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### X-RAY CHARACTERISTICS OF THE DYSPLASTIC HIP JOINT IN ADULTS BEFORE AND AFTER ENDOPROSTHETIC SURGERY

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Based on the results of X-ray studies of 49 dysplastic hip joints before and after arthroplasty, it was found that such indices of the dysplastic hip joint in adults as the cervical-diaphyseal angle of the femur, the depth of the acetabulum and the thickness of its bottom before and after the arthroplasty surgery significantly differ from each other. The parameters of the cervical-diaphyseal angle in women had significant differences before and after surgery. The cervical-diaphyseal angle in women after arthroplasty was significantly higher than in men. Abductor strength shoulder indices significantly increase in women after surgery. In men, there was a tendency to reduce the shoulder strength of the abductors after surgery. The parameters of the hip joint, which affect the magnitude of the hip abductors' arm, should be considered as biomechanical criteria for the efficiency of the hip joint muscles. Based on the results of X-ray studies of 49 dysplastic hip joints before and after arthroplasty, it was found that such indices of the dysplastic hip joint in adults as the cervical-diaphyseal angle of the femur, the depth of the acetabulum and the thickness of its bottom before and after the arthroplasty surgery significantly differ from each other. Improving the biomechanics of the dysplastic hip joint can be achieved by restoring the geometric parameters of the hip joint as a result of arthroplasty.

**Key words:** hip joint, dysplasia, hip arthroplasty, X-ray indices

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### РЕНТГЕНОЛОГІЧНА ХАРАКТЕРИСТИКА ДИСПЛАСТИЧНОГО СТЕГНОВОГО СУГЛОБУ У ДОРΟΣЛИХ ДО ТА ПІСЛЯ ОПЕРАЦІЇ ЕНДОПРОТЕЗУВАННЯ

На підставі результатів рентгенометричних досліджень 49 диспластичних тазостегнових суглобів до і після ендопротезування встановлено, що такі показники диспластичного тазостегнового суглоба у дорослих як шийково-діафізарний кут стегнової кістки, глибина вертлужної западини і товщина її дна до і після операції достовірно відрізняються між собою. Показники шийно-діафізарного кута у жінок мали достовірні відмінності до та після операції. Шийково-діафізарний кут у жінок після ендопротезування був достовірно вищим, ніж у чоловіків. Показники плеча сили абдукторів після операції достовірно зростають у жінок. У чоловіків відзначено тенденцію до зменшення плеча сили абдукторів після операції. Параметри кульшового суглоба, що впливають на величину плеча сили абдукторів стегна, доцільно розглядати як біомеханічні критерії ефективності роботи м'язів кульшового суглоба. Поліпшення біомеханіки диспластичного кульшового суглоба може бути досягнуто шляхом відновлення геометричних параметрів кульшового суглоба в результаті ендопротезування.

**Ключові слова:** тазостегновий суглоб, дисплазія, ендопротезування, рентгенометричні показники

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Dysplastic coxarthrosis is one of the most severe manifestations of degenerative-dystrophic lesions of the hip joint. And hip arthroplasty in case of its dysplastic lesion refers to surgery of increased complexity [2, 9].

The changes described in dysplastic coxarthrosis not only complicate the selection of components and the implementation of the endoprosthesis installation stage, but also make the endoprosthesis replacement unpredictable. In particular, a change in the shape and structure of the bones that form the hip joint, a change in the position of the center of rotation of the femoral head, cause disruption of the pelvic girdle muscles involved in the abduction mechanism. It is known that the main factors that ensure the efficiency of the abduction mechanism are the geometric parameters of the joint, which determine the shoulder of muscle strength and muscle strength [5, 6]. A change in the geometric parameters of the hip joint in dysplasia is accompanied by a change, mainly a decrease, in the shoulder strength of the pelvic girdle muscles, which disrupts their function, namely the efficiency of the abduction mechanism. That is, in this case, we can talk about a violation of the biomechanics of the joint. Based on the above, we can conclude that the listed geometric parameters and their relationship should be considered as biomechanical criteria for the state of the pelvic girdle and lower extremities function, the change of which leads to a violation of their function. That is why one of the main tasks of arthroplasty is, if not normalization, then at least improvement of the hip joint's geometric parameters, which determine the biomechanical criteria for its function.

Due to the diversity of geometric joint disorders, optimization of preoperative planning is of particular importance [11]. The latter provides for taking into account the existing qualitative and quantitative changes in the elements of the hip joint, which determine the biomechanical criteria for the function of the joint, according to which not only the selection of endoprosthesis components is carried out, but also during the surgical intervention, conditions are created for restoring the biomechanics of the artificial joint, which ensures the effective functioning of the pelvic girdle muscles [1, 8, 10, 12, 16].

**The purpose** of the study was, based on the results of X-ray studies, to determine the biomechanical criteria for dysplastic hip joint dysfunction in order to optimize the preoperative planning of arthroplasty.

**Materials and methods.** The studies were carried out based on data from the archives of the State Institution "Sytenko IPPS, NAMS of Ukraine". For this, a selection of case histories and radiographs of 39 patients with hip dysplasia of I-III degree was made, on the basis of which an X-ray study was performed. When studying the radiometric parameters of the dysplastic hip joint in adults, only those parameters were assessed that had a direct impact on the hip joint's biomechanics by changing the length of the shoulder or the angle of action of the muscles. These indices included the cervical-diaphyseal angle (CDA), the depth of the acetabulum and the thickness of its bottom, as well as the decentration of the femoral head, which we measured according to the methods given in the literature [3, 7].

Additionally, the length of the abductor's arm before surgery and the total femoral offset after arthroplasty were measured [4]. The center of the femoral head rotation and the center of rotation of the hip joint were determined using a template (in the form of concentric circles). These geometric parameters of the acetabulum and the proximal femur that we studied were assessed from the point of view of the hip joint's function as biomechanical criteria for the effective operation of the abduction mechanism.

When carrying out an X-ray study, the projection magnification of X-ray images was evaluated, attention was paid to the rotation and adduction of the femurs, and the projection distortion of the studied

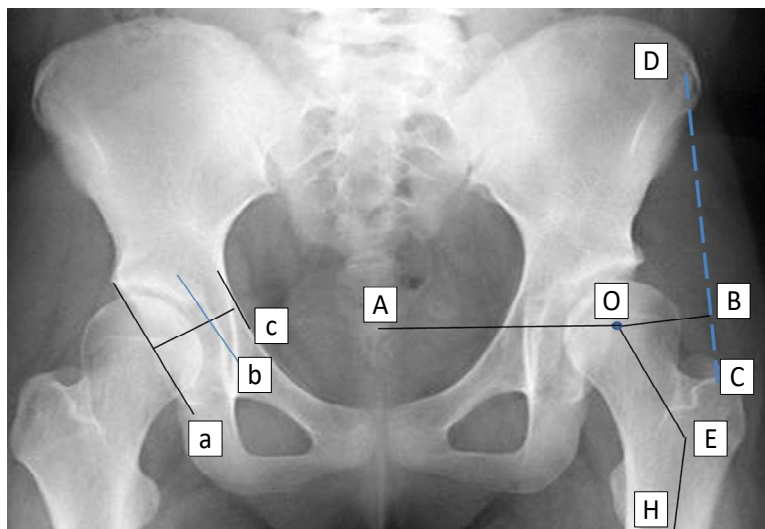


Fig. 1. Scheme of X-ray measurements.

parameters was taken into account. In this study we did not take into account some standard parameters of the dysplastic joint, such as the Wiberg angle, the degree of femoral head's overlap, the Sharpe angle, and even the linear parameters of the acetabulum, for example, its length, width, etc., since these parameters, although affect the preoperative planning and selection of endoprosthesis components, but do not per se change the length of the arm or the angle of action of the hip abductors.

The X-ray scheme and indices' values are shown in fig.1.

Measured radiometric indices:

– Depth of the acetabulum is a segment of the perpendicular between the lines “a” and “b”, restored from the center of the hip joint rotation of the line connecting the upper and lower edges of the acetabulum.

– Thickness of the acetabulum bottom is continuation of the same perpendicular from the joint space to the internal cortical plate of the pelvis (the distance between the lines “b” and “c”).

– Acetabular depth index is the ratio of the bottom thickness to the depth of the acetabulum (normally is).

– Shoulder length of the thigh abductors is the length of the perpendicular [O–B), restored from the line connecting the anterior superior spine of the pelvis and the top of the greater trochanter (C–D line) to the center of the femoral head’s rotation.

– Arm length of the gravitational force is the length of the perpendicular [O–A), restored from the line connecting the center of the pubic symphysis and the line of the spinous processes to the center of femoral head’s rotation.

– Height and lateralization of the center of femoral head’s rotation, relative to the center of the acetabulum rotation.

Material for the analysis was radiographs of 39 patients (49 hip joints), including 12 men (14 hip joints) and 27 women (35 hip joints) aged 21 to 62 years, on average (49.6±10.6) years.

The data were processed statistically. The mean (M) and standard deviation (SD), minimum (min) and maximum (max) values of the parameters were calculated. The difference between the observation periods was determined using a paired T-test, the differences between the sexes were determined using a T-test for independent samples. The analysis was carried out using the IBM SPSS Statistics 20.0 application package.

**Results of the study and their discussion.** The results of the X-ray studies performed are shown in table 1.

Table 1

**X-ray parameters of the dysplastic hip joint before and after total arthroplasty, the average for the sample (excluding gender differences)**

Hip- joint parameters	Before the surgery	After the surgery	Statistical difference between observations (t, p)
Cervical-diaphyseal angle	139.9±7.5 130.0÷155.0	131.5±2.3 130.0÷135.0	t=5.118 p=0.001
Arm of the abductors’ strength	53.3±8.6 34.0÷69.0	54.4±6.4 43.0÷69.0	t=-0.892 p=0.382
Height of head’s rotation center	23.4±4.8 16.0÷33.0	22.9±3.7 16.0÷29.0	t=0.594 p=0.562
Depth of the acetabulum	21.8±5.1 13.0÷36.0	27.4±5.7 20.0÷37.0	t=-3.880 p=0.001
Length of the acetabulum	62.7±5.8 50.0÷78.0	63.7±5.4 55.0÷72.0	t=-0.721 p=0.480
Acetabular heigh	22.5±4.2 14.0÷32.0	21.7±4.3 14.0÷29.0	t=1.257 p=0.224
Thickness of the acetabulum bottom	16.7±4.6 8.0÷24.0	11.0±4.7 4.0÷19.0	t=6.012 p=0.001

As analysis of the obtained radiometric parameters showed that such parameters of the dysplastic hip joint in adults as the cervical-diaphyseal femoral angle, the depth of the acetabulum and the thickness of its bottom before and after the arthroplasty surgery significantly differ from each other. At the same time, the index of the acetabulum depth (the ratio of the thickness of the acetabulum bottom to its depth) averaged 0.92±0.17 before the operation, which is significantly higher than the norm (from 0.3 to 0.6). After the operation, this index was 0.40±0.04, i.e. corresponded to normal values. These tabular data did not include gender differences in radiometric parameters, however, they give an idea of the geometrical parameters of the hip joint that are the most changeable as a result of arthroplasty.

The results of X-ray studies, taking into account gender differences in the studied parameters, are shown in table 2.

Analysis of the radiometric parameters of the dysplastic hip joint’s geometric parameters, taking into account gender differences, showed that only such indices as the depth of the acetabulum and the thickness of its bottom in both men and women had significant differences before and after surgery. As for the cervical-diaphyseal angle, only in women this index had significant differences before and after surgery. On the other hand, after the operation, CDA in women was significantly higher than in men.

**X-ray parameters of the dysplastic hip joint before and after total arthroplasty, taking into account gender differences**

Parameters	Gender	Before surgery M±SD min – max	After surgery M±SD min – max	Statistic difference between observations (t, p)
CDA	Women	141.6±7.5 130÷155	132.0±2.4 130÷135	t=5.037 p=0.001
	Men	135.0±5.8 130÷140	130.0±0 130÷130	t=1.732 p=0.182
	Statistic difference between genders (t,p)	t=1.595 p=0.135	t=2.708 p=0.022	
Height of rotation heads center	Women	22.8±4.7 16÷32	22.3±3.9 16÷29	t=0.559 p=0.588
	Men	25.5±5.4 21÷33	24.5±2.9 22÷27	t=0.249 p=0.820
	Statistic difference between genders (t,p)	t=-0.996 p=0.332	t=-1.039 p=0.318	
Shoulder of abductors' strength	Women	52.5±4.8 34÷61	55.9±3.9 43÷60	t=-2.122 p=0.048
	Men	57.0±5.1 44÷63	50.8±3.2 45÷53	t=1.481 p=0.045
	Statistic difference between genders (t,p)	t=-0.946 p=0.355	t=0.913 p=0.047	
Depth acetabulum	Women	21.5±5.5 13÷36	25.6±4.6 20÷34	t=-2.688 p=0.015
	Men	23.3±2.8 20÷26	35.8±1.3 34÷37	t=-14.434 p=0.001
	Statistic difference between genders (t,p)	t=-0.627 p=0.538	t=-8.239 p=0.001	
Length of acetabulum	Women	61.9±6.1 50÷78	62.2±4.9 55÷72	t=0.071 p=0.944
	Men	66.3±1.3 65÷68	69.5±3.0 66÷72	t=-1.722 p=0.184
	Statistic difference between genders (t,p)	t=-1.384 p=0.182	t=-2.806 p=0.012	
Hight of acetabulum	Women	22.1±4.4 14÷32	21.1±4.4 14÷29	t=1.424 p=0.175
	Men	24.3±2.1 22÷26	24.5±2.9 22÷27	t=-0.151 p=0.889
	Statistic difference between genders (t,p)	t=-0.931 p=0.363	t=-1.477 p=0.157	
thickness of the acetabulum bottom	Women	16.2±4.8 8÷24	10.7±4.5 4÷19	t=4.936 p=0.001
	Men	19.0±3.5 16÷22	12.8±5.6 8÷19	t=5.290 p=0.013
	Statistic difference between genders (t,p)	t=-1.104 p=0.282	t=-0.796 p=0.435	

An analysis of the radiometric parameters of the dysplastic hip joint's geometric parameters, taking into account gender differences, showed that when comparing the magnitude of the abductor strength arm, the indices before and after the surgery had significant differences in both women and men. But if in women this index significantly increased after the surgery, then in men after the operation of endoprosthesis replacement, a decrease in the abductors' shoulder strength was noted. In addition, after the surgery, the magnitude of the abductor strength shoulder in women is significantly higher than in men.

The depth and length of the acetabulum after surgery in men had significantly greater values than in women.

The depth index of the acetabulum (the ratio of the acetabular bottom thickness to its depth) was  $0.89 \pm 0.15$  in women before surgery, and  $0.93 \pm 0.09$  in men, which exceeded normal values.

After the surgery, this index was  $0.43 \pm 0.04$  in women and  $0.39 \pm 0.09$  in men, which corresponded to normal values.

We also performed an analysis of the nomenclature endoprosthesis components characteristics given in the case histories. It was established that endoprosthesis were implanted in men, the head sizes of which ranged from 28 to 36 mm, the average size of the endoprosthesis head in men was  $(33.3 \pm 4.6)$  mm. Women were implanted with endoprosthesis, the head sizes of which ranged from 28 to 38 mm, and the mean size of the prosthesis head was  $(33.2 \pm 3.7)$  mm. The difference is not statistically significant ( $t=0.047$ ;  $p=0.963$ ).

The endoprosthesis offset values in men averaged  $(47.5 \pm 1.7)$  mm (from 46 to 49 mm), and in women it was somewhat less –  $(44.7 \pm 3.5)$  mm (from 40 to 52 mm), the differences are also not statistically significant ( $t=-1.536$ ;  $p=0.139$ ).

We also determined the value of the total femoral offset, which consisted of the parameters of the stem offset and the cervical-diaphyseal angle of the endoprosthesis, the depth of the endoprosthesis head and the thickness of the acetabular insert. It was noted that in men there is a decrease in the value of the total femoral offset in comparison with similar indices in women, and the differences in the value of the total femoral offset in men and women after hip arthroplasty turned out to be statistically significant.

The radiometric studies of the dysplastic hip joint's parameters performed by us before the surgery and their qualitative and quantitative assessment showed that the most characteristic changes in the dysplastic hip joint are the depth of the acetabulum and the thickness of its bottom, as well as the ratio of these indices, which we consider as biomechanical criteria for the effective operation of the hip joint's abduction mechanism.

The results of the performed studies were taken into account when planning the surgical intervention. Taking into account the planned correction, the selection of endoprosthesis components was also carried out. An integrated approach to the planning of surgical intervention permitted to achieve positive results of the correction.

Statistical results of X-ray studies of the dysplastic hip joint's parameters before and after the arthroplasty show that a number of the studied parameters change markedly. Moreover, these changes relate mainly to those parameters that, one way or another, affect the biomechanics of the hip joint – changing the magnitude of the strength shoulder of the pelvic girdle muscles and the angle of inclination of these forces' line of action. Changes in these parameters change the working conditions of the muscles, which inevitably affects the biomechanics of the hip joint, namely, increasing the efficiency of the abduction mechanism.

Our results are consistent with literature data [7, 15], although we understand that our studies had certain limitations. So, in our study, we did not separate the indices according to the degrees of acetabular dysplasia, as, for example, in the work of A.Ye. Loskutov [3], but collectively studied the indices of patients with acetabular dysplasia of I-III degrees according to Crow. However, in this study, we were not interested in quantitative indices depending on the degree of acetabular dysplasia, but in the mean indices and their differences before and after surgery, as well as mean gender differences.

As for such an index as the shoulder strength of the hip abductors, the results we obtained are very indicative. Our X-ray studies have shown that such an important index as the shoulder strength of the thigh abductors before and after the surgery had serious changes in both men and women. Thus, the mean value of the abductor muscles' shoulder after surgery significantly increased in women, and significantly decreased in men. These data coincide with the results of the study conducted earlier by some authors [4, 14].

When comparing gender indices, a significant decrease in the abductor muscles' shoulder length in men compared to women was noted, which differs from the results of the same work. These differences can be explained by the fact that in the previous work, idiopathic coxarthrosis was considered, and in this work it was dysplastic, and the number of hip joints studied in men was almost three times less than in women.

The X-ray studies of the dysplastic hip joint's geometric parameters, which affect the magnitude of the abductor muscle strength shoulder, showed not only their change but also a change in the ratios of a number of indices. In particular, a decrease in the shoulder strength of the abductor muscles, which reduces the efficiency of the abduction mechanism, that is, disrupts the biomechanics of the hip joint. This gives us a reason to consider the studied parameters and their ratios as biomechanical criteria for the function of the hip joint.

Normalization of the hip joint's biomechanics can be achieved by restoring the geometric parameters of the joint, which is only possible with careful preoperative planning of arthroplasty [13].

### Conclusion

Comparative assessment of the performed X-ray studies results suggests that the planning of endoprosthetics, taking into account the geometric changes in the elements of the dysplastic hip joint, permits not only to make an adequate selection of the elements of the endoprosthesis, but also to eliminate the existing violations of the joint geometry during the surgery. In particular, after arthroplasty of the dysplastic hip joint, there is a significant decrease in the CDA, a significant deepening of the acetabulum and a significant decrease in the thickness of the acetabular bottom, i.e. improvement of geometric parameters that affect the normalization of biomechanical criteria that determine the function of the joint.

It should be noted that the magnitude of the abductor muscles' strength shoulder, as a result of endoprosthetics in women, significantly increases the magnitude of the abductor muscles' strength shoulder, which is a factor that positively affects the hip joint's biomechanics. While in men there is a clear trend towards a decrease in the value of the shoulder strength of the abductor muscles.

Thus, endoprosthesis replacement of a dysplastic hip joint in women more often provides an improvement in the biomechanical conditions for the operation of the abduction mechanism in comparison with men.

The results of our studies can serve as a serious basis for constructing a mathematical model for studying the work of the hip joint's muscles, in particular, the efficacy of the abduction mechanism under various operating conditions.

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