений опорных элементов вертлужной области при типе дефектов 3B по классификации Paprosky. При пяти выделенных вариантах отмечается разнообразие, близкое к максимально возможному. Важными факторами, влияющими на вариант повреждения, являются перипротезная инфекция в анамнезе и количество выполненных накануне ревизионных операций. Обязательное трехмерное моделирование при обширных дефектах вертлужной области дает хирургу более информативную картину о потерянных и сохранившихся опорных элементах.

Ключевые слова: ревизионное эндопротезирование тазобедренного сустава; дефекты вертлужной впадины; классификация Paprosky; трехмерная реконструкция дефектов; индекс Шеннона.

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INTRODUCTION

At present, there is a continuing trend toward an increase in the number of revision hip arthroplasty (RHA) procedures. Moreover, predictive models forecast a further rise in their incidence [1]. According to the data from the local registry of Vreden National Medical Research Center of Traumatology and Orthopedics. The frequency of using complex and high-cost acetabular implants in RHA is increasing, indirectly indicating a substantial proportion of severe acetabular bone defects [2]. Under these circumstances, accurate preopera-tive assessment of the extent of bone loss becomes even more important, as it determines the surgical strategy and ultimately influences the outcomes of RHA [3].

Various classifications have been proposed to assess acetabular bone defects [4, 5, 6, 7]. All of them aim to address several objectives — from providing a universal language to describe the degree of skeletal damage to guiding the choice of surgical reconstruction strategies. The Paprosky classification is most commonly used to standardize acetabular defects [8]. It is based on the evaluation of four radiographic criteria: migration of the hip rotation center, ischial osteolysis, teardrop osteolysis, and disruption of Köhler's line. The most extensive and challenging defects to treat, according to the Paprosky classification, are type 3B defects. At the same time, reconstruction options for this defect type encompass a wide range of both standard and patient-specific implants. The variability of technical reconstruction approaches within a single defect type highlights the limitations of the Paprosky classification.

A major drawback of existing classifications is that relying solely on plain radiographs makes it difficult to accurately assess the anatomical characteristics of bone defects, especially in cases of extensive destruction. In such situations, three-dimensional (3D) reconstruction of the acetabular defect region based on computed tomography (CT) data is a valuable visualization tool. When used in addition to radiographic evaluation, this method can significantly influence the surgeon's perception of the defect's severity and affect surgical planning at the preoperative stage [9, 10].

The lack of a unified approach to managing Paprosky type 3B acetabular defects, as well as our routine experience with 3D reconstruction technology at the preoperative stage, led us to formulate the following research questions:

1. What variants and combinations of acetabular structural damage can be identified in patients with Paprosky type 3B defects undergoing aseptic and septic revision?
2. What degree of heterogeneity exists among these variants within type 3B defects?
3. Does the formation of different damage variants depend on patient-related factors such as sex, age, history of periprosthetic joint infection (PJI), time since primary arthroplasty, or the number of previous revisions?

METHODS

Study design

The study design was retrospective.

Inclusion criteria were as follows: (1) presence of a Paprosky type 3B acetabular defect confirmed by radiographic evaluation, and (2) availability of preoperative CT scans.

A total of 132 patients who underwent revision RHA with acetabular component replacement between 2016 and 2023 at our clinic, all operated on by the same surgeon, were included in the study.

The baseline characteristics of the patients are presented in Table 1.

A wide range of surgical implants and their combinations were used, including jumbo cups, modular augments, antiprotrusio cages, cap-cages, and various patient-specific solutions for acetabular reconstruction. The evaluation of treatment outcomes was not within the scope of the present study. Based on the CT data, 3D reconstructions of the pelvis were created. The following acetabular supporting structures were assessed: the iliac wing, anterior column, posterior column, medial wall, and ischium. Each structure was evaluated according to three levels of integrity: anatomically pre-served, partially preserved/lytic destruction, and complete loss of support/full defect.

Patients with acetabular defects involving pelvic ring disruption, which are not represented in the original Paprosky classification, were excluded from the study.

Table 1

Baseline characteristics of the patients

Characteristic	Number of patients	Percentage share / Me [Q_1; Q_3]	min-max
Gender			
male	30	22.7%	–
female	102	77.3%	–
Age, years	132	61 [52; 70]	28-85
History of PJI			
yes	47	35.6%	–
no	85	64.4%	–
Number of previous revision operations	132	1 [0; 2]	0-8
Time since primary arthroplasty, years	106	13 [8; 19]	0-34
	26	No data available	

Statistical analysis

Prior to performing statistical analysis, the normality of distribution of quantitative variables (age, time since primary arthroplasty, and number of previous revision operations) was tested using the Shapiro-Wilk and Kolmogorov-Smirnov tests (with Lilliefors correction). All quantitative variables demonstrated deviation from normal distribution ($p < 0.05$). Therefore, quantitative variables were described using the median (Me) and interquartile range [Q_1; Q_3]. Qualitative variables were presented as absolute frequencies and percentages. To assess the heterogeneity of defect variants, descriptive statistics and diversity analysis were performed using the normalized Shannon diversity index, calculated with the Past 4.16 software package. The association between identified defect variants and patient-related factors was evaluated using multivariate ordinal logistic regression with calculation of odds ratios (OR) for each factor.

RESULTS

Characteristic variants of defects

The analysis of acetabular defects classified as type 3B according to Paprosky in patients indicated for revision of the acetabular component revealed that isolated defects of individual supporting elements of the acetabulum were practically not observed. Such defects were usually combined either with complete destruction of other supporting structures or with lytic bone lesions of varying severity. Therefore, all defects of the supporting elements without complete destruction of at least one of them were grouped separately. Since the analysis included defects with a high migration of the rotation center, all cases demonstrated varying degrees of destruction of the iliac wing.

Thus, five variants of defects were identified (Table 2):

1) lytic defects with partial destruction of the acetabular supporting elements;

2) complete defects of the anterior column with complete or partial preservation of the medial wall and posterior column;

3) complete defects of the medial wall with complete or partial preservation of the anterior and posterior columns;

4) combination of complete defects of the medial wall and anterior column with complete or partial preservation of the posterior column;

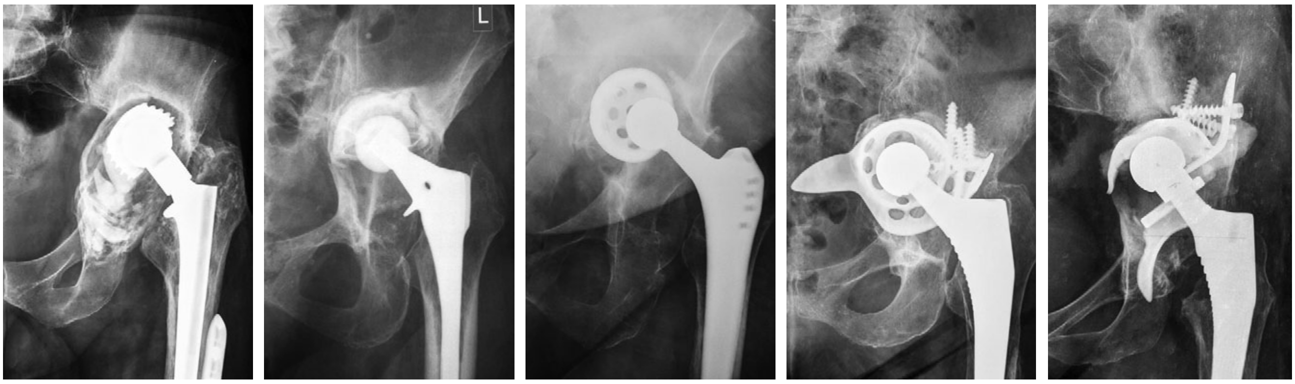
5) combination of complete defects of the medial wall and posterior column with complete or partial preservation of the anterior column.

Table 2

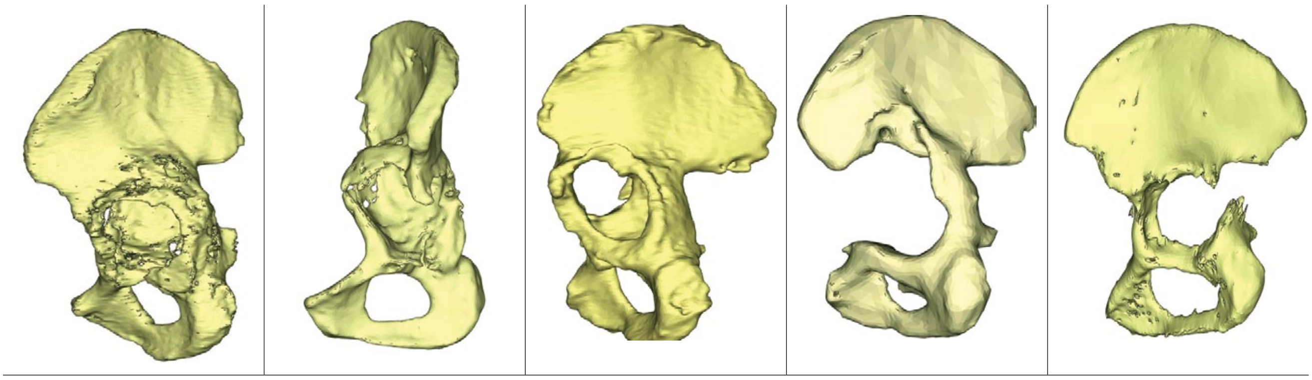
Characteristic variants of defects in patients with Paprosky type 3B defects

Lytic defect with partial destruction of the acetabular supporting elements	Complete defect of the anterior column with preservation of the medial wall and posterior column	Complete defect of the medial wall with preservation of the anterior and posterior columns	Combination of complete defect of the medial wall and anterior column with preservation of the posterior column	Combination of complete defect of the medial wall and posterior column with preservation of the anterior column

X-rays of patients with defects



Three-dimensional reconstructions of the pelvis of the same patients from the side of defect



Statistical assessment of defect heterogeneity

The statistical analysis in the observation group revealed that the most common variant of defect structure within Paprosky type 3B was the combination of a complete medial wall defect and an anterior column defect. This configuration (medial wall + anterior column) occurred almost seven times more frequently than the rarest variant (isolated anterior column defect). The proportions of different defect variants within Paprosky type 3B are shown in Figure 1.

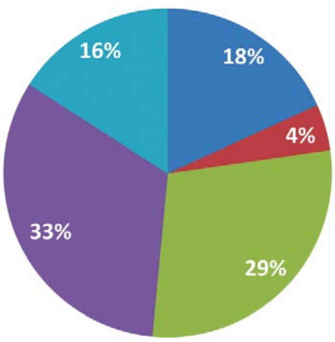


Figure 1. The structure of variants of acetabular damage in Paprosky type 3B defects

The Shannon diversity index indicated that the Paprosky type 3B defect demonstrated moderate heterogeneity (H = 1.465). In addition, the normalized Shannon index, ranging from 0 (no diversity) to 1 (maximum diversity), was 0.91 (H/Hmax), suggesting that, for the five identified variants, the heterogeneity of type 3B defects approaches the maximum possible level. Thus, defects classified as Paprosky type 3B cannot be regarded as a single uniform entity.

Statistical assessment of patient-related factors influencing the defect pattern

Significant factors affecting the pattern of acetabular damage were a history of PJI and the number of previous revision operations. A prior PJI increased the OR of developing a defect pattern with more extensive involvement of load-bearing structures by nearly 2.5 times, while each additional revision procedure increased the risk by 65% (Table 3). The time elapsed since the primary arthroplasty showed a weaker statistical association with the defect category. Patient age and sex had no influence on the type of defect.

Table 3

Impact of patient-related factors on the odds of developing a more severe damage pattern in Paprosky type 3B defects

Patient factor	Coefficient	OR (95% CI)	p-value
History of PJI	0.94	2.56 (1.31-5.01)	0.006
Number of previous revision operations	0.5	1.65 (1.26-2.17)	< 0.001
Time since primary arthroplasty	0.08	1.08 (1.03-1.14)	0.004
Age	-0.01	0.99 (0.97-1.01)	0.370
Sex	0.3	1.35 (0.68-2.68)	0.390

DISCUSSION

Classification systems for acetabular defects in RHA emerged as an attempt to systematize the situations encountered by surgeons and to propose appropriate treatment options. However, the continuous increase in the number of such classifications and the ongoing efforts to introduce new modifications indicate that existing systems fail to encompass all possible defect types, particularly in cases of extensive bone loss [11, 12].

At present, the Paprosky classification has gained the widest acceptance [13]. It is characterized by logical structure, clear criteria, relative simplicity, and the ability to determine the defect type based on standard X-rays routinely obtained during preoperative assessment. Nevertheless, accumulated clinical experience has shown that even this classification does not cover all possible defect patterns [14]. Another limitation is that two-dimensional X-rays cannot fully reflect the complexity of 3D bone morphology.

The widespread use of CT and 3D visualization has substantially increased the informativeness of preoperative imaging and allows for a more accurate assessment of the defect type [15, 16, 17]. In this context, new classification systems have been proposed, based on quantitative evaluation of bone density and 3D reconstruction of the acetabular region [18, 19]. However, their implementation requires specialized software and technical expertise, which may not always be available to practicing surgeons. At present, 3D-based classifications still need to prove their practical utility. Nonetheless, it is already evident that the implementation and widespread adoption of such systems in clinical practice will be determined by their convenience and ease of use, just as was the case with the Paprosky classification.

In the studies evaluating the techniques and outcomes of managing extensive acetabular defects, the Paprosky classification [20, 21] continues to be widely used, even though 3D imaging is increasingly applied for defect assessment and surgical planning in RHA. However, it can be observed that when referring to type 3B defects, researchers often describe different reconstruction approaches within the same defect category [9, 10].

As demonstrated by our findings, Paprosky type 3B defects may represent a range of distinct damage patterns. In addition to identifying the specific variant of the defect, 3D imaging makes it possible to assess such an important parameter as the extent of bone loss [9]. Therefore, the evaluation of the remaining supporting elements through 3D modeling of the pelvis and acetabular region is of substantial importance [11].

Distinguishing between different variants of damage within extensive acetabular defects has significant practical relevance. It allows the surgeon to anticipate the need for different implant types, including patient-specific designs, thereby providing additional time for their planning and fabrication, or to determine the appropriate configuration of available standard revision systems.

Lytic defects and complete defects of the anterior column, despite their extent, require the restoration of the sphericity of the acetabular region, which can be reconstructed using bone grafts, augments, and standard hemispherical components (Figure 2 a, b).

Reconstruction of complete medial wall defects, as well as combined complete defects of the medial wall and anterior column, requires the use of antiprotrusio devices to ensure the stability of the acetabular component. For this combination of defects, a wide range of types and sizes of standard cages may be necessary (Figure 2 c, d). In cases of combined complete defects of the medial wall and posterior column — the most challenging in terms of biomechanical stability of the acetabular component — there is a need for a highly reliable primary fixation of the implant, which cannot always be achieved with standard revision systems (Figure 2 e).

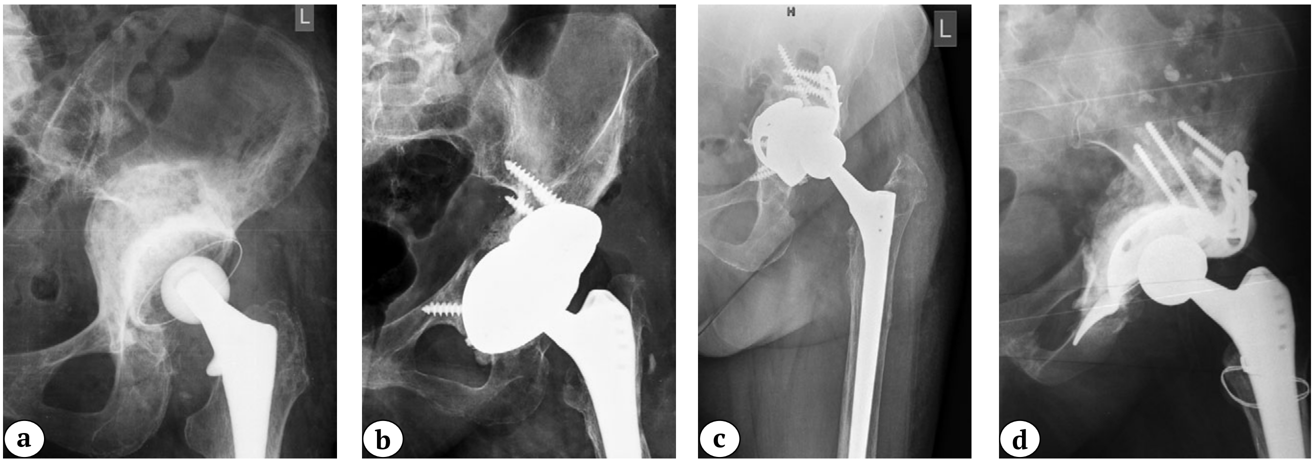


Figure 2. Various options for acetabular reconstruction in Paprosky type 3B defect:

a — lytic acetabular defect reconstructed using impaction bone grafting with implantation of a standard cemented acetabular component;

b — complete anterior column defect reconstructed with an augment and a hemispherical acetabular component;

c — complete medial wall defect reconstructed with augmentation and combined implantation of a hemicap cage;

d — combination of complete medial wall and anterior column defects reconstructed with a Burch-Schneider antiprotrusio cage and a cemented acetabular component;

e — combination of complete medial wall and posterior column defects reconstructed with a patient-specific acetabular component

In addition, the knowledge of the approximate proportion of different types of acetabular defects can help optimize the allocation of financial resources for patient treatment in specialized orthopedic departments.

In the available literature, we found no studies directly assessing the influence of the number of revision operations and PJI on the extent of the defect. However, several authors have noted that PJI is an indication for revision hip RHA and may be associated with bone loss in the acetabular region [22]. Reconstruction of acetabular defects can represent a significant challenge during revision operations performed for PJI [23]. S. Hayashi et al. reported that multiple revision procedures and the size of the acetabular defect may serve as predictors of poorer clinical outcomes [24]. Thus, the available evidence indirectly indicates the complexity and extent of acetabular defects that develop as a result of PJI and repeated revisions.

CONCLUSIONS

The results obtained in this study indicate that Paprosky type 3B acetabular defects represent a heterogeneous group of lesions, within which at least five distinct variants of load-bearing element damage can be identified. Therefore, type 3B defects according to the Paprosky classification cannot be considered uniform, and it is essential to specify which anatomical structures remain supportive in order to determine the appropriate surgical strategy. Notably, among the five identified variants, the diversity approaches its maximal possible level.

The most significant factors influencing the defect variant were a history of periprosthetic joint infection and the number of previous revision operations. The strategic importance of these findings lies in the necessity to improve the quality of both primary and revision arthroplasties, ensure prevention and effective management of infectious complications, and thereby reduce the need for repeated revisions.

Mandatory three-dimensional modeling in cases of extensive acetabular defects provides the surgeon with a more informative understanding of the lost and preserved load-bearing structures, which, in turn, facilitates the selection of the most reliable reconstruction option and timely preoperative preparation. Existing classifications of acetabular defects require refinement or revision in light of the growing use of three-dimensional assessment techniques. At the same time, any classification that incorporates the three-dimensional configuration of the defect should remain clear, practical, and easy to apply in routine surgical practice.

DISCLAIMERS

Author contribution

Kovalenko A.N. — study concept and design, data acquisition, analysis and interpretation, drafting the manuscript.

Tikhilov R.M. — study concept and design, editing the manuscript.

Dzhavadov A.A. — data acquisition, analysis and interpretation, editing the manuscript.

Shubnyakov I.I. — study concept and design, editing the manuscript.

Sankin A.V. — data acquisition, analysis and interpretation.

Vasiukova A.S. — data acquisition, analysis and interpretation.

All authors have read and approved the final version of the manuscript of the article. All authors agree to bear responsibility for all aspects of the study to ensure proper consideration and resolution of all possible issues related to the correctness and reliability of any part of the work.

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Use of artificial intelligence. No generative artificial intelligence technologies were used in the preparation of this manuscript.

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