



The optimization of the length of the lower limbs after hip arthroplasty

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Abstract

Background The purpose of this research was to evaluate the effectiveness of hip joint arthroplasty in patients with different correction of the length of the legs and identifying factors that influence the outcome.

Material and methods We analyzed 93 patients operated upon with an initial shortening of the limb length by more than 3 cm. The difference in the length of the limbs ranged from 3 to 12 cm, which averaged 5 cm. Immediately after surgery and after three to 12 months, a control examination was performed with measurement of the length of the lower extremities and the function of the joint, using the Harris scale.

Results The study revealed three versions of the result of the correction of the length of the limb after hip joint arthroplasty: saving limb shortening ($n = 16$ (17%) with HHS 80 (95% CI, 78.4 to 83.4%); full restoration of limb length ($n = 70$ (75.5%) with HHS 78 (95% CI, 74.6 to 80.2%); excess limb lengthening ($n = 7$ (7.5%) with HHS 68 (95% CI, 63.5 to 73.5%).

Conclusions So that, incorrect lengthening of the lower limb during arthroplasty leads to lameness, discomfort, muscle tension, which ultimately leads to pain. Optimal result of hip arthroplasty and ensure the necessary amplitude of movements, it is advisable to use prediction criteria of the leveling of the limb length, which are: the duration of the disease, presence of consequences of previous operations, gender, age, degree of tissue rigidity, severity of hip-spine syndrome, and scoliotic deformity.

Keywords Hip arthroplasty · Optimization of the length of the legs · Complications

As known, the difference in the length of the legs leads to certain compensatory and adaptive changes on the part of the musculoskeletal system of a person with negative manifestations, starting from the psycho-emotional state of patients ending with persistent anatomical and functional disorders [1, 2].

One of the reasons of the difference in length of the legs is severe pathology of hip joint. According to the register of the Vreden Russian Research Institute of Traumatology and

Orthopedic, 87% of patients, who need to replace the hip joint with an artificial one, after hip arthroplasty (2011–2015) have a difference in the length of legs, the elimination of which is the cherished desire of patients and one of the tasks of the operating surgeon. Moreover, out of 8564 hospitalized patients in 1370 (6%), a difference in the length of the lower extremities was detected by more than 3 cm.

In contrast, during the hip arthroplasty, it is not always possible to completely eliminate the shortening of the lower limb. In addition, with long-term shortening, its elimination can lead to undesirable side effects in the form of pain in the operated limb and in the lumbar spine, as well as limiting the amplitude of movement in the joint, which ultimately leads to a decrease in “quality of life.” [3].

If the elimination of limb shortening during hip joint arthroplasty by 1–2 cm does not in itself pose a particular problem, then excessive lengthening in total with the size of the initial shortening can cause some negative manifestations. At the same time, insufficient attention is paid to the issues of optimizing the correction of the length of the operated limb among the many different problems of hip arthroplasty.

The original version of this article was revised: Authors first and last names for the first and third authors have been interchanged. The correct presentation is given above.

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Objective

The reason of this research was to evaluate the effectiveness of hip joint arthroplasty in patients with different correction of the length of the legs and identifying factors that influence the outcome.

Material and methods

We analyzed 93 patients that were operated upon with an initial shortening of the limb length by more than 3 cm. The difference in the length of the limbs ranged from 3 to 12 cm, which averaged 5 cm. Among them: 64 patients (68.9%) with hip dysplasia (type B, C according to Hartofilakidis), 8 patients (1%) with a false joint, 15 patients with aseptic necrosis of the femoral head (IV Art. FICAT), six patients with post-traumatic coxarthrosis in combination with a central or posterior dislocation of the femoral head. Eight patients with hip dysplasia and two patients with post-traumatic coxarthrosis were operated on earlier and had significant scars in the hip joint.

Measuring the length of the limbs was carried out according to methods adopted in orthopaedics, differentiating relative, or absolute length with functional elongation or shortening.

- (1) Clinically (Fig. 1a), according to the difference of distances (right and left) from the anterior upper spine of the pelvis to the inner ankle (relative length). With scoliotic deformity of the lumbar spine, the presence of flexion or adduction of the hip or knee joints, the functional length was determined. For this, we carried out a segment-by-segment measurement, comparing the data obtained with the opposite side. The length of the hip is measured from the projection of the tip of the greater trochanter to the external joint gap of the knee joint, and the length of the leg from the joint of the knee joint to the ankle (Fig. 1a).

- (2) According to the X-Ray, measured the distance from the small skewer to the line connecting the mounds of the ischial bones, and compared with the opposite joint (Fig. 1b). The results of clinical and radiological measurements were compared with each other. If these data differed, they measured the length of the hip, lower leg, examined the condition of the knee, ankle joints and feet, which can also cause different lengths of the legs. When measuring the length of the limb, the position of the patient was taken into account, which is very important for correct measurement [4].

All patients, depending on the size of the shortening of one of their lower limbs, were divided into three groups. The first group consisted of 69 patients (38 f, 31 m) with shortening of the limb from 3 to 4 cm (average 3.6 ± 0.41), the second 16 people (10 f, 6 m) with shortening from 4 to 5 cm (average 4.68 ± 0.31) and the third group of eight people (7 f, 1 m) included patients with a shortening of the limb more than 5 cm (average 5.38 ± 0.82) (Table 1).

All of the above patients underwent hip joint arthroplasty using the standard technique using Harding-type access, also using osteotomy according to T. Paavilainen and with posterior post-traumatic dislocation of the femoral head, back-lateral access according to Kocher.

Before and after the operation, all patients filled out questionnaires in which they reflected their key expectations from the operation, in particular: getting rid of pain, restoring the amplitude of movements and support ability of the limb, and leveling the length of the legs. (Questionnaire “Coordination of the results of restoring the length of limbs in hip joint arthroplasty”).

Immediately after surgery and after three to 12 months, a control examination was performed with measurement of the length of the lower extremities and the function of the joint, using the Harris scale.

Fig. 1 Methods for determining limb length: **a**) clinical, **b**) radiological

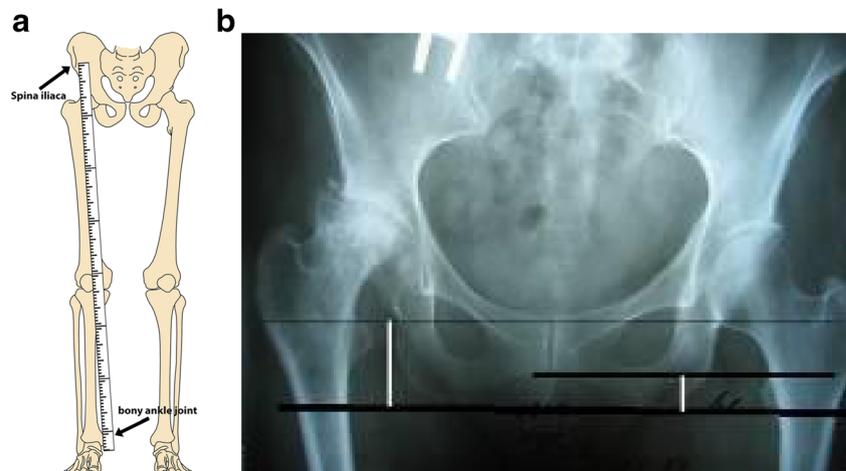


Table 1 Groups of patients with a difference in the length of the lower extremities by more than 3 cm

Groups	Shortening	(N) %	Female	Male
I	3–4 (3.6 ± 0.41)	69 (74%)	38	31
II	4–5 cm (4.68 ± 0.31)	16 (18%)	10	6
III	> 5 cm (5.38 ± 0.82)	8 (8%)	7	1

Results

The study revealed three versions of the result of the correction of the length of the limb after hip joint arthroplasty (Table 2).

1. Saving limb shortening.
2. Full restoration of limb length (leveling).
3. Excess limb lengthening.

The shortening of the lower limb was preserved in 16 (17%) operated patients (groups II and III). In all patients of these groups, the initial limb shortening exceeded 4 cm (on average 4.27 ± 0.82) with a disease duration from seven to 72 years. The average limb shortening after surgery was 2.3 ± 0.46 cm. The reason for incomplete elimination of leg shortening was a high risk of traction damage to the femoral and sciatic nerves, rigidity of para-articular tissues, and the presence of gross post-operative scars. The Harris score for long-term endoprosthesis replacement averaged 80 points.

Complete elimination of shortening was achieved in 70 (75.5%) patients who were examined. The difference in length of the lower extremities averaged 3.5 ± 0.84 cm. The duration of the disease averaged 12 ± 8.86 years. The Harris scale averaged 78 points. Almost all patients in this group were more or less satisfied with the results of treatment; however, it was noted that patients with a greater initial shortening of the limb had Harris scores in the post-operative period below. Moreover, the main indicators that reduce the overall assessment were a significant limitation of the amplitude of

movements in the hip joint and the presence of pain, most often along the front surface of the thigh. In addition, traction neuropathy of the sciatic nerve was observed in two patients and femoral neuropathy requiring prolonged treatment were observed in three patients.

The patients who we examined, excessive lengthening of the operated limb was detected in seven (7.5%) patients. Disease duration averaged 4.6 ± 2.56 years. The average limb shortening before the operation was 3.7 ± 0.76 cm. The average excess lengthening after the operation was 1.67 ± 1.03 cm, and the total, taking into account its initial shortening, from 3 to 5 cm. Harris score was 68 points. Moreover, the main criterion that lowered this indicator was pain syndrome and restriction of the amplitude of movement in the operated joint.

So that, it was noted that the restoration of the length of the limb during hip joint arthroplasty by more than 3 cm and with a long period of joint disease (more than 3 years) is accompanied by a limitation of the amplitude of movements.

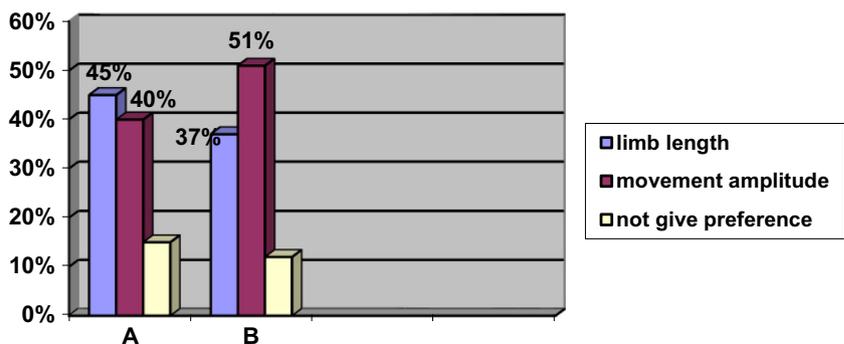
After detailed examination of their expectations and informing about the possibilities of this operation, patients who had planned the operation of hip joint were asked to choose between the amplitude of movement in the joint or the length of the limb. The results are as follows: 42 (45%) patients for normalizing limb length, 38 (40%) patients for restoring movement amplitude, and 13 (15%) patients could not give preference to one or another parameter (Fig. 2). A survey of patients previously operated upon for more than one year, which eliminated or practically eliminated shortening of the limb ($N = 78$) (except for patients with excessive lengthening), showed that if they had been given a choice between the amplitude of movement and the limb length, then 40 (51%) patients would prefer joint mobility, 29 (37%) leveling of limb length and 9 (12%) patients did not determine preferences (Fig. 2).

When analyzing the age composition of the interviewed patients, it should be noted that before the operation and after it the most of patients who preferred the length of the limb were patients aged 45 years on average (from 18 to 56), while older patients preferred normalization the amplitude of movement in the hip joint ($p < 0.05$) (Figs. 3 and 4).

Table 2 The results of changing the length of the limb after endoprosthesis of the hip joint

Versions of the result of the correction	Disease duration (years)	Difference of leg length before surgery (cm)	The difference in the length of the legs after surgery (cm)	HHS
Saving limb shortening $n = 16$ (17%)	7–72 (42.3 ± 24.5)	> 4 cm (4.27 ± 0.82)	Limb shortening 2–3 cm (2.3 ± 0.46)	80 (95% CI, 78.4 to 83.4%)
Full restoration of limb length (leveling) $n = 70$ (75.5%)	4–26 (12 ± 8.86)	3–4 cm (3.5 ± 0.84)	0	78 (95% CI, 74.6 to 80.2%)
Excess limb lengthening $n = 7$ (7.5%)	0.5–8 (4.6 ± 2.56)	3–4 cm (3.7 ± 0.76)	Limb lengthening 1–2 cm (1.67 ± 0.6)	68 (95% CI, 63.5 to 73.5%)

Fig. 2 Comparative chart of patients' wishes regarding preferences between leveling the length of the limbs and joint mobility **a** before the operation, **b** after the operation of the hip joint arthroplasty



Discussion

According to previously obtained data, lengthening of the lower limb in 48.28% causes pain syndrome of various localization: in the inguinal region in 30%, the anterior surface of the thigh in 21%, the lumbosacral spine in 43%, the gluteal region in 5%, the lateral surface thighs in 16% and on the back of the thighs in 6% [5].

Considering the results of the study performed for hip joint endoprosthesis with limb shortening of more than 3 cm, it should be borne in mind that the elimination of limb shortening may not always give a positive result. So, before the operation, it is necessary to analyze all the factors that may have an impact on this.

First of all, this is the magnitude of the original shortening. It is absolutely clear that the larger it is, the more difficult and traumatic the operation will be and moreover the tension of the soft tissues, including vessels and nerves, with all the ensuing consequences, will be expressed.

The second factor is the age of existence of this shortening. Long-existing uncompensated by shoes shortening gradually forms a stable compensatory-adaptive reaction with irreversible changes on the part of the musculoskeletal system in the form of pelvic distortion, spinal curvature, muscular-ligamentous retraction, and movement stereotype [6].

The elimination of shortening the limb on this background causes regression of the compensations of the musculoskeletal system formed during the long-term existence of the vicious

position of the lower limbs it is accompanied by a long and painful condition. [7]. In such patients, it is advisable to perform CT scan evaluation of length and whole body X-ray (EOS system).

The third factor is age. As we know, many body properties are gradually lost with age: muscle tone changes, the amplitude of movements in joints decreases, a person's ability to adapt to new conditions of existence is lost, rehabilitation treatment exercises are difficult to master, etc. So, the older the patient is, the less likely it is to restore the range of motion, providing basic self-care techniques (walking the stairs, putting on shoes, using public transport, etc.)

The fourth is previous operations on the hip joint, after which coarse cicatricial tissues are formed in the joint area, significantly limiting the mobility of the joint.

The fifth factor: individual rigidity and plasticity of tissues that affect the mobility of the joints. In turn, the rigidity or stiffness of soft tissues is due to the state of collagen fibres, consisting of interconnected using chemical bonds of microfibrils. The strength of such bonds determines the physical properties of a particular type of collagen. The more connections are, the harder the collagen fibre. The quantity and quality of these bonds depend both on the innate characteristics and the level and nature of the metabolism [8]. The plasticity of tissue is provided by protein—elastin. The amount of which also varies. In medicine, it is common to use medium—statistical indicators of the amplitude of movement in each particular joint. At the same time, it is known that from 15

Fig. 3 Comparative chart of preferences of patients aged up to 45 years between the leveling of the length of the limbs and the mobility of the joint **a** before the operation, **b** after the operation of the hip joint arthroplasty

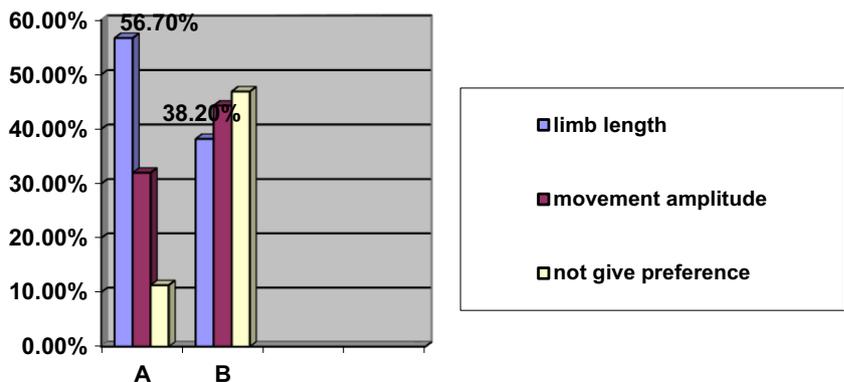
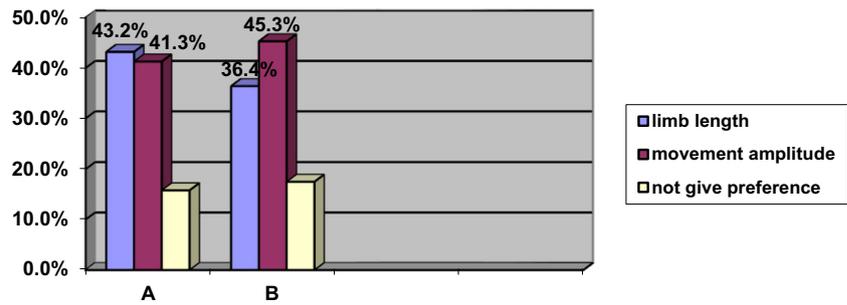


Fig. 4 Comparative chart of preferences of patients over the age of 45 years between the leveling of the length of the limbs and joint mobility **a** before surgery, **b** after surgery of the hip joint



to 25% of people are capable of performing movements in the amount slightly exceeding average statistical indicators. This condition is known as joint hypermobility. This may be a version of the norm and occurs at teenagers and young people, mostly female, and also as pathological deviation.

The opposite is the restriction of mobility in the joints, due to the increased rigidity of the soft tissues (joint capsule, increased muscle tone, stiffness of the tendon-ligament apparatus).

Accordingly, the amplitude of movement in the operated joint, accompanied by lengthening of the limb in these patients will be reduced.

The next factor that can cause a complication in the elimination of limb shortening during the hip joint arthroplasty is the patient's neurological status. As already mentioned, with a long-term shortening of one of the lower extremities, persistent compensatory changes are formed primarily from the side of the spine, which contributes to the appearance of neurological disorders. There can be the interrelated changes in the spine and lower extremities, known as hip-spine syndrome. The leading place among the neurological complications is occupied by neuropathies of the sciatic and femoral nerves of varying severity, which can occur with excessive lengthening of the limb [9, 10].

According to Sunderland, lengthening of the lower limb by more than 6% of its original length caused damage to the nerves and if we consider that the average value of the sciatic nerve is 75 cm, that is, 4 cm (6%)—this is the critical value of elongation [11]. The experiments on the animals shown that stretching the nerve reduces the cross-sectional area of the bundles, increases intrafascial pressure, and reduces intrafascicular blood flow [8]. Ippolito et al. noted that stretching by only 8% showed the first signs of reduced blood supply, and that an elongation of 15% caused almost complete ischemia [12].

Pre-operative skeletal traction for the gradual reduction of the femoral head to the true acetabulum does not bring the desired results, so many orthopaedic surgeons have refused it [13].

In the process of lengthening of the limb during hip joint arthroplasty, the provoked nerve roots may experience the excessive tension, which leads to traction injury. In order to

avoid such complications, it is necessary to carry out tests of patients for stretching the femoral and sciatic nerves [14].

Conclusion and recommendations

So that, incorrect lengthening of the lower limb during arthroplasty leads to lameness, discomfort, muscle tension, which ultimately leads to pain. A special position among this category of patients is occupied by patients with a long-existing large difference in the length of the limbs. They include patients with congenital or old traumatic dislocations of the femur, false joints of the femoral neck in which shortening of more than 4 cm was observed for over three years.

Momentary elimination of leg shortening during hip joint arthroplasty in this category of patients leads to some deviations from the desired result. Often, this is accompanied by long dragging pains. More than 63% of operated on such patients have limited movement in the joint, especially flexion [5].

Considering the possibility of the appearance of such effects, we must carefully analyze the pre-operative planning of hip arthroplasty. It should be borne in mind that the length of the lower limb in hip joint arthroplasty is influenced by three parameters: the depth of the femoral component relative to the tip of the greater trochanter, the position of the acetabular component relative to the centre of rotation of the joint and the amount of offset. Each of these techniques has its own characteristics and influence on the biomechanics of the joint [15].

As known, the optimal version for arthroplasty is to install the components of the endoprosthesis in accordance with the normal anatomical parameters; however, taking into account the shortening of the limb, this is not always advisable or technically achievable.

Moreover, in order to ensure an optimal result of hip arthroplasty and ensure the necessary amplitude of movements, it is advisable to use prediction criteria of the leveling of the limb length, which are:

1. The duration of the disease
2. Presence of consequences of previous operations

3. Gender, age,
4. Degree of tissue rigidity
5. Severity of hip-spine syndrome and scoliotic deformity.

So in pre-operative planning, it is advisable to analyze the mobility not only in the unhealthy, but also in healthy joints, which will help to obtain information about the rigidity and hypermobility of para-articular tissues and to predict the fullness of the recovery movement. To do this, you can use the method of Beyton, assessing the ability of the subject to perform five movements at a certain angle.

For the prevention of traction damage to the sciatic or femoral nerves, a characteristic we used to identify the symptom of Lasegue [14]. If a positive symptom is detected during this process, the traction damage during hip joint arthroplasty, and especially accompanied by lengthening of the limb, increases dramatically. So, together with neurosurgeons, it is necessary to conduct additional research and at first eliminate the cause of nerve root compression and only then perform hip arthroplasty.

So in practice, it is not always necessary to strive for the full restoration of the length of the operated limb, which even more can be compensated with shoes.

This is especially true for the old people, for whom the process of rehabilitation in the conditions of a significant changes or restoration of the length of the limb becomes very hard and sometimes impossible. Much more important for them, than the same length of the legs, is the restoration of the amplitude of movement in the joint, which one provides the possibility of full self-care, painless musculoskeletal function of the joint, and so that the high “quality” of life.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent Informed consent was obtained from all individual participants.

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