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Parameters of the intercondylar fossa of the femur in childrenin normal conditions and with congenital malformations of the lower limbs

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According to literature sources, radiography can indirectly visualize congenital insufficiency of the cruciate ligaments both in isolated form and in combination with other congenital malformations of the lower extremities. Objective. To study the parameters of the intercondylar fossa of the femur in children of different age groups with stable/unstable knee joints due to congenital malformations of the lower limbs using instrumental imaging methods. Methods. A prospective diagnostic study was conducted of 359 knee joints of 217 children who were treated at the pediatric orthopedics clinic from 2019 to 2022 and with a retrospective control group (2010–2021). limbs, as well as with congenital malformations of the lower limbs. X-ray examinations were performed on the OPERA T90cex X-ray and fluoroscopic system. Results. 217 patients took part in the study, including 105 patients without knee joint pathology and 112 with congenital malformations of the lower limbs. Comparison of the accuracy of radiological diagnostic indicators was performed using the Student's t-test with the results of computer and magnetic resonance imaging studies, which showed the absence of a statistically significant difference in the results research. A diagnostic study was also conducted to find the regularity of the development of the knee joints and to identify the parameters of the radiological norm of the development of the intercondylar fossa of the femur in children of different age categories. Conclusions. Using the results of instrumental studies, the parameters of the intercondylar fossa of the femur in children of different age categories with stable and unstable knee joints due to congenital malformations of the lower limbs were investigated. The results of the study should be taken into account for the diagnosis of congenital defects of the knee joint.

Згідно з літературними джерелами, рентгенографія може опосередковано візуалізувати вроджену недостатність схрещених зв'язок як в ізольованій формі, так і в поєднанні з іншими вродженими вадами розвитку нижніх кінцівок. Мета. Вивчити параметри міжвиросткової ямки стегнової кістки в дітей різної вікової категорії зі стабільними/нестабільними колінними суглобами за вроджених вад розвитку нижніх кінцівок за допомогою інструментальних методів візуалізації. Методи. Проведено проспективне діагностичне дослідження 359 колінних суглобів 217 дітей, які проходили лікування в клініці дитячої ортопедії з 2019 по 2022 рік, із ретроспективною контрольною групою (2010–2021 рр). У дослідженні взяли участь діти віком від 2 до 18 років, як без патології нижніх кінцівок, так і з уродженими вадами розвитку цієї локалізації. Діагностування виконували на рентгенографічній і флюороскопічній системі OPERA T90cex. Результати. У дослідженні прийняли участь 217 пацієнтів, з них 105 пацієнтів без патології колінних суглобів та 112 із уродженими вадами розвитку нижніх кінцівок. Порівняння точності показників рентгенологічної діагностики виконано за допомогою t-критерію Стьюдента з результатами комп'ютерних і магнітно-резонансних томографічних досліджень, які показали відсутність статистично значущої різниці в результатах дослідження. Також проведено діагностичний аналіз для знаходження закономірності розвитку колінних суглобів і виявлення параметрів рентгенологічної норми розвитку міжвиросткової ямки стегнової кістки у дітей різних вікових категорій. Висновки. Використовуючи результати інструментальних досліджень було виявлено параметри міжвиросткової ямки стегнової кістки в дітей різної вікової категорії зі стабільними та нестабільними колінними суглобами за вроджених вад розвитку нижніх кінцівок. Результати дослідження доцільно враховувати для діагностики вроджених вад колінних суглобів. Ключові слова. Колінний суглоб, уроджені вади нижньої кінцівки, рентгенометрія, нестабільність колінного суглоба.

Keywords. Knee joint, congenital defects of the lower limb, radiography, instability of the knee joint

Introduction

According to the literature, radiography can indirectly visualize congenital insufficiency of the cruciate ligaments, which occurs in 0.017 per 1,000 newborns and manifests itself both in an isolated form and in combination with other congenital malformations of the lower limbs (CMLL) (fibular hemimelia, congenital shortened hip, etc.) [1, 2]. Radiography can be useful for the differential diagnosis of knee joint instability (KJI) after injuries, as well as for the choice of further tactics during the planning of treatment and correction of CMLL in children. D. Paley et al. [3] pointed out that in patients with such defects, it is necessary to take into account the duration and stages of treatment, and the fact that at the beginning of treatment, clinically and symptomatically, KJI due to a deficiency of cruciate ligaments may have few manifestations, but may appear already during the correction of limb deformation due to destabilization compensatory mechanisms and increased load on the limb [4, 5].

One of the scientists who nevertheless paid attention to this were N. M. Manner et al. [6], who in their study proved a direct relationship between the change in the shape of the intercondylar fossa of the femur (IFF) and the deficiency of the cruciate ligaments using radiography and arthroscopic control. J. L. Walker et al. [7], while investigating the KJI with fibular hemimelia, found a regularity in the underdevelopment of the intercondylar elevation of the tibia in the case of cruciate ligament deficiency. The mentioned works are of scientific significance, but at the same time of little practical use, since radiological parameters were studied in children with full or almost full growth. Usually, the literature does not specify the parameters of the age norm for children of different age categories, which could be used in clinical practice for the differential diagnosis of KJI after injuries or during the planning of treatment of children with CMLL.

Purpose: to study the parameters of the intercondylar fossa of the femur in children of different age groups with healthy (stable) and unstable knee joints with congenital malformations of the lower limbs using instrumental imaging methods.

Material and methods

On the basis of State Establishment “Professor M. I. Sytenko Institute of Spine and Joint Pathology of the National Academy of Sciences of Ukraine”, after the approval of the committee of bioethics (Protocol No. 17 dated 26.11.2019), a prospective diagnostic study was conducted of 359 knee joints of 217 children who were treated in the pediatric orthopedics clinic from 2019 to 2022, and with a retrospective control group (2010–2021).

The study involved children aged 2 to 18 years, both without pathology of the lower extremities and with CMLL. All patients (or their representatives) gave informed consent to participate in the study.

The children were divided into two cohorts. The first included persons from 2 to 18 years old who were undergoing diagnosis or treatment at the institution at the time of the study. Patients from this cohort were divided into two groups. The first was completed by patients without pathology of the lower extremities, the second by children with CMLL. These groups were divided into 6 subgroups by age (the age gradation was chosen according to Sadofyeva [8]), where group I consisted of patients from 2 to 3 years old, II — 3.5–5, III — 6–7, IV — 8–11, V — 12–14 years, VI — 15–18. They underwent a clinical examination for the stability of the KJ (Lachmann and sliding drawer test) and further radiography in the tunnel projection. Patients were positioned according to Holmblad's method [9], which does not lead to projection distortions (Fig. 1).

The second cohort included patients from 2 to 18 years of age, who were treated in the department from 2010 to 2021, and whose history contained computed tomography (CT) or magnetic resonance imaging (MRI) studies of the knee joints. Division into groups and subgroups was carried out similarly to the first cohort. At the beginning of the study, it was planned to use the method proposed by Manner et al. [6, 10], which determined the height of the fossa from the joint gap to the top of the dome and the width of the fossa and the distal part of the thigh parallel to the joint gap at the level of the popliteal groove. During the analysis of the results of X-ray studies, we encountered the problem that the popliteal groove was not visualized in children younger than 10 years. In order to standardize all age groups, we changed the calculation method, in which the height was measured as indicated above, and the width of the distal part of the femur and the IFF at the level of the joint space, while, if necessary, extending the line of the fossa along the inner surface of the lateral condyle.

To compare and derive the parameters of the norm, parameter indicators were entered, i. e. the ratio of the width of the IFF to the width of the femoral condyles (index A), the ratio of the width of the condyles to the width of the IFF (index B), the ratio of the width to the height of the IFF (index C) (Fig. 2).

Fig. 1. Performing radiography in the tunnel projection (location by Holmblad)

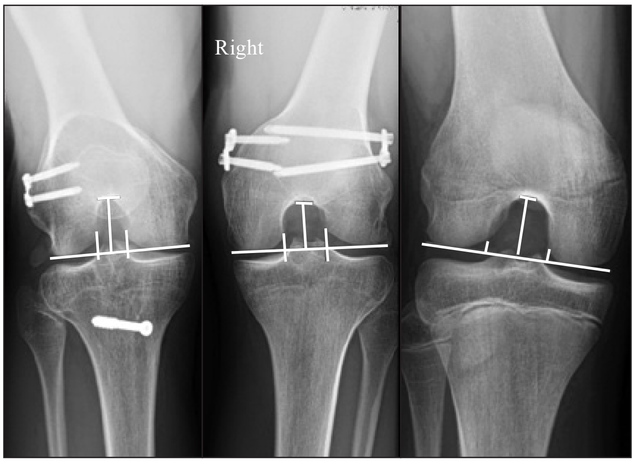

Fig. 2. Schematic representation of parameter indices in children with various pathologies of the knee joint

Table 1

Distribution of study participants by age

Group (years)	Cohort I (without KJ pathology)		Cohort II (with CMLL)	
	number			
	patients	KJ	patients	KJ
I (2–3)	15	20	11	19
II (3,5–5)	6	11	12	20
III (6–7)	7	13	12	21
IV (8–11)	30	47	31	58
V (12–14)	21	31	18	35
VI (15–18)	26	38	28	46
Total	105	160	112	199

Table 2

Distribution of patients of different age groups according to knee joint pathologies

Group (years)	Cohort I (without KJ pathology)	Cohort II (with CMLL)	
	patients	stable	unstable
I (2–3)	10	5	5
II (3,5–5)	10	10	1
III (6–7)	10	9	2
IV (8–11)	20	17	9
V (12–14)	14	11	1
VI (15–18)	20	20	3
Total	84	72	21

The diagnostic analysis was performed on the radiographic and fluoroscopic system OPERA T90cex (General Medical Merate S. p. a., Italy) by an experienced radiologist. Measurements were made in the following programs: Myrian®, RadiAnt® AutoCAD2021®. Calculations and graphs were processed in the Excel® software.

To determine the accuracy of the results of X-ray diagnostics, a comparison was made using the Student's t-test based on the results of CT and MRI studies.

Results

217 patients were involved in the study, including 105 patients without KJ pathology and 112 with CMLL, the distribution by age groups is shown in Table 1.

90 (180 KJ) children were clinically analyzed and radiological examination of 90 patients (177 CS) was performed (Table 2).

The results of 84 (119 KJ) CT studies were assessed, of which 64 KJ were without pathology and 55 were with CMLL. From the sample of patients with congenital malformations of the lower limbs, 6 had KJI and underwent surgical treatment for this reason.

The results of 42 (42 KJ) MRI results were analyzed, of which 20 KJ without congenital pathology and 22 with CMLL, among which 9 had a history of KJI and underwent surgical treatment for this reason.

To clarify the numerical parameters and study the results of the indices obtained in children with stable KJ under various types of instrumental studies, comparative graphs were created, which compare indices A (Fig. 3), B (Fig. 4), C (Fig. 5).

The results of statistical processing of the variation series of parameters of a stable KJ are given in Tables 3–6.

A comparison of the parameters of the obtained indices in children with stable KJ and KJI according to CMLL is shown in the comparison graphs: A (Fig. 6), B (Fig. 7), C (Fig. 8).

Table 3

Results of X-ray examinations

IIndex	Age group	Number of observations (n)	Arithmetic mean (M)	Median (Me)	Standard deviation (σ)	Coefficient of variation (Cv), %	Mean error of the arithmetic mean (m)
C	I (2–3)	15	2.85	2.95	0.35	12.33	0.09
	II (3,5–5)	20	2.55	2.51	0.24	9.26	0.05
	III (6–7)	19	1.92	1.90	0.18	9.28	0.04
	IV (8–11)	37	1.48	1.43	0.38	25.49	0.06
	V (12–14)	25	0.90	0.89	0.23	25.76	0.05
	VI (15–18)	40	0.99	0.96	0.16	16.51	0.03
A	I (2–3)	15	0.37	0.36	0.03	7.49	0.01
	II (3,5–5)	20	0.38	0.37	0.06	15.21	0.01
	III (6–7)	19	0.34	0.34	0.02	6.66	0.01
	IV (8–11)	37	0.35	0.34	0.03	9.08	0.01
	V (12–14)	25	0.29	0.30	0.02	8.62	0.01
	VI (15–18)	40	0.30	0.31	0.03	10.17	0.00
B	I (2–3)	15	2.65	2.64	0.09	3.34	0.02
	II (3,5–5)	20	2.79	2.77	0.22	7.81	0.05
	III (6–7)	19	2.89	2.91	0.14	4.89	0.03
	IV (8–11)	37	2.84	2.89	0.28	10.50	0.05
	V (12–14)	25	3.40	3.33	0.30	8.62	0.01
	VI (15–18)	40	2.86	2.82	0.30	25.76	0.05

Table 4

Results of computer tomography studies

IIndex	Age group	Number of observations (n)	Arithmetic mean (M)	Median (Me)	Standard deviation (σ)	Coefficient of variation (Cv), %	Mean error of the arithmetic mean (m)
C	I (2–3)	299	2.65	2.84	0.44	16.59	0.16
	II (3,5–5)	9	2.60	2.87	0.49	18.65	0.17
	III (6–7)	11	1.37	1.37	0.24	17.17	0.07
	IV (8–11)	43	1.44	1.34	0.43	29.77	0.07
	V (12–14)	33	1.00	0.97	0.17	16.92	0.03
	VI (15–18)	29	0.99	0.94	0.18	17.87	0.03
A	I (2–3)	9	0.48	0.48	0.06	13.56	0.02
	II (3,5–5)	9	0.41	0.42	0.03	7.84	0.01
	III (6–7)	11	0.40	0.40	0.02	4.85	0.01
	IV (8–11)	43	0.41	0.40	0.05	11.69	0.01
	V (12–14)	33	0.36	0.36	0.06	15.44	0.01
	VI (15–18)	29	0.34	0.34	0.03	9.72	0.10
B	I (2–3)	9	2.10	2.04	0.28	13.38	0.10
	II (3,5–5)	9	2.39	2.36	0.18	7.70	0.07
	III (6–7)	11	2.46	2.46	0.12	18.65	0.17
	IV (8–11)	43	2.43	2.49	0.24	9.97	0.04
	V (12–14)	33	2.82	2.77	0.43	15.37	0.08
	VI (15–18)	29	2.80	2.86	0.54	19.14	0.10

Table 5

Results of magnetic resonance imaging studies

IIndex	Age group	Number of observations (n)	Arithmetic mean (M)	Median (Me)	Standard deviation (σ)	Coefficient of variation (Cv), %	Mean error of the arithmetic mean (m)
C	I (2–3)	8	2.44	2.35	0.53	21.83	0.20
	II (3,5–5)	—	—	—	—	—	—
	III (6–7)	—	—	—	—	—	—
	IV (8–11)	10	1.02	1.02	0.16	15.52	0.05
	V (12–14)	5	1.03	1.06	0.10	9.34	0.05
	VI (15–18)	9	0.91	0.91	0.07	8.31	0.03
A	I (2–3)	8	0.44	0.44	0.07	15.57	0.03
	II (3,5–5)	—	—	—	—	—	—
	III (6–7)	—	—	—	—	—	—
	IV (8–11)	10	0.39	0.39	0.05	13.02	0.02
	V (12–14)	5	0.35	0.37	0.03	8.62	0.02
	VI (15–18)	9	0.35	0.36	0.04	11.08	0.01
B	I (2–3)	8	2.29	2.35	0.34	14.90	0.13
	II (3,5–5)	—	—	—	—	—	—
	III (6–7)	—	—	—	—	—	—
	IV (8–11)	10	2,58	2,51	0,36	13,91	0,12
	V (12–14)	5	2,81	2,67	0,25	9,05	0,13
	VI (15–18)	9	2,84	2,73	0,32	11,16	0,11

Table 6

Results of processing of generalized indicators

IIndex	Age group	Number of observations (n)	Arithmetic mean (M)	Median (Me)	Standard deviation (σ)	Coefficient of variation (Cv), %	Mean error of the arithmetic mean (m)
C	I (2–3)	32	2.69	2.87	0.44	16.31	0.08
	II (3,5–5)	30	2.54	2.51	0.35	13.69	0.06
	III (6–7)	30	1.72	1.79	0.33	19.13	0.06
	IV (8–11)	90	1.41	1.34	0.41	29.05	0.04
	V (12–14)	63	0.98	0.97	0.15	15.79	0.02
	VI (15–18)	78	0.98	0.93	0.16	16.44	0.02
A	I (2–3)	32	0.42	0.40	0.07	16.43	0.01
	II (3,5–5)	30	0.39	0.38	0.05	13.43	0.01
	III (6–7)	30	0.37	0.35	0.03	9.02	0.01
	IV (8–11)	90	0.38	0.39	0.05	13.54	0.01
	V (12–14)	63	0.33	0.32	0.05	16.53	0.01
	VI (15–18)	78	0.32	0.32	0.04	12.14	0.00
B	I (2–3)	32	2.40	2.55	0.33	13.61	0.06
	II (3,5–5)	30	2.64	2.70	0.30	11.35	0.05
	III (6–7)	30	2.73	2.80	0.24	8.91	0.04
	IV (8–11)	90	2.62	2.57	0.33	12.67	0.03
	V (12–14)	63	3.05	3.07	0.47	15.30	0.06
	VI (15–18)	78	2.87	2.82	0.29	10.07	0.03

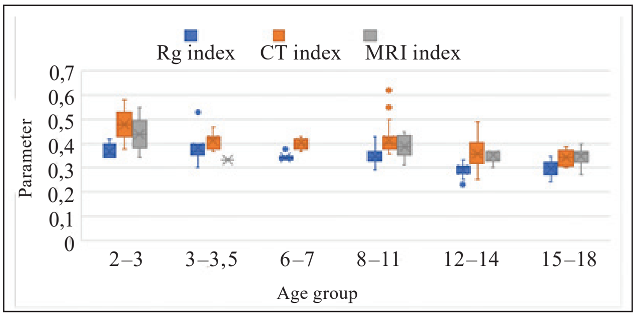

Fig. 3. Graph comparing the ratio of the width of the IFF to the width of the femoral condyles (Index A)

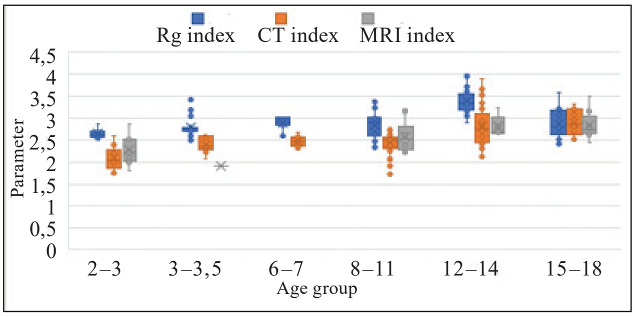

Fig. 4. Graph comparing the ratio of the width of the condyles to the width of the IFF (Index B)

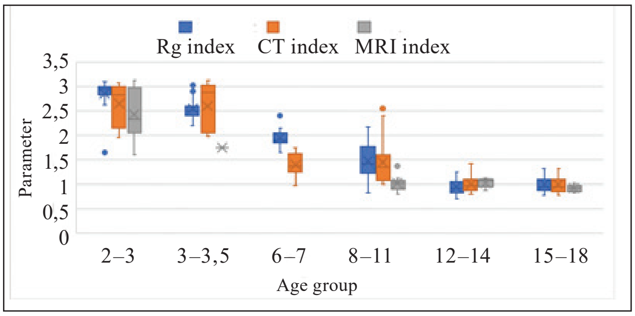

Fig. 5. Graph comparing the ratio of the width to the height of the IFF (Index C)

In order to find out the accuracy of the results of the performed X-ray diagnosis, a comparison was made using the Student's t-test with the indicators of computer and magnetic resonance imaging studies. According to their results, it was proved that there is no statistically significant difference in the material we have processed. For instance, as a result of comparing the C index (the ratio of the width to the height of the IFF) using the calculation of the value of the paired t-criterion = 1.18; p = 0.24282, which shows the statistical insignificance of the differences, the number of degrees of freedom f = 67. The critical value of the Student's t-test for this number of degrees of freedom is 1.997 under the conditions of the level of significance α = 0.05.

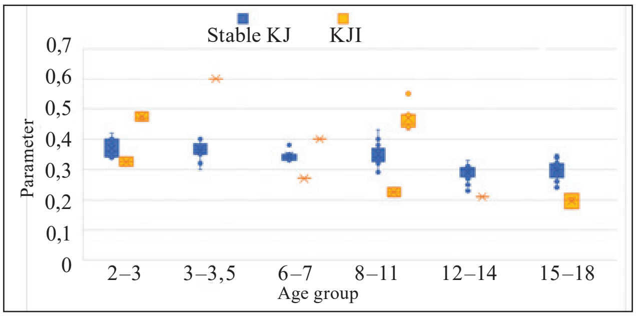

Fig. 6. Graph comparing index A in different age groups between normal and pathological parameters

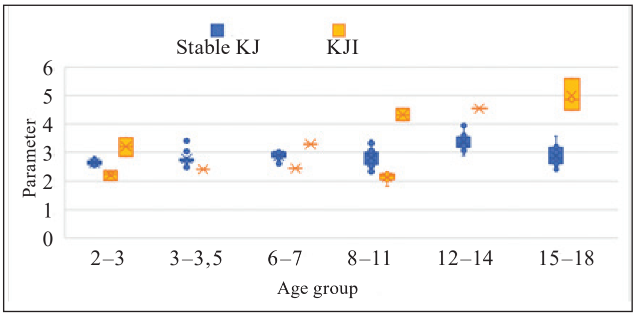

Fig. 7. Graph comparing index B in different age groups between normal and pathological parameters

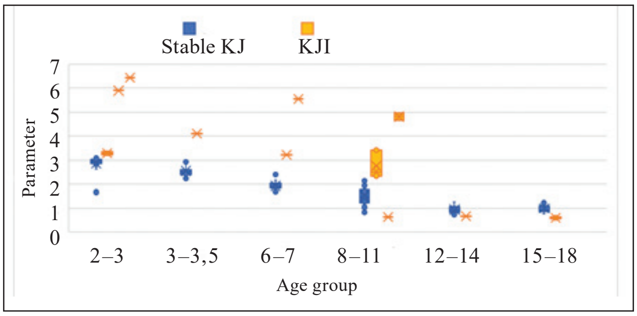

Fig. 8. Graph comparing index C in different age groups between normal and pathological parameters

Discussion

One of the features of children's orthopedics is that the parameters of the locomotor system change with age, therefore, knowledge of age norms is required for successful diagnosis and treatment of patients of different age groups. For example, Figures 9–11 show photoprints of radiographs of knee joints of patients of different age groups.

G. T. Manner et al. [5] in their study already highlighted the radiological parameters of IFF in children with KJI, but the limitation of this work is that a small sample was selected for the study and the children were of an older age group with complete or almost complete growth. However, the parameters of the age norm for children of different age categories are not specified in the literature.

Fig. 9. Photographs of the radiograph of a stable KJ of a 14-year-old patient N.

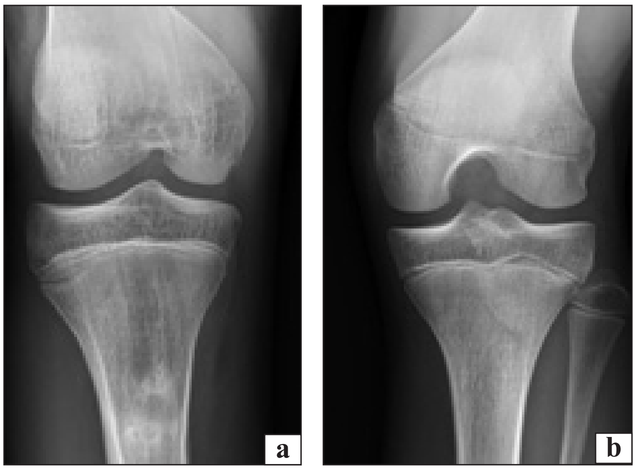

Fig. 10. Photographs of X-rays of a 15-year-old patient N.: a) stable hip joint; b) unstable KJ in CMLL

Therefore, we conducted a large diagnostic study to find the regularity of the development of KJ and to identify the parameters of the radiological norm of the development of IFF in children of different age categories.

All three indices selected for characterizing the parameters of the norm of the IFF and the studied features of the KJI according to the CMLL were informative (Figs. 6–8). But, in our opinion, the most optimal C index is the ratio of the width to the depth of the IFF.

We calculated the parameters of the norm for each index and age group (Table 7).

Conclusions

Using the results of instrumental studies (Rg, CT, MRI) of 359 knee joints in 217 subjects, the parameters of myasthenia gravis in children of different age categories with healthy (stable) knee joints and VJI according to CMLL were studied. Using the Student's t-test, the results of X-ray, CT, and MRI studies were compared and the results were found to have no statis-

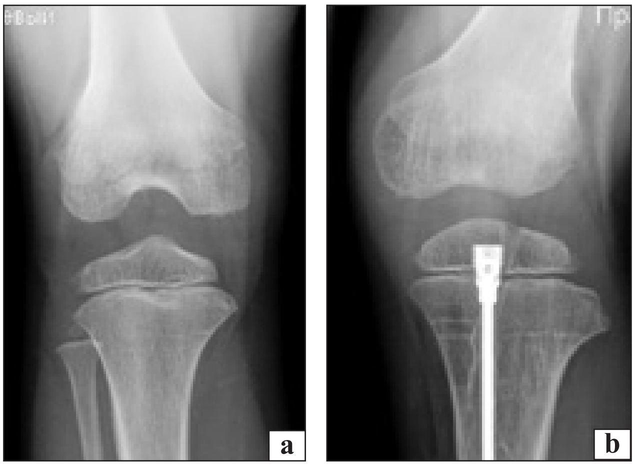

Рис. 11. Фотовідбитки рентгенограм КС пацієнтки Н., 7 років: а) стабільний КС; б) нестабільний КС за ВВРНК

Table 7

Normal parameters for each index depending on the age group

IIndex	Age group	Parameter	Standard deviation
C	I (2–3)	2.87	± 0.44
	II (3,5–5)	2.51	± 0.35
	III (6–7)	1.79	± 0.33
	IV (8–11)	1.34	± 0.41
	V (12–14)	0.97	± 0.15
	VI (15–18)	0.93	± 0.16
A	I (2–3)	0.40	± 0.07
	II (3,5–5)	0.38	± 0.05
	III (6–7)	0.35	± 0.03
	IV (8–11)	0.39	± 0.05
	V (12–14)	0.32	± 0.05
	VI (15–18)	0.32	± 0.04
B	I (2–3)	2.55	± 0.33
	II (3,5–5)	2.70	± 0.30
	III (6–7)	2.80	± 0.24
	IV (8–11)	2.57	± 0.33
	V (12–14)	3.07	± 0.47
	VI (15–18)	2.82	± 0.29

tically significant difference. The results of the study should be considered for the diagnosis of congenital defects of the knee joint.

Conflict of interest. The authors declare no conflict of interest.

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PARAMETERS OF THE INTERCONDYLAR FOSSA OF THE FEMUR IN CHILDRENIN NORMAL CONDITIONS AND WITH CONGENITAL MALFORMATIONS OF THE LOWER LIMBS

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