Clinical case
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Impaction bone grafting as a method of choice in bone defect management in the revision hip arthroplasty: a cases series

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Abstract

Introduction Reconstruction of the acetabulum during revision arthroplasty is a challenging task in the setting of massive bone defects. Often the only effective method is impaction bone grafting (IBG).

The purpose is to demonstrate the capabilities of the X-Change impaction bone grafting technology in replacing acetabular defects as a method of choice for revision hip arthroplasty.

Materials and methods In the presented series of cases, the use (IBG) turned out to be the method of choice, allowing for high-quality reconstruction. In each presented case, revision hip arthroplasty was performed with augmentation with a reconstructive mesh or trabecular metal augment to create support and contain the defect to retain the osteoplastic material.

Results During follow-up periods of 4.8 to 6.5 years there were no signs of resorption or loosening. According to the Harris hip score the results were 96, 97 and 89 points respectively.

Discussion Impaction bone grafting technology is quite versatile. It can be used in various coditions of revision arthroplasty with contained defects of the acetabulum. In contrast to the use of modular revision augmentation systems and additive technologies it makes possible to achieve dense filling of the smallest defects and profile a bed congruent with the acetabular component. The use of cemented fixation makes it possible to further stabilize the impacted bone chips and use mechanotransduction mechanisms that stimulate the bone remodeling. The use of IBG has proven to be an effective technique for the reconstruction of medium-sized acetabular defects in combination with mesh and cement cup, as well as in combination with trabecular metal augments.

Conclusion The use of IBG during revision hip arthroplasty can be especially effective for small acetabulum sizes. Combining IBG with trabecular metal augments significantly expands the application of this technology. The use of IBG makes it possible to create a bone reserve, which creates more favorable conditions for inevitable repeated revision interventions.

Keywords: Impaction bone grafting, trabecular metal augments, acetabular defects, revision arthroplasty

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INTRODUCTION

Reconstruction of the acetabulum in revision or primary complex arthroplasty is a difficult task in the conditions of massive bone defects. This problem is especially relevant in the treatment of young patients, when it is important to restore the center of rotation of the femur, achieve stable fixation of the implant, restore the anatomy of the acetabulum and the bone mass of the pelvic bone. To date, various methods of bone defect filling have been known such as reconstructive cages [1], structural grafts [2], modular augmentation systems [3], additive technologies that have been developed in recent years [4] and impaction bone grafting [5]. The location, geometric shape, size and bone defect extention usually determine the choice of reconstruction method [6, 7]. Each of the listed above methods has certain advantages and disadvantages, but sometimes the limitations that arise allow the use of only one possible method of effective arthroplasty. In a specific situation, this method may be a fairly universal technology of impaction bone grafting, the main advantage of which is the ability to restore the lost pelvic bone mass and thereby create the prerequisites for the success of subsequent inevitable revisions [8].

Purpose Demonstration of the capabilities of the X-Change impaction bone grafting technology in the management of acetabular defects as a method of choice in revision hip arthroplasty.

MATERIALS AND METHODS

A retrospective analysis of clinical data on the use of impaction bone grafting with the original "X-Change" technology and specialized instrumentation in cases of primary complex and revision hip arthroplasty for management of bone defects in the acetabulum area was carried out.

From 2015 to 2022, 87 operations on the hip joints in 83 patients were performed at the Federal State Budgetary Institution Federal Center of Traumatology, Orthopedics and Arthroplasty of the Ministry of Health of Russia (Barnaul) using impaction bone grafting with the "X-Change" technology as the main technique. Of those, the technology was used for primary complex arthroplasty in 10 cases, three operations on the femoral segment, seven on the acetabulum. In 77 revision arthroplasties, IBG was used in 36 cases on the acetabular component, in 29 cases on the femoral component, and in 12 cases simultaneously on the pelvic and femoral segments. In some cases of pelvic reconstruction, the use of IBG at the time of surgery turned out to be the only available method that enabled to perform high-quality reconstruction of the acetabulum. Three clinical cases were included in this demonstration series which fully reflected the philosophy of IBG.

The indications for the use of IBG on the pelvic segment were massive limited and combined defects of the acetabulum:

1) Case 1 was a massive 3D defect according to Paprosky or type III according to the AAOS classification of complex geometry, caused by secondary deformation due to mechanical wear of a loosened pelvic component;
2) Case2 was 2B Paprosky defect with minimal bone stock due to dysplasia and previous primary arthroplasty failure;
3) Case 3 had a massive iatrogenic defect of AAOS type III after removal of the pelvic component due to periprosthetic infection, which had its own indications for the installation of a spacer and its subsequent removal.

At the time of surgical treatment, infection was excluded in all cases that was proven by cytological, microscopic and bacteriological preoperative examination of synovial fluid aspirate from the joint. It was also confirmed by the results of bacteriological study of biopsies taken during the surgery and removed components.

Bone chips made from allobone that underwent thermal disinfection according to the Marburg bone bank system were used as a bone plastic material (BPM). For pelvic bone grafting, chips were hand-cut to a size of approximately 10 mm^3 using Luer cutters. The BPM compaction was performed with profiling impactors for the acetabulum from the specialized X-Change instrumentation set (Stryker). In all three cases, additional structures were used in combination with IBG such as reconstructive meshes in two cases and tantalum augment in one.

Case report 1 Female patient B., 38 years old, was admitted to the Federal Center (Barnaul) with complaints of pain in the right hip joint, severe limitation of movements in it, shortening of the right lower limb, and lameness. From the anamnesis it was revealed that at the age of 26 years she suffered hematogenous osteomyelitis of the head of the right femur. Surgical debridement was performed and a flushing drainage system on the right hip joint was installed; the fistulas in the area of the right hip joint closed within a year. A year after the debridement of the source of infection, due to the progression of pain and impaired support function of the limb, arthroplasty of the right hip joint was performed with a DePuy Corail/Triloc anti-hybrid system. Healing after the arthroplasty intervention ran without complications. However, 7 years after the arthroplasty surgery, the patient began to feel periodic pain, which gradually progressed, limited movements, and lameness appeared. The examination revealed signs of loosening of the pelvic component and she was referred to perform revision arthroplasty at the Federal Center for Orthopedics and Arthrplasty in Barnaul. At the time of admission to the Center, she walked independently, limped on his right leg, the configuration of the joint was not visually changed; there was a postoperative scar in the area of the right hip joint without signs of inflammation. She did not feel pain on palpation in the joint area. Moderate muscle hypotrophy of the pelvic girdle and thigh on the right was present. The relative shortening of the right lower limb was 3 cm. Range of active motion was flexion up to 80°, abduction 10°, rotation 5–0–5°, adduction 10°. There was moderate pain by moving. The functional Harris score was 55 points. Radiographs revealed loosening of the pelvic component, IIIB Paprosky defect of the acetabulum, signs of periprosthetic osteolysis in the proximal femur in Gruen zones 1 and 7 (Fig. 1 a). Based on the results of cytological and bacteriological examination of the synovial fluid, no evidence of an infectious process in the joint was detected. However, due to the history of infection and the volume of required reconstruction, a decision was made on a two-stage revision arthroplasty by applying joint spacer at first stage and a repeated microbiological study of intraoperative biopsy specimens. After the first stage of revision arthroplasty and negative results of bacteriological examination, a decision was made to carry out the second stage of revision arthroplasty (Fig. 1 b). The planning of the joint surgery took into account that the use of porous augments for reconstruction would require additional adaptation of the bone bed and would lead to an even greater bone deficit. To fill the defect, several augments would have been required, and filling such an extent with metal, would have made a most probable repeated revision in the future even more difficult due to the young age of the patient. Given the generally limited shape of the segmental defect by the medial wall and superior rim of the acetabulum, which could be constrained by a mesh, acetabular impaction grafting using a cemented pelvic component was chosen as the method of choice at the final stage of reconstruction. The reconstruction surgery was performed 6 weeks after the first stage. Augmentation of the upper edge and medial wall of the acetabulum was performed with a Stryker mesh and fixation with screws. To fill in the bone defect, osteoplastic material (chips of about 8–10 mm3) was prepared. Impaction bone grafting of the acetabulum was performed using Stryker "X-Change" revision instruments. Upon achieving cement-based volume restoration, a Zimmer ZCA 47 mm socket was implanted. The femoral canal was freed from cement residues. Preliminarily, due to low quality of the bone under the lesser trochanter, a wire cerclage was performed and the Zimmer Alloclassic SLL femoral component was implanted (Fig. 1 c). In the postoperative period, the patient was activated; rehabilitation was carried out at stage 1 and without complications she was discharged on the 12th day after the surgery. In the postoperative period, dosed loads on the involved limb were recommended for 12 weeks. At the time of the last follow-up examination, 6.5 years after the revision intervention, she had no complaints, walked with full weight-bearing without additional means of support, and did not experience any household or social restrictions. On the control radiographs 6.5 years after the operation, there were radiological signs of the osteoplastic material restructuring in the acetabulum area, there were no lucent lines at the bone-plastic material-cement border; the position of the implant components was correct, without signs of migration, subsidence or loosening. There was a decentration of the implant head in the acetabulum, as well as a 4 mm cranial displacement of the center of rotation (Fig. 1 d).

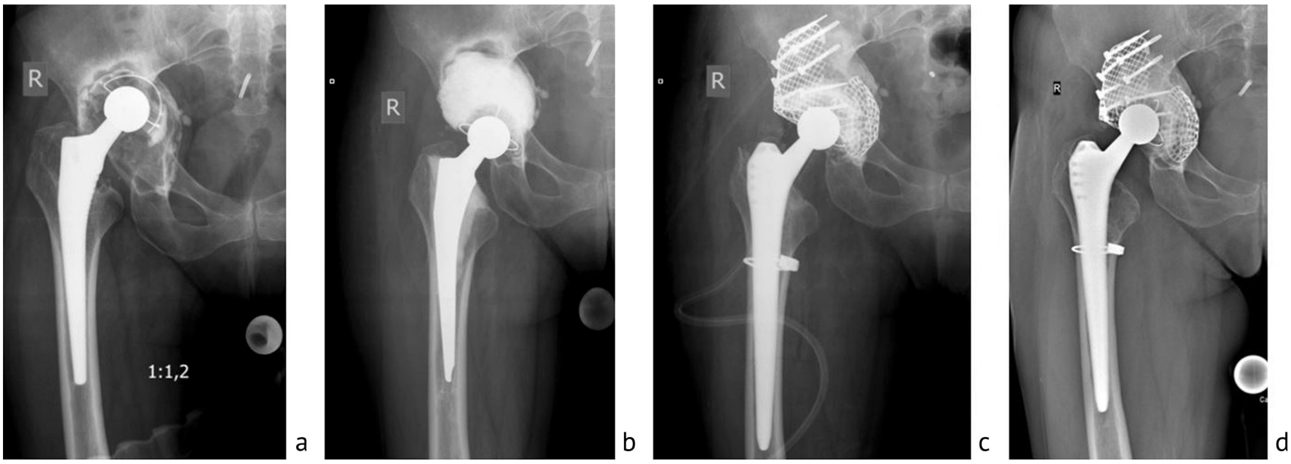

Fig. 1 Patient B., 38 years old. Radiographs of the right hip joint at the main stages of treatment: *a* before surgery; *b* after installing a hip joint spacer; *c* after reconstruction using IBG and mesh; *d* at the last follow-up 6.5 years after joint reconstruction

Case report 2 Female patient B., 37 years old, was referred to the Federal Center for revision arthroplasty of the left hip joint. From her medical record, it was known that reconstructive surgical interventions were performed on both hip joints for bilateral congenital dislocation of the femurs in childhood. Subsequently, due to the development of coxarthrosis, replacement of the left hip joint was performed with the additional use of the Muller Ring strengthening structure. However, 10 years after the operation, loosening and migration of the pelvic component developed. At the time of her admission to the Center, there was left leg lameness, the area of the left hip joint was deformed, but the postoperative scar in the area of the left hip joint was without signs of inflammation. Moderate muscle hypotrophy of the pelvic girdle and thigh on the right was noted. Relative shortening of the right lower limb by 2 cm. Range of active movements was: flexion up to 75°, abduction 0°, rotation movements 5–0–5°, adduction 5°. She experiences moderate pain by moving. The functional Harris score was 52 points. X-ray of the pelvis diagnosed migration of the pelvic component with an associated formation of Paprosky type IIB acetabulum defect (Fig. 2 a). The CT findings also revealed that the minimum transverse size of the pelvic bone at the level of the acetabulum was 45 mm, which is completely insufficient to install the minimum available component at that time with a highly porous coating of 44 mm in diameter (Fig. 2 b). There was also a deficiency of bone coverage of the acetabulum. It was, in total, probably caused by insufficient fixation and subsequent migration of the pelvic component. There were no signs of femoral component loosening. When choosing a method for reconstructing the acetabulum, we considered the extremely small size of the pelvic bone in the area of the left acetabulum, caused by joint dysplasia. Thus, additional treatment of the acetabulum could lead to worsening bone deficiency or the development of a severe complication such as dissociation of the pelvic bone. Therefore, it was decided to consider impaction bone grafting as the method of choice and augmentation of the supra-acetabular mass with a reconstruction mesh. Intraoperatively, trying to form a bed for a 44 mm acetabular component, the findings on the deficit in the bone coverage of the cavity were confirmed. The patient underwent revision arthroplasty of the left hip joint with reconstruction of the acetabulum using IBG and augmentation of the defect with a Stryker mesh using the "X-change" technology and specialized instrumentation. After filling the bone defect with the IBP using specialized instrumentation and achieving restoration of the shape of the acetabulum on a cement basis, an insert of HH size was installed under the 32 mm head of the Zimmer Trilogy IT pelvic component after its preliminary abrasive preparation for better adhesion of the bone cement. Control radiographs after surgery showed restoration of the center of rotation, filling of the area of the supra-acetabular mass with osteoplastic material reinforced with reconstructive mesh (Fig. 2 c). After 2 years, the patient underwent arthroplasty of the contralateral joint. The results of treatment were monitored over 5.5 years. There were no radiological signs of loosening, implant components migration or graft resorption (Fig. 2 d).

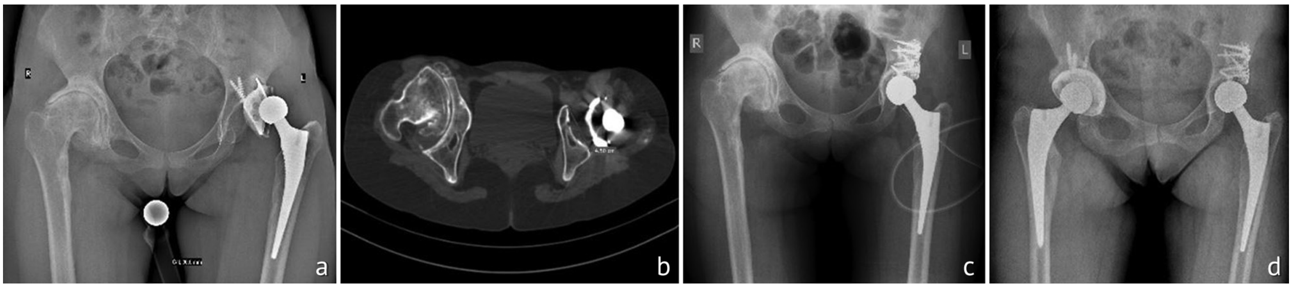

Fig. 2 Patient B., 37 years old. X-ray findings at the main stages: *a* plain X-ray of the pelvis in a direct projection before surgery; *b* CT scan of the pelvis in the axial projection at the level of the acetabulum middle third before surgery, the transverse size of the pelvic bone is 45 mm; *c* control radiograph of the pelvis after surgery; *d* radiograph of the pelvis 5.5 years after revision arthroplasty of the left hip joint

Case report 3 Female patient B., 74 years old, referred to the Federal Center for Traumatology, Orthopedics and Arthroplasty in Barnaul with a massive iatrogenic combined AAOS type III defect of the acetabulum after removal of the unstable acetabulum and femoral components in one of the clinics due to periprosthetic infection (Fig. 3 a). At the time of presentation, the patient moved with the help of crutches, the left lower limb was not weightbearing. The relative shortening of the left lower limb was 16 cm due to the absence of the proximal epiphysis of the femur, acetabulum defect and chondrodysplasia of the left tibia. In the area of the left hip joint, scar deformation of the soft tissues was due to previous surgical interventions. The functional Harris score was 54 points. The examination revealed no clinical and laboratory signs of an infectious process. Since additive technologies were not actively used in our Center at the time of her surgical intervention and taking into account the size of the bone defect, the option of bone grafting in combination with a reconstructive Burch – Schneider cage was considered. However, during the revision operation when installing the Burch – Schneider cage, its iliac flange was placed at the very edge of the bone support, and the screws were thus directed into the defect, so it was impossible to reliably fix the structure. Due to those circumstances, impaction bone grafting in combination with the installation of a trabecular metal augment was considered the most optimal method. In the supra-acetabular mass, along the outer edge of the defect, a bed for the augment was formed using a 60 mm cutter. A trabecular metal augment measuring 54/20 mm was installed on the prepared surface and fixed with two 6.5 mm screws, each 30 mm long. The additional use of the metal augment limited the bone defect and strengthened the supra-acetabular mass, thereby covering a part of the defect. After filling the remaining cavity with bone chips using the "X-change" technique, a Smith&Nephew Polarcup 47 mm double-mobility cement-based socket was implanted. The choice of a cup with dual mobility is due to the high risks of implant dislocation associated with possible positioning errors, compromised muscular system due to repeated surgical interventions, and the initial shortening of the left lower limb due to chondrodysplasia of the left leg bones. The Zimmer Alloclassic SLL revision femoral component was implanted without any special features. The control postoperative radiographs showed dense IBG filling of the defect, the cup was installed with partial support on the augment and impacted allobone. There was also a cranialization of the center of rotation by 1 cm (Fig. 3 b). At 4.8-year follow-up, clear radiological signs of IBG reorganization and osseointegration of the trabecular metal augment were visible. Signs of loosening of the components and their migration are not determined (Fig. 3 c).

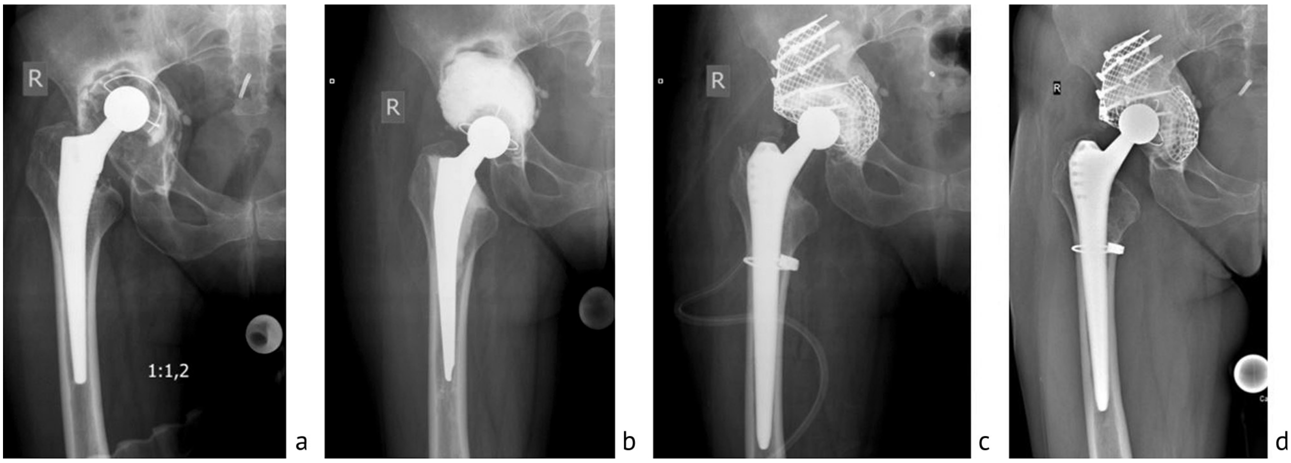

Fig. 3 Patient B., 74 years old. Radiographs of the left hip joint in a direct projection: *a* before revision arthroplasty; *b* after surgery; *c* 4.8 years after hip joint reconstruction

RESULTS

Long-term results were monitored in the case 1 patient for 6.5 years, in case 2 for at 5.5 years and in case 3 for 4.8 years. Excellent and good functional Harris scale score results were achieved, 96, 97 and 89 points, respectively, with complete labor and social rehabilitation of patients. X-rays at the last follow-ups indicated above did not show any signs of loosening or migration of the implant, augment or mesh cage. In the available fields of view there were clear signs of IBG remodeling; no reliable radiological symptoms of osteolysis were detected. In case 1, decentration of the implant head was noted, associated with polyethylene wear, and cranialization of the center of rotation by 4 mm due to IBG retraction.

DISCUSSION

At the present stage of revision hip arthroplasty development, the interest of surgeons has shifted towards more technological methods of bone defect management, such as additive technologies and modular revision systems made of porous metals [3]. The great advantage of modular augmentation systems is their versatility and standardization of indications in various clinical situations [9]. Additive technologies are capable to manufacture customized implants and have largely closed the issue of treating regular bone defects of the acetabulum [4]. However, there are also limitations in using these systems that are associated with the need for additional modeling of the bone bed for the augment, which aggravates the bone deficiency, as well as the time limit required for the design, manufacture and implantation of a customized structure. Filling of massive defects with metal may also limit the possibility of installing revision components during subsequent surgical interventions. Impaction bone grafting technology is more universal in this regard. It can be used in various situations of revision and primary complex arthroplasty, such as protrusion of the acetabulum, aseptic loosening of components and associated defects of the pelvic and femoral bones, and even in the treatment of periprosthetic infection, provided that the limiting structures and cavity walls are preserved and enable to exercise pressure in order to compact the bone material [5]. We belive that the series of clinical cases presented in our study is an example of the situations in which the use of impaction bone grafting turned out to be the only possible effective method at the time of surgical intervention at our Center.

One of the technical problems in hip replacement for dysplastic coxarthrosis is an extremely small size of the acetabulum, cranialization of the center of rotation and the lack of bone substance for reliable fixation of the cup. Therefore the use of cementless acetabular components with a diameter of 42–44 mm is quite common [10, 11, 12]. Frequently, even these sizes turn out to be excessive, and during revision interventions due to hip dysplasia, reconstruction with standard small implants is also very difficult. In this situation, the question arises about the manufacture of customized implants [13] or the use of various revision structures that make it possible to transfer the load to other parts of the acetabulum and pelvis that retain support [14]. Current revision arthroplasty systems offer a large number of augments of various shapes and sizes, but in most cases the line is designed for standard anatomical sizes. Therefore, in case of repeated operations or complicated situations requiring reconstruction, small anatomical dimensions can become a significant limitation for the use of reconstructive cages or metal augments, as was demonstrated in one of our clinical cases. The use of impaction bone grafting, especially for defects of a relatively small size but significant for small bone sizes, which is typical for dysplasia, has shown its reliability and good results [12]. The possibility of defect augmentation using a metal mesh and impaction bone grafting enables to fill relatively small defects of irregular shape without additional expansion or adaptation for IBG [16].

In massive defects of a segmental nature, especially Paprosky type 3A, the combination of IBG with a reconstructive mesh is prognostically less successful. In defects that accounted for more than 50 % of the acetabular cavity, long-term results showed low survival rate [17].

A number of authors also emphasize that the use of impaction bone grafting with mesh and a cement cup should be considered for the reconstruction of medium-sized acetabular defects, but not for massive combined defects [18, 19].

Wilson et al. from the Exeter Orthopedic Center analyzed 129 cases of primary acetabular arthroplasty using IBG to restore its defects, which were classified as cavitary in 74 and segmental in 55 hip joints. After a mean of 9.1 (6.2–14.3) years, survival was 100 % for cavitary defects compared with 82.6 % for segmental defects [12].

However, the combination of IBG with tantalum augments has significantly improved this technique for large unconfined defects and has shown quite promising results [20]. Gill et al. assessed the results of fifteen revision interventions on the hip joints in 14 patients, with an average follow-up period of 39 (25–83) months. All cases achieved good clinical results and the absence of radiological signs of loosening or migration of the cup [21].

The study of Borland et al. included 24 patients with large Paprosky 3A and 3B defects that were treated with complex acetabular reconstruction using a trabecular metal augment, impaction bone grafting, and a cemented high-density polyethylene cup at a mean age of 62 years. Median follow-up was 61 (32–81) months. In five cases, there was migration of the polyethylene cup of more than 5 mm; an augment fracture occurred in one case and required re-intervention 13 months after the revision surgery. Other patients did not require revision [22].

De la Torre-Escuredo et al. analyzed the results of using IBG in combination with a reconstructive mesh supplemented with a porous tantalum augment in revision hip arthroplasty in 5 young patients (⩽ 50 years old at the time of surgery) with Paprosky defects 3A and 3B who showed significant improvement in clinical scores over a mean follow-up of 79 months (60–101). When radiographic data were assessed, there were no significant differences in abduction angle (p = 0.27) or cup migration (p = 0.31) between the postoperative position and the last follow-up. No patients had lucency lines at the bone-cement interface at last follow-ups and no patients had signs of loosening around the augments [23].

In our clinical case 3, the use of this combination limited the defect using an augment and created additional support and conditions for retaining the impacted bone mass in the defect that enabled to fill in a significant defect with restoration of the bone mass. To achieve construct stability, it was important that the augment was in close contact with the ilium when placed in the most appropriate position. It was important to use at least two 6.5 mm screws to secure the augment.

In that case, the augment acts as a scaffold for bone ingrowth and remodeling, while providing load-bearing structural support [20, 21, 22]. The excellent results obtained in cases of using trabecular metal augments are confirmed not only by the osteoconductive properties of this material, but also by its osteoinductive properties [24]. Another important advantage of tantalum is the absence of associated resorption, in contrast to structural allografts.

Long-term results of using tantalum augments with a cementless cup in acetabular reconstruction show a high survival rate of the latter [25]. However, in extremely large defects, complete replacement with metal augments requires high-quality preparation of the bone bed, which must geometrically correspond to the shape of the augment [26, 27]. In conditions of bone deficiency, such as AAOS type 3 defect with segmental-cavitary bone deficiency, this can lead to even greater bone loss. Replacing the entire volume of the bone defect with metal also leaves no chance for creating a bone reserve in the acetabulum area for the successful implementation of possible future revisions, especially in young patients. At the same time, the use of bone chips for impaction bone grafting provides dense filling of the smallest defects and shape a bed which is congruent with the pelvic component. The use of cemented fixation implants allows additional stabilization of the impacted crushed graft with the cement mantle itself and mechanotransduction mechanisms that stimulate the restructuring of the osteoplastic material [28].

Quite reliable solutions for managing extremely large bone defects have been currently offered by additive technologies [4]. One important difference between these systems is the filling of defects with a large volume of metal, without further prospects for bone reserve in the acetabulum area. Regarding the extremely high risks in using customized designs in patients, medium-term survival rates of 75–82.7 % [29, 30, 31] may be considered acceptable, but quite modest if life expectancy is up to 85–90 years.

CONCLUSION

Impaction bone grafting is a universal technology for managing acetabular bone defects in revision and primary complex hip arthroplasty. The creation of a bone stock in the defect area provides more favorable conditions for possible repeated revision interventions in the future, which is its main advantage over other current technologies. Combining IBG with metal augments made of trabecular metal enables a stable support for the cemented cavity and limits the defect, providing favorable conditions for reconstruction, which significantly expands the possibilities of using this technology for massive segmental defects of the acetabulum. In some non-standard cases, due to individual anatomy, dysplasia, or ultra-small size of the acetabulum combined with the complex bone defect geometry, IBG can be used as the method of choice, allowing high-quality reconstruction with restoration of the anatomical relationships in the hip joint, which significantly increases the arsenal of technical capabilities for the orthopedic surgeon.

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