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Early results of revision acetabular endoprosthetics using individual designs

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ABSTRACT

BACKGROUND: 3D-printed implants are one of the options for acetabulum reconstruction. The popularity of this technique is increasing every year.

AIM: To evaluate the early clinical, radiological and functional results of revision arthroplasty using individual acetabular components in patients with acetabulum bone defects.

MATERIALS AND METHODS: Revision endoprosthetics was performed in 50 patients. There were 36 female and 14 male patients. The patients' mean age was 60.4±13.4 (23–89) years. According to the Paprosky classification, the defects in 1 case corresponded to type IIC, in 12 cases to type IIIA, in 37 cases to type IIIB, including 8 cases with violation of the acetabulum integrity. Hip joint function was assessed using the Harris Hip Score (HHS), pain severity using the Visual Analogue Scale (VAS), and social adjustment using the Western Ontario and McMaster Universities Arthritis Index (WOMAC).

RESULTS: Significant improvement was obtained on all assessment scales. The HHS score improved on average from 33.6 to 87.1 points, the VAS scale from 78.1 to 4.7 points, and the WOMAC from 75.8 to 11.6 points. There were 8 cases (21%) with complications in total. In one case with a violation of the acetabulum integrity we observed migration of the sciatic bone from the lower flange of the construct.

CONCLUSION: Thus, the results of the acetabulum reconstruction using individually fabricated acetabular components are promising.

Keywords: hip joint; revision arthroplasty; acetabular defect; individual acetabular component.

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Ранние результаты ревизионного эндопротезирования вертлужной впадины с применением индивидуальных конструкций

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АННОТАЦИЯ

Введение. Одним из вариантов реконструкции вертлужной впадины являются имплантаты, созданные методом 3D-печати. Популярность данной методики с каждым годом растёт.

Цель. Оценить ранние клинико-рентгенологические и функциональные результаты ревизионного эндопротезирования с применением индивидуальных вертлужных компонентов у пациентов с костными дефектами вертлужной впадины.

Материалы и методы. Ревизионное эндопротезирование выполнено 50 пациентам. Среди них было 36 женщин и 14 мужчин в возрасте 23–89 лет.. Средний возраст пациентов составил 60,4±13,4 года. По классификации Paprosky дефекты в 1 случае соответствовали типу IIC, в 12 — типу IIIA, в 37 — типу IIIB, в том числе 8 случаев с нарушением целостности вертлужной впадины. Функцию тазобедренного сустава оценивали по шкале Harris Hip Score (HHS), выраженность болевого синдрома — по визуально-аналоговой шкале (ВАШ), а социальную адаптацию — по Western Ontario and McMaster Universities Arthritis Index (WOMAC).

Результаты. Значительное улучшение получено по всем оценочным шкалам. Значение по шкале HHS в среднем улучшилось с 33,6 до 87,1 балла, по шкале ВАШ — с 78,1 до 4,7 балла, WOMAC — с 75,8 до 11,6 балла. Общее количество осложнений составило 8 случаев (21%). В одном случае с нарушением целостности вертлужной впадины наблюдалась миграция седалищной кости от нижнего фланца конструкции.

Заключение. Результаты реконструкции вертлужной впадины с использованием индивидуально изготовленных вертлужных компонентов являются перспективными.

Ключевые слова: тазобедренный сустав; ревизионное эндопротезирование; дефект вертлужной впадины; индивидуальный вертлужный компонент.

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INTRODUCTION

Endoprosthetics showed the highest efficiency in the treatment of degenerative and dystrophic diseases and traumatic injuries of the hip joint. Over one million hip replacements are performed annually worldwide, and this number is projected to double over the next two decades. This trend leads to a steady increase in the number of revision surgeries [1–5]. An analysis of revision interventions performed in our clinic between 1992 and 2014 showed that the number of revisions increased eightfold on average. The instability of the acetabular component is the most common cause of revision surgeries [6–8]. Prolonged instability and repeated surgeries lead to severe bone defects [9, 10]. The severity of the bone defect plays a crucial role in choosing the techniques of revision hip arthroplasty [11–13]. In bone defect assessment, attention is paid to several factors, such as the amount and quality of the remaining bone tissue, integrity of the acetabular floor and walls, and presence or absence of acetabular discontinuity. Various classifications were proposed for the assessment of bone defects, and the most common is that by Paprosky [11].

Different designs and methods are used for acetabular reconstruction, including revision endoprosthetics with acetabular component placement using the high-hip center technique [14], large hemispherical acetabular components (jumbo cups) [15], classic surgery using antiprotrusion rings in combination with bone grafting [16], cup-cage technique [17], and highly porous trabecular tantalum components [18, 19]. However, the condition of the bone tissue and the severity and geometry of the defect requires technical solutions for adapting the acetabular bed to serial components (cups and augments) [20–22]. The search for alternative reconstruction options led to the introduction of additive technologies in endoprosthetics, which allow creating and printing of an individual implant for each defect using three-dimensional (3D) modeling [9, 23–26, 27]. Implants of this type have the following features [9]:

- One to three flanges with screw holes for contact with the ilium, pubis, and ischium
- Possibility of placing a double-mobility cement fixation system
- Optimal spatial orientation of the hemispherical part (40° inclination and 15° anteversion)
- Optimal direction and length of the screws specified in the design, which allows for achieving a strong primary fixation
- Porous surface of the component, providing further osseointegration

These features allow acetabular reconstruction with maximum accuracy. The aim of the study was to assess the early clinical, radiological, and functional results of revision arthroplasty using individual acetabular components in patients with acetabular bone defects.

MATERIALS AND METHODS

STUDY DESIGN

This prospective cohort study analyzed patients who underwent surgery with the placement of individual acetabular components between September 2017 and September 2020.

ELIGIBILITY CRITERIA

Inclusion criteria: Indications for revision hip arthroplasty with placement of individual acetabular components (loosening of the components of the endoprosthesis or hip spacer or neoarthrosis after the removal of the endoprosthesis) and type IIC, IIIA, and IIIB acetabular defects according to the Paprosky classification.

Exclusion criteria: Contraindications to surgical treatment, patient's disagreement with the proposed treatment method, and failure to conduct follow-ups after hospital discharge.

STUDY SETTINGS

During the study, all patients reached a minimum follow-up of 12 months. On average, 6.5±5.3 (range, 0–18) years passed from the time of previous surgery to the onset of pain syndrome and 3.2±3.5 (range, 1–17) years from the onset of pain syndrome to the time of revision arthroplasty with the placement of an individual acetabular component.

DESCRIPTION OF MEDICAL INTERVENTION

All patients underwent plain-film X-ray imaging of the pelvis including the hip joints. Preoperative X-ray images allowed assessing the position of unstable implant components and the amount of bone loss around the implant components, whereas the position of the installed prosthesis was assessed postoperatively. Bone defects were assessed according to the Paprosky classification. Preoperatively, all patients underwent computed tomography (CT) to create a 3D model and further print the implant.

The acetabular defect corresponded to type IIC in 1 patient, type IIIA in 12, and severe type IIIB defects in 37 (including 8 cases with a pelvic bone divergence). The process and technique of creating individual acetabular components were previously described [9]. In our patients, a direct lateral Hardinge approach was used to place an individual acetabular component. Twenty-one patients had a history of one to several revision surgeries. Four patients had evidence of treatment for periprosthetic infection.

During surgery, the material was necessarily collected for further microbiological analysis. In all cases, baseline antibiotic prophylaxis was performed. Check-ups of patients were performed 3 months, 6 months, and 1 year after surgery and annually thereafter.

Hip function, pain syndrome, and social adjustment were assessed pre- and postoperatively using the Harris hip score (HHS), visual analog scale (VAS), and Western Ontario and McMaster Universities Arthritis Index (WOMAC), respectively. Assessment was performed 6 and 24 months after surgery. All patients were available for assessment of postoperative hip function.

STUDY ETHICS

The study was approved at the Local Ethics Committee Meeting No. 3 of 2016 and is fully compliant with the ethical principles of the Declaration of Helsinki as revised in 2013. Informed voluntary consent to participate in the study was obtained from all patients.

STATISTICAL ANALYSIS

Data were statistically processed using IBM SPSS Statistics version 22 (IBM Corp., Armonk, NY, USA). Quantitative variables were presented as mean and standard deviation, whereas qualitative variables were reported as absolute and relative frequencies. For the comparison of pre- and postoperative values on HHS, VAS, and WOMAC scales, a sign test for dependent samples was applied. The significance level was assumed at 5%.

RESULTS

STUDY PARTICIPANTS

The study included 50 patients (50 hip joints), including 36 women and 14 men, aged 23–89 (mean age 60.4±13.4) years, who underwent surgery using individual acetabular components between September 2017 and September 2020. During the study, all 50 patients reached a minimum follow-up of 12 months.

MAIN RESULTS OF THE STUDY

The average duration of surgical intervention was 159.9±44.6 (range, 80–270) min, and the average intraoperative blood loss was 1269±802 (range, 300–5000) mL. The dependence of blood loss on the surgical duration is shown in Fig. 1.

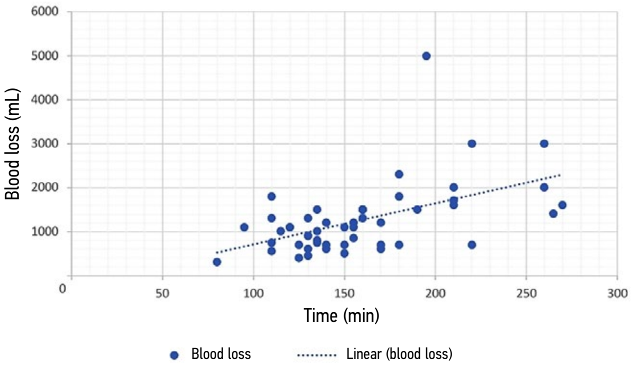

Fig. 1. Blood loss depending on the operation duration.

On average, the reconstruction of type IIIA defects took 146.7±26.7 (range, 110–210) min, and the average blood loss was 1,045.9±495 (range, 400–2,000) mL. In cases with type IIIB defects, the average intraoperative time was 164.5±48.8 (range, 80–265) min, with an average blood loss of 1363.5±869 (range, 500–5000) mL.

An average of 7.16±1.44 screws (range, 4–11) were required to fix the individual component. Total revision was required in 21 of 50 cases (42%). The average follow-up duration was 37.8±8.7 (range, 24–49) months.

For the radiological assessment of the hip joint, standard anteroposterior X-ray imaging of the pelvis was performed. Postoperative X-ray images were used to assess the inclination of the acetabular component and the position of the center of rotation of the hip joint. The preoperative position of the center of rotation of the hip joint relative to the line connecting the teardrop was 53.6±9.9 mm (range, 29–68 mm). On postoperative images, this figure was 21.9±0.9 mm (range, 20–24 mm).

For an objective assessment of the results, control X-ray imaging was performed at 3, 6, and 12 months and annually thereafter, and CT was performed selectively. When comparing a series of X-ray images, no signs of instability and no migration of components were observed.

In the comparison of pre- and postoperative limb-length parameters, the average preoperative limb shortening on the affected side was 3.4±1.1 cm (2–6 cm in length). After surgery, the difference between the extremities averaged 0.6±0.2 cm (0–1 cm in length).

The HHS scale was used in the pre- and postoperative assessment of hip joint function. The assessment was performed 6 and 24 months after surgery (Table 1).

Table 1. Pre- and postoperative assessment of hip joint function using HHS scales, *n*=50

HHS scale	Mean	Standard deviation	Root-mean-square error
Before surgery	33,660	15,7643	2,2294
6 months after surgery	87,120	5,2940	0,7487
2 years after surgery	91,780	3,8135	0,5393

Table 2. Pre- and postoperative severity of pain syndrome according to VAS scales, *n*=50

VAS scale	Mean	Standard deviation	Root-mean-square error
Before surgery	78,180	8,3145	1,1758
6 months after surgery	4,660	2,5040	0,3541
2 years after surgery	2,240	1,6728	0,2366

Table 3. Pre- and postoperative social adaptation according to WOMAC scales, *n*=50

WOMAC scale	Mean	Standard deviation	Root-mean-square error
Before surgery	75,860	11,8028	1,6692
6 months after surgery	11,620	11,1555	1,5776
2 years after surgery	4,960	1,7723	0,2506

To improve the reliability of the obtained data, a statistical analysis was conducted. According to a paired-sample t-test, the difference between the mean pre- and postoperative HHS values was statistically significant at the 99% confidence level (p <0.01).

The functional pre- and postoperative results after 6 months and 2 years were statistically significantly different between the groups. Similarly, a statistically significant difference was found between the postoperative functional results 6 months and 2 years after surgery.

The VAS scale was used in the pre- and postoperative assessment of pain syndrome severity. The assessment was performed 6 and 24 months after surgery (Table 2).

According to a paired-sample t-test, the difference between the mean pre- and postoperative VAS values was statistically significant at the 99% confidence level (p <0.01).

The results of the assessment of pre- and postoperative pain syndrome after 6 months and 2 years were statistically significantly different between the groups. In addition, the results of the assessment of pain syndrome 6 months and 2 years after surgery were statistically significantly different.

The WOMAC scale was used in the pre- and postoperative assessment of social adjustment. The assessment was performed 6 and 24 months after surgery (Table 3).

According to a paired-sample t-test, the difference between the mean pre- and postoperative WOMAC values was statistically significant at the 99% confidence level (p <0.01). The results of pre- and postoperative social adjustment assessment after 6 months and 2 years were statistically significantly different between the groups. Similarly, a statistically significant difference was found when comparing the results of social adjustment 6 months and 2 years after surgery.

A comparative assessment between pre- and postoperative data obtained after 6 months proved a significant statistical improvement in the studied parameters. Similar results were obtained when comparing pre- and postoperative data after 2 years. In addition, a comparison of postoperative indices after 2 years and 6 months showed a significant statistical improvement.

ADVERSE EVENTS

A superior gluteal artery injury was observed in a patient with a type IIIB defect, which was associated with the need to mobilize the ilium to place an upper flange. Visualizing and ligating the vessel were impossible. Tamponade with a hemostatic sponge was performed, after which the bleeding stopped.

In three postoperative cases, paresis of the peroneal portion of the sciatic nerve developed in patients with

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Paprosky type IIIB defects. This complication was associated with traumatic access and traction ischemia of the sciatic nerve. The patients received appropriate treatment. At the follow-up after 3 months, two patients exhibited complete recovery of the function of the peroneal portion of the sciatic nerve, whereas neurological symptoms persisted in one patient.

Dislocation of the endoprosthesis was observed in three cases (7.9%). A recurrent dislocation was observed in two of three cases and was corrected by revision with the placement of a double-mobility cup. In the third case, the dislocation was reported by telephone, and a closed reduction was performed at the patient's residence.

In one patient who was initially diagnosed with instability of the acetabular component and compromised integrity of the acetabulum 3 months after surgery, X-ray images revealed migration of the ischium relative to the implant. However, the implant was radiographically stable. (This clinical case will be described in detail in the next paper.)

No cases of deep infection, pulmonary embolism, or death were observed in this group. No negative dynamics were detected in patients who overcame the minimum 6-month follow-up period (⩾12 months after surgery), and the patients were satisfied with the joint function and quality of life.

DISCUSSION

In revision endoprosthetics, the reconstruction of severe acetabular defects remains a major problem. Various options exist for acetabulum reconstruction, including 3D printing and additive techniques. The first references to individual acetabular components are found since 1992. At that time, the milling method was used to make the implant [20]. The first surgeries with the use of individual designs in Russia began only in 2015 [28]. The Department of Large Joint Endoprosthetics at the Priorov National Medical Research Center for Traumatology and Orthopedics began performing revision surgeries using individual acetabular components in 2017. Based on the results, this direction is considered promising.

The use of individual designs showed good results for both postoperative joint function and implant fixation. No complications associated with the aseptic instability of endoprostheses were observed in the study group. Moreover, foreign and Russian studies have shown good fixation results for this type of implants, where the number of complications resulting from aseptic instability does not exceed 4% [29–32].

In our group, the number of postoperative dislocations was 7.9%, whereas the complications of this type vary in other studies, reaching 33% [26, 29, 30, 32, 33]. According to Citak et al. [26], the large number of postoperative dislocations was associated with a significant number of previous hip surgeries (5 on average). In addition, Berend et al. observed a direct correlation between the number of postoperative dislocations (6.4%) and previous surgeries (1.6 [1–3] on average) [30]. According to Taunton et al. [33], the migration of the greater trochanter due to severe osteolysis or trauma leading to a periprosthetic fracture may be a risk factor for recurrent dislocation of the endoprosthesis head. The authors suggested performing additional plasty of the thigh abductor muscles or using double-mobility components or the constrained system to eliminate this problem. Barlow et al. [31] assumed that mispositioning of the acetabular component, particularly excessive verticalization due to a pronounced deficit of anatomical landmarks, led to dislocation. According to Korytkin et al. [32], several complications (17%) were associated with preoperative errors, that is, with designing an individual prosthesis with a small hemispherical part. The placement of 46-mm components subsequently limited the options for the use of the articulating pair. In our study, double-mobility components were used in two of three cases to repair recurrent dislocations.

The main tool for assessing hip joint function is the rating scale. HHS, VAS, and WOMAC are the most commonly used scales. Comparative results of rating scales obtained before and 6 months after surgery showed a significant improvement in hip joint function, which is comparable with the results of other authors [25, 26, 29, 30, 32, 34, 35].

In the assessment of the post-implant positioning accuracy of individual designs performed in 20 patients with an average age of 53 (22–72) years, in revision arthroplasty using these implants, the probability of implant deviation from the planned position was high; however, such deviation did not lead to negative consequences during the follow-up [36].

The main objective of revision arthroplasty is a reliable and durable fixation of components in an anatomically correct position to maximize full recovery. The peculiarity of individually designed acetabular components is the presence of additional fixation points, such as support flanges with holes for screws, with a porous coating of the contact surfaces. These designs are advantageous for the reconstruction of Paprosky type III defects, allowing a more accurate reconstruction of the acetabulum and improving the results. This is evidenced by the statistical improvement in joint function, reduction or absence of pain syndrome, and social adjustment of patients. In addition, by using these designs, no bone grafting of the acetabulum is needed, and this minimizes the risks of infectious complications and early instability.

CONCLUSIONS

The comparison of functional results of the hip joint with similar results obtained 6 months and 2 years after surgery revealed a statistically significant improvement on all rating scales. Similar data were obtained when comparing the results obtained at 6 months with those at 2 years after surgery. According to radiological data obtained at 3, 6, and 12 months and annually thereafter, no signs of instability and no migration of components were detected. Osseointegration of individual designs was the only process observed. Extensive 3D modeling capabilities allow the creation of implants for defects of any complexity and provide the most accurate restoration of the anatomical rotation center of the hip joint, minimize the risks of infectious complications associated with allografts, and achieve primary firm fixation and stabilization of the hip bone in pelvic fractures. The above-mentioned characteristics of these designs lead to improved postoperative functional results and quality of life. Individual acetabular components may be used effectively in the reconstruction of acetabular defects. Previous results obtained in revision arthroplasty using these implants are encouraging. If positive results are maintained in the mid- and long-term follow-up, acetabular reconstruction using individual components may be the method of choice.

ADDITIONAL INFO / ДОПОЛНИТЕЛЬНАЯ ИНФОРМАЦИЯ

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