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Original Study Article

The choice of pelvic osteotomy technique in young children with hip dysplasia

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BACKGROUND: The choice of pelvic osteotomy in young children with late diagnosis of hip dysplasia most often depends on the experience and preferences of the surgeon, and the diagnosis of the degree of violation of the ratios is based on the generally accepted classification of hip dysplasia without considering possible variants of the deformation of the acetabulum. We hypothesized that the choice of the pelvic osteotomy technique in the surgical treatment of children with hip dysplasia of varying severity should be based on the variant of acetabulum deformation and the corrective capabilities of pelvic osteotomy.

AIM: This study aimed to compare and analyze the results of the surgical treatment of children with hip dysplasia of varying severity and to evaluate the effectiveness of the proposed differentiated approach to the choice of the pelvic osteotomy technique.

MATERIALS AND METHODS: The study included 150 patients (150 hip joints) aged 2–4 years (3.1 ± 0.45) with grade II–IV hip dysplasia, according to the supplemented classification of Tönnis. Depending on the verified variant of acetabulum deformity and taking into account the corrective capabilities of various osteotomies, we divided the patients into three groups. All patients underwent conventional clinical and X-ray examinations. During radiometry, the following indicators were evaluated: acetabular index (AI), Wiberg angle, neck–shaft angle (NSA), anteversion angle of the proximal femur, degree of bone coverage, acetabulum depth (AD) and pelvic height, length of the acetabular arch (LAA), and presence or absence of a bone oriel (BO).

RESULTS: In the comparative analysis of the radiographic anatomical condition of the hip joint in children with hip dysplasia of varying severity, the differentiated use of the modified Salter pelvic osteotomy without autograft and pericapsular acetabuloplasty according to Pemberton and Pembersal surgery led to adequate correction of various variants of congenital acetabular deformity with approximately normal anatomy of the acetabulum and not lead to significant deformation of the hemipelvis, such as elongation.

CONCLUSIONS: The results of the surgical treatment of young children with hip dysplasia of varying severity according to the proposed differentiated approach to the choice of the pelvic osteotomy technique, which is based on the variant of acetabulum deformation, indicate the achievement of adequate correction of congenital deformity of the acetabular component of the joint with the restoration of its anatomical structure and avoidance of secondary deformation of the hemipelvis. The effectiveness of the proposed approach to the choice of pelvic osteotomy technique in the treatment of young children with hip dysplasia of varying severity is confirmed by the changes in AI, Wiberg angle, AD, and PH, whose values became close to the individual norm ($p > 0.05$), and reduction of possible secondary deformities.

Keywords: hip dysplasia; acetabulum deformity; classification; pelvic osteotomies.

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Оригинальное исследование

К вопросу о выборе методики остеотомии таза у детей младшего возраста с дисплазией тазобедренного сустава

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Обоснование. Выбор остеотомии таза при поздней диагностике дисплазии тазобедренного сустава у детей младшего возраста чаще всего зависит от опыта и предпочтений хирурга, а диагностика степени нарушения соотношений основана на общепринятой классификации дисплазии тазобедренных суставов без учета возможных вариантов деформации вертлужной впадины. Нами выдвинута гипотеза о том, что выбор методики остеотомии таза при хирургическом лечении детей с дисплазией тазобедренного сустава различной степени тяжести должен определяться вариантом деформации вертлужной впадины и корригирующими возможностями самой остеотомии.

Цель — на основании сравнительного анализа результатов хирургического лечения детей с дисплазией тазобедренных суставов различной степени тяжести оценить эффективность предлагаемого дифференцированного подхода к выбору методики остеотомии таза.

Материалы и методы. В исследование вошли 150 пациентов (150 тазобедренных суставов) в возрасте от 2 до 4 лет (3,1 ± 0,45) с II–IV степенями тяжести дисплазии тазобедренных суставов согласно дополненной классификации D. Tönnis. В зависимости от верифицированного варианта деформации вертлужной впадины с учетом корригирующих возможностей различных типов остеотомий пациенты были разделены на три группы. Всем пациентам проводили общепринятое клиническое и лучевое обследование. При рентгенометрии оценивали следующие показатели: ацетабулярный индекс, угол Wiberg, шеечно-диафизарный угол, угол антеверсии проксимального отдела бедренной кости, степень костного покрытия, глубину вертлужной впадины и высоту таза, протяженность свода вертлужной впадины и наличие или отсутствие костного эркера.

Результаты. Сравнительный анализ рентген-анатомического состояния тазобедренного сустава у детей с дисплазией тазобедренных суставов различной степени тяжести свидетельствует, что дифференцированное применение модифицированной остеотомии таза по Salter без использования аутотрансплантата, перикапсулярной ацетабулопластики по Pemberton и операции Pembersal позволяет обеспечить адекватную коррекцию при различных вариантах врожденной ацетабулярной деформации с приближением к нормальным значениям анатомии вертлужной впадины и не приводит к значительной деформации гемипельвиса в виде его удлинения.

Заключение. При лечении детей младшего возраста с дисплазией тазобедренного сустава различной степени тяжести с применением предложенного дифференцированного подхода к выбору методики остеотомии таза, основанного на варианте деформации вертлужной впадины, удается достичь адекватной коррекции врожденной деформации ацетабулярного компонента сустава с восстановлением его анатомического строения и избежать формирования вторичной деформации со стороны гемипельвиса на стороне операции. Эффективность предложенного подходка к выбору методики остеотомии таза при лечении детей младшего возраста с дисплазией тазобедренных суставов различной степени тяжести подтверждается изменением показателей ацетабулярного индекса, угла Wiberg, глубины вертлужной впадины, высоты таза с достижением значений, близких к индивидуальной норме (*p* > 0,05), а также нивелированием возможных вторичных деформаций.

Ключевые слова: дисплазия тазобедренных суставов; деформация вертлужной впадины; классификация; остеотомии таза.

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BACKGROUND

In the treatment of young children with hip dysplasia of varying severity, many Russian and international surgeons have convincingly proven the high efficiency of various techniques of pelvic osteotomy, in particular Salter reorienting pelvic osteotomy, Pemberton pericapsular acetabuloplasty, Dega acetabuloplasty, and the combination of Pemberton and Salter surgeries (Pembersal) first described by Perlik [1–6]. Until now, the choice of pelvic osteotomy in late diagnostics of hip dysplasia in young children most often depends on the experience and preference of the surgeon [7], and the extent of imbalance in the ratios is diagnosed based on the generally accepted classification of hip dysplasia developed by Tönnis and the modified classification by the International Hip Dysplasia Institute (IHDI) [8, 9].

In the treatment of pediatric patients with hip subluxation and dislocation, some authors prefer Salter reorienting pelvic osteotomy and its modifications [10–12]. Others promote various types of acetabuloplasty and consider them reference surgery in the treatment of these patients [13–15]. Moreover, the "ideal" pelvic osteotomy, which eliminates equally effectively any variants of congenital deformity of the acetabular hood and does not cause complications such as premature closure of the Y-shaped cartilage, aseptic necrosis of the femoral head, and secondary deformities in the hemipelvis, is not yet established. For example, the modification of the Salter pelvic osteotomy using an autograft from the femur results in a significant lengthening of the hemipelvis, while figured iliac bone osteotomy insignificantly affects the downward displacement of the hip joint relative to the contralateral one [7, 16]. Moreover, various corrective possibilities of surgeries aimed at reorienting the acetabulum and changing its shape are well known [1, 7, 17–21]. Incorrect performance of acetabuloplasty can damage the Y-shaped cartilage and malposition the autograft with the loss of the correction achieved intraoperatively, which will undoubtedly necessitate repeated interventions causing a significant deterioration in both the radiographic anatomical, clinical, and functional results in general [22–24]. During the study, we identified the most typical variants of acetabular deformity in hip subluxation and dislocation (Tönnis types II–IV), which, in our opinion, should be considered in preoperative planning [25] (Fig. 1).

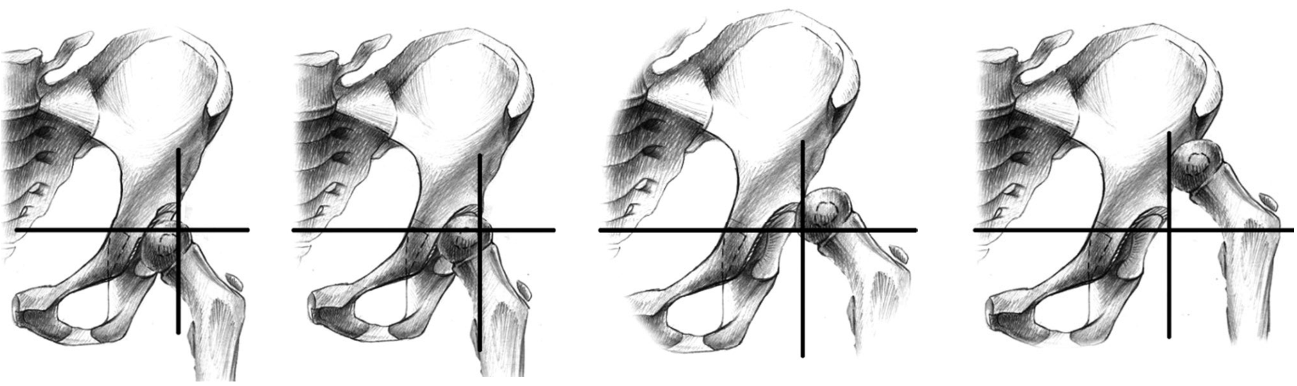
Based on the foregoing, we hypothesized that the choice of a pelvic osteotomy technique in the surgical treatment of pediatric patients with hip dysplasia of varying severity should be based on the type of acetabular deformity and corrective possibilities of the osteotomy.

This study aimed to evaluate the efficiency of the proposed differentiated approach to the selection of a pelvic osteotomy technique based on a comparative analysis of the surgical treatment outcomes of pediatric patients with hip dysplasia of varying severity.

MATERIALS AND METHODS

Study design

A single-center, cohort-comparative, controlled retrospective study was performed.



I (healthy hip joint)

II-1 (femoral subluxation with AI ⩽ 35°, short acetabular hood, and bony prominence)
II-2 (hip subluxation with AI > 35°, extended acetabular hood, and absence of a bony prominence)

III-1 (marginal dislocation of the hip with AI ⩽ 35°, short acetabular hood, and bony prominence)
III-2 (marginal dislocation of the hip with AI > 35°, extended acetabular hood, and absence of a bony prominence)
III-3 (marginal dislocation of the hip with AI > 35°, short acetabular arch, and bony prominence)

IV-1 (supra-acetabular dislocation of the hip with AI ⩽ 35°, short acetabular hood, and bony prominence)
IV-2 (supra-acetabular dislocation of the hip with AI > 35°, extended acetabular hood, and absence of a bony prominence)
IV-3 (supra-acetabular dislocation of the hip with AI > 35°, short acetabular hood, and bony prominence)

Fig. 1. Tönnis supplemented the classification of the severity of hip dysplasia. AI, acetabular index

The inclusion criteria were as follows:

- Age 2–4 years
- Unilateral hip dysplasia (Tönnis types II–IV)
- Absence of surgical interventions on the hip joint
- No signs of aseptic necrosis of the femoral head according to Tönnis classification [26]
- Absence of confirmed neurological diseases
- Absence of genetic diseases and systemic skeletal dysplasia
- Consent of the patient's legal representatives to participate in the study

The exclusion criteria were as follows:

- Age <2 years and >4 years
- Bilateral changes in dysplastic genesis
- History of surgical interventions on the hip joint
- Emerging or formed multiplanar deformities of the proximal femur
- Neurological, systemic, and genetic diseases
- Refusal to fill out informed consent to participate in the study.

The study included 150 patients (150 hip joints) aged 2–4 years (3.1 ± 0.45 years) with Tönnis type II–IV hip dysplasia, who were treated at the Clinic of the H.I. Turner National Medical Research Center for Children's Orthopedics and Trauma Surgery between 2021 and 2022.

Depending on the verified variant of acetabular deformity, taking into account the corrective possibilities of various types of pelvic osteotomy, patients were distributed into three groups [1, 27–30] (Fig. 2).

Group 1 included 47 patients (47 hip joints) with hip subluxation or dislocation and Tönnis type 1 acetabular deformity, who underwent modified Salter iliac pelvic osteotomy without an autograft (RF patent for the invention No. 2405486 dated 12/10/2010). Acetabular fragment rotation was performed along the bisector between the frontal and sagittal planes, which enabled us to ensure the lateral tilt of the acetabulum and level the risk of retroversion of the latter, in contrast to the classical variant of Salter surgery in which the acetabulum is strictly rotated in the sagittal plane. Group 2 included 64 patients (64 hip joints) with hip subluxation or dislocation and Tönnis type 2 acetabular deformity, who underwent Pemberton pericapsular acetabuloplasty using the surgical technique described by the author. Group 3 included 39 patients (39 hip joints) with Tönnis type 3 acetabular deformity, occurring only in grade III and IV hip dysplasia (i.e., hip dislocation), who underwent Pembersal surgery, which combines the elements of both Salter pelvic osteotomy and Pemberton pericapsular acetabuloplasty.

In patients with hip dislocation, tenotomy of the *m. iliopsoas* at the acetabulum level, followed by arthrotomy and revision, was an obligatory stage of the surgery. Intertrochanteric corrective osteotomy of the femur was performed in all patients with grade III and IV hip dysplasia, and in patients with grade II, it was performed depending on the angular values of the proximal femur [31].

All patients underwent a clinical examination typical for this hip joint disease and a radiographic examination, which included radiography of the hip joints in the frontal view in

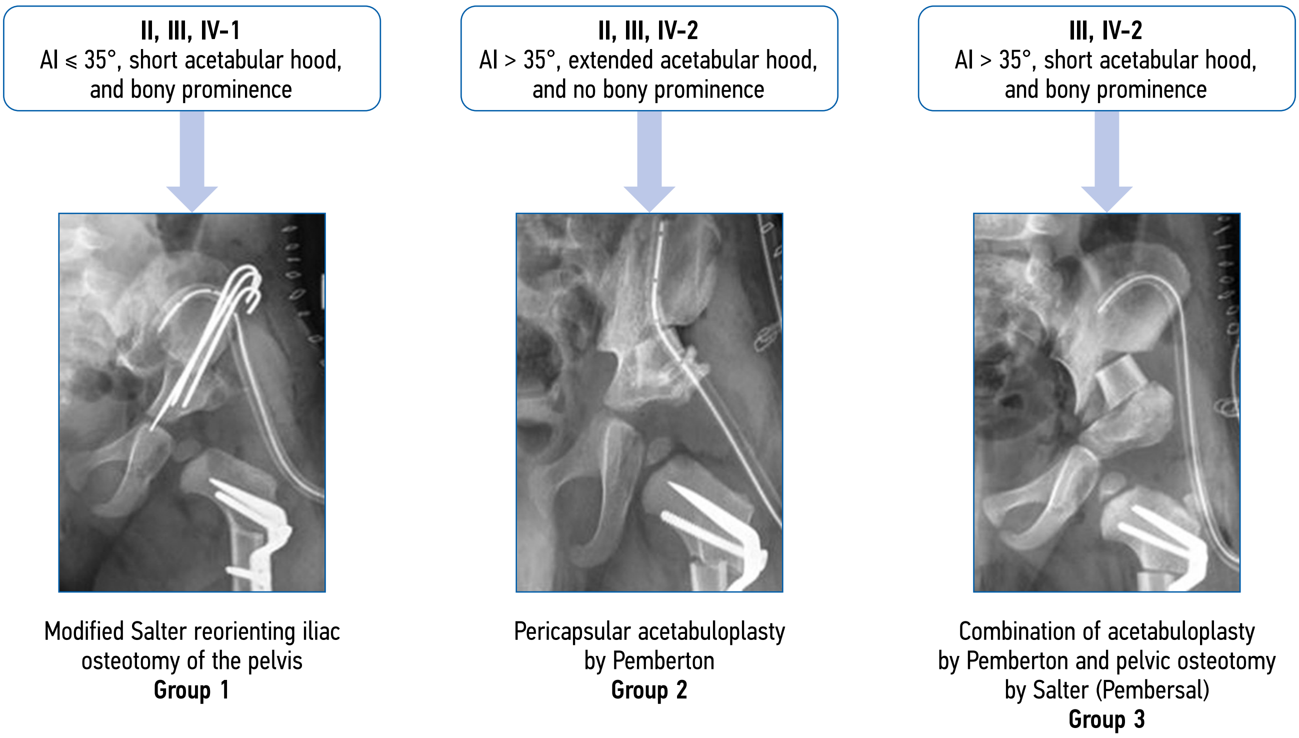
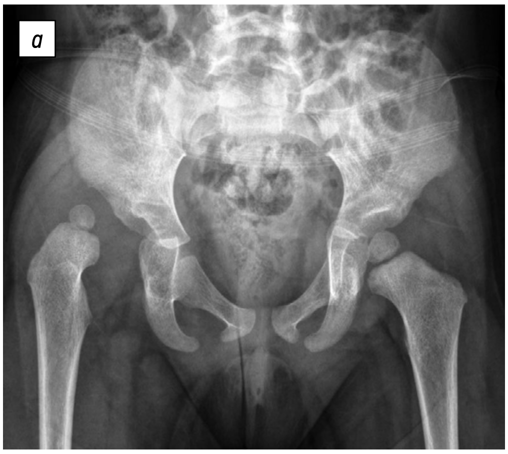


Fig. 2. Proposed differentiated approach to the choice of pelvic osteotomy depending on the type of the acetabular deformity (Tönnis supplemented classification) and the corrective possibilities of surgical technologies. AI, acetabular index [25]



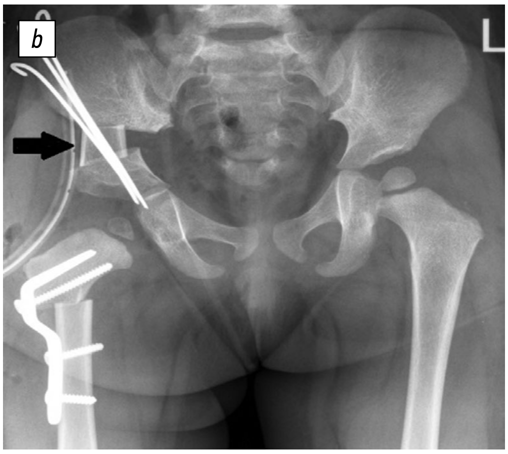


Fig. 3. Radiograph of patient Z., 3 years old, with Tönnis grade III dysplasia of the right hip joint: *a*, before surgery; *b*, after radical reconstruction with a modified Salter surgery using an autograft from the femur (indicated by an arrow)

the Lauenstein position and abduction and internal rotation of the lower extremities before and after surgery. This study mainly emphasizes the assessment of the transformation of the radiographic anatomical structure of the acetabulum after surgical correction. Radiographic measurements were used to assess the acetabular index (AI), Wiberg angle, cervical–diaphyseal angle, anteversion angle of the proximal femur, degree of bone coverage, acetabular depth (AD), and pelvic height (PH), acetabular hood extension (AHE), and presence or absence of a bony prominence.

For adequate comparative analysis, similar indicators of the contralateral ("healthy") joint were analyzed using archived radiographs of 50 patients (50 hip joints) with Tönnis grade II–IV hip dysplasia, who underwent the modified Salter surgery, which was traditionally performed in the Department of the Hip Joint Pathology of the H.I. Turner National Medical Research Center for Children's Orthopedics and Trauma Surgery, without verification of the type of acetabular deformity, using an autograft from the femur, which was placed in the diastasis of the iliac fragments (Fig. 3).

Statistical analysis was performed using the IBM SPSS Statistics version 26 (IBM Corp., Armonk, NY, USA). Arithmetic means (M), standard deviation (SD), and median (Me) with quartiles (25%–75%) were calculated. Intergroup analysis was performed using the nonparametric Mann–Whitney *U*-test. Within the groups, data were analyzed using the Wilcoxon test. The result was considered statistically significant at $p < 0.05$.

RESULTS

On hospital admission, the parents in all study groups complained that their children exhibited lameness. The lower limb was relatively shortened by 1.9 ± 0.7 cm. During the assessment of the range of motion, changes characteristic of dysplastic instability of the hip joint were revealed on the lesion side, such as limitation of the abduction amplitude compared with the contralateral joint (31° ± 5° and 46° ± 4°, respectively) and excessive amplitude of the internal (65° ± 10°) and external (55° ± 10°) rotation. No significant differences in rotational movements were noted.

As shown in Table, all patients exhibited changes in hip joint components, typical for the dysplastic genesis of the disease, which manifest as increased AI, decreased Wiberg angle, and zero bone coverage and negative values for hip dislocation, decreased AD and PH, and *coxa valga antetorta*. On the contrary, radiometry characterizes manifestations of congenital acetabular deformity in hip dysplasia of varying severity, which presents as an underdeveloped acetabular hood, AD changes, and presence or absence of a stepwise transition of the upper edge of the acetabulum to the iliac wing (bony prominence). In addition, intergroup statistical analysis showed that the AI and AD differed statistically significantly ($p < 0.05$) between group 1 and groups 2 and 3, and AHE differed between group 2 and groups 1 and 3 ($p < 0.05$). Despite significant statistical differences in some indicators in the study groups, all patients demonstrated abnormalities in the rates of dysplastic hip joint origin of varying severity (subluxation, marginal, and supra-acetabular dislocation), which not only confirms acetabular deformities in dysplasia but also necessitates a differentiated approach when choosing a pelvic osteotomy technique to correct the deformity and achieve close-to-physiological ratios in the hip joint. On radiographs of the hip joint in the comparison group, all variants of acetabular deformity in the general cohort were revealed, as evidenced by AI and AHE changes, presence or absence of bony prominence, and AD indicators. This indicates that a specific deformity of the acetabular hood was not differentiated when planning a surgical intervention.

After surgical treatment of the three groups, parameters characterizing the radiographic anatomical structure of the acetabulum and proximal femur were significantly different in comparison with preoperative data ($p < 0.05$),

Table. Indicators of the radiographic anatomical structure of the acetabulum and proximal femur, hip joint ratio, and dynamics of their changes in patients before and after the surgery, M ± SD, Me (25%; 75%)

Parameter	Group 1 before surgery	Group 1 after surgery	AVC	Group 2 before surgery	Group 2 after surgery	AVC	Group 3 before surgery	Group 3 after surgery	AVC	Contralateral joint [7, 10]	Comparison group before surgery	Comparison group after surgery	AVC
AI, °	33.5 ± 1.6* 34 (32; 35)	17 ± 2.7*** 17 (15; 19)	−16.5	41.4 ± 3.6* 42 (39; 43)	16.4 ± 2.4*** 16 (14; 17)	−25	41.6 ± 3.2* 42 (39; 43)	15.5 ± 2*** 15 (14;17)	−26	20.6 ± 2 20.5 (19; 22.8)	37.8 ± 3.5 39 (35; 41)	12.6 ± 1.6*** 12 (11.8; 14)	−25.5
Wiberg angle, °	2.8 ± 3.6 0 (0; 5)	35.9 ± 2.7 36 (34; 38)	33.5	3 ± 3.3 0 (0; 6)	37.1 ± 2.1 37 (36; 39)	34.5	Negative values	38.2 ± 2 38 (37; 40)	38.5	28.7 ± 2 29 (27; 30.5)	3.5 ± 4 3 (0; 7)	38.1 ± 3.5 39 (37; 40)	35
AD, мм	7.9 ± 0.9* 7.8 (7.3; 8.4)	7.9 ± 0.9*** 7.8 (7.3; 8.4)	0	6.2 ± 0.8* 6.1 (5.6; 6.5)	9.9 ± 0.6*** 9.8 (9.3; 10.3)	3.7	6.5 ± 0.7* 6.3 (5.9; 7.1)	9.5 ± 0.5*** 9.4 (9.1; 9.9)	3.2	9.6 ± 1 9.5 (9; 10.4)	7.2 ± 1.2 7.3 (6.2; 8.1)	7.2 ± 1.2*** 7.3 (6.2; 8.1)	0
PH, мм	55.4 ± 5.2 55.8 (51.4; 58.4)	60.6 ± 6.4*** 59.5 (56.1; 63.1)	4.8	53 ± 3.7 53.2 (50.8; 56.1)	61.3 ± 5.7*** 60.8 (57.3; 64.7)	7.9	53.7 ± 3.9 54.6 (51.1; 56.3)	62 ± 5*** 61.2 (57.7; 65.1)	8.2	55.9 ± 5.8 56.1 (51.3; 60.2)	54.5 ± 5 55.3 (51; 58)	69.7 ± 5.3*** 70 (66.3; 72.6)	14.5
AHE, мм	13.3 ± 1.9** 13.4 (11.7; 14.9)	13.3 ± 1.9 13.4 (11.7; 14.9)	0	17.2 ± 3** 17.2 (14.8; 19.3)	17.2 ± 3 17.2 (14.8; 19.3)	0	13.8 ± 2.2** 14.1 (12.3; 15.2)	13.8 ± 2.2 14.1 (12.3; 15.2)	0	19.3 ± 2.6 19.4 (17.2; 21.4)	16 ± 3.4 15.7 (13.5; 18.3)	16 ± 3.4 15.7 (13.5; 18.3)	0
BP	+	+		−	−		+	+		+(42 %) −(58 %)	+(42 %) −(58 %)	+(42 %) −(58 %)	
CDA, °	141.7 ± 4 142 (139; 144)	128.2 ± 4.7 128 (124; 132)	−13.2	142.1 ± 4.2 142 (140; 145)	128.6 ± 4.6 129 (124; 132)	−14	141.6 ± 3.7 142 (139; 144)	127.6 ± 4.3 128 (123.7; 131)	−13.5	142.2 ± 4.1 142 (140; 144)	142.5 ± 4.3 142.5 (140.3; 144.8)	128.1 ± 4.8 128 (124.5; 132.3)	−14
AA, °	41.2 ± 3.6 41 (38.3; 43.2)	15 ± 3.5 15 (12.5; 18.3)	−26.2	40.9 ± 3.8 41 (37.8; 43.1)	15.6 ± 2.7 15.5 (14; 17.5)	−25.5	40.4 ± 3.7 40.3 (37.5; 43)	16.1 ± 3 15.3 (13.5; 18.5)	−25	40.3 ± 3.6 40 (37.9; 42.3)	46 ± 5.6 45.5 (40.3; 50.8)	14.9 ± 3.3 15 (12.8; 18)	−28.5
BCD, %	22.4 ± 26.4 0 (0; 52)	85.5 ± 4.7 85 (80; 90)	62.5	26 ± 27 0 (0; 52)	87 ± 4.5 90 (85; 90)	63	−	89 ± 3.5 90 (85; 90)	86.5	90 ± 6 90 (85; 95)	24.1 ± 25.7 0 (0; 52)	101.6 ± 5.2 100 (98.6; 105)	75.5

* Significant differences ($p < 0.05$) in group 1 and groups 2 and 3.
** Significant differences ($p < 0.05$) in group 2 and groups 1 and 3.
*** Significant differences ($p < 0.05$) in groups 1, 2, and 3 and the comparison group.
Note: AA, angle of anteversion of the proximal femur; AD, acetabular depth; AHE, acetabular hood extension; AI, acetabular index; AVC, average value of the correction; BCD, bone coverage degree; BP, bony prominence; CDA, collum-diaphyseal angle; PH, pelvic height.

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which indicates the elimination of hip joint problems such as subluxation or dislocation and restoration of general stability. Moreover, no significant differences ($p > 0.05$) were found in the AI between the groups, including their approximation to the parameters of the contralateral joint and their presence ($p < 0.05$) relative to the comparison group, which indicates that hypercorrection of the acetabulum position was achieved following modified Salter pelvic osteotomy using an autograft from the femur. In addition, the average value of the correction (AVC) proves the different corrective possibilities of the indicated pelvic osteotomy techniques, i.e., pericapsular acetabuloplasty and Pembersal surgery have a greater corrective potential than the Salter surgery. Moreover, the AVCs in the comparison group were nearly identical to those in groups 2 and 3, which were achieved, in our opinion, by the use of an autograft from the femoral bone.

The postoperative Wiberg angle did not differ significantly among each patient of groups 1–3 ($p > 0.05$). They also did not differ from those in the comparison group after surgery. However, after the intervention, the Wiberg angle in the main and comparison groups significantly exceeded the normative values in the contralateral (healthy) joints. The high Wiberg angle in groups 1–3 and the control group compared with the Wiberg angle on the contralateral joint can be due to the variation and decrease in anteversion of the proximal femur in all patients after surgery. In group 1, the postoperative AD did not change significantly compared with the preoperative AD ($p > 0.05$), which was due to the effect of the modified Salter surgery, where the acetabular fragment is rotated without changing its shape. Moreover, these patients initially showed a slight decrease in AD compared with the AD in the intact joint. In groups 2 and 3, the postoperative AD significantly increased ($p < 0.05$), which was due to a change in the acetabulum shape. In addition, AD values nearly reached the values in healthy joints. Note that the AD value was different ($p < 0.05$) in the joints of groups 1–3 and from that in the healthy joints. This indicates the need for individualized selection of surgical interventions that adequately affect the AD. The postoperative PH did not differ significantly ($p > 0.05$) between groups of patients and differed insignificantly from those of the contralateral joint. In addition, significant differences ($p < 0.05$) in postoperative PH were observed in the comparison group, whose hemipelvis lengthening averaged 12–15 mm compared with the opposite joint, which was due to the placement of an autograft from the femur between fragments of the iliac bone. In groups 1–3, the average hemipelvis lengthening on the side of the surgical intervention was 6.5 mm.

Thus, the differentiated use of the modified Salter pelvic osteotomy without an autograft, Pemberton pericapsular acetabuloplasty, and Pembersal surgery enables us to achieve adequate correction in various types of congenital acetabular deformity, approaching normal values of the acetabular anatomy and does not cause significant deformity in the hemipelvis, such as its elongation.

DISCUSSION

At present, numerous publications in global scientific databases have proved the high efficiency of the correction of acetabular dysplasia in young children with varying degrees of severity of the hip joint instability of dysplastic origin by performing various modifications of Salter pelvic osteotomy, Pemberton pericapsular acetabuloplasty, their combination (Pembersal), and acetabuloplasty according to Dega and San Diego [32–36]. However, the vast majority of these works focused on the analysis of results by comparing the amount of AI correction or the effectiveness of the methods used. Moreover, the diagnostics of the radiographic anatomical state of the hip joint was performed according to existing international classifications, which presented only the degree of the impaired relationship between the proximal epiphysis of the femur and the acetabulum and did not imply a possible variant of the deformity of the latter [8, 9, 37–40]. For example, Dello Russo and Candia Tapia reported that Pemberton pericapsular acetabuloplasty had greater corrective potential than the author's Salter surgery [37]. Similar data were demonstrated by Ezirmik and Yildiz [38]. Gharanizadeh et al., having comparatively analyzed the efficiency of the Salter surgery modified by Kalamchi and the classical Pemberton acetabuloplasty, revealed no significant difference in the results and concluded that these corrective methods of pelvic osteotomies were equally effective [40]. However, in the author's version of the Salter surgery, as well as in various modifications, the autograft was taken from the iliac wing to replace the diastasis after correction and did not significantly affect the height of the hemipelvis, which was not noted in the modified Salter surgery using an autograft from the femur, which results in the formation of a secondary deformity such as a significant elongation of the hemipelvis, and this, in our opinion, cannot but affect the frontal and sagittal spinopelvic ratios in the long term. In our opinion, this technique can be applied to a limited extent in the surgical treatment of pediatric patients with bilateral dysplastic pathology of the hip joint.

According to literature data, AD is affected by surgeries aimed at changing its shape, such as various types of acetabuloplasty [2–4, 41]. However, in the above studies, the choice of the pelvic osteotomy technique did not depend on the indicators of the radiographic anatomical structure of the acetabulum, in particular on the AD, but apparently on the preferences of the operating surgeon, which to some extent reduces their scientific value. To date, we have found the only work that presents the algorithm for choosing the pelvic osteotomy technique in different age groups of pediatric patients with hip dysplasia [18]. Venkatadass et al. used the presence of primary dysplasia, namely, hip subluxation or dislocation (i.e., absence of any treatment), or residual defects in acetabulum development (i.e., patients who underwent either conservative or surgical treatment) as a criterion for choosing a pelvic osteotomy technique. However, they only described the techniques of various variants of reorienting pelvic osteotomy, including triple and periacetabular osteotomy, and acetabuloplasty, and some potential of these methods for use as surgical treatment were noted. Compared with the present study, these previous studies did not compare and analyze the advantages, disadvantages, and efficiency of the methods used.

Study limitation

The study was restricted by the follow-up period and the radiometry of the selected indicators. In the future, comprehensive radiographic anatomical and clinical and functional analyses of the state of both the hip joints and vertebral–pelvic complex in these patients in the medium- and long-term periods are planned.

CONCLUSION

The results of this study indicated that the proposed differentiated approach to the selection of an appropriate pelvic osteotomy technique in young children with hip dysplasia of varying severity, based on the variant of acetabular deformity, enables us to restore its anatomical structure and does not cause secondary deformity in the hemipelvis, which is confirmed by the AI, AD, and PH values approaching the individual norm.

ADDITIONAL INFORMATION

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Ethical consideration. The study was approved by the local ethics committee of the H.I. Turner National Medical Research Center for Children's Orthopedics and Trauma Surgery of the Ministry of Health of Russia, Protocol No. 21-3 dated August 4, 2021. The consent of patients (their representatives) to the processing and publication of personal data has been obtained.

Author contributions. *P.I. Bortulev* created the study concept and design, collected the data and performed its statistical analysis, analyzed the literature, and wrote the text of the article. *S.V. Vissarionov* edited the text of the article. *T.V. Baskaeva, D.B. Barsukov, I.Yu. Pozdnikin,* and *M.S. Poznovich* collected the data and edited the article text. *V.E. Baskov* and *P.N. Kornyakov* performed the literature analysis and edited the article text.

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