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Use of customized acetabular components for hip joint arthroplasty in posttraumatic coxarthrosis

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Introduction The increase in the number of primary hip joint arthroplasties leads to a steady increase in revision interventions. The category of complex arthroplasty also includes patients with extensive acetabular injuries due to high-energy trauma. Amplification of clinical cases requires an individual approach when planning the configuration of the acetabular component. In recent years, clinics have been actively introducing into practice the technology of 3D-modeling of hip replacement components. **The purpose of the study** was to assess the short and medium-term results of hip joint arthroplasty in posttraumatic coxarthrosis with significant bone defects, using individual acetabular components, with the presentation of clinical cases. **Material** was five arthroplasty cases operated using customized implants produced with a 3D printer. All five patients were males of working age who suffered high-energy injuries. Three of them had previous operations on the hip joint (from 1 to 5 operations). Anamnesis, characteristics of patients, bone defects types by Paprosky, follow-ups after surgery, X-ray data, the dynamics of the quality of life on the Harris scale were studied. Personalized acetabular components produced on a 3D printer were successfully implanted in four patients; in one case, the installation failed due to excessive lateralization of the rotation center and technical difficulties in adjusting the implant head. The follow-up period of three patients was 16.7 ± 3.7 months; two had operations three and 4 months ago respectfully. **Results** Dynamic assessment on the Harris scale in all patients showed an increase from 26 ± 5.2 to 77 ± 6.6 points. X-ray monitoring revealed a stable position of the implant components with satisfactory bone integration. **Conclusion** The study showed good short-and medium-term results of the use of customized acetabulum components manufactured using a 3D printer in patients with significant bone defects of the acetabulum on the background of post-traumatic coxarthrosis.

Keywords: revision arthroplasty of the hip joint, customized acetabular component, 3D printers in orthopedics, acetabular defects, post-traumatic coxarthrosis

INTRODUCTION

An increase in the number of total hip arthroplasties (THA) inevitably leads to a growth in the number of revision interventions throughout the world. They take from 13 to 18 % in the general structure of THAs [1, 2, 3]. It is not always possible to conduct a timely revision surgery in patients with friction wear or instability due to loosening of the implant as patients frequently miss follow-up examinations. Moreover, such operations are complex and costs of the revision are high [4, 5]. Over time, severe destruction of the acetabulum makes it difficult to achieve implant stability. Post-traumatic injuries, multiple surgical interventions in the area of the affected hip joint also result in bone loss and acetabular defects. The number of such patients has been steadily increasing [6, 7, 8].

Bone defects are frequently the result of various injuries. Injuries of the knee and hip joint prevail. About a third of coxarthrosis cases are caused by injuries, mainly in traffic accidents due to the development of high-speed road transport, as well as to other traumatic factors. Severe bone fractures and smashing of joint bones lead to the development of severe arthritis, and sometimes to a complete immobility of the affected joint. In young people, post-accident injuries of the joints respond well to treatment while in old people the treatment of post-traumatic arthritis frequently necessitates great efforts [9].

Fractures of pelvic bones and acetabulum make up from 3 to 8 % of all skeletal fractures. In the structure of pelvic injuries, acetabular fractures range from 7 to 20 %; in polytrauma they reach 20 %. Catatrauma accounts for 40 % of cases of severe damage to the acetabulum. The main cause of acetabular fractures is road accidents (90 % of cases). Acetabular fractures are mostly sustained by people of mature age, younger than 50 years. This fact has a significant socio-economic importance [10].

Recent literature data show that degenerative changes in the hip joint occurred in 12 to 57 % of the injured persons over time; deforming osteoarthrosis

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developed in 20 %, heterotopic ossification in 25.6 %, and aseptic necrosis of the femoral head in 10 % of them [10].

Improvement of surgical techniques as well as the use of modern technologies and materials enables to successfully manage extensive defects of the acetabulum in cases of complex arthroplasty. The main tasks at the stage of treatment of the acetabulum are (1) to create a bed for implanting the component so that bone and soft tissue damage is minimal; (2) achieve primary stable fixation and (3) manage bone defects and, if possible, restore the bone loss. Their implementation will relieve pain and will improve function. Successful reconstruction of the acetabulum during THA requires a deep understanding of the problem: assessment of the sphericity of the acetabulum and bone defect size. Various classifications are used to assess these defects and plan the surgery. The most commonly used systems are the classification of the American Academy of Orthopedic Surgeons (AAOS) and the classification of acetabular defects according to Paprosky [11].

Acetabular components of mass production do not always provide the hip joint biomechanics and anatomy in massive bone defects. In these cases, a personalized implant, and more precisely, its acetabular component may assist [12, 13, 14, 15, 16]. Positive results of using customized components fabricated with a 3D printer have been described by some authors for using in patients with bone defects of type III B according to Paprosky; however, due to a low number of such operations, personal experience and clinical examples seem of practical interest.

Purpose of study was to assess short and mid-term results of hip joint arthroplasty in posttraumatic coxarthrosis with significant bone defects using customized acetabular components and presentation of clinical cases.

MATERIAL AND METHODS

Patients of the Federal Centre for Traumotology, Orthopedics and Arthroplasty of the ministry of health of Russia (Cheboksary) diagnosed with coxarthrosis underwent arthroplasty with personalized acetabular components fabricated with 3D printer and were retrospectively studied.

The study conformed to the ethical principles of the Helsinki declaration.

Demographic, average inpatient stay and catamnesis data were collected. Previous interventions on the hip joint were considered as well as follow-ups after the index surgery (months). Radiographic control was three months and more after the arthroplasty.

Prior to admission, hip joint condition and diagnosis was verified using radiography and CT with the slices of not more than 1 mm, including 3D reconstruction. Acetabular bone tissue deficit and defect type were defined according to W. Paprosky, as this technique is more informative as compared with the one of AAOS due to its spatial and not planar evaluation of the defect.

Personalized acetabular components were fabricated in collaboration with ITK ENDOPRINT Ltd., avoiding the stage of printing a plaster mold. Image processing and 3-D printing of components made from titanium powder was executed. Company's engineer processed the image of multispiral CT in the DICOM format and produced a 3-D model of the pelvic half. After coordinating the model in pdf format with the surgeon, the manufacturer printed the acetabular component on a Concept Laser M2 Cusing 3D printer (USA) from Rematitan titanium powder (Germany). Sterilization of the component was performed by autoclaving at the clinic.

Surgical intervention was performed according the standard technique from the Harding anterolateral approach. Sizes of bone tissue defect were verified intraoperatively.

The dynamics of patient's quality of life were evaluated using the Harris scale before and after surgical treatment (3 months and later after discharge).

Statistical processing of the data was performed using the Microsoft EXCELL 2010 software package. Data variability was subject to the laws of normal distribution, which made it possible to reflect the results as the arithmetic mean (M) and mean deviation (m).

From November 2016 to November 2018, we carried out five surgical interventions of primary complex THA in order to implant customized acetabular components manufactured using a 3D printer. All patients were males in the average age of 53.6 ± 7.6 years, BMI of 28.3 ± 0.7 kg/m^2, and duration of hospitalization was 8 days.

Posttraumatic coxarthrosis with massive bone defects in all cases was caused by high-energy trauma. Some patients had a history of hip joint surgeries before THA with the use of the customized component. There were differences in the fixation type of the implants. Two patients were operated on in 2018, the follow-up period was 3 and 4 months; in the three other cases, the follow-up was 16.7 ± 3.7 months (Table 1).

Various modifications of acetabular components were implanted.

At follow-ups, the function of the hip joint on the Harris scale improved significantly in all patients (**Fig. 1**). The average HHS before surgery was 26 ± 5.2, and 77 ± 6.6 points three months after surgery (**Fig. 1**).

X-ray control in all patients after 3 months post-surgery showed a stable position of the acetabular and femoral components with satisfactory osseointegration; the head of the implant was centered and located in the acetabulum.

Clinical case 1, a 62-year old patient In 2015, he was consulted due to polytrauma sustained in an accident which was a closed fracture of the acetabulum bottom and associated injuries and received conservative treatment at his residence hospital. In 2016, X-rays detected left-side posttraumatic coxarthrosis in stage 3; malunion of multifragmented transacetabular fracture of the bones forming the left acetabulum; the acetabular part of the ilium (with the transition to the wing of the ileum) was shifted to the pelvic side by 10 mm and proximal by 8 mm; diastasis between the sciatic and iliac bone was 10 mm; the total area of the defect of the acetabulum measured 1 × 1 × 4 cm; there was aseptic necrosis of the head of the left femur in stage 3, local osteoporosis of the femoral condyles and acetabulum. HHS was 20 points. THA was performed in November 2016.

The defect of the acetabulum was replaced by a customized implant with additional fixation with 4 screws; installation of the DePuy cement implant: the acetabular component Triloc II Cup 46 mm OD / 32 mm ID with fixation on cement CMW 1 Gentamicin Bone Cement 40 g., Femoral component Corail Hip System Cemented Femoral Stem Size 15 High Offset No Collar Fixed on Cement De Puy CMW 3 Gentamicin Bone Cement 40g, Articul / EZE Femoral Head 32mm / + 1 / 12/14 Taper.

According to the control X-ray in March (4 months after the operation) and in November 2018 (24 months), the position of the implant head in the artificial cavity was correct; lateral tilt of the acetabular component 41°; neutral position of the femoral component; the cement mantle around the stem was evenly distributed; the position of the implant components was stable (**Fig. 2**).

Table 1

Characteristics of patients

Case #	Gender	Age, years	BMI*, kg/m^2	Number of previous surgeries	P**	Fixation type	Follow-up (months)
1	m	62	28.4	0	IIC	Cemented	24
2	m	27	26.8	2	IIIB	Hybrid	14
3	m	62	30.8	0	IIB	Cementless	12
4	m	70	28.7	1	IIB	Cemented	4
5	m	47	27	5	IIIB	Hybrid	3

BMI* – bone mass index; P** –Paprosky classification

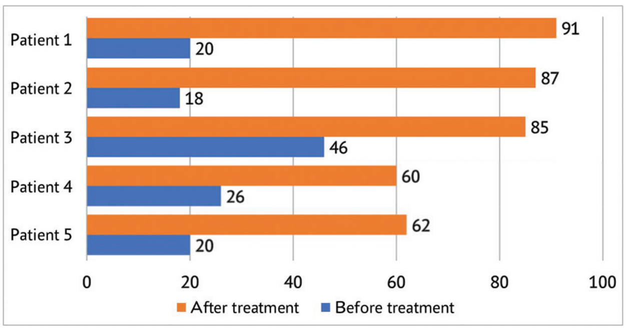

Fig. 1 Dynamics of hip joint function on the Harris scale before treatment and after 3 months, points

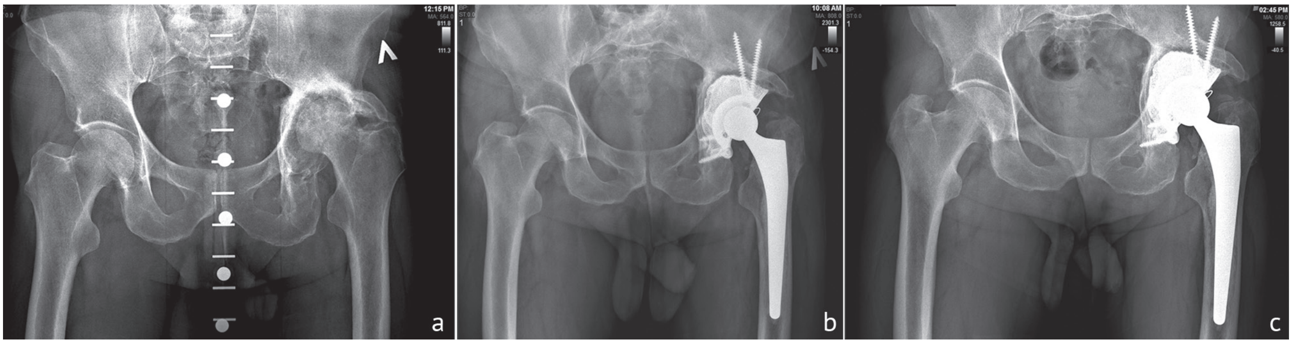

Fig. 2 AP radiographs of the pelvis in patient N.: ***a*** before surgery; ***b*** 3 months after operation; ***c*** 24 months after operation

Hip joint function on the Harris scale after 3 months was 84 points.

Clinical case 2, a 27-year old patient After a high-energy injury in an accident in 2015 (closed comminuted transacetabular fracture of the right ilium, posterior dislocation of the right hip), an open osteosynthesis of the posterior edge of the right acetabulum with a reconstructive plate was performed at his residence hospital. He was consulted by us in 2017 and was clinically and radiologically diagnosed with right-side post-traumatic coxarthrosis in stage 3, aseptic necrosis of the head of the right femur in stage 2-3, local osteoporosis of the greater trochanter of the femur and the subchondral part of the acetabulum. In the X-rays, a fragment of the screw in the projection of the medial part of the hip joint space was visualized; malunion fracture of the posterior margin of the right acetabulum. At the same time, the metal structure remained stable. In the punctate from the right hip joint, Staphylococcus epidermidis MRSE 10 × 1 CFU / g was isolated. In January 2017, debridement of the right hip joint, removal of metal structures, resection of the femoral head, and installation of an articulating spacer were performed. Revision arthroplasty of the right hip joint followed after two months. Bone defects of the medial and posterior quadrilateral surface (irregular shape, about 10 × 7.5 × 2.5 cm in size, the ischium was not lysed, the center of rotation was shifted upwards by 3.0 cm) were classified as type III B by Paprosky. The acetabular defect was replaced by a customized implant with fixation with 6 screws and the installation of the Zimmer hybrid implant: acetabular component Cemented Cup ZCA 49 mm O.D./32mm I.D. with fixation on cement CMW 1 Gentamicin Bone Cement 40 g, the femoral component of cementless fixation Avenir Stand., stem 4, head Protasul 32 / -3,5. The result of microbiological study of the intraoperative material (tissue biopsy - material for microscopy) in March-April 2017 was negative. Control s in July 2017 (after 6 months) and May 2018 (16 months) showed the condition after revision arthroplasty of the right hip joint using a customized acetabular component, additionally fixed with 6 screws. Hybrid fixation of components was performed: cement fixation of the cup and cementless fixation of the stem. The position of the implant head in the artificial cavity was correct. Lateral inclination of the acetabular component 44°; neutral position of the femoral component with stable fixation and bone ingrowth in the distal regions. The implant components in the right hip joint were stable (**Fig. 3**).

Hip joint function on the Harris scale increased from 18 points (before treatment) up to 87 (after treatment).

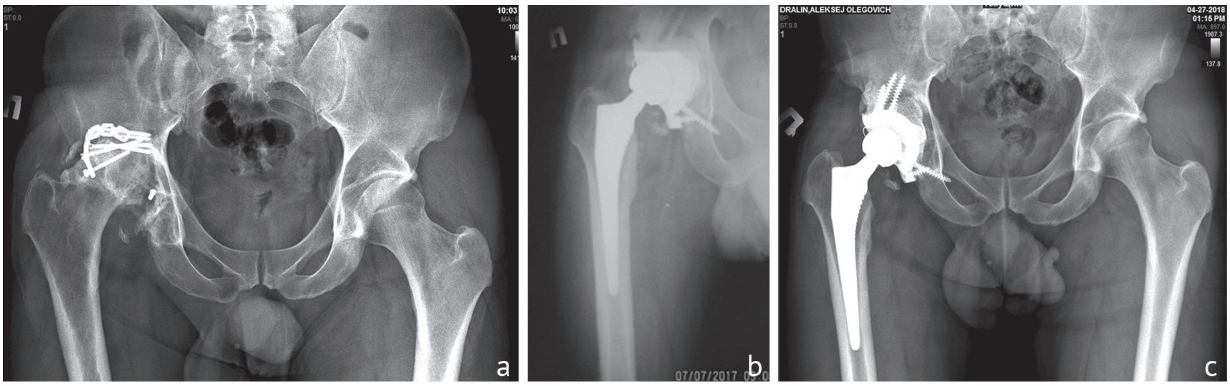

Fig. 3 AP radiographs of the pelvis in patient D.: a before surgery; b 6 months after operation; c 16 months after operation

Complications

In one of the patients (patient 3), a discrepancy between the bone base of the acetabulum bottom and the thickness of the augment was detected by installing the acetabular component. The X-ray control revealed a wrong position of the acetabular component, as a result of which the augment was removed, and the defect was replaced with structural autograft taken from the femoral head of the bone and additionally fixed with two screws, and Aesculap cement-free system was implanted. Plazmafit Plus 3 CUP Size 52 mm I acetabular component was additionally fixed with three screws, TRJ Stem lateralized Size-5 (12/14) femoral component, Isodur Prosthesis Head 12/14 28 S head, Vitelene Insert I 28 mm polyethylene liner. In this case, the unsatisfactory result of arthroplasty may be explained, in our opinion, by the excessive lateralization of the center of rotation, which subsequently led to technical difficulties in reduction of the implant head. The shape of the implant was developed taking into account the surgical approach and the surrounding soft tissues.

At a one-year follow-up, the patient walks independently; the area of the right hip joint is not changed. The right hip joint is painless by palpation and the postoperative scar is normal. Hip joint range of motion: right-side flexion / extension 90/0/0, on the left 90/0/0, 20/0/40 adduction /abduction on the right, 25/0/55 on the left, external and internal rotation 40/0/20 on the right, 55/0/25 on the left. There are no vascular and neurological disorders, the function is unlimited. The implant is stable in the radiographs.

Analyzing this situation retrospectively, we found that one should not strive for maximum (detailed) reproduction of the bone defect shape by planning the configuration of a 3D implant due to the complexity of its installation in the acetabulum.

RESULTS AND DISCUSSION

The increase in the hip joint pathology in our country results in a bigger number of surgical interventions in this body area [2, 12].

Repeated surgical interventions on the joint decrease the bone mass, which further complicates the reconstruction of damaged structures [6, 7, 8]. In our study, these were patients 2 and 5, who had sustained repeated operations on the hip joint. The deficit of the acetabulum bone tissue was classified in them as the most significant (IIIB).

A lot of clinics have been successfully introducing the 3D technology in the manufacture of customized implants of various modifications [4, 5, 15, 16]. They are mostly used in revision arthroplasty [1, 3, 5, 6].

Results close to ours (stable acetabular components in the short- and mid-terms after the operation) were also obtained by our colleagues [1].

Severe destruction of the bone structure of the acetabulum due to coxarthrosis of various origins, especially post-traumatic, creates technical difficulties for hip joint arthroplasty with the use of implants of mass production that do not take into account the individual relief of the acetabulum surface [9, 10, 12]. We faced a similar situation with patient 3.

Customized acetabular implants are defect-specific components used in complex primary and revision THA, which allow restoration of the center of rotation and reliable primary fixation in extensive bone defects of the acetabulum. By constructing a three-dimensional bone defect, prototyping an implant, it is possible to perform reconstruction in the situations where other methods are unable to provide it [13]. However, the ideal coincidence of the configuration of the acetabulum and the surface of the customized acetabular component is a very controversial point in clinical practice [14], which is confirmed by our case 3.

Our study confirmed the assumption that in the process of planning the configuration of a 3D implant, it is necessary to take into account the complexity of its installation in the acetabulum in case of the ideal copying of all the features of its relief in the manufactured acetabular component. In our opinion, it increases the time of the intervention resulting in significant blood loss; requires expansion of the planned surgical approach, causes additional trauma to soft tissues, and in some cases makes the installation of a customized acetabular component impossible. The short-term and mid-term results obtained by us by the use of customized acetabular components, fabricated with 3D technology, in posttraumatic coxarthrosis, allow us to recommend the technique for the use in patients with significant defects of the acetabulum.

CONCLUSIONS

1. The study showed good short-term and mid-term results of the use of customized acetabular components fabricated using a 3D printer in patients with significant defects of the acetabular tissue due to post-traumatic coxarthrosis. By the time of this paper completion, all the implants were stable and no cases of implant instability or periprosthetic infection have been recorded.

2. Customized implants (acetabular components) are a promising technology that facilitates the surgeon's tasks in primary complicated hip joint arthroplasty with massive bone defects of the acetabulum of a post-traumatic nature.

3. In the future, when planning a 3D implant, we consider it expedient to have a preliminary treatment of the acetabulum surface with spherical burrs to shape it most congruent with the acetabular 3D component. It technically simplifies the implantation, reducing the time of the operation, and at the same time achieves a better contact of the acetabular 3D component with the defect of the acetabulum, providing a more efficient osseointegration with its surface.

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