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OUR EXPERIENCE OF THE MODIFIED DUNN PROCEDURE IN CHILDREN WITH SLIPPED CAPITAL FEMORAL EPIPHYSIS (PRELIMINARY RESULTS)

© D.B. Barsukov, A.G. Baindurashvili, P.I. Bortulev, V.E. Baskov, I.Yu. Pozdnikin, A.I. Krasnov, M.S. Poznovich, M.S. Asadulaev

The Turner Scientific Research Institute for Children's Orthopedics, Saint Petersburg, Russia

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Background. The spatial correlations of the epiphysis and acetabulum during slipped capital femoral epiphysis (SCFE) with acute (at the stage of partial synostosis) and chronic displacement of the epiphysis to a severe degree were restored using different extra-articular corrective hip osteotomy techniques and the standard Dunn procedure. A large number of postoperative ischemic complications and/or the remaining residual displacement of the epiphysis, which is the cause of FAI, was the rationale for improving traditional surgical methods. In 2007, a modified technique of the classic Dunn procedure was proposed using a low traumatic surgical hip dislocation.

Aim. The aim of the study was to evaluate the effectiveness of the modified Dunn procedure in the treatment of children with SCFE.

Materials and methods. The data of preoperative and postoperative clinical and radiological studies of 10 patients (six males and four females) aged 11–15 years who were suffering from SCFE with severe epiphyseal displacement were analyzed. In five cases, the displacement of the epiphysis was chronic, in four cases it was acute associated with chronic, and in one case it was primarily acute. In the joints with acute displacement at the time of surgery, there were signs of partial synostosis at the level of the epiphyseal growth plate. All children underwent a modified Dunn procedure with strict adherence to the author's technique. The maximum follow-up period was 1.5 years.

Results. Evaluation of the most short-term anatomical and functional treatment results confirmed a satisfactory result in half (5/10) of the observations with the possibility of an additional three. In two cases, a poor treatment result was obtained due to the development of an early complication in the form of aseptic necrosis of the femoral head. The number of early complications of surgical treatment that were recorded is consistent with the literature.

Conclusions. To date, the modified Dunn procedure is the only intervention with a relatively small number of complications that provides a complete and accurate reposition of the epiphysis, thereby eliminating FAI in the above anatomical situations. The modified Dunn procedure can be characterized as an effective intervention for SCFE with severe, acute (at the stage of partial synostosis), and chronic displacements of the epiphysis. The authors intend to continue using the procedure in practice.

Keywords: slipped capital femoral epiphysis; hip joint; children; modified Dunn procedure; femoroacetabular impingement.

НАШ ОПЫТ ПРИМЕНЕНИЯ МОДИФИЦИРОВАННОЙ ОПЕРАЦИИ DUNN У ДЕТЕЙ С ЮНОШЕСКИМ ЭПИФИЗЕОЛИЗОМ ГОЛОВКИ БЕДРЕННОЙ КОСТИ (ПРЕДВАРИТЕЛЬНЫЕ РЕЗУЛЬТАТЫ)

© Д.Б. Барсуков, А.Г. Баиндурашвили, П.И. Бортулёв, В.Е. Басков, И.Ю. Поздникин, А.И. Краснов, М.С. Познович, М.С. Асадулаев

ФГБУ «Научно-исследовательский детский ортопедический институт им. Г.И. Турнера» Минздрава России, Санкт-Петербург

■ Для цитирования: Барсуков Д.Б., Баиндурашвили А.Г., Бортулёв П.И., и др. Наш опыт применения модифицированной операции Dunn у детей с юношеским эпифизеолизом головки бедренной кости (предварительные результаты) // Ортопедия, травматология и восстановительная хирургия детского возраста. – 2019. – Т. 7. – Вып. 4. – С. 27–36. https://doi.org/10.17816/PTORS7427-36

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Обоснование. Пространственные соотношения эпифиза и вертлужной впадины при юношеском эпифизеолизе головки бедренной кости с острым (на этапе частичного синостозирования) и хроническим смещениями эпифиза тяжелой степени восстанавливали при помощи различных разновидностей внесуставной корригирующей остеотомии бедра и классической операции Dunn. Большое количество послеоперационных ишемических осложнений и/или сохраняющееся остаточное смещение эпифиза, служащее причиной феморо-ацетабулярного импинджмента, послужили поводом для усовершенствования традиционных хирургических методов. В частности, в 2007 г. предложена модифицированная техника классической операции Dunn с применением малотравматичного хирургического вывиха бедра.

Цель — оценка эффективности модифицированной операции Dunn при лечении детей с юношеским эпифизеолизом головки бедренной кости.

Материалы и методы. Проанализированы данные пред- и послеоперационного клинико-рентгенологического исследования 10 пациентов (6 мальчиков и 4 девочек) в возрасте от 11 до 15 лет, страдающих юношеским эпифизеолизом головки бедренной кости со смещение эпифиза тяжелой степени. В пяти наблюдениях смещение эпифиза было хроническим, в четырех — острым на фоне хронического и в одном — первично-острым. В суставах с острым смещением на момент операции наблюдались признаки частичного синостозирования на уровне эпифизарной ростковой пластинки. Всем детям выполнена модифицированная операция Dunn по авторской методике. Максимальный срок послеоперационного наблюдения составил 1,5 года.

Результаты. Удовлетворительный результат достигнут в пяти и, возможно, будет получен еще в трех из 10 случаев. В двух наблюдениях результат лечения оказался неудовлетворительным по причине развития раннего осложнения в виде асептического некроза головки бедра. Количество ранних осложнений хирургического лечения соответствует данным литературы.

Заключение. На сегодняшний день модифицированная операция Dunn является единственным хирургическим вмешательством, дающим относительно небольшое количество осложнений и обеспечивающим полную и точную репозицию эпифиза и, следовательно, устранение феморо-ацетабулярного импинджмента в вышеупомянутых анатомических ситуациях. Модифицированную операцию Dunn можно охарактеризовать как эффективное вмешательство при юношеском эпифизеолизе головки бедренной кости с острым (на этапе частичного синостозирования) и хроническим смещениями эпифиза тяжелой степени, поэтому мы планируем продолжить ее применение.

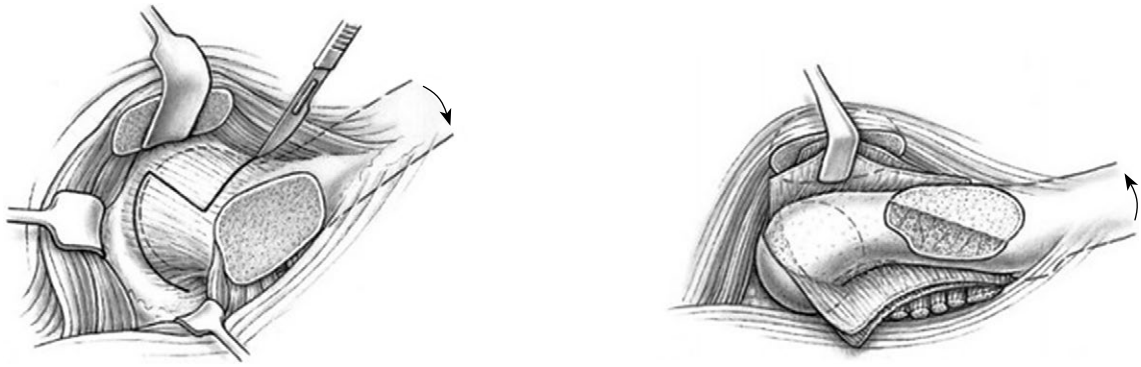
Ключевые слова: юношеский эпифизеолиз головки бедренной кости; тазобедренный сустав; дети; модифицированная операция Dunn; феморо-ацетабулярный импинджмент.

The late stages of slipped capital femoral epiphysis (SCFE) are characterized by a pronounced displacement of the epiphysis, which can be chronic or acute along with chronic. Primary-acute displacement of the epiphysis, which is much less common, is also generally severe. Chronic displacement in typical cases of the disease occurs either in a posterior-downward direction or only posteriorly. Synostosis of the epiphysis and metaphysis in a vicious position in the absence of treatment after acute displacement usually starts already on day 2–3 [1–4].

For several decades, the spatial relationships of the epiphysis and acetabulum with pronounced acute (at the stage of partial synostosis) and chronic displacements were restored by using various types of extra-articular corrective hip osteotomy and classical Dunn surgery [5–7]. However, these interventions, especially the latter, are characterized by an unacceptably large number of early complications in the form of chondrolysis of the hip joint and aseptic necrosis of the femoral head. Limitation of rotation of the proximal femur anteriorly during extra-articular corrective hip osteotomy to an angle of 45° enables avoidance of the above complications and obtains good treatment results with displacement of the epiphysis posteriorly by no more than 45°. Meanwhile, with a shift of more than 45° in the postoperative period, the residual displacement of the epiphysis with respect to the articular cavity persists [8–11]. Even slight residual displacement causes femoroacetabular impingement, the destructive effect of which on the affected joint has been proven convincingly in recent studies [12–14].

In 2007, a group of surgeons from Switzerland, led by M. Leunig, improved the technique of classical Dunn surgery through the use of a low-trauma surgical dislocation of the hip and the formation of a massive graft nourishing the epiphysis, which reduced significantly the number of postoperative ischemic complications [15–18]. Surgeons used a modified Dunn surgery in SCFE with moderate and severe displacement of the epiphysis.

This work aimed to evaluate the effectiveness of modified Dunn surgery in the treatment of pediatric patients with SCFE.



a *b*

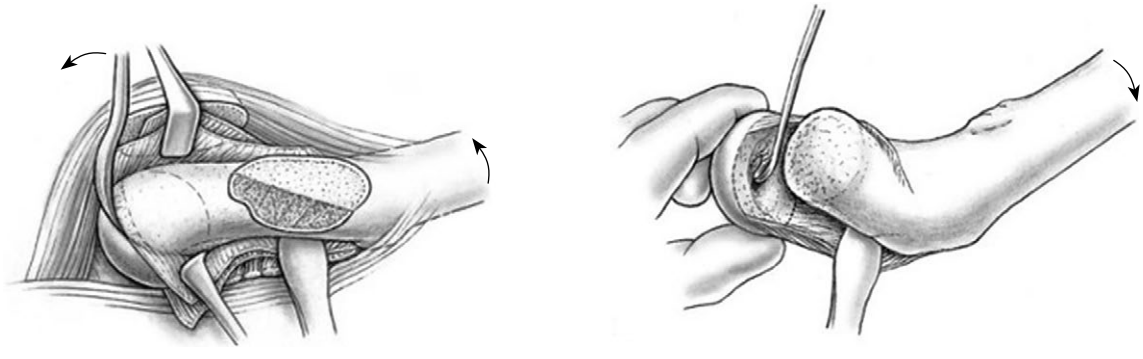
Fig. 1. Technique of the modified Dunn surgery: *a* — Z-shaped section of the joint capsule; *b* — subperiosteal femoral neck isolation [19]

Materials and methods

Since 2017 at the Turner Scientific Research Institute for Children's Orthopedics, 10 patients (6 boys and 4 girls) aged 11 to 15 years, with SCFE with a severe displacement of the epiphysis, underwent modified Dunn surgery. According to the nature of the displacement of the epiphysis, the affected joints were distributed as follows: chronic in five cases (three of which were posterior-downward displacements and only two were posterior displacements), acute while chronic in four cases and primary acute in one case. In all five joints with acute displacement at the time of the surgery, there were signs of partial synostosis of the epiphysis and metaphysis. In the contralateral joint, there was no epiphysis displacement (pre-slip) in all 10 cases. Clinical and radiological (radiography and multispiral computed tomography) research methods were used.

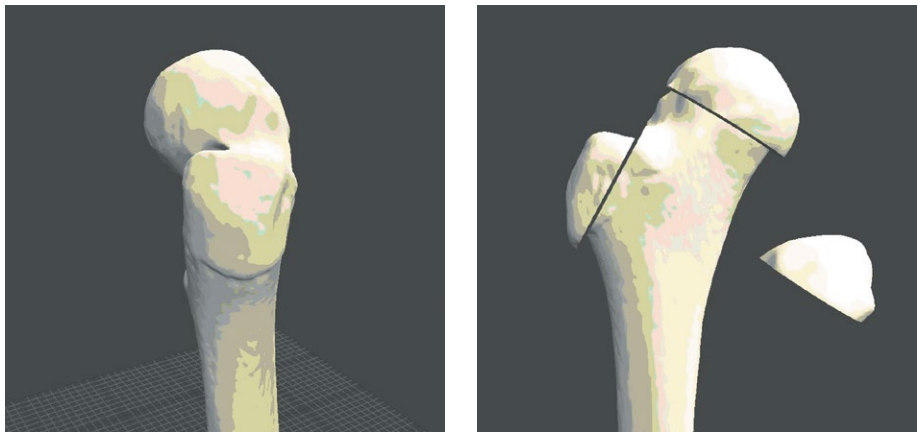
An indication for a modified Dunn surgery was SCFE with a chronic, acute when chronic and primary-acute severe displacement of the epiphysis (more than 60° posteriorly and/or more than 30° downward) in the presence of partial synostosis of the epiphysis and metaphysis in cases of acute displacement. Contraindications were the development of early complications of SCFE, chondrolysis of the hip joint, and aseptic necrosis of the femoral head.

The most detailed description of the modified Dunn surgery technique, in our opinion, was given by Ziebarth et al. in 2009 [19]. In our work, we strove for strict adherence to the author's technique, including all the described details of the intervention. Particular attention was paid to determining the direction and length of the joint capsule dissection (Z-shaped during surgery on the right and anti-Z-shaped during surgery on the left joint) (Fig. 1, *a*) and careful subperiosteal isolation of the femoral neck, allowing us to obtain a massive graft nourishing the epiphysis (Fig. 1, *b*). In addition, in order to avoid damage to the formed nourishing graft containing ascending branches of *a. circumflexa femoris medialis*, it is necessary to be extremely careful when performing a neck osteotomy (Fig. 2, *a*) and removal of the subepiphyseal trabecular bone with the remains



a *b*

Fig. 2. Technique of modified Dunn surgery: *a* — osteotomy of the femoral neck; *b* — removal of the subepiphyseal trabecular bone with the remains of the growth plate [19]



a *b*

Fig. 3. Multispiral computed tomogram of the hip joints of patient H., 13 years old, 6 months. Diagnosis: slipped capital femoral epiphysis, stage III on the right and stage I on the left: *a* — proximal end of the right femur before 3D-modeling of the surgery; *b* — proximal end of the right femur after 3D modeling of the surgery and the resected fragment of the neck

of the growth plate (Fig. 2, *b*). To determine the presence and intensity of blood flow in the epiphysis, immediately after dislocation of the femoral head from the joint cavity, a hole in its anterior pole was drilled with a Kirschner wire. The absence of bleeding from the hole after osteosynthesis of the epiphysis and metaphysis indicated excessive tension of the nourishing graft; therefore, it was necessary to perform additional shortening of the neck. Depending on the severity of regional osteoporosis, two or three wires with a diameter of 2.5 mm were used to fix the epiphysis with bent threads on the end, which were brought into different planes from the side of the epiphysis (from the *fovea capitis ossis femoris*) and metaphysis.

Surgical intervention was planned by using a personal computer and software to create a 3D model of the reconstructed hip joint based on multispiral computed tomography (Fig. 3). As a result, it became possible to determine more accurately the shape and size of the resected fragment of the femoral neck depending on the nature and severity of its deformity and the related level of fixation of the previously excised greater trochanter to the femur.

The surgery was performed under general anesthesia with prolonged epidural anesthesia, which lasted for 2–3 days. From day 2 of the postoperative period, under the supervision of an exercise therapy instructor, therapeutic exercises for flexion, abduction and internal rotation of the hip were started with appropriate laying and mechanotherapy on the Artromot apparatus.

On the contralateral side, all 10 patients had an extra-articular fixation of the femoral head epiphysis with a cannulated screw.

Results and discussion

Careful collection of anamnestic data enabled us to determine accurately the time of occurrence and the nature of the first complaints, the type of displacement of the epiphysis (chronic, acute, or acute when chronic) and the date of acute displacement, as well as to clarify the features of previous treatment measures. The correct diagnosis was established on average 17.3 weeks (from 4 to 32 weeks) after onset of the first clinical symptoms of SCFE, while strict bed rest was prescribed only to 6 out of 10 patients, and only 4 pediatric patients followed it. In four of the five cases with an acute displacement of the epiphysis, the treatment included the application of skeletal or cuff traction, and derotational gypsum boot in one case. In two of the three cases, not only was the joint unloaded during skeletal traction, but the epiphysis was also repositioned. In five cases with a chronic epiphysis displacement, a modified Dunn surgery was performed on average 38.4 weeks (from 28 to 56 weeks) after the appearance of the first clinical signs of the disease, and in five cases with acute displacement, 37.6 weeks (12–64 weeks) after an acute displacement.

A clinical study in the preoperative period, due to the high risk of epiphysis separation, was performed only with the patient in a horizontal position. In all cases, the vicious position of the external limb

rotation on the affected side was revealed, on average 53.5 ± 13.6°. Relative shortening of the limb was noted in all pediatric patients and averaged 2.1 ± 0.7 cm. In all affected joints, an excessive range of external rotation (average 77.0 ± 11.1°) and a limited range of abduction (average 26.5 ± 9.5°) were recorded, while movements within the possible amplitude were free. A positive Drehmann symptom was registered in all patients, the vicious position of the external rotation of the hip when it was bent by 90° averaged 48.0 ± 12.1°. The Thomas test was negative in all cases.

An X-ray examination of the hip joints in standard projections (anteroposterior and by Lauenstein) in the preoperative period was performed to assess the direction and degree of epiphysis displacement, the nature and severity of the metaphysis deformity, and the severity of the pathological process in the contralateral joint, as well as to avoid early complications of SCFE. In the presence of an acute displacement in the history, the degree of synostosis of the epiphysis and metaphysis was determined. The degree of posterior epiphysis displacement was estimated by the difference between the values of the epiphyseal angle in the joint without displacement and in the affected joint, and the degree of downward displacement was determined by the difference between the projection caput-collum-diaphyseal angle and epiphyseal-diaphyseal angle in the affected joint. Out of nine cases with a chronic epiphysis displacement and an acute displacement with the chronic one, in five cases, a posterior-downward displacement was revealed, and in four cases, there was only a posterior displacement, with a posterior displacement of 63–86°, and a downward displacement of 7–19°. In one case with a primary-acute epiphysis displacement, the latter occurred only downward and amounted to 32°. Severe deformity of the femoral neck was registered in 9 out of 10 patients, the neck was bent downward and posteriorly (a swan neck symptom) in accordance with the direction of the chronic epiphysis displacement, and in only one patient with primary-acute displacement, it had a normal shape. In joints with an acute epiphysis displacement, the transition of the anterior surface of the femoral neck to the head was always step-like, and in joints with chronic displacement, it was smooth. In all 10 affected joints in the femoral neck, directly under the epiphyseal growth plate, the foci of osteoporosis were traced, located separately and merging with each other and with the growth plate. In three cases, similar changes were also found in the contralateral joint. In all five joints with acute displacement and in three joints with chronic displacement, diffuse osteoporosis of the epiphysis was noted. It should be emphasized that none of the 10 affected joints had signs of aseptic necrosis of the femoral head or chondrolysis. A sign of synostosis of the epiphysis and metaphysis, which began after an acute displacement, was the presence of newly formed bone tissue with a trabecular structure between them. The degree of synostosis depended on the number of these sites (the so-called bone bridges), the number of which was determined by a CT scan if necessary.

Radiography of the hip joints in standard projections was also performed on the operating table immediately after completion of the intervention. These radiographs mainly evaluated the spatial position of the epiphysis after correction and the correct location of the hardware installed. The minimum residual displacement (within 5°) was maintained in 6 out of 10 affected joints (posterior to downward in 2 cases, only posterior in 3 cases, and only downward in 1 case). Hypercorrection of the epiphysis position was not allowed in any case.

During the first year of the postoperative period, a clinical examination of the patients was performed at months 1, 6, and 12, and X-ray was performed at months 1, 3, 6, 9, and 12.

We divided the immediate anatomical and functional results of treatment into satisfactory and unsatisfactory. The treatment result was considered satisfactory with a combination of the symptoms after 6 months after surgery, namely the spherical shape of the femoral head, the absence of subluxation in the joint, the presence of congruency in the articular surfaces, the absence of early complications (chondrolysis of the hip joint and aseptic necrosis of the femoral head), and a progressive increase in the range of femoral movements, including internal rotation. In other cases, the result was considered unsatisfactory.

On radiographs a month after the surgery, in all 10 cases, stable fixation of the epiphysis and greater trochanter was noted without loss of correction of their position and initial signs of consolidation at the level of osteotomies. In six of the eight joints with diffuse osteoporosis of the epiphysis, its

severity increased slightly, and osteoporosis of the epiphysis appeared in two more joints. In a clinical study, none of the patients had a vicious position of the limb, but its relative shortening persisted; in four cases, the latter increased by 0.5–1.0 cm. In all patients, the amplitude of the hip movements increased significantly, with soreness at the extreme points. The Drehmann symptom in all joints was negative.

Upon X-ray examination of the first seven patients, 6 months after the surgery, in all cases, the spatial position of the epiphysis and the greater trochanter had not changed, and there were signs of completion of consolidation at the osteotomy level. In two cases, the initial phenomena of aseptic necrosis of the femoral head were noted, but in five others, there was a significant decrease in the severity of the epiphysis osteoporosis. There were no signs of hip chondrolysis in any cases. Clinically, in five joints with positive X-ray changes, an even greater increase in the amplitude of hip movements was revealed, and in one of the joints with incipient epiphysis necrosis, there was a slight decrease associated with the development of secondary synovitis. In all seven patients, at month 7 of the postoperative period, the hardware was removed.

One year after surgery, a clinical and radiological examination was performed on the first five patients. Radiographic signs of aseptic necrosis of the femoral head were found only in one of them, in the joint, in which epiphysis necrosis had already begun, according to the previous study. The entire epiphysis was involved in the focus of necrosis, a pronounced deformity of the latter was seen, which deteriorated the congruence of the articular surfaces. In the remaining four cases, the femoral head was spherical in shape and had practically no structural abnormalities; however, some shortening of the neck was still noted. Regional diffuse osteoporosis was moderately expressed in both the pelvic and femoral joint components. The X-ray joint gap in these joints along the entire length remained at a normal height, which indicated the absence of chondrolysis. No disorders of joint stability were noted in any of the cases. Clinical manifestations on the lesion side in these four patients were represented by moderate muscle hypotrophy of the buttock and hip, relative shortening of the limb from 0.5 to 1.5 cm and limitation of the amplitude of the internal rotation of the hip. A child with aseptic necrosis of the femoral head complained of pain during movements of the affected joint. The flexion-adduction contracture of the hip began to form, due to which a functional shortening of the limb appeared. Further treatment of this patient with the aim of suppressing inflammatory phenomena in the joint and increasing the amplitude of hip movements was performed using cuff traction. A gradual increase in the supporting load on the affected leg was recommended to all four pediatric patients with positive dynamics, with complete

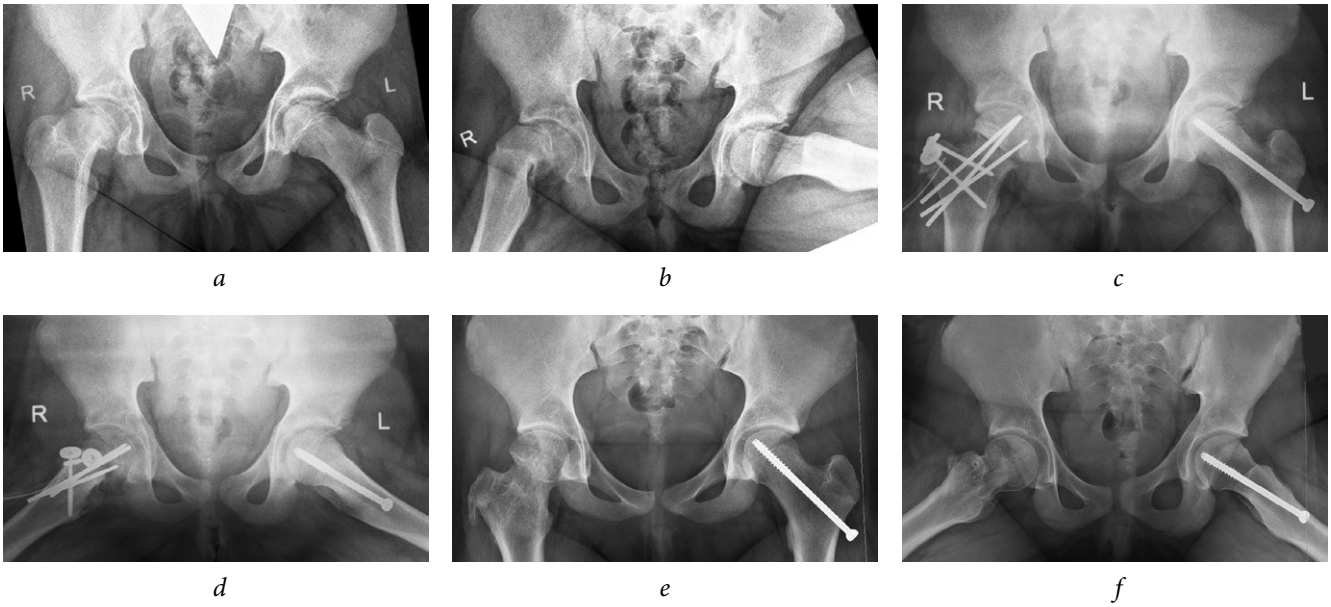


Fig. 4. Radiographs of the hip joints in the anteroposterior projection and in the Lauenstein projection of patient Z., 12 years 1 month. Diagnosis of slipped capital femoral epiphysis of the stage III on the left and stage I on the right: *a*, *b* — before the surgery; *c*, *d* — immediately after the surgery; *d*, *e* — 1.5 years after the surgery

rejection of crutches within a month and partial compensation for shortening.

An X-ray examination of the first two patients 1.5 years after the surgery in the reconstructed joints showed no signs of aseptic necrosis of the femoral head or chondrolysis. There was no subluxation of the femoral head, and the latter had a spherical shape, due to which congruency of the articular surfaces was preserved. The shape of the femoral component of the joint as a whole was approaching normal, with the exception of some shortening of the femoral neck and the associated moderately high position of the greater trochanter. However, the apex of the latter, being above the center of the femoral head, still did not reach its upper pole. Under the influence of axial load on the limb, regional osteoporosis decreased significantly (Fig. 4). A slight gait disturbance occurred only with prolonged walking. Despite the moderate hypotrophy of the muscles of the buttocks and hips remaining on the side of the lesion, the Duchenne-Trendelenburg symptom was negative. The relative limb shortening in one case was 1.0 cm, and in the other case, it was 1.5 cm. The Drehmann symptom and the impingement test were negative, while a slight (15°) limitation of the amplitude of the internal rotation of the hip was still determined in both joints. The patients received rehabilitation treatment (exercise therapy, massage, and physiotherapy) under conditions of a sparing load regime and compensation of limb shortening with individual insoles.

Thus, a clinical and radiological evaluation of the immediate anatomical and functional results of the modified Dunn surgery in 10 patients with SCFE with a severe epiphysis displacement showed that a satisfactory result was obtained in five and, possibly, will be obtained in three of these cases. In two patients, the treatment result was unsatisfactory due to an early complication in the form of aseptic necrosis of the femoral head.

Indications and contraindications for the modified Dunn surgery, which we adhered to in our work, as well as the technique of intervention used by us, are completely consistent with the literature data [20–22]. Meanwhile, unlike the majority of authors [23–26], we have no experience in performing this surgery with SCFE with an epiphysis displacement of moderate severity. The clinical and radiological characteristics of our patients in the postoperative period under consideration, as well as the number of early complications of surgical treatment, also correspond to the published data [27–29].

Conclusion

The modified Dunn surgery enables to achieve a complete and accurate reposition of the epiphysis in SCFE with a severe epiphysis displacement and thereby eliminate femoroacetabular impingement in the reconstructed joint. To date, it is the only surgical intervention with a relatively small number of complications that ensures the elimination of femoroacetabular impingement in the considered anatomical situations. The number of unsatisfactory results of surgical treatment did not exceed that reported in the literature. Summarizing the above, we can characterize the modified Dunn surgery as an effective intervention in SCFE with acute (at the stage of partial synostosis) and chronic epiphysis displacement of a severe degree. We plan to continue its application with an analysis of the results.

Additional information

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Conflict of interest. The authors declare no obvious or potential conflict of interest related to the publication of this article.

Ethical consideration. The study was performed in accordance with the ethical standards of the Helsinki Declaration of the World Medical Association as amended by the Ministry of Health of Russia, and approved by the ethics committee of the Turner Scientific Research Institute for Children's Orthopedics (protocol No. 19-1 of 01.07.2019).

Parents of patients agreed to the processing of personal data and their publication.

Contribution of authors

D.B. Barsukov created the study design, wrote all sections of the article, performed data collection and analysis, literature analysis, and surgical treatment of patients.

A.G. Baindurashvili developed the study methodology, statement of aim, staged and final editing of the article text.

P.I. Bortulev, I.Yu. Pozdnikin, M.S. Asadulaev were involved in the data collection, surgical treatment of the patients.

V.E. Baskov performed staged editing of the article, surgical treatment of patients.

A.I. Krasnov performed staged editing of the article.

M.S. Poznovich performed 3D-modeling of surgical interventions.

All authors made a significant contribution to the research and preparation of the article, read and approved the final version before its publication.

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Information about the authors

Dmitrii B. Barsukov* — MD, PhD, Senior Research Associate of the Department of Hip Pathology. The Turner Scientific Research Institute for Children's Orthopedics, Saint Petersburg, Russia. https://orcid.org/0000-0002-9084-5634. E-mail: dbbarsukov@gmail.com.

Alexei G. Baindurashvili — MD, PhD, D.Sc., Professor, Member of RAS, Director of The Turner Scientific Research Institute for Children's Orthopedics, Saint Petersburg, Russia. https://orcid.org/0000-0001-8123-6944. E-mail: turner01@mail.ru.

Pavel I. Bortulev — MD, Research Associate of the Department of Hip Pathology. The Turner Scientific Research Institute for Children's Orthopedics, Saint Petersburg, Russia. https://orcid.org/0000-0003-4931-2817. E-mail: pavel.bortulev@yandex.ru.

Vladimir E. Baskov — MD, PhD, Head of the Department of Hip Pathology. The Turner Scientific Research Institute for Children's Orthopedics, Saint Petersburg, Russia. https://orcid.org/0000-0003-0647-412X. E-mail: dr.baskov@mail.ru.

Ivan Yu. Pozdnikin — MD, PhD, Research Associate of the Department of Hip Pathology. The Turner Scientific Research Institute for Children's Orthopedics, Saint Petersburg, Russia. https://orcid.org/0000-0002-7026-1586. E-mail: pozdnikin@gmail.com.

Дмитрий Борисович Барсуков* — канд. мед. наук, старший научный сотрудник отделения патологии тазобедренного сустава ФГБУ «НИДОИ им. Г.И. Турнера» Минздрава России, Санкт-Петербург. https://orcid.org/0000-0002-9084-5634. E-mail: dbbarsukov@gmail.com.

Алексей Георгиевич Баиндурашвили — д-р мед. наук, профессор, академик РАН, директор ФГБУ «НИДОИ им. Г.И. Турнера» Минздрава России, Санкт-Петербург. https://orcid.org/0000-0001-8123-6944. E-mail: turner01@mail.ru.

Павел Игоревич Бортулёв — научный сотрудник отделения патологии тазобедренного сустава ФГБУ «НИДОИ им. Г.И. Турнера» Минздрава России, Санкт-Петербург. https://orcid.org/0000-0003-4931-2817. E-mail: pavel.bortulev@yandex.ru.

Владимир Евгеньевич Басков — канд. мед. наук, руководитель отделения патологии тазобедренного сустава ФГБУ «НИДОИ им. Г.И. Турнера» Минздрава России, Санкт-Петербург. https://orcid.org/0000-0003-0647-412X. E-mail: dr.baskov@mail.ru.

Иван Юрьевич Поздникин — канд. мед. наук, научный сотрудник отделения патологии тазобедренного сустава ФГБУ «НИДОИ им. Г.И. Турнера» Минздрава России, Санкт-Петербург. https://orcid.org/0000-0002-7026-1586. E-mail: pozdnikin@gmail.com.

Andrey I. Krasnov — MD, PhD, Orthopedic and Trauma Surgeon of the Consultative and Diagnostic Department. The Turner Scientific Research Institute for Children's Orthopedics, Saint Petersburg, Russia. https://orcid.org/0000-0001-9067-3732. E-mail: turner02@mail.ru.

Mahmud S. Poznovich — MD, Research Associate of the Genetic Laboratory of the Center for Rare and Hereditary Diseases in Children and Neurosurgery. The Turner Scientific Research Institute for Children's Orthopedics, Saint Petersburg, Russia. https://orcid.org/0000-0003-2534-9252. E-mail: poznovich@bk.ru.

Marat S. Asadulaev — MD, Clinical Resident. The Turner Scientific Research Institute for Children's Orthopedics, Saint Petersburg, Russia. https://orcid.org/0000-0002-1768-2402. E-mail: marat.asadulaev@yandex.ru.

Андрей Иванович Краснов — канд. мед. наук, врач — травматолог-ортопед консультативно-диагностического отделения ФГБУ «НИДОИ им. Г.И. Турнера» Минздрава России, Санкт-Петербург. https://orcid.org/0000-0001-9067-3732. E-mail: turner02@mail.ru.

Махмуд Станиславович Познович — научный сотрудник Генетической лаборатории Центра редких и наследственных заболеваний у детей и нейрохирургии ФГБУ «НИДОИ им. Г.И. Турнера» Минздрава России, Санкт-Петербург. https://orcid.org/0000-0003-2534-9252. E-mail: poznovich@bk.ru.

Марат Сергеевич Асадулаев — клинический ординатор ФГБУ «НИДОИ им. Г.И. Турнера» Минздрава России, Санкт-Петербург. https://orcid.org/0000-0002-1768-2402. E-mail: marat.asadulaev@yandex.ru.