

УДК 616.748:616.728.3-053.3]-089](045)

DOI: <http://dx.doi.org/10.15674/0030-59872024441-47>

## The treatment of knee joint instability in congenital limb deformities

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*The defect in the formation and subsequent genesis of crossed ligaments manifests as knee joint instability and is accompanied by a range of consequences of congenital developmental disorders of the lower limbs. Objective. To analyze and summarize the knowledge and practical experience in treating children with knee joint instability due to congenital developmental disorders of the lower limbs at the Children's Orthopedic Clinic of the State Institution «Institute of Spine and Joint Pathology named after Prof. M. I. Sytenko of the National Academy of Medical Sciences of Ukraine». Methods. A prospective study was conducted on patients treated from 2019 to 2024, with a retrospective control group (32 healthy children) treated from 2008 to 2019. Results. Surgical intervention was performed using the classical SUPER knee procedure. Our team identified shortcomings and therefore added the Yamamoto procedure, as well as a combination of the Yamamoto procedure and tibial tuberosity transfer to improve treatment outcomes. Additionally, to correct moderate axis deformities of the limb, the method of hemiepiphysiodesis using our patented metal construction and instrumentation was preferred. Adequate rehabilitation treatment is a key stage in restoring knee joint function, as it reduces the risk of complications such as joint contractures and stagnant vascular manifestations in the lower limbs. Conclusions. Early and high-quality surgical treatment allows for the prevention of knee joint instability and enhances its functional capabilities. The modifications made to the SUPER knee procedure have improved knee joint stability in the postoperative period compared to the classical technique, as evidenced by the absence of medial instability and a lower degree of anterior displacement. Comprehensive treatment increases the functionality of the knee joints and reduces further degenerative changes, thereby improving the patient's quality of life.*

*Дефект закладки і подальшого генезу схрещених зв'язок проявляється у вигляді нестабільності колінного суглоба та супроводжує комплекс наслідків уроджених вад розвитку нижніх кінцівок. Мета. Проаналізувати й узагальнити знання та практичний досвід лікування дітей з нестабільністю колінного суглоба внаслідок уроджених вад розвитку нижніх кінцівок у клініці дитячої ортопедії ДУ «Інститут патології хребта та суглобів ім. проф. М. І. Ситенка НАМН України». Методи. Проведено проспективне дослідження пацієнтів, які лікувалися в період з 2019 по 2024 роки з ретроспективною контрольною групою (32 здорові дитини), яка лікувалася в період з 2008 по 2019 роки. Результати. Виконано оперативне втручання за класичною процедурою SUPER knee, нашою командою враховано недоліки, тому додано операцію Yamamoto, комбінацію операції Yamamoto та транспозиції горбистості великогомілкової кістки для покращення результатів лікування. Також із метою корекції помірних порушень вісі кінцівки надано перевагу методиці геміепіфізіодезу за допомогою запатентованої нами металоконструкції й інструментарію. Адекватне реабілітаційне лікування є ключовим етапом у відновленні функції колінного суглоба, бо зменшує ризик ускладнень у вигляді контрактур суглоба, застійних судинних проявів у нижніх кінцівках. Висновки. Раннє та якісно проведене оперативне лікування дозволяє уникнути нестабільності колінного суглоба та збільшити його функціональні можливості. Зміни внесені в процедуру SUPER knee покращили стабільність колінного суглоба в післяопераційному періоді порівняно з класичною методикою, що підтверджується відсутністю медіальної нестабільності та меншим ступенем прояву переднього зміщення. Комплексне лікування дозволяє збільшити функціональність колінних суглобів і зменшити подальші дистрофічні зміни в ньому, а отже покращує комфорт життя пацієнта. Ключові слова. Колінний суглоб, уроджені вади розвитку нижніх кінцівок, лікування, реабілітація, діти.*

**Keywords.** Knee joint, congenital malformations of the lower extremities, treatment, rehabilitation, children.

## Introduction

A defect in the formation and subsequent development of cruciate ligaments manifests itself in the form of knee instability (KI) and accompanies a complex of consequences of congenital malformations of the lower extremities (CMLE). KI is difficult to diagnose early due to the lack of load on the lower extremity. Symptoms of KI arise during the treatment of longitudinal defects, which increases the functionality of the limb and the load on the joint, and are manifested as a result of a violation of intra-articular compensatory mechanisms. This gave rise to a misconception among clinicians that all cases of KI are the consequences of incorrectly performed correction of deformation and shortening for CMLE, so they did not pay attention to the peculiarities of the anatomy of the knee joint in each individual clinical case [1]. In order to prevent the progression of KI during CMLE treatment, the distraction schemes and designs of external fixation devices (EFD) were modified, which had a result only at the time of correction and did not prevent or stop the development of KI in the future. Previously published works [2–4] highlighted that the main cause of KI development in CMLE is the initially clinically undetected congenital impairment of the cruciate ligaments and its consequences in the form of changes in the anatomy and spatial configuration of most joint structures, which develop as a compensatory mechanism.

Analyzing the scientific literature, we found only various options for surgical correction of congenital malformations of the cruciate ligaments in the form of descriptions of successful clinical cases, which determined the chosen topic of the study.

*Purpose:* to analyze and summarize the knowledge and practical experience of treating children with knee joint instability due to congenital malformations of the lower extremities in the pediatric orthopedics clinic of the State Establishment “Professor M. I. Sytenko Institute of Spine and Joint Pathology of the NAMS of Ukraine”.

## Materials and methods

On the basis of the State Establishment “Professor M. I. Sytenko Institute of Spine and Joint Pathology of the NAMS of Ukraine”, after approval by the Ethics Committee (Protocol No. 247 dated 25.11.2024), a prospective study of patients treated in the period from 2019 to 2024 with a retrospective control group (32 healthy children) treated in the period from 2008 to 2019 was conducted.

Two separate studies were carried out within the framework of this research. The first analyzed

the effectiveness of reconstructive interventions on the capsular ligament apparatus of the knee joint in 45 children (group A, which was further divided into subgroups A1 and A2) and 19 individuals (group B), who were treated conservatively in the period from 2014 to 2024. The second study compared the results of treatment of 19 children (subgroup A1) who received the classic SUPER knee (Systematic Utilitarian Procedure for Extremity Reconstruction knee) operation [6, 7] in the period from 2014 to 2018 and 26 children (subgroup A2) who underwent systemic treatment, which included additional examinations, modifications to the SUPER knee procedure, and a developed postoperative rehabilitation regimen used in the period from 2019 to 2024.

Among the children of group B, 5 children with KI in CMLE were separately observed, who received conservative treatment, 3 of them were recommended for surgical intervention, but the parents decided to treat the children conservatively. According to the results of testing and clinical examination, after the rehabilitation, the condition of 2 children (with minor manifestations of KI) improved. In patients with significant manifestations of KI, who chose conservative treatment contrary to recommendations, it worsened within 3 years.

To objectify and analyze the condition of the knee joints (KJ) in children who participated in the study, a questionnaire and assessment were carried out using the Pedi-IKDC scale. Due to the fact that the adaptation of Pedi-IKDC into the Ukrainian language was absent and began to be used by our team only in 2020 [8], the condition of patients from group A1 and most of group B was unfortunately assessed only after treatment, and the obtained indicators were used to compare the results between groups of patients in order to identify the effectiveness of different types of treatment.

In patients of group A2, information was collected before and after surgery and rehabilitation, which made it possible to assess the effectiveness within the group. Considering that children with CMLE periodically undergo surgery to correct the length of the limb, the questionnaire was carried out in the period between these stages.

All study participants underwent an X-ray examination of both knees with calculation of the parameters of the shape of the intercondylar fossa of the femur (ICFF) for the diagnosis of congenital malformations of the cruciate ligaments. The methods and comparisons with the parameters of the norm described in the previous article [5] were used. X-rays

were performed on the OPERA T90cex radiographic and fluoroscopic system.

All patients underwent ultrasound diagnosis (US) of both knees to detect cruciate ligament defects. The examination was performed on the TOSHIBA Aplio 500 (TUS-A500) ultrasound diagnostic system.

Electroneuromyography (ENMG) of the muscles of both lower extremities was also performed to study changes in their activity in KI in children with CMLE and to evaluate the muscle response to the treatment. The examination was performed using an electroneuromyograph NEURO-MVP-8 (Neurosoft). The assessment was performed using turn-amplitude analysis. Due to the large age difference between the examined patients, a mathematical comparison of the parameters with a healthy limb was used to study the condition of the muscles of the limb in CMLE and the difference was expressed in percentages. During the examination, the following parameters were studied: maximum, average, total amplitude, average frequency, and the ratio of amplitude to frequency of electrical signals.

All patients underwent a manual examination of the anterior-posterior stability of the KJ using the sliding drawer test.

Considering that CMLE is mostly a unilateral pathology, the KJ of the healthy limb was chosen as the standard for assessing the condition of KJ in CMLE.

We did not use the Lachman test (pivot-shift, Macintosh test) because it did not allow us to visually assess and measure the degree of instability.

In the case of detection of anterior-posterior instability, its degree was determined projectionally by means of photofixation of the knee joint at a distance of 1 m before the test and at the point of maximum displacement on the camera with subsequent calibration of the ruler of the processing program to the ruler applied to the thigh during photography. The degree of displacement was measured in millimeters.

For information processing, Myrian®, AutoCAD2021®, Excel® software was used.

All obtained statistical data were summarized and compared using Student's t-test.

### Results and their discussion

Based on the results of the examination of 154 KJ (64 healthy KJ and 90 KI) using clinical tests, we would like to note several features:

- unlike traumatic KI in children with CMLE, manual examination of KI is a painless procedure, so muscle tone does not interfere;
- in displacement of the tibia in KI in CMLE, there is a soft stopping point;
- during the anterior drawer test, in addition to the feeling of displacement of the tibia relative to the thigh, it is also visible how a fossa is formed between the lower edge of the patella and the tuberosity (hump) of the tibia;
- displacement of the tibia relative to the thigh of up to 2 mm is often found in healthy KJ, so it was accepted as the norm.

After analyzing the data obtained from the drawer test and taking into account the Pedi-IKDC survey, we divided the results (Table 1) by displacement indicators:

- 1) 0–2 mm — stable, (average Pedi-IKDC result — more than 75);
- 2) 2–4 mm — clinically present instability, which is weakly symptomatic (average Pedi-IKDC result — 65–75);
- 3) 5–7 mm — instability, which leads to a slight limitation of activity (average Pedi-IKDC result — 45–65);
- 4) more than 7 mm — instability with significant discomfort and limitation of the child's activity (average Pedi-IKDC result up to 45).

Having analyzed the obtained indicators of lateral stability of the knee joint, we divided the results (Table 2) as follows:

Table 1

**Analysis of the drawer test data with Pedi-IKDC results**

Group	Ratio before the period of surgical treatment	Total number of KJ	Displacement of the shin relative to the thigh, mm			
			0–2	2–4	5–7	more than 7
Healthy	none	64	64 (100 %)	—	—	—
A <sub>1</sub>	after	19	—	14 (74 %)	4 (21 %)	1 (5 %)*
A <sub>2</sub>	before	26	—	—	8 (31 %)	18 (69 %)
	after	26	16 (62 %)	10 (38 %)	—	—
B	none	19	—	2 (10 %)	3 (16 %)	14 (74 %)

Note. \* — The child suffered a post-operative injury from a fall while playing football, which resulted in a rupture of the grafts (confirmed by MRI).

- negative test — no lateral opening;
- conditionally positive test — slight lateral opening with a soft stopping point.

According to the radiological examination, all healthy knee joints corresponded to the parameters of the age norm specified in our previously published article [5] (Table 3).

The parameters of 62 knee joints that had instability significantly differed from the established normal values. However, 2 children with CMLE who had instability (slight deviation from the norm) were recommended to first undergo conservative and rehabilitation treatment.

During the Pedi-IKDC questionnaire, the data described in Table 4, except for the following cases:

- one patient from group A1 who tore the graft while playing football (after stabilization, the func-

tion of the KJ was restored, the child was still able to play sports);

- two people from group B who were recommended conservative treatment — their results were sharply different from the study group (42 points before and 68 after; 41 points before and 71 after).

The results obtained were analyzed and calculations were studied using the Student's t-test, the following was established: the well-being of children after surgical stabilization was significantly better than in patients with KI before and with conservative treatment. The value of the unpaired t-test was 26.84; and the number of degrees of freedom  $f$  was 85. The critical value of the Student's t-test was 1.99; at a significance level of  $\alpha$  — 0.05.

The best result was recorded in group A2 after treatment and rehabilitation. Compared with group A1, the value of the unpaired t-test was 24.89; its critical value was 2.018; and the number of degrees of freedom  $f$  was 42, at a significance level of  $\alpha$  — 0.05. The difference between group A2 before and after surgery and rehabilitation was statistically significant, the result of the calculations of the paired t-test was 53.379; and the number of degrees of freedom  $f$  was 24. The critical value of the Student's t-test for this number of degrees of freedom was 2.064.

The well-being and condition of the KI gradually worsens as the child grows older and with increasing

Table 2

**Analysis of test data on lateral stability of the KJ**

Group	Total number of KJ	Ratio before the period of surgical treatment	Negative test	Positive test
Healthy	64	none	64	—
A <sub>1</sub>	19	after	9	10
A <sub>2</sub>	26	before	4	22
		after	26	—
B	19	none	4	15

Table 3

**Parameters of the age norm of KJ during radiological examination**

Index	Age groups	Parameter	Standard deviation
The ratio of the width of the intercondylar fossa of the femur to the depth, C	6 (18–15)	0.93	± 0.16
	5 (14–12)	0.97	± 0.15
	4 (11–8)	1.34	± 0.41
	3 (7–6)	1.79	± 0.33
	2 (5–3,5)	2.51	± 0.35
	1 (3–2)	2.87	± 0.44
The ratio of the width of the intercondylar fossa of the femur to the width of the condyles of the femur, A	6 (18–15)	0.32	± 0.04
	5 (14–12)	0.32	± 0.05
	4 (11–8)	0.39	± 0.05
	3 (7–6)	0.35	± 0.03
	2 (5–3,5)	0.38	± 0.05
	1 (3–2)	0.40	± 0.07
The ratio of the width of the femoral condyles to the width of the intercondylar fossa of the femur, B	6 (18–15)	2.82	± 0.29
	5 (14–12)	3.07	± 0.47
	4 (11–8)	2.57	± 0.33
	3 (7–6)	2.80	± 0.24
	2 (5–3,5)	2.70	± 0.30
	1 (3–2)	2.55	± 0.33



Table 4

**Pedi-IKDC survey results**

Group	Period of surgical treatment	Number of observation units (n)	Arithmetic mean (M)	Median (Me)	Standard deviation ( $\sigma$ )	Coefficient of variation (Cv, %)	Standard error of an arithmetic mean (m)
A <sub>1</sub>	after	19	64.05	64	1.14	2.30	0.35
A <sub>2</sub>	before	26	41.73	42	2.24	5.36	0.45
	after	26	78.04	78	2.59	3.32	0.53
B	none	17	35.71	36	1.53	4.29	0.38
After surgical treatment		44	72.00	75	7.25	10.07	1.09
Before surgical treatment + conservative treatment		43	39.35	40	3.35	8.97	0.54

Table 5

**Electroneuromyography findings**

Patient group		Max. ampl.	Aver. ampl.	Tot. ampl.	Aver. part.	Ampl./part.
A <sub>1</sub>		-15.2	-18.7	-18.5	-19.4	-22.3
A <sub>2</sub>	before intervention	-26.8	-27.1	-27.6	-26.9	-27.7
	after intervention	-6.9	-5.4	+5.5	+6.4	-7.2
B		-34.4	-31.2	-34.2	-29.8	-31.6

Note. – indicates the lag of the values of the limb with CMLE compared to the healthy one, + — increase in the values of the limb with CMLE compared to the healthy one

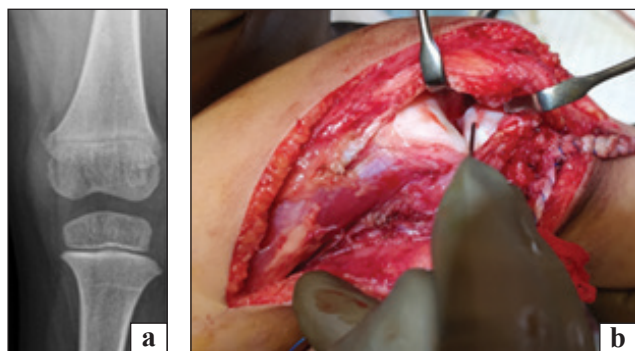


Fig. 1. Photographic impressions of the KJ in CMLE: a) X-ray of the tunnel projection with signs of underdevelopment of the ICFF; b) intraoperative view of the KJ



Fig. 2. Appearance of the formed autoligament

activity (comparing patients in group A2 before treatment and group B).

Comparison showed that in group A1 the value of the unpaired t-test was 10.22; the number of degrees

of freedom *f* was 41. The critical value of the Student t-test was 2.021; at the level of significance  $\alpha$  was 0.05 (corresponding to the already published one).

In the process of studying the diagnostic ultrasound data, it has been found that it is of little use for determining the etiology of KI in young children, because at 8 years of age it is almost impossible to visualize the cruciate ligaments [9], and the planning of treatment tactics occurs at the early stages in children of the younger age group.

After electroneuromyography, the results shown in Table 5 were obtained.

The surgical intervention (Fig. 1) was performed according to the classical SUPER knee procedure [6], our team considered the shortcomings, therefore, the Yamamoto operation [10], the combination of the Yamamoto operation and the transposition of the tibial tuberosity [11, 12] were added to improve the treatment results. Also, to correct moderate violations of the limb axis, the hemiepiphysiodesis technique was preferred using our patented metal structure and instruments [13, 14].

According to the classical SUPER knee, autoligaments were taken from the broad fascia of the thigh, for this purpose, a massive surgical arc-shaped incision was performed along the entire thigh, which, together with the long duration of the operation, led to ischemia of soft tissues and complications with

subsequent wound healing [5–18]. However, these actions were necessary for the selection of the graft and the high-quality formation of autoligaments (Fig. 2).

Summarizing the statistical and mathematical data, the best result was recorded in patients after reconstruction of the ligamentous-capsular apparatus of the knee joint. No complications were detected during the subsequent stages of treatment, namely, distraction of the limb using EFD [19, 20]. The introduced changes to the classical SUPER knee procedure and the developed rehabilitation program significantly improved the results of treatment of the KI [21–23].

The first steps of rehabilitation begin before the treatment process. Practice has shown that children after surgery respond more quickly to rehabilitation if they are taught basic exercises before surgery [24–29]. During rehabilitation treatment, the doctor must be careful and keep a reasonable balance between learning exercises, their consolidation and increased training.

Adequate rehabilitation treatment is a key stage in restoring the function of the knee joint, as it reduces the risk of complications in the form of joint contractures, congestive vascular manifestations in the lower extremities.

## Conclusions

Early and qualitatively performed surgical treatment allows you to avoid instability of the knee joint and increase its functional capabilities. Changes made to the SUPER knee procedure improved the stability of the knee joint in the postoperative period compared to the classical method, which is confirmed by the absence of medial instability and a lower degree of manifestation of anterior displacement in group A2 compared to A1.

The proposed changes to the classic SUPER knee technique and the rehabilitation program significantly improved the outcome of KI treatment, as confirmed by Pedi-IKDC testing and electroneuromyography indicators.

Comprehensive treatment allows to increase the functionality of the knee joints and reduce further dystrophic changes in it, and therefore improves the patient's life quality.

**Conflict of interest.** The authors declare the absence of a conflict of interest.

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The article has been sent to the editors 29.10.2024

## THE TREATMENT OF KNEE JOINT INSTABILITY IN CONGENITAL LIMB DEFORMITIES

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