doi: 10.21823/2311-2905-2020-26-2-60-70

Effects of 3D Imaging on Surgical Tactics in Primary and Revision Hip Arthroplasty

V.A. Bazlov [1], T.Z. Mamuladze [1], O.I. Golenkov [1], M.V. Efimenko [1], A.A. Pronskikh [1], K.N. Kharitonov [1], A.A. Panchenko [2], V.V. Pavlov [1]

[1] *Tsivyan Novosibirsk Research Institute of Traumatology and Orthopedics, Novosibirsk, Russian Federation*

[2] *Logeeks Medical Systems, Novosibirsk, Russian Federation*

Abstract

Background. 3D imaging tools significantly expand the ability to assess the bone tissue condition, both in terms of its qualitative properties and in terms of accurate determination of bone defect geometry and volume. ***The purpose of the study*** was to determine the 3D imaging potential for the preoperative planning and correction of surgical tactics in hip arthroplasty. ***Materials and Methods.*** A retrospective analysis of the preoperative planning of 110 primary and revision hip arthroplasties with 3D imaging was performed. The following specialized software were employed: RadiAnt DICOM Viewer file converter — for 3D models production; 3D/CAD designers — for volumetric models processing and correction; InVesalius 3.0 program — for bone density evaluation by the Hounsfield scale; K-Pacs — for viewing MSCT and X-ray images. All patients underwent pelvic bones radiography in the front and anterior-lateral planes. Post-traumatic acetabular deformity was described in accordance with the X-ray picture in each individual clinical case. For revision arthroplasty, the acetabular defect was determined according to the W.G. Paprosky classification. In 36 patients (32.7%), the acetabulum defect was the result of trauma. In 74 patients (67.3%), the cause of surgery was endoprosthesis components loosening. ***Results.*** In 80% of cases (88 patients), the analysis of the 3D model did not change the surgical tactics determined in the preoperative planning using pelvic radiographs; in 20% of cases (22 patients), the use of 3D imaging revealed new circumstances and changed the surgical tactics. ***Conclusion.*** In standard cases, it is possible to use the traditional preoperative planning using radiographs in several planes. In primary hip arthroplasty in the patients with post-traumatic deformity, including a false joint of acetabulum bottom or 2 to 3 degree osteopenia, it is advisable to perform 3D imaging. In the case of revision arthroplasty, 3D visualization is indicated in acetabulum Paprosky IIIA, IIIB defects with pelvic discontinuity.

Keywords: hip arthroplasty, 3D visualization, preoperative planning, individual implants, surgical tactics.

Cite as: Bazlov V.A., Mamuladze T.Z., Golenkov O.I., Efimenko M.V., Pronskikh A.A., Kharitonov K.N., Panchenko A.A., Pavlov V.V. [Effects of 3D Imaging on Surgical Tactics in Primary and Revision Hip Arthroplasty]. *Travmatologiya i ortopediya Rossii* [Traumatology and Orthopedics of Russia]. 2020;26(2):60-70. (In Russian). doi: 10.21823/2311-2905-2020-26-2-60-70.

Vyacheslav A. Bazlov; e-mail: sbazlov@yandex.ru

Received: 19.03.2020. Accepted for publication: 26.05.2020.

Introduction

There has been an increase in the number of primary and revision total hip arthroplasties (THA) with additive technologies (AT) worldwide [1, 2, 3, 4].

The revision THA requires significant material resources, highly skilled operating surgeon, as well as the exact choice of surgical tactics [5, 6, 7]. Preoperative planning of the complex cases of primary and revision THA is a complex task, usually requiring a number of additional studies, including *multislice computed tomography* (MSCT). The surgery outcome depends on the tactics chosen during the planning process: an adequate choice of the implant, the need and the possibility of using bone grafting, the operative time and a number of other factors that make up the patient's further well-being [8]. The objectives of preoperative planning using *volumetric visualization* (VV) are as follows: long-term endoprosthesis survival, proper biomechanics, ensuring the stable primary fixation of the acetabular implant, and adequate compensation for bone deficiency [9].

Nowadays, most clinics of the Russian Federation do not have the possibility to use the AT in the preoperative period. Therefore, the course of THA is usually determined on the basis of a series of pelvic bones X-rays analysis. In preoperative planning using 2D tools, it is possible to correctly determine the center of rotation and the necessary femoral compensation, adjust the axis of the limb and select the standard components of the hip prosthesis [10, 11, 12]. VV tools significantly expand the ability of bone tissue evaluation both in terms of bone quality and in terms of accurate determination the geometry and the volume of acetabulum bone tissue defect. This information opens up new approaches to preoperative planning, allowing maximum preservation of bone tissue in the course of individual implant modeling or selection of standard components, to determine the character and the volume of bone grafting.

The purpose of the study was to demonstrate the possibilities of VV in the preoperative planning of THA for the choice of surgical tactics.

Materials and Methods

Design: retrospective single-center observational study.

A retrospective analysis of 110 clinical cases of preoperative planning of primary (36 patients) revision (74 patients) THA using VV was performed from December 2016 to November 2019. The analyzing group included 48 men and 62 women with an average age of 52±12 years (from 27 to 77), an average body mass index of 26.3±5.1 kg/m^2. The follow-up time after the surgery averaged 21±12 months (from 1 to 34).

Inclusion criteria: the patients with the diagnoses of "post-traumatic acetabular deformity" or "aseptic loosening of endoprosthesis components" undergone primary or revision THA using VV.

Exclusion criteria: patients with "dysplastic coxarthrosis". The decision not to include the patients with dysplastic coxarthrosis in the study was made for the following reason. The bone defects in post-traumatic acetabulum deformity or endoprosthesis components loosening are made artificially (by injury or as a consequence of a surgery). In contrast, in dysplastic coxarthrosis, an improperly formed hip has been presented initially. Dysplasia is a congenital abnormal development of the hip, that is, this condition has a completely different nature.

In the preoperative period, all the patients underwent the pelvic bones X-rays in the frontal and anterior-lateral planes. The post-traumatic acetabular deformity was described by the X-ray picture in each clinical case. For revision THA, an acetabular defect was classified according to the generally accepted W.G. Paprosky classification [13].

Periprosthetic infection (PPI) in the patients undergone revision THA was excluded by the hip puncture followed by bacteriological examination of the obtained material. PPI was excluded in all 74 cases of revision THA.

Preoperative planning

The process of preoperative planning using VV begins with the construction of a 3D model based on the MSCT. Conversion a series of MSCT (DICOM) images into a single 3D-format file (*.stl) was carried out using specialized software RadiAnt DICOM Viewer (Medixant, Poland). Next, the obtained 3D model was processed in the InVesalius 3.0 program (CTI, Brazil) to make it possible to assess the bone density on the Hounsfield scale in the region of interest. As a rule, this is the area of the supposed major bone-implant contact (Fig. 1).

With the standard InVesalius tools, the 3D model foreign bodies were virtually removed from the acetabulum and the proximal third of the thigh, in particular the endoprosthesis components.

To further obtain the “working” model, the pelvic bones were visualized. Figure 2 presents the model in the regime of 650 Hounsfield units (HU), within the density range of 400–600 HU, which is considered the relative norm for bone tissue of this anatomical region [12].

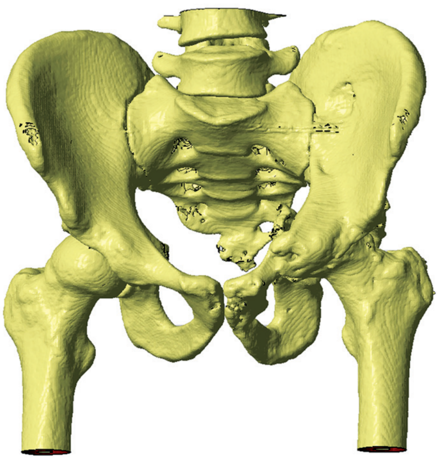

Fig. 1. 3D model processed with InVesalius program. The bone density of the region of interest is estimated by the Hounsfield scale.

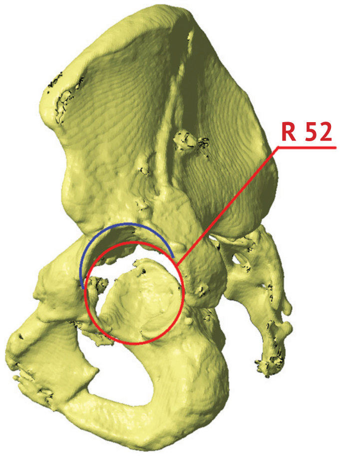

Fig. 2. The «working» model. The pelvic bones are visualized within a density of 400–600 HU.

The next stage was the direct planning of operative tactics on the resulting “working” 3D model of the pelvic bones. For this purpose, we used the specialized Autodesk Netfabb software. For the latter, we created a standard components database by 3D scanning. Some of the endoprosthesis components were made independently according to the principle of matching geometric shapes. The Autodesk Netfabb capabilities allowed the preoperative planning on an existing volumetric model of the pelvis by arranging templates in the acetabulum area. Thus, in a given clinical situation, it is possible to determine which component is more appropriate to use to maximize bone preservation and optimize the course of surgical treatment. E.g., in case of an acetabulum roof defect (cavitary defect corresponding to Paprosky type IIB), bone grafting and a endoprosthesis standard component can be used or jumbo cup without bone grafting. In the same situation, it is also possible to perform the maximum volume bone grafting, to place an individual augment, thereby creating a support block along the defect contour, and to place a standard acetabular component of the smallest possible size (Fig. 3).

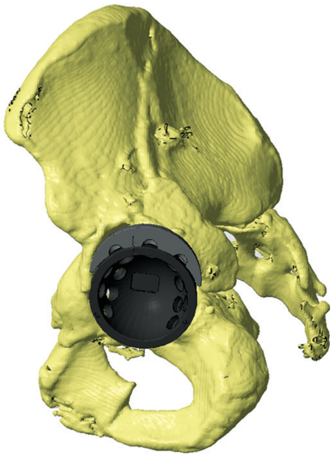

Fig. 3. Preoperative planning on the 3D model of the pelvis bones: a defect of the upper edge of the acetabulum is replaced with an individual augment, it is planned to install an individual acetabular component of a hemispherical shape.

Such an approach makes it possible to preserve the intact bone tissue, maximize the use of bone grafting and to predict with high probability the reliable primary fixation of the endoprosthesis components. In the process of individual constructions developing, the standard Autodesk Netfabb tools allow the surgeon to set the desired anteversion and inclination of the acetabular component, determine the possible bone grafting sites, and correctly orientate the fasteners. This will greatly facilitate further modeling of the implant to the bioengineer, who, as a rule, is not an operating surgeon and is not familiar with the intricacies of large joint arthroplasty.

Results

In 36 patients (32.7%), an acetabulum defect was the result of traumatic exposure; 74 patients (67.3%) required surgery due to the loosening of the previously placed endoprosthesis components. In 16 cases out of 74 (21.6%), the acetabular defects were classified as type IIB, in 8 (10.8%) — IIC, in 22 (29.7%) — IIIA, in 20 (27.1%) — IIIB, 8 patients (10.8%) were diagnosed the pelvic ring discontinuity.

In 80% of cases (88 patients), the analysis of the 3D model did not change the tactics of surgical intervention determined during preoperative planning with pelvic X-rays in a various planes. However, in these cases, VV helped to determine the volume and nature of bone grafting, the fixation points of the fasteners in areas of the most dense bone tissue.

Preoperative planning with VV in 20% of cases (22 patients) helped to reveal new circumstances and a change in the surgical tactics in favor of an individual construction or in favor of standard components in combination with or without bone grafting (see Table).

Of the 10 cases of primary THA due to post-traumatic acetabular deformity, in which the surgical tactics were changed after VV, in 7 cases the pathological process was accompanied by the presence of a pseudarthrosis in the acetabulum bottom, in 3 cases — osteopenia of 2 to 3 degree (T-test from -1.7 to -2.4 SD).

Table

Correction of surgical tactics due to employment of volumetric visualization in preoperative planning

Type of surgery and patient's diagnosis	Preoperative planning of surgical tactics	
	Before volumetric visualization	After 3D model construction, assessment bone density, calculation of possible bone grafting volume
Total hip arthroplasty for post-traumatic acetabular deformity (*n* = 10)	Jumbo cup multiholes, additional fixation with screws (sciatic, pubic, above acetabulum bone mass)	Standard augment + individual acetabular component (hemispherical with segmental openings (sciatic, pubic, above acetabulum mass) + bone autograft
Revision hip arthroplasty for aseptic loosening of endoprosthesis components (*n* = 12)	Standard augments + bone allograft + standard hemispherical acetabular component	Minimum required individual construction + bone allograft

Of 12 revision THA for aseptic loosening, the tactics of which changed after VV, in 3 cases (25%) the acetabular defect was classified as IIIA, in 4 cases (33%) — IIIB, in 5 patients (42%) — pelvic ring discontinuity.

Case report 1

A 27-year-old patient was admitted to the Central District Hospital in December 2018 with a multiple injury in a traffic accident. A closed fracture of the acetabulum bottom on the left, a comminuted fracture of the acetabulum roof on the left, and a posterior dislocation of the left femoral head were diagnosed. 9 months later from the time of injury, all metal constructions of the left acetabular area were removed at the patient's place of residence and an orthopedic traumatologist consultation at the Tsivian Novosibirsk Scientific Research Institute of Traumatology and Orthopedics was recommended.

At the time of admission in December 2019, the following clinical picture was observed: a relative shortening of the left lower limb by 7 cm, a Harris score of 20 points, and VAS score of 7 points. The X-ray picture is presented in Figure 4.

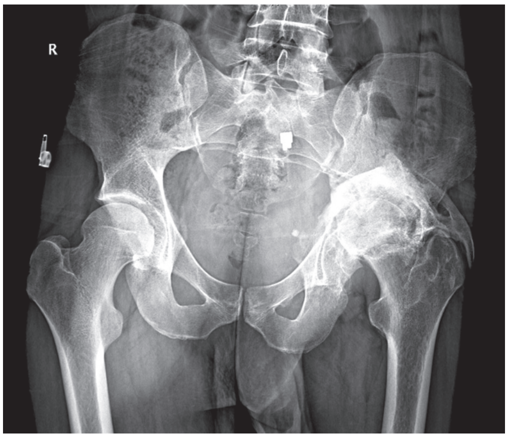

Fig. 4. X-ray of a patient 27 y.o. on admission: left-sided 3-stage post-traumatic hip osteoarthritis with cyst-like restructuring and aseptic necrosis of the left femoral head apex, massive paraarticular ossificates, left acetabulum fracture consolidated in the displacement position, consolidated fracture of the left acetabulum posterior wall.

The MSCT was performed (layer thickness 0.5 mm, radiation dose 2.0±0.9 mSv, 32-slice Philips apparatus). On the basis of MSCT a 3D model of the patient's pelvic bones was constructed (Fig. 5).

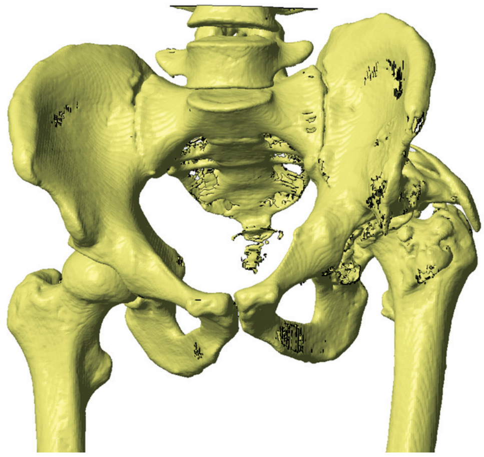

Fig. 5. 3D model of pelvic bones in the mode of 400–600 HU.

The further preoperative planning was carried out by InVesalius and Autodesk Netfabb programs in bone density mode from 400 to 600 HU.

During the preoperative planning, the options for the standard Jumbo cup placement with acetabulum bone grafting were considered. However, in this case it was necessary to remove a significant amount of intact bone tissue for reliable fixation of the acetabular component. The use of standard hemispherical augments is difficult due to the impossibility of their fixation into the deformed acetabulum roof and development of a reliable support for the acetabular component. Considering the patient's young age and the possibility of performing bone autografting using the left femoral head, it was decided to calculate the maximum possible volume of bone autograft and, based on the volume obtained, to model an individual construction, and then to perform left THA with standard Smith & Nephew components.

Using the capabilities of the Autodesk Netfabb program, we calculated the volume of the femoral head and the volume of the acetabular defect on the left. This was necessary for further modeling of an individual construction with the minimum possible use of a metal component (Fig. 6, a, b). Direct modeling of an individual construction was performed by contour grafting of the acetabular roof region, taking into account the virtual filling of the defect with a bone autograft (Fig. 6 c).

The surgery was performed using the standard surgical instruments, lasted 110 minutes, intraoperative blood loss was 550 ml. The control X-rays were taken in the operating room (Fig. 7).

The patient was activated on the 2nd day after surgery, received therapy in accordance with the protocol for the management of the patients after primary THA. The total length of hospitalization was 14 days. At the control examination a month later, the Harris questionnaire revealed 67 points, VAS 3 points. The patient moved with a cane.

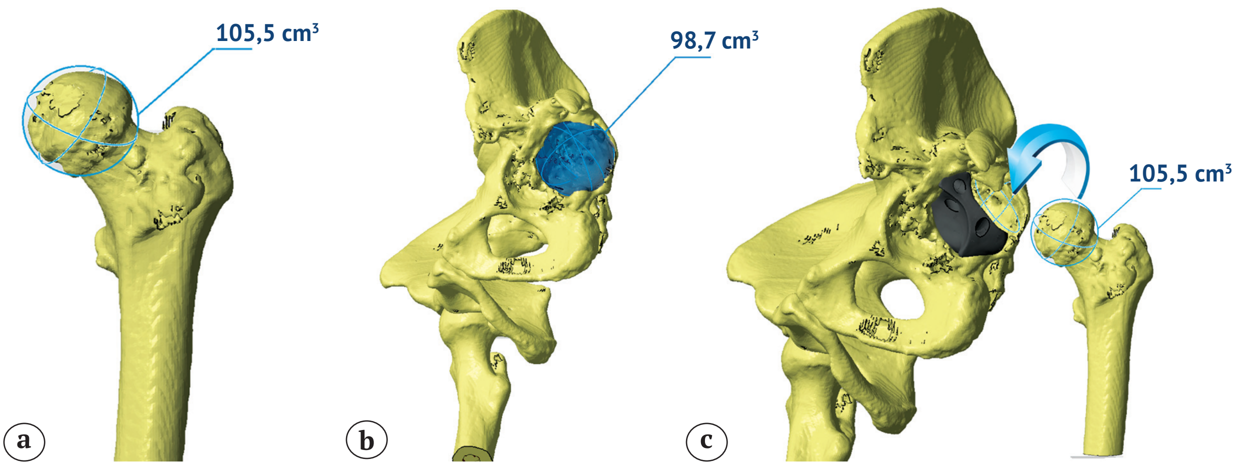

Fig. 6. Stages of preoperative planning:
a — calculation of the volume of the femoral head (105.5 cm^3);
b — calculation of the volume of the defect of the posterior edge of the acetabulum (98.7 cm^3);
c — modeling of an individual implant.

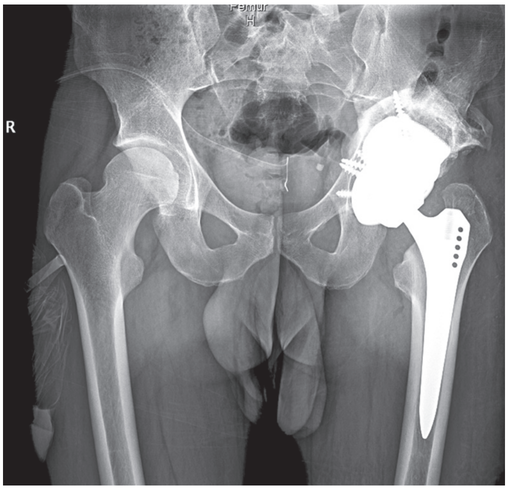

Fig. 7. X-ray of the patient: the left hip joint was replaced by an individual endoprosthesis, primary fixation with 7 screws; the position of the components of the endoprosthesis is correct.

Case report 2

A female patient of 62 years old underwent primary left THA in 2005. In 2016, the left hip endoprosthesis components were removed due to a deep periprosthetic infection. In April 2017, the patient was admitted at the Tsivian Novosibirsk Scientific Research Institute of Traumatology and Orthopedics. Harris score was 20 points, VAS — 7 points. An X-ray of the pelvic bones in a frontal plane was performed (Fig. 8).

During preoperative planning, it was decided to use three standard augments to recreate the support along the acetabulum front and lower edges, then to replace the defect in the area of the acetabulum roof, and after it to place the standard acetabular component (Fig. 9).

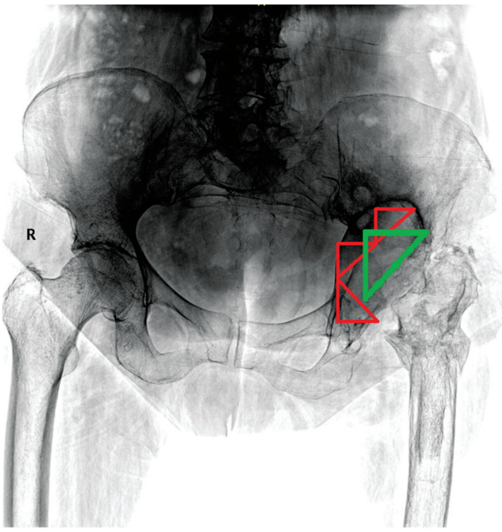

Fig. 9. Preoperative planning of revision hip arthroplasty. Three red triangles indicate the attachment points of standard augments, a green triangle showes the acetabular component location.

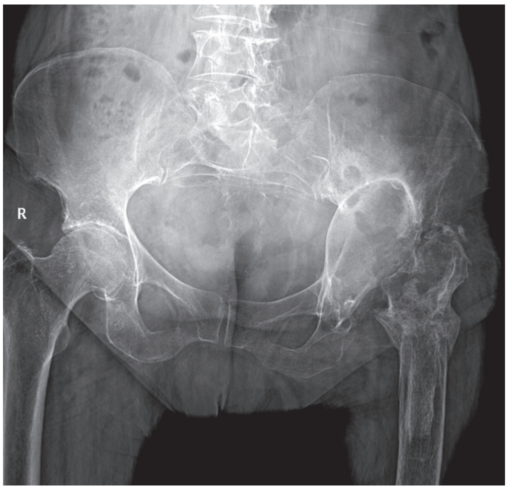

Fig. 8. X-ray of female patient 62 y.o.: post-implantation Paprosky IIIB defect of the left acetabulum.

3D reconstruction was performed according to the results of MSCT. During the analysis of the acetabular defect, it was found that the implantation of standard augments was difficult, because there was a pronounced osteoporosis of the acetabular bones, and the complex geometry of the defect would not contribute to reliable fixation of the augments. It was decided to maximize the use of bone allograft with acetabular reconstruction with an individual 3D construction (Fig. 10).

The surgery was carried out using standard surgical instruments and passed without technical difficulties, duration — 123 minutes, blood loss — 450 ml. An X-ray of the patient's pelvis after the surgery is shown in Figure 11.

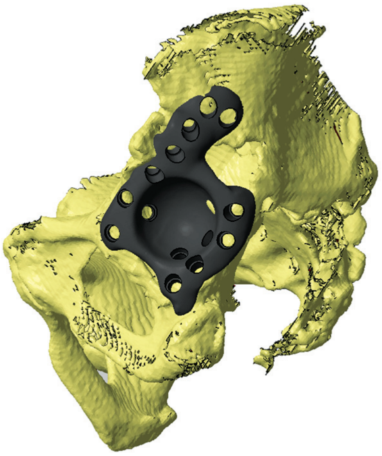

Fig. 10. Modelling of an individual implant.
The inclination and direction of the holes correspond to the optimal route of the fasteners.

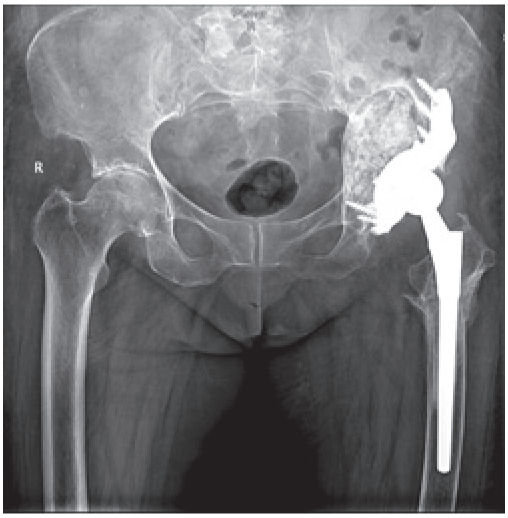

Fig. 11. Postoperative X-ray of female patient, 62 y.o.: the left acetabular defect was replaced by 180 cm^3 bone allograft. The left hip is replaced by individual 3D implant.

The patient was activated on the 3rd day after the surgery. She received therapy in accordance with the patient management protocol after revision THA. The total length of hospitalization was 16 days. At the control examination after 6 months, the Harris questionnaire score was 68 points, VAS 2 points. The patient moved using a cane.

Discussion

The problem of the tactics choice for primary and revision THA in complex cases remains unresolved [14, 15, 16, 17]. In such cases, it is advisable to use AT in the preoperative period both for modeling individual constructions and for planning the course of surgery [18, 19, 20]. Nowadays, the use of AT is already not revolutionary. The widespread introduction of 3D printing and AT began in Russia in 2015 [21, 22, 23]. Until now, there are a number of fundamental questions that cannot be answered unambiguously: determining the necessary and sufficient contact area of an individual construction with bone tissue, the minimum required number of fasteners, the possibility and necessity of using bone allograft [24]. In such situations, it is possible to use VV as an additional option in search of an answer to some of the above questions. In our practice, 3D technologies were used not only for modeling and manufacturing of individual constructions, but also as a tool for preoperative planning for THA with both serial and individual constructions. As a result of more detailed preoperative planning using VV from 110 studied clinical cases, the surgical tactics was adjusted in 22 (20%), see Table.

Conclusion

Preoperative planning on 3D models makes it possible to maximally preserve the acetabulum, to provide the possibility of contact of the implant with a denser bone tissue, to determine the volume of bone grafting, and in some cases abandon complex individual constructions.

Note that at the moment there is no "gold standard" for THA, a lot in preoperative planning depends on the preferences and experience of the surgeon. We are not talking about the need to use VV in standard cases of primary endoprosthetics, but VV can be an additional tool for complex cases of primary and revision endoprosthetics. Since for 3D visualization, MSCT, additional software, painstaking work of a bioengineer are necessary, the hospitalization period increases by an average of 2 to 3 days, the patient's expectations and the cost of treatment increase respectively. Therefore, in ordinary cases it is reasonable to content with the standard preoperative planning using X-rays in several planes. However, in case of primary total THA, when it comes to post-traumatic deformity, including the presence acetabular bottom pseudarthrosis or osteopenia of 2 to 3 degree, it is advisable to perform VV. In the case of revision THA, it makes sense to conduct 3D visualization in the presence of Paprosky IIIA, IIIB acetabular defects and pelvic ring discontinuity.

Publication Ethics

The study was approved by the local ethics committee. All patients signed a voluntary informed consent for participation in the study and publication clinical cases.

Conflict of interest: The authors declare no conflict of interest.

Funding: The state budget.

Authors' contributions

V.A. Bazlov — research concept and design, data interpretation and analysis, text editing.

T.Z. Mamuladze — collection of material and data processing, research conduction, text preparation.

O.I. Golenkov — text editing, coordination of study participants, data interpretation and analysis.

M.V. Efimenko — coordination of study participants, data interpretation and analysis, text editing.

A.A. Pronskikh — data interpretation and analysis, text editing.

K.N. Kharitonov — data interpretation and analysis, text editing.

A.A. Panchenko — text editing, coordination of study participants, data interpretation and analysis.

V.V. Pavlov — research concept and design, data interpretation and analysis, data interpretation and analysis.

References

1. Kovalenko A.N., Dzhavadov A.A., Shubnykov I.I., Bilyk S.S., Denisov A.O., Cherkasov M.A. et al. [Mid-term outcomes of using custom-made implants for revision hip arthroplasty]. *Travmatologiya i ortopediya Rossii* [Traumatology and Orthopedics of Russia]. 2019;25(3):37-46. (In Russian). doi: 10.21823/2311-2905-2019-25-3-37-46.
2. Gwam C.U., Mistry J.B., Mohamed N.S., Thomas M., Bigart K.S., Mont M.A., Delanois R.E. Current epidemiology of revision total hip arthroplasty in the United States: National Inpatient Sample 2009 to 2013. *J Arthroplasty.* 2019;32(7):2088-2092. doi: 10.1016/j.arth.2017.02.046.
3. Patel A., Pavlou G., Mujica-Mota R.E., Toms A.D. The epidemiology of revision total knee and hip arthroplasty in England and Wales: a comparative analysis with projections for the United States. A study using the National Joint Registry dataset. *Bone Joint J.* 2015;97-B(8):1076-1081. doi: 10.1302/0301-620X.97B8.35170.
4. Kowalik T.D., DeHart M., Gehling H., Gehling P., Schabel K., Duwelius P., Mirza A. The epidemiology of primary and revision total hip arthroplasty in teaching and nonteaching hospitals in the United States. *J Am Acad Orthop Surg.* 2016;24(6):393-398. doi: 10.5435/JAA0S-D-15-00596.
5. Yoon P.W., Lee Y.K., Ahn J., Jang E.J., Kim Y., Kwak H.S. et al. Epidemiology of hip replacements in Korea from

2007 to 2011. *J Korean Med Sci.* 2014;29(6):852-858. doi: 10.3346/jkms.2014.29.6.852.
6. Jafari S.M., Coyle C., Mortazavi S.M., Sharkey P.F., Parvizi J. Revision hip arthroplasty: infection is the most common cause of failure. Clin *Orthop Relat Res.* 2010;468(8):2046-2051. doi: 10.1007/ s11999-010-1251-6.
7. Hosny H.A.H., El-Bakoury A., Fekry H., Keenan J. Mid-term results of graft augmentation prosthesis II cage and impacted allograft bone in revision hip arthroplasty. *J Arthroplasty.* 2018;33(5):1487-1493. doi: 10.1016/j.arth.2017.11.060.
8. Deirmengian G.K., Zmistowski B., O'Neil J.T., Hozack W.J. Management of acetabular bone loss in revision total hip arthroplasty. *J Bone Joint Surg Am.* 2011;93(19): 1842-1852. doi: 10.2106/jbjs.j.01197.
9. Von Roth P., Abdel M.P., Harmsen W.S., Berry D.J. Uncemented jumbo cups for revision total hip arthroplasty: a concise follow-up, at a mean of twenty years, of a previous report. *J Bone Joint Surg Am.* 2015; 97(4):284-287. doi: 10.2106/jbjs.n.00798.
10. Amenabar T., Rahman W.A., Hetaimish B.M., Kuzyk P.R., Safir O.A., Gross A.E. Promising mid-term results with a cup-cage construct for large acetabular defects and pelvic discontinuity. *Clin Orthop Relat Res.* 2016;474(2):408-414. doi: 10.1007/s11999-015-4210-4.
11. Sadovoy M.A., Pavlov V.V., Bazlov V.A., Mamuladze T.Z., Efimenko M.V., Aronov A.M., Panchenko A.A. [Potentialities of 3D-visualization in preoperative planning of primary and revision total hip arthroplasty]. *Vestnik travmatologii i ortopedii im N.N. Priorova* [N.N. Priorov Journal of Traumatology and Orthopedics]. 2017;(3):37-42. (In Russian).
12. Khoruzhik S.A., Mikhaylov A.N. [Fundamentals of CT visualization. Part 1. Images viewing and quantification]. *Radiologiya-praktika* [Radiology - Practice]. 2011;(3): 62-75. (In Russian).
13. Paprosky W.G., Perona P.G., Lawrence J.M. Acetabular defect classification and surgical reconstruction in revision arthroplasty. A 6-year follow-up evaluation. *J Arthroplasty.* 1994;9(1):33-44. doi: 10.1016/0883-5403(94)90135-x.
14. Rukin Ya., Murylev V., Lychagin A., Elizarov P., Grichyuk A., Yavlieva R. Revision hip arthroplasty in patients with pelvic dissociation. *Vrach* [The Doctor]. 2017;(12):66-70. (In Russian).
15. Pavlov V.V., Pronskikh A.A., Mamyladze T.Z., Bazlov V.A., Efimenko M.V., Zhilenko V.Yu., Tsegelnikov M.M. [Staged Surgical Reconstruction of Massive pelvic defect]. *Travmatologiya i ortopediya Rossii* [Traumatology and Orthopedics of Russia]. 2018;24(3):125-134. doi: 10.21823/2311-2905-2018-24-3-125-134.
16. Baauw M., van Hellemondt G.G., van Hooff M.L., Spruit M. The accuracy of positioning of a custom-made implant within a large acetabular defect at revision arthroplasty of the hip. *Bone Joint J.* 2015;97-B(6):780-785. doi: 10.1302/0301-620X.97B6.35129.
17. Korytkin A.A., Smirnov A.A., Zakharova D.V., Novikova Ia.S., Kovaldov K.A., El' Mudni Iu.M. [Experience with external fixation devices during preoperative preparation and planning of primary and revision hip arthroplasty in complicated cases of rigid hip deformity]. *Genij ortopedii.* 2018;24(1):18-23. (In Russian). doi: 10.18019/1028-4427-2018-24-1-18-23.
18. Kovalenko A.N., Tikhilov R.M., Bilyk S.S., Shubnyakov I.I., Cherkasov M.A., Denisov A.O. [Positioning of custommade acetabular components at revision hip arthroplasty: do they really match as «a key and a lock»?]. *Vestnik travmatologii i ortopedii im. N.N. Priorova* [N.N. Priorov Journal of Traumatology and Orthopedics]. 2017;(4):31-37. (In Russian). doi: 10.32414/0869-8678-2017-4-31-37.
19. Kavalersky G., Murylev V., Rukin Ya., Elizarov Ya., Dzhenzhera E. [3D Technologies for revision total hip arthroplasty]. *Vrach* [The Doctor]. 2016;(11):47-49. (In Russian).
20. Berasi C.C., Berend K.R., Adams J.B., Ruh E.L, Lombardi A.V. Are custom triflange acetabular components effective for reconstruction of catastrophic bone loss? *Clin Orthop Relat Res.* 2015;473(2):528-535. doi: 10.1007/s11999-014-3969-z.
21. Tikhilov R.M., Shubnyakov I.I., Kovalenko A.N., Bilyk C.C., Tsybin A.V., Denisov A.O., Dmitrevich G.D., Vopilovsky P.N. [Using custom triflange implant in revision hip arthroplasty in patient with pelvic discontinuity (case report)]. *Travmatologiya i ortopediya Rossii* [Traumatology and Orthopedics of Russia]. 2016;(1):108-116. (In Russian). doi: 10.21823/2311-2905-2016-0-1-108-116.
22. Korytkin A.A., Zakharova D.V., Novikova Ya.S., Gorbatov R.O., Kovaldov K.A., El Moudni Y.M. [Custom triflange acetabular components in revision hip replacement (experience review)]. *Travmatologiya i ortopediya Rossii* [Traumatology and Orthopedics of Russia]. 2017;23(4):101-111. (In Russian). doi: 10.21823/2311-2905-2017-23-4-101-111.
23. Kavalerskiy G.M., Murylev V.Y., Rukin Y.A., Elizarov P.M., Lychagin A.V., Tselisheva E.Y. Three-dimensional models in planning of revision hip arthroplasty with complex acetabular defects. *Indian J Orthop.* 2018;52(6):625-630. doi: 10.4103/ortho.IJOrtho_556_16.
24. Baauw M., van Hellemondt G.G., van Hooff M.L., Spruit M. The accuracy of positioning of a custom-made implant within a large acetabular defect at revision arthroplasty of the hip. *Bone Joint J.* 2015; 97-B(6):780-785. doi: 10.1302/0301-620X.97B6.35129.

AUTHORS' INFORMATION:

Vyacheslav A. Bazlov — Researcher, Department of Arthroplasty and Arthroscopy, Tsivyan Novosibirsk Research Institute of Traumatology and Orthopedics, Novosibirsk, Russian Federation

Tariel Z. Mamuladze — Researcher, Department of Arthroplasty and Arthroscopy, Tsivyan Novosibirsk Research Institute of Traumatology and Orthopedics, Novosibirsk, Russian Federation

Oleg I. Golenkov — Orthopedic Surgeon, Tsivyan Novosibirsk Research Institute of Traumatology and Orthopedics, Novosibirsk, Russian Federation

Maxim V. Efimenko — Orthopedic Surgeon, Tsivyan Novosibirsk Research Institute of Traumatology and Orthopedics, Novosibirsk, Russian Federation

Alexander A. Pronskikh — Cand. Sci. (Med.), Researcher, Department of Arthroplasty and Arthroscopy, Tsivyan Novosibirsk Research Institute of Traumatology and Orthopedics, Novosibirsk, Russian Federation

Konstantin N. Kharitonov — Orthopedic Surgeon, Tsivyan Novosibirsk Research Institute of Traumatology and Orthopedics, Novosibirsk, Russian Federation

Andrey A. Panchenko — Technical Director, Logeeks Medical Systems, Novosibirsk, Russian Federation

Vitaly V. Pavlov — Dr. Sci. (Med.), Head of the Department of Traumatology and Orthopedics, Tsivyan Novosibirsk Research Institute of Traumatology and Orthopedics, Novosibirsk, Russian Federation