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The Medium-Term Results of Complex Treatment of the Children with I-II Stage Dysplastic Osteoarthritis

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Abstract

Background. The frequency of hip dysplasia does not decrease and ranges from 2 to 50 or more per 1000 newborns. The generally accepted standard for the treatment of children under 1 year of age with hip dysplasia is the functional method. At the same time, the number of patients with untimely revealed hip dysplasia, as well as with an unsatisfactory outcome of functional treatment, for example, according to the A. Lorenz technique, remains at a fairly high level. In this regard, the use of corrective surgical interventions remains relevant. ***The purpose of this study*** was to evaluate the medium-term results of the treatment of children with I–II stage dysplastic hip osteoarthritis using the authors' rehabilitation algorithm based on the functional state of the hip. ***Materials and Methods.*** The study was based on the results of a comprehensive examination of 41 patients (48 hip joints) with stage I–IIa dysplastic hip osteoarthritis undergone the surgery and rehabilitation according to the authors' algorithm in the period from 2016 to 2018. To compare the obtained results, we performed a retrospective analysis of the clinical records of 32 patients (39 hip joints) undergone the similar surgery, although with the routine rehabilitation. All patients underwent a clinical examination with a mandatory assessment of step cycle, periarticular muscles endurance, and filling out specialized questionnaires. Radiological evaluation included hip X-ray and multi-spiral computed tomography. To obtain the most objective information of the hip functional state and lower extremities, we used electrophysiological (EMG) and biomechanics (stabilometry) studies. ***Results.*** Clinical and functional results were evaluated no earlier than 24 months after the treatment. The patients undergone rehabilitation according to the authors' algorithm demonstrated the significant (p<0.05) increase in the strength and endurance of their hip area muscles, as well as in their electromyographic indicators, resulting in the improvement of their clinical and biomechanical parameters. This did not observed in the patients undergone the routine rehabilitation. ***Conclusion.*** The analysis of the medium-term results of the complex treatment of children with stage I–II dysplastic hip osteoarthritis, including surgical stable fixation and the authors' rehabilitation method, led to a significant (p<0.05) improvement in the static-dynamic function of the lower extremities. This was confirmed by the results of clinical, electrophysiological, biomechanical evaluation, as well as by the employment of specialized scales that took into account the hip function, quality of life, and social adaptation of the patient.

Keywords: children, dysplastic hip osteoarthritis, triple pelvic osteotomy, rehabilitation.

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The incidence of *developmental dysplasia of the hip* (DDH) in various countries ranges from 2 to 50 or more cases per 1000 newborns [1, 2, 3]. The generally accepted standard of treatment children under one year old with DDH is a functional method. Its effectiveness has been proven in numerous domestic and foreign publications [4, 5, 6]. However, the number of patients with late diagnosed DDH, as well as after the treatment by A. Lorenz, remains at a fairly high level [7]. The absence concentric reduction femoral head into the acetabulum and the occurrence secondary proximal femur deformities due to various severity postrepositional ischemic necrosis of the femoral head leads to the formation of residual subluxations, and the latter, already in adolescence, create preconditions for the formation and DDH progression [6, 8, 9]. Numerous studies have proved that the maximum corrective potential in the treatment this disease belongs to pelvic reorienting osteotomy. The surgery changes the spatial position of dysplastic acetabulum and provides an optimal contact area for cartilaginous models pelvic and femoral hip components [10, 11, 12, 13, 14].

Undoubtedly, one of the important aspects of the surgery effectiveness is the choice osteosynthesis option. Currently, the stable osteosynthesis is carried out with spongy screws and LCP Pediatric Hip Plates. They have angular stability due to the threaded connection between the plate and the screw, as well as limited contact with the periosteum. The latter aspect prevents intraosseous circulation disturbance [15, 16].

In addition, an integral part of the treatment is full-fledged rehabilitation, the absence of which can reduce or completely neutralize the positive effect of the surgery. There are few publications on the adult rehabilitation after periacetabular and triple pelvic osteotomy [17, 18], as well as devoted to the rehabilitation of children after hip surgeries. They mainly concern the issues of rehabilitation after the long-term immobilization [19]. Also, there are only single publications concerning the possibility of early rehabilitation in stable osteosynthesis with angular stability plate and the absence of plaster immobilization. The latter publications are devoted to the preschool children rehabilitation [20]. In addition, today there is no unified view of the necessary set of exercises to maximize the effect of the treatment.

The purpose of this study was to evaluate the mid-term treatment results of the children with I-II stage DDH according to the developed rehabilitation algorithm based on the hip functional state.

Materials and Methods

Study design

Monocentric cohort prospective with retrospective control study.

Inclusion criteria:

– age from 13 to 18 years old;

– the presence of clinical and radiological signs of I-IIa stage DDH according to the DDH classification in children and adolescents, developed at the H. Turner National Medical Research Center for Children's Orthopedics and Trauma Surgery (Turner Center) [21] and J.F. Crowe I;

– the absence of previously performed hip surgeries;

– absence of neurological, systemic and genetic diseases;

– the consent of the patient or his legal representative to participate in the study.

Exclusion criteria:

– age under 13 and over 18 years;

– the presence of clinical and radiological signs of IIb-III stage DDH according to the DDH classification in children and adolescents, developed at the Turner Center and J.F. Crowe II–IV;

– a history of hip surgery;

– the presence of neurological, systemic and genetic diseases;

– refusal to fill out informed consent to participate in the study.

The present study included 50 patients (60 hips) aged 13 to 18 years (15.1 ± 1.8 years) treated at the Turner Center from 2016 to 2018, the *main group* (MG). For the comparison, we retrospectively analyzed the charts of 35 patients (43 hips), identical in age and the pathology nature treated at the same Turner Center from 2014 to 2015 with outpatient follow-up, the *control group* (CG).

The treatment results analysis was carried out during the follow-up of at least 24 months in 41 patients (48 hips) of the MG and in 32 patients (39 hips) of the CG, which amounted to 82% and 91% of the patients in these groups, respectively. Some of the patients withdrew from the study due to reaching the adulthood. They went under the supervision of orthopedic traumatologists of the adult outpatient network (Figure 1).

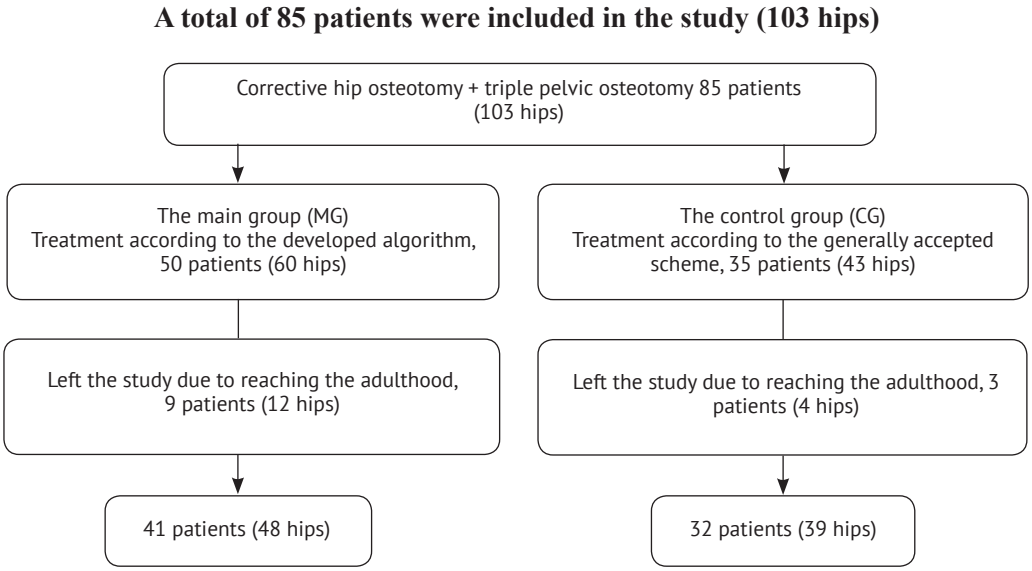

Figure 1. The study flowchart.

Patients

Of 41 patients (48 hips) of the MG, 34 had unilateral lesions (83%). 23 (67.6%) of them had the degenerative process stage I, and 11 (32.4%) – stage IIa. 7 patients (17%) had bilateral lesions: 4 (57.1%) – stage I and 3 (42.9%) – IIa. 25 patients of the CG (78.1%) had unilateral DDH, of them 17 patients (68%) had stage I, and 8 (32%) – IIa. 7 patients (21.9%) had both hip lesion, 5 of whom (71.4%) had stage I, and 2 (28.6%) – IIa.

The patients examination was carried out according to the generally accepted method with a mandatory walking cycle visual assessment, tests to determine the periarticular muscles endurance, specific impingement tests (FADIR, FABER) and filling out questionnaires Harris Hip Score, VAS and the quality of life of a teenager, which was developed at the Turner Center. The radiological methods included X-rays in the antero-posterior and axial planes, as well as in the functional position of the lower limb (depending on the presence angular and torsion proximal femur deformity) and multi-spiral computed tomography. To assess the lower extremities muscles functional state and the characteristics of the lower extremities static load distribution, electrophysiological (electromyography) and biomechanical (stabilometry) studies were performed.

Surgical technique

To restore the anatomical relationships and to achieve the stability of the hip, the pa-

tients of both groups underwent triple pelvic osteotomy in combination with corrective osteotomy of the femur, depending on the angular values of the proximal femur [22]. In the patients of both groups, cancellous screws and angularly stable LCP plates were used as the structures for the ilium and femur osteosynthesis, respectively (Figure 2).

Provision of compression at the iliac fragments level and angular stability at the proximal femur osteotomy level made it possible to dispense with plaster immobilization and begin early rehabilitation.

The patients of the CG underwent rehabilitation according to the generally accepted scheme: passive movements in the operated joint with the help of the "Artromot K1" apparatus began from the 3rd day of the postoperative period, active movements – from the 10th day. The further rehabilitation was carried out in outpatient clinics or in rehabilitation centers at the place of residence.

The patients of the MG underwent rehabilitation according to the developed algorithm, the main provisions of which are shown in Figure 3.

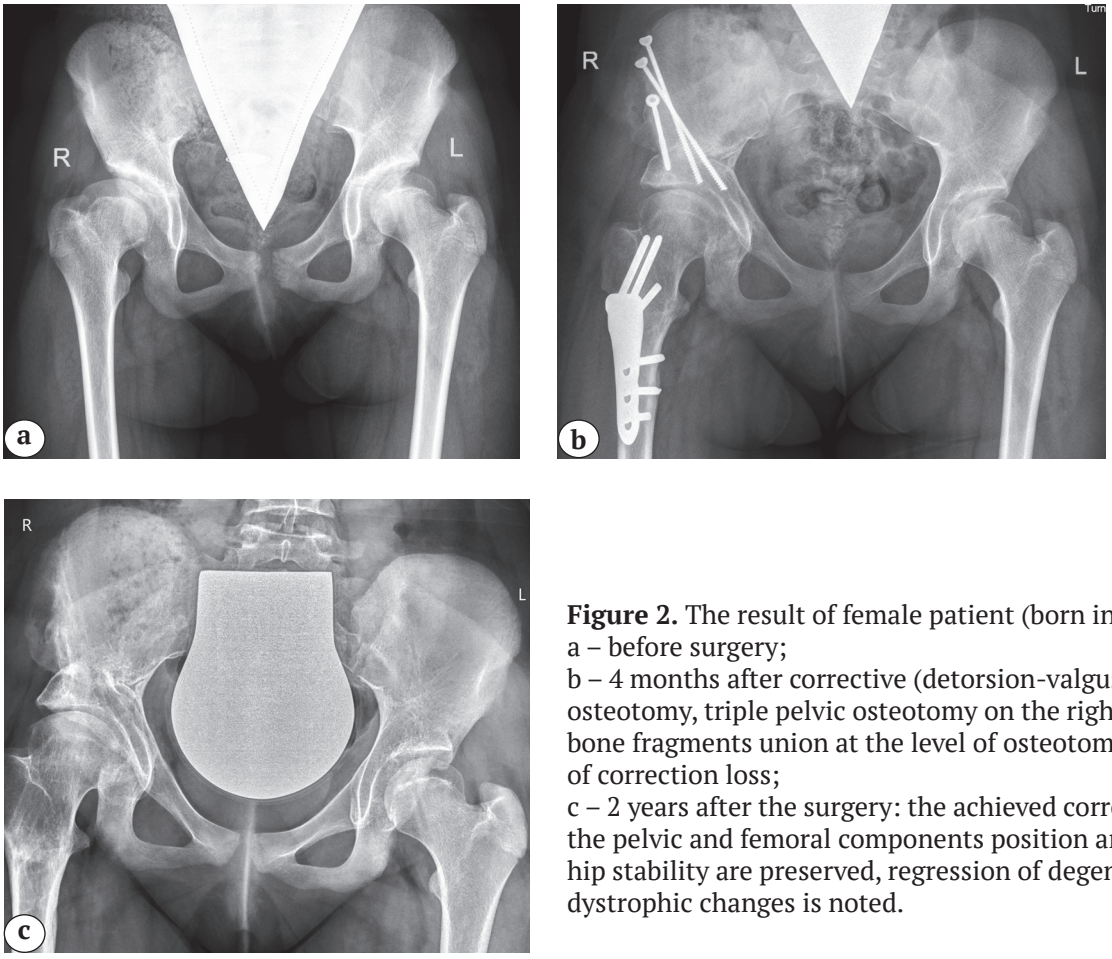

Figure 2. The result of female patient (born in 2001) surgery:
a – before surgery;
b – 4 months after corrective (detorsion-valgusing) femur osteotomy, triple pelvic osteotomy on the right, completion of bone fragments union at the level of osteotomy without signs of correction loss;
c – 2 years after the surgery: the achieved correction of the pelvic and femoral components position and the right hip stability are preserved, regression of degenerative and dystrophic changes is noted.

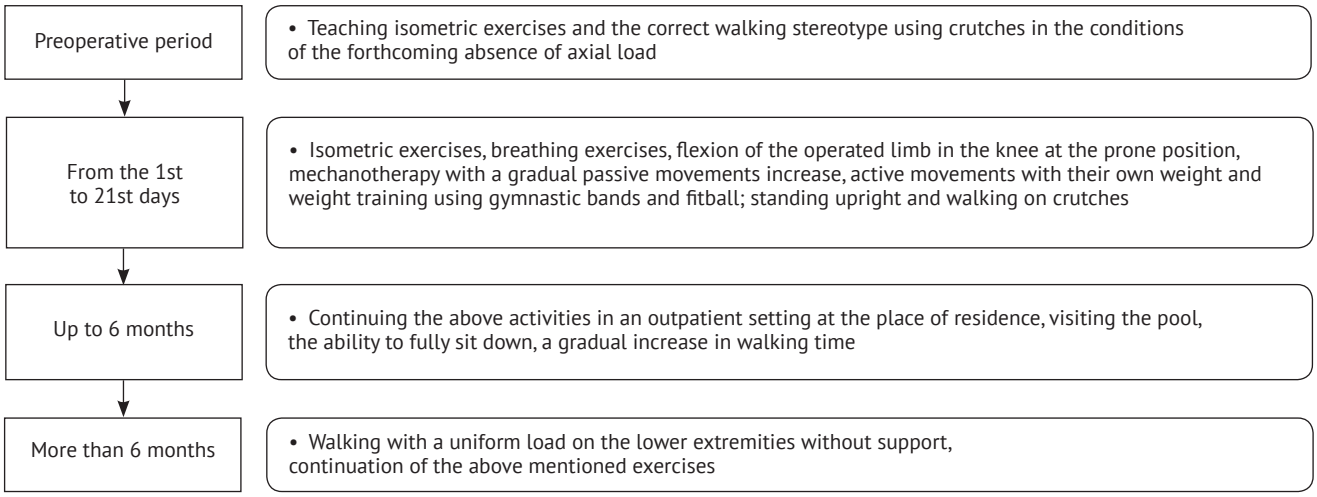

Figure 3. The rehabilitation algorithm of the children with I-II stage developmental dysplasia of the hip after reconstructive surgery.

The fundamental is the 2nd stage of rehabilitation, which begins in the intensive care unit. From the 2nd day after the surgery, under the conditions of prolonged epidural anesthesia, the patients started isometric exercises to improve the muscle tone of the operated limb by muscle pump activation. In addition, the patients performed the operated limb knee flexion in the prone position to stretch the muscles of the anterior and posterior surfaces of the thigh. From the 3rd day, the patients began mechanotherapy using the "Artromot K1" apparatus. From the 4th day, the patients began active movements in the operated hip with a gradual increase in amplitude. On the 7th to 8th day after the relief of pain syndrome and reduction of the postoperative wound edema, the patients were verticalized and taught to walk with crutches with imitation of all phases of the walking cycle in the complete absence of support on the leg. From day 10, the patients performed active exercises with weights (gymnastic tape, fitball) lying down and standing.

After discharge from the hospital, the patients continued physical therapy according to the developed program aimed at increasing the range of motion in the operated joint, the strength and endurance of the main hip muscles, restoring the correct gait stereotype, as well as mastering self-care skills in everyday life. In 6 months after triple pelvic osteotomy, the patients were allowed to walk with a uniform load on the lower extremities without supporting aids, visit the pool, and also exercise on a stationary bike stand.

The main criteria for the treatment results evaluation:

– gait stereotype (correct following the walking cycle);

– goniometry;

– positive/negative impingement tests with the definition of pain by VAS;

– endurance of the hip muscles in seconds (the time of keeping the lower limb in a neutral position alternately in the supine position and lying on the opposite side). The data of a similar test on a healthy lower limb were used as a standard indicator, the mean values of which were 30.5 ± 6.4 and 35.7 ± 6.3 sec. respectively;

– number of points on functional scales;

– main radiological indices of the hip (Sharp's,Wiberg's, cervico-diaphyseal and proximal femur anteversion angles, and degree of bone coverage;

– degenerative and dystrophic processes dynamics (according to X-ray and multi-spiral computed tomography);

– electrogenesis muscles amplitude: rec-

tus femoris, adductor longus, gluteus medius;

– determination projection of the general mass center in the frontal and sagittal planes, the length and area of the statokinesiogram.

Statistical analysis

The statistical analysis was carried out using the IBM SPSS v.26 program. The intragroup analysis was performed using the nonparametric Wilcoxon test, the intergroup analysis was performed using the nonparametric Mann–Whitney U test with a probability of type I error less than 5% ($p < 0.05$). The correlation analysis was performed using Pearson's test.

Results

On admission to the Turner Center, the main complaint in both patients groups was pain in the hip and static and dynamic gait disturbances in the form of lameness in the affected limb. All patients were diagnosed with DDH of various degree of severity in infancy, followed by conservative treatment at the place of residence. In the overwhelming majority of cases (77.6%), reduction and femoral heads fixation were performed according to A. Lorenz. The average period of plaster immobilization was 132 ± 15 days. The remaining 22.4% of the patients received their treatment with abduction structures, namely Frejka's pillow or Wilensky's splint. The average period lower extremities fixation with functional splints was 108 ± 11 days. The concentric femoral head reduction was not achieved in any patient. The average values in points of Harris Hip Score, VAS, quality of life questionnaires in the patients of the MG were 61.8 ± 4.6, 5.2 ± 1 and 5.6 ± 1, respectively. The similar data in the patients of the CG amounted to 59.1 ± 5; 5.3 ± 1.1 and 5.7 ± 1 points, respectively. These results indicate the presence pronounced functional hip disturbances with moderate pain and a decrease in the quality of life. Long walks, sports, aerobics, dancing, etc., typical for this age group of children, were inaccessible to them.

According to the comprehensive examination, the patients of both groups were determined:

– lameness which severity depended on the magnitude of the shortening;

– a decrease of the swing phase and the inversion type of load on the foot;

– positive impingement test with the severity of pain from 3.7 ± 1.0 to 5.7 ± 1.1 points according to VAS, depending on the stage of the degenerative process;

– the presence of "classical" radiological hip changes in the underdevelopment anterior superior edge of the acetabular edge and an increase of the cervico-diaphyseal angle and anteversion angle of the proximal femur;

– a decrease of the electrogenesis potentials mean amplitude of the main hip muscles on the affected side by an average of 40% of the age norm;

– displacement of the general center of mass projection to the contralateral side in the frontal plane in the patients with the unilateral lesion and significant deviation of this indicator forward in the sagittal plane – with the bilateral.

The above clinical, functional, anatomical and radiological changes in the children with stage I–II DDH have been studied and described in detail in O.V. Bortuleva's dissertation (2019)[1]. Clinical and functional results in the patients of both groups were assessed at least in 24 months after the surgery.

The patients of both groups noted the complete relief of pain in the affected hip in 80.8% of cases. The unpleasant sensations after intense physical exercises (long running, visiting a gym, dancing, etc.) were felt by 19.2% of them. It was possible to achieve the equality of the lower extremities length after the surgery in 93% of cases with the residual shortening of no more than 1 cm. At

[1] Bortuleva O.V. Assessment of the clinical and functional state of the hip at the stages of complex treatment of I–II developmental dysplasia of the hip in children. Dissertation of Cand Med Sci. St-Petersburg, 2019.

the same time, the survey using the Harris Hip Score and the adolescent quality of life scale revealed the significant differences ($p < 0.05$) between both groups: 91.2 ± 5.9 and 0.4 ± 0.5 points in the MG and 84.7 ± 5.2 and 1.25 ± 0.4 in the CG.

75% of the patients in the CG retained a gait disturbance in the form of lameness due to a decrease of the swing phase and the inversion type of load on the foot. Thus, despite the improvement of the hip functional state, the patients of the CG maintained a decline in their quality of life. 87.8% patients of the MG had the correct swing phase and load distribution on the foot (heel-toe roll).

Goniometry in the patients of both groups revealed the significant differences ($p < 0.05$) of the hip motion range in all three planes (Figure 4).

A positive FADIR test was observed in 29.2% of the patients in the MG and in 31.3% in the CG.

The study of the main periarticular muscles endurance showed significant differences ($p < 0.05$) in the studied groups of the patients. Thus, in the MG, the time of keeping the straight lower limb in the supine position was 30.2 ± 4.8 sec and lying on the side – 29.3 ± 5.4 sec. Thus, the muscle endurance in the MG increased almost threefold compared to the indicators before the treatment. In the CG, the similar indicators were 13.3 ± 3.4 and 15.5 ± 2.9 sec. respectively. In this category of patients, there was no significant increase in periarticular muscle endurance.

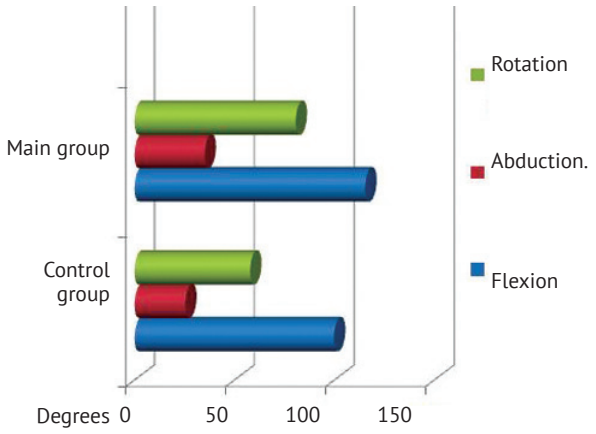

Figure 4. The diagram of goniometry indices of the main and comparison groups in 24 months after the surgery.

The radiological analysis results of the main indices characterizing the anatomical structure of the hip pelvic and femoral components, their stability in general are presented in Table 1.

The data presented in Table 1 showed that the surgery in both studied groups was radically reconstructive. The latter is substantiated by the significant changes of X-ray parameters. Thus, the indicators directly reflecting the acetabulum degree of reorientation (Sharp's angle) and the joint stability as a whole (Wiberg's angle, degree of bone coverage) began to correspond to the physiological norm values, and in some cases even to exceed them. The proximal femur anteversion angle often went beyond the physiological norm lower limit. At the same time, in all cases, hip stability was achieved. This reflected in a significant change of the Wiberg's angle and the bone coverage degree.

Evaluation of the degree of DDH severity showed significant positive changes. Thus, out of 49 joints with stage I DDH, 81.6% demonstrated the complete regression of degenerative and dystrophic changes. The stabilization of degenerative and dystrophic changes was achieved in 20.4%. Of 24 joints with stage IIa DDH, 45.8% also showed the complete regression of their degenerative and dystrophic manifestations, 37.5% decreased their stages to stage I, and 16.7% stabilized degenerative and dystrophic status.

The changes in the functional state of the main hip muscles are presented in Table 2.

Table 1

Hip X-ray indicators of both studied groups in 2 years after the surgery, M±SD (min-max)

Indicator	Main patients group	Control patients group
Sharp's angle, degrees	30.2±10.2 (12–46)	31.4±8.7 (18–48)
Wiberg's angle, degrees	37.4±8.3 (25–54)	36.6±8.7 (24–52)
Bone coverage degree,%	104.5±7.4 (85–110)	104.1±6.7 (90–115)
Cranial displacement, cm	0.1±0.05 (0.0–0.3)	0.15±0.06 (0.0–0.4)
Cervico-diaphyseal angle, degrees	127.7±5.8 (120–140)	126.5±5.0 (120–140)
Anteversion angle, degrees	15.1±2.8 (10–20)	13.8±4.5 (5–20)

Table 2

The main hip muscles electrogenesis amplitude in the patients of both groups in 2 years after the surgery, M±SD (min-max), μV

Studied muscles	Main patients group		Control patients group	
	Unilateral DDH	Bilateral DDH	Unilateral DDH	Bilateral DDH
M. gluteus medius	304.6±54.0 (201–410)	301.9±50.0 (208–389)	235.6±51.0 (167–356)	227.3±57.0 (171–332)
M. rectus femoris	313.5±62.0 (201–421)	306.5±48.0 (234–389)	242.8±45.0 (187–309)	237.5±41.0 (187–308)
M. adductor longus	231.4±43.0 (178–378)	233.0±44.5 (189–301)	199.3±55.0 (139–308)	197.3±28.0 (154–221)

The comparative statistical data analysis presented in Table 2 proved the significant differences ($p < 0.05$) of the electrogenesis amplitude means of the indicated muscles. In the MG, the electrogenesis of the gluteus medius increased by 54%, adductor longus – by 33%, rectus femoris – by 47%. In the CG, after the treatment, the similar indicators only slightly exceeded the preoperative values.

The correlation analysis between the interconnection of hip main muscles strength and endurance and the electrophysiological data showed the direct strong interdependence of the quantitative characteristics under the study for gluteus medius ($r = 0.85$) and rectus femoris ($r = 0.75$), as well as the high Chaddock scale correlation, only for the MG.

The stabilometry revealed an improvement in the indicators of the statokinetic system only in the patients of the MG ($p < 0.05$). This was shown as the stabilization of the mass projection general center in the frontal and sagittal planes (Figure 5).

At the same time, the patients of the CG with unilateral DDH retained lateralization of the general center of mass projection in the frontal plane. The patients of the CG with bilateral DDH also demonstrated the forward deviation of this projection in the sagittal plane (Figure 6).

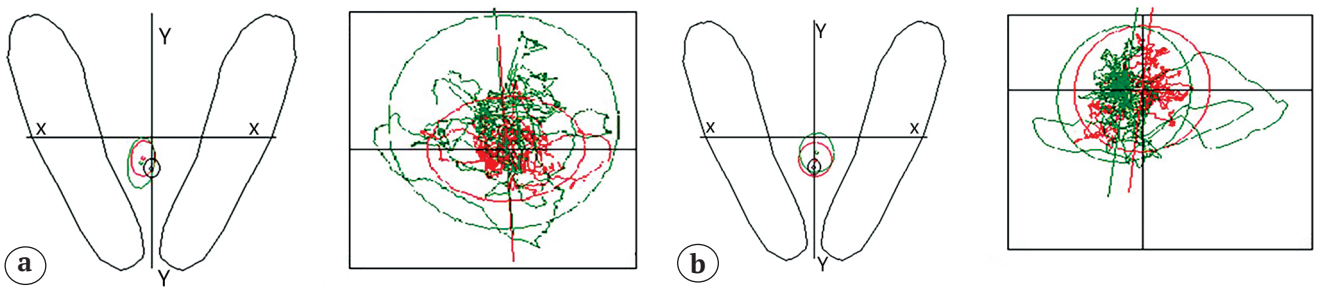

Figure 5. Body mass center stabilization in the patients of the main group: a – unilateral developmental dysplasia of the hip; b – bilateral developmental dysplasia of the hip.

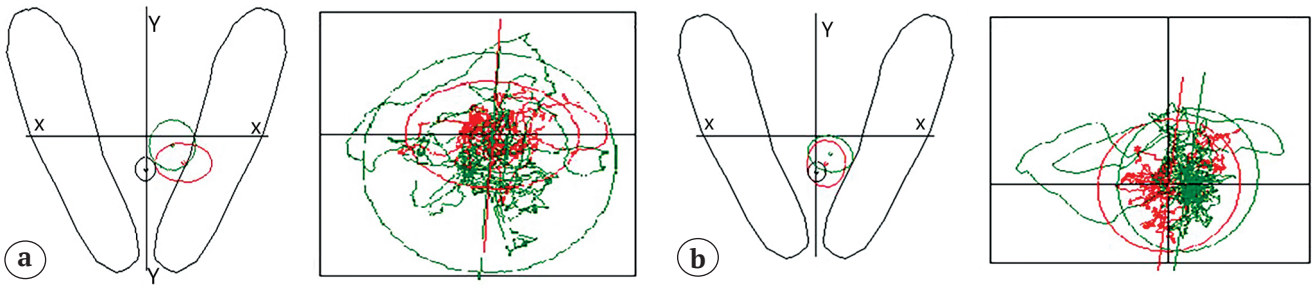

Figure 6. Persistent deviation of the general center of mass projection in the patients of the control group: a – lateralization to the right in the frontal plane in the patients with left-sided developmental dysplasia of the hip; b – anterior deviation in the sagittal plane in the patients with bilateral developmental dysplasia of the hip.

Discussion

It is well known that degenerative and dystrophic changes in the hip lead to a pronounced deterioration in the patient's physical condition due to the progression of pain syndrome, which, in turn, leads to disturbance in affected joint biomechanics. The only pathogenetically justified method of such patients treatment is surgery. To date, the surgical techniques for both adult patients with developmental hip dysplasia and children have been well developed and standardized [8, 9, 13, 23]. The modern metal constructions make it possible to achieve the long-term reliable and stable fixation providing adequate conditions for the union bone fragments.

However, despite the achievement of hip stability, all patients of the present study demonstrated the excess of the physiological norm upper or lower limit of the pelvic and femoral joint components X-ray parameters of about 35%. This revealed by the positive impingement test. The condition further contributed to the pathology relapse, already due to the pincer type of femoro-acetabular impingement [24, 25, 26]. In addition, the excessive varus of the proximal femur further leads to progressive weakness of the abductor muscle group and gait disturbance. This dictates the need to revise the indications for hip corrective osteotomy with the determination of the optimal degree of its angular and torsional deformities correction. Also, it

is necessary to improve the accuracy of such operations to level the acetabular position overcorrection [27].

At the same time, it should be emphasized that the issues of rehabilitation of the children after hip radical reconstructive surgery did not receive due attention. Numerous studies have repeatedly emphasized that an integrated approach to the treatment of such patients, including an important stage of rehabilitation, is the key to the success of the surgery. The patient adaptation in the absence of proper attention to rehabilitation takes much longer and may turn out to be incomplete. This will dramatically slows down the patient's return to common lifestyle [28]. Authors from the Clinic for Orthopedics and Traumatology in Heidelberg (Germany) described the early children rehabilitation method at an average age of 3.4 years after acetabuloplasty according to Dega and corrective hip osteotomy [20]. Its use became possible as a result of the abandon a long postoperative period lower extremities plaster immobilization in favor of a special individual foam form developed by the authors. The patient was placed in such a form immediately after the operation. The results of the complex treatment presented by the authors were based on the radiological indicators of stability and the assessment of the range motion. All the patients begin a full axial load in 3 to 4 weeks after the surgery. And it is interesting that the authors did not note any complications in the loss correction form or aseptic necrosis of the femoral head or acetabulum.

In another study, a group of japanese orthopedists conducted a retrospective analysis of the use standard and accelerated methods restorative treatment after periacetabular pelvic osteotomy in adults [17]. It was found that the reduction in the duration of rehabilitation was determined by the rate of muscle tone recovery. At the same time, the rate of loss of the achieved immediately after surgery correction due to early axial load in the patients of this group was much higher than with the use of the standard rehabilitation.

A few publications assessed the gait and muscle strength in the women, on average, aged 35 years after triple pelvic osteotomy for DDH. The postoperative rehabilitation consisted in restoring the range of motion and exercising for 3 to 12 months to strengthen muscles. All patients had the long-term gait disturbance and the weakness of the abductor muscle group [18]. Other authors, also analyzing the gait and hip muscle strength after post-rotational pelvic osteotomy, similarly noted the lameness on the side of the surgery, as well as the weakness of the thigh flexors, despite excellent results on questionnaire scales. Summing up the results of their research, the authors declared the need for more intensive postoperative rehabilitation [29].

Thus, today there is no common view when to start and how to conduct the rehabilitation after hip extra-articular reconstructive plastic surgery in both children and adults. In addition, in the available studies, the interpretation of the treatment results was limited by the restoration of the range of motion, the achievement of the X-ray signs of hip stability and the presence or absence of complications.

In our work, we tried to conduct a multifactorial assessment of the hip condition before and after the radical reconstructive surgery.

In our opinion, an important aspect of early rehabilitation is the flexion of the operated limb in the knee, followed by the use of mechanotherapy from the 1st day after the surgery treatment. These make it possible to smooth the muscles stretching in the hip and knee. Subsequently, this contributed to the leveling of pain syndrome and muscle spasm in the operation zone. At the same time, the early patient's verticalization and the load on the operated limb against a background of stable fixation immediately after the complete relief of the pain syndrome and elimi-

nation of the postoperative wound edema make it possible to start the early restoration of the correct gait stereotype. The early start of rehabilitation, it possible made to avoid postimmobilization contractures and to develope the correct gait stereotype in the conditions of the restored hip muscle corset. The use of active movements with weights during rehabilitation contributed to the optimal and gradual adjustment of the patients to the lower extremities daily loads and the social adaptation of the convalescent children.

Thus, the mid-term results analysis of the complex treatment of the children with stage I-II DDH showed that surgical treatment with stable fixation and the developed method of rehabilitation led to a significant ($p < 0.05$) improvement in the static and dynamic functions of the lower extremities. This is substantiated by the data of clinical, radiological, electrophysiological and biomechanical studies, as well as specialized scales taken into account the hip function, the quality of patient's life and their social adaptation.

Ethics approval

The study reviewed and approved by the ethics committee of the H. Turner National Medical Research Center for Children's Orthopedics and Trauma Surgery of the Ministry of Health of the Russian Federation. The patients and their representatives gave a voluntary informed consent for the participation in this study and publication of its results.

Competing interests

The authors have no conflicts of interest to disclose.

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Authors' contributions

P.I. Bortulev – research design, collection of material and data analysis, literature review, text preparation, surgical treatment of the patients.

S.V. Vissarionov – text correction, staged and final editing.

O.V. Bortuleva – literature review, collection of material and data analysis, the author's algorithm development and implementation.

V.E. Baskov – staged and final editing, surgical treatment of the patients.

D.B. Barsukov – collection of material, surgical treatment of the patients.

I.Yu. Pozdnikin – collection of material, surgical treatment of the patients.

T.V. Baskaeva – collection of material, surgical treatment of the patients.

All authors made a significant contribution to the research and preparation of the article and read and approved the final version before its publication. They agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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