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Chapter

Knee Dislocation: Comprehensive Rehabilitation Program after Two-Stage Ligament Reconstruction

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Abstract

Knee dislocation is a multi-structure injury that usually requires surgical treatment. One of procedures is two-stage reconstruction that gives possibility to carry out rehabilitation after each of the stages in accordance with the requirements resulting from graft anatomy and biomechanics of the joint. The aim of the study is to analyze possibilities of using created rehabilitation program and to evaluate its effectiveness in a young woman who suffered an accident while practicing sports. The study of peak power shows differences between limbs primarily in maximum strength of the quadriceps muscle. With increasing load, differences in power in knee extension were 32, 17, and 61%. The rate of power development examination on force platform showed similar possibilities of operated and unoperated limb (best 19.5 cm test, 70–74 W/kg/s), however, in each subsequent trial operated limb achieved a worse result, which was not observed in healthy limb. Good results in Lysholm and IKDC 2000 knee assessment questionnaire (in sequence 95 and 81.6 points) 6 months after completed rehabilitation indicate good functional preparation of the joint, which is additionally confirmed by the jump test. Peak power test indicates the need to increase the elements of strength and endurance training in rehabilitation.

Keywords: knee dislocation, two-stage reconstruction, PCL, ACL, rehabilitation after reconstruction

1. Introduction

In light of epidemiological studies, 30% of joint injury cases concern knee joints. Of all knee ligament reconstructions, anterior cruciate ligament (ACL) reconstructions account for 80%, with 65% cases occurring during physical activity, both during recreational activity and practicing sports [1]. The most frequent injury mechanism is twisting movement at stabilized foot and flexed knee. Knee dislocation is usually connected with the impact of substantial external forces and is characterized by permanent or temporary losing the contact by the opposite articular surfaces [2]. In order for the injury to be categorized as dislocation, at least two of four ligaments that stabilize knee joint should be torn [3]. This injury is connected with the damage of various articular structures, sometimes also neurological and vascular.

Crucial ligaments protect the knee joint from excessive anterior-posterior translation. The posterior cruciate ligament (PCL) ensures the major force that resists the posterior drawer effect (95% of the force), whereas the anterior cruciate ligament (ACL) prevents the anterior drawer displacements and overextension of the leg in the knee joint [4]. The ligaments interweave with each other, thus limiting internal rotation of the knee. Another function of cruciate ligaments is also initiation of the correct sliding of the joint surfaces in the direction opposite to the rolling motion. Two collateral ligaments control joint displacements in the frontal plane: tibial collateral ligament, which prevents from the valgus movement, and fibular collateral ligament, preventing from the varus movement, with the most effective stabilization observed at the extended knee.

Structural deformation and the related functional failure of the ligament typically lead to the development of joint instability, termed disturbed joint movement control. In the case of tearing an individual ligament, the instability pattern is simple (e.g. tibial collateral ligament rupture: medial instability) or rotational (ACL rupture: anterior-medial-anterior-lateral instability). Knee dislocation with damage to all the stabilizing elements represents a complex instability: in addition to all the above types of instability, additional anterior-lateral-posterior-lateral instability and anterior-medial-posterior-medial instability are also observed [5].

Conservative therapies and surgical interventions have been used in the treatment of cruciate ligament injuries. The conservative treatment is used in the case of partial ligament damage, without substantial symptoms of joint instability in people with low physical activity aged over 40 years of age, leading little active lifestyles [6]. In the case of acute injuries, conservative treatment is aimed to eliminate edema, joint hydrarthrosis, and pain syndromes, ensuring proper and painless joint mobility and adequate muscular tension and neuromuscular control (proprioception).

The surgical interventions are used in patients with positive results of functional tests for evaluation of anterior cruciate ligament, such as the Lachman test, the anterior drawer test, and the pivot-shift test with coexistence of subjective symptoms of instability reported by patients during the interview, such as knee giving way. In young patients, especially those who are involved in sports, the sufficient indication for the surgery is ligament rupture diagnosed during a diagnostic examination using magnetic resonance (MR) or ultrasonography examinations.

An integral part of the patient treatment process is preoperative and postoperative rehabilitation. The procedures before the surgery are mainly aimed to obtain the range of joint motion needed for the reconstruction, prevent muscle atrophy, increase muscle strength, and improve proprioception. Early postoperative rehabilitation accelerates recovery and is usually started a day after the surgery. This procedure impacts significantly on reducing the time of patient's regaining full health [7, 8].

2. Study aim

In the case discussed in the study, patient's knee dislocation led to breaking the anterior and posterior cruciate ligament and fibular and tibial collateral ligaments with grade 1 injury to the medial meniscus (X-ray, MRI). For this complex injury, followed by multiple-stage treatment, an individual rehabilitation program was developed, with consideration for the type of injury, time between injury and the first and another reconstruction, method to perform reconstruction and available orthopedic aids. The aim of the study is to analyze the possibilities of using a comprehensive rehabilitation program and to evaluate its effectiveness after a two-stage reconstruction of knee ligaments.

3. Material and methods

The patient was female, aged 28 years, with body height of 170 cm and body mass of 55 kg (BMI 18.69). The injury occurred during a sport climbing activity due to the insufficiently protected landing surface. The training experience was 10 years of climbing, the trainings were usually completed three times a week with endurance components (running, swimming). Based on the information collected during the interview, the patient was a physically and professionally active person, which had a significant effect on the level of determination in activities leading to full recovery. The patient was qualified by the case physician for operative intervention. The entire process of diagnosis and surgical treatment was supervised by the same orthopedic surgeon and the surgery was performed in the same medical center.

3.1 Medical procedure and rehabilitation

After diagnostic examinations (knee joint X-ray examination) and excluding the damage of the popliteal artery and the peroneal nerve (ultrasound diagnosis of the popliteal fossa), the knee was reset into the proper position and immobilized by means of a knee joint immobilization bar (Sporlastic Genustabil 0°). A week later, the MRI examination revealed ruptured anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), and fibular and tibial collateral ligaments (MCL) with grade 1 injury to the medial meniscus. The operating intervention involved two separate reconstruction procedures. The first one concerned the posterior cruciate ligament, whereas the second was used to reconstruct the anterior and fibular ligaments. An additional procedure used before the reconstruction was arthroscopy in order to remove arthrofibrosis.

The individual program of rehabilitation developed for the purposes of the discussed case took into consideration the damages to all structures formed during the injury, guidelines of the case physician, and the basic principles of rehabilitation [9]. The complete rehabilitation procedure was divided into four stages.

The first stage directly after the injury lasted 10 weeks. The most important elements of the rehabilitation procedure together with the marked moment of their implementation are presented below (**Table 1**).

Due to the damaged falciform cartilage, the first stage focused on creation of the conditions for the cartilage growth: immobilization of the joint for 4 weeks, complete absence of the load to the limb. At this stage, the activities also involved stimulation of creation of the scar in the location of the tibial collateral ligament through transverse massage (this ligament is fused with the joint capsule and the correctly formed scar can successfully overtake the function of the ligament). An additional recommendation in the period of immobilization was to use a Medi PTS orthosis, which ensured complete extension of the leg and, through the special pad fixed under the knee, it pushed the lower leg to the front, thus preventing the joint capsule contraction. Preparation of the joint for posterior cruciate ligament reconstruction was started after 4 weeks from immobilization and consisted mainly in reaching 100–110° of relaxed flexion movement in the knee joint (the range required for reconstruction). After around 2 weeks and reaching 90°, the meniscal block was observed. After consultation with the doctor, the meniscus was excluded as a cause of mobility limitation and, since the range of motion needed for the reconstruction was not achieved, the arthroscopy was performed to remove arthrofibrosis.

After the arthroscopy which was performed to remove the resulting arthrofibrosis (ROM 0–80), the second stage of rehabilitation was started for 6 weeks and focused on the preparation of the joint and limb for reconstruction (**Table 2**).

Stage 1: directly after the injury: MRI: total rupture of ACL, PCL, MLC, PLC, grade 1 injury to the medial meniscus.					
Procedure	**Time after injury (weeks)**	**1**	**2–4**	**5–7**	**8–10**
PRICE and kinesiotaping (to reduce hematoma and edema)		+			
Elimination of the load to the joint		+	+		
Immobilization using Medi PTC (day/night) orthosis		+/+	+/+	−/+	−/+
Isometric exercises		+	+		
Stretching (to remove muscle tone) of muscles of rear and medial parts of the thigh		—	+	+	+
Joint mobilization (0–60°): passive, self-controlled exercises, patella mobilization		—	—	+	
Partial loading/learning to walk on crutches		—	—	+	
Proprioception learning		—	—	+	+
Full load		—	—	—	+
Further joint mobilization (>60°): active exercises in closed kinematic chain (CKC), mobilization		—	—	—	+

Table 1.
The first stage of rehabilitation.

Stage 2: following the arthroscopy aimed to remove arthrofibrosis and ACL stump debridement				
Procedure	**Time after injury (weeks)**	**Day 1–3**	**1–2**	**3+**
PRICE and kinesiotaping (to reduce edema)		+		
Joint mobilization (>90°): passive, self-controlled exercises		+		
Partial loading		+	+	
Immobilization using Medi PTC (day/night) orthosis		−/+	−/+	−/+
Isometric exercises		+	+	
Stretching (to remove muscle tone) of the hamstring muscles		—	+	+
Proprioception learning		—	+	+
Full load		—	—	+
Strengthening exercises (load + CKC)		—	—	+
Orthosis Jack PCL worn over the day from the second week.				

Table 2.
The second stage of rehabilitation.

The procedure following the arthroscopy was oriented at reaching 110° of the knee flexion as soon as possible. The active joint movement on the first day following the intervention was ca. 70°, which was a good prognosis for further improvement in mobility. The required range of motion was reached after 2 weeks. Therefore, active exercises were included, focused on increasing the strength of the quadriceps femoris muscles, hamstring muscles, and the gastrocnemius muscle. In order not to lead to tibia displacements with respect to the femur that are observed during muscle contraction, the exercises were performed only in closed kinematic chain (CKC). The elements of the proprioception training were also introduced

(initially with partial load and then with full load), approaching it more as learning and preparation to the postreconstruction period. It was suggested that a dynamic orthosis (Jack PCL) that pushes the lower leg to the front with constant force during limb loading and knee movements should be used for the remaining 4 weeks after the surgery.

The third stage started just after the reconstruction of the posterior cruciate ligament. The components of the rehabilitation procedure together with the time interval in which they were introduced for therapy are presented in **Table 3**. Attention can be paid, among others, delayed mobilization and loading of the limb.

Four months after the injury, PCL was already reconstructed. For the first 2 weeks, the isometric contraction of the quadriceps femoris muscles, thigh adductors, and knee flexors was performed. The knee joint during these exercises was slightly flexed and a pad was inserted under the lower leg to push the tibia forward. Similar extension of the knee joint occurred at a light knee flexion. The iliotibial band was relaxed manually and the patella was mobilized. All these interventions were continued for the following weeks. After 2 weeks, the passive movement in the joint was introduced, with the range of 10–30°. This is the range of motion in which none of the parts of the anterior cruciate ligament are tensed. During passive movements in the open kinematic chain, the tissues of the anterolateral fascicle are contracted up to 30°, whereas for the posteromedial fascicle—at full extension [10]. In order to maintain knee extension, the exercises of extension in the range of 30–0° were performed in closed kinematic chain (pressing the foot against the mattress leaning against the wall; later, the mattress was replaced with a ball). Closing the system and pressing the articular surfaces against each other minimized tension of the posteromedial fascicle (safe range of motion for the posterior cruciate ligament in the closed chain is 0–60°, [11]). After 4 weeks, these exercises were performed in partial load to the limb (using the crutches/ladder). With the reduced graft strength [12], the patient was informed about the absolute prohibition of performing the twisting movement of the limb, waving the limb, and maintaining relaxed limb in the standing position. The patient was wearing the orthosis all the time (the orthosis was removed only for the time of exercises), initially using the Medi PTS and, when the hydrarthrosis reduced, Jack PCL was used over the night and Medi PTS was worn at night. Joint mobilization was started after 8 weeks. Although the threshold of 30° was not exceeded for a long time, the knee responded very well to passive movements, with the range of motion increasing gradually (it was 0–90 after 2 weeks). Furthermore, the patients performed exercises that supported flexion combined with active extensions at home, in the lying position, with the healthy leg resting on the wall at a right angle and the operated leg (straight) moved downward sliding on the wall and returning to the initial position (initially the healthy leg put under the heel of the operated leg). After introduction of gentle joint immobilization in week 13, the flexion reached 120°. The focus was on increasing strength, with much work in closed kinematic chains in the range of 0–60 (the highest shear forces were recorded for 85–105°) and open kinematic chain (extension)—initially in the range of 0–30 increasing gradually to 0–75° (shear forces were the highest for 75–90°) and in flexion (due to high shear forces, it is safe to introduce them 4 months after reconstruction) [13, 14]. Wherever the hamstring group was engaged, the tibia was additionally protected against the posterior translation (counterpressure) [10]. The components of proprioceptive training were added, with gradually increased difficulty (by e.g. more unstable ground, i.e. patient distraction) and the elements of preoperative patient's activity were added. From week 15, the patients exercised on her own, focusing on increasing the strength and muscle endurance. All the exercises except for proprioceptive training were performed while wearing a Jack PCL orthosis (at maximal lower leg pushing

Stage 3: following the PCL reconstruction (*double-strand ST and G tendons, TightRope fixation with bioabsorbable screw, tibia-interference screw (bioabsorbable), additional fixation: bone bridge with Hi-Fi suture thread, repair of posteromedial fascicle of the PCL using the titanium anchor with double Hi-Fi suture thread)*									
Procedure	**Time after injury (weeks)**	**Day 1–3**	**1–2**	**3–4**	**5–6**	**7–8**	**9–10**	**11–15**	**16+**
PRICE and kinesiotaping (to reduce edema)		+							
Joint immobilization		+	+						
Isometric exercises of the quadriceps femoris muscle and adductors of the hip[*,**]		+	+						
Stretching exercises of the muscles of the hamstrings and the calf[*,**]		+	+	+	+	+			
mobilization of the patella and iliotibial band (ITB), prevention of the patellofemoral pain syndrome (PFPS)		—	+	+	+	+	+	+	
Passive exercises in the range of 10–30°		—	—	+	+	+			
Passive exercises of extension in CKC in the range of 0–30°[**]		—	—	+	+	+			
Partial loading		—	—	—	+	+			
Proprioception learning		—	—	—	+	+	+	+	+
Joint mobilization (>30°): passive, self-controlled exercises (with active extension)		—	—	—	—	—	+	+	
Full load		—	—	—	—	—	+	+	
Strengthening exercises (load + CKC 0–60°)		—	—	—	—	—	—	+	+
Endurance exercises for the limb		—	—	—	—	—	—	—	+
Muscle strength exercises in the open kinematic chain (OKC) in extension (initially 30–0, next 75–0) and flexion		—	—	—	—	—	—	—	+

Medi PTS orthosis for first 4 weeks (24 h), and next (from the moment when load was added) Jack PCL orthosis worn over the day and Medi PTS worn at night.
**Performed in light flexion.*
***With counterpressure at proximal section of the calf (orthosis pad, therapist hands).*

Table 3.
The third stage of rehabilitation.

force). A clear surgeon's recommendation was used to this type of orthosis during all activities for half a year following the reconstruction.

The second stage of recovery of the knee joint stabilizing structure, i.e. ACL reconstruction combined with fibular collateral ligament reconstruction was performed 18 weeks following the anterior cruciate ligament reconstruction and it was the starting point for the last—fourth stage of rehabilitation. The rehabilitation

proceedings differed significantly from the rehabilitation protocols after the reconstruction of the anterior cruciate ligament itself. Therapeutic elements, also with time reference, are shown in **Table 4**.

Orthopedic surgeon's recommendation was to immobilize the joint for 6 weeks. The procedure for the first 2 weeks differed from the previous stage, in that the lower leg was not supported in the posterior part in lying supine, and the isometric contraction was accompanied by co-contraction of the hamstrings. After 2 weeks, minimal flexion movements were added (passively, with the help of the therapist, 0–20°), with

Stage 4: following the reconstruction of ACL and PLC ***(ACL: middle third of the quadriceps femoris aponeurosis with bone block of the patella; fixation: thigh—7 × 20 mm titanium interference screw, tibia: 9 × 25 mm titanium interference screw, PLC (modified Larson's method) double-strand ST tendon from the contralateral limb; fixation: thigh—TightRope, peroneum—bone bridge around the peroneum with Hi-Fi suture thread)***

Procedure	Time after injury (weeks)	Day 1–3	1–2	3–4	5–6	7–12	13–15	16+
PRICE and kinesiotaping (to reduce edema)		+						
Joint immobilization		+	+					
Isometric exercises of the quadriceps femoris muscle and adductors of the hip		+	+					
Stretching (to remove muscle tone) of the hamstring muscles		+	+	+	+	+		
Mobilization of the patella and iliotibial band (prevention of PFPF)		—	+	+	+	+	+	
Passive exercises in the range of 0–20°		—	—	+	+	+		
Isometric exercises with co-contraction at full extension and slight flexion		—	—	+				
Partial loading		—	—	+	+	+		
Proprioception learning		—	—	+	+	+	+	+
Joint mobilization >20°: passive, self-controlled exercises (with active extension)		—	—	—	+	+	+	
Full load		—	—	—	+	+	+	
Correct gait exercises, exercises for proprioception with load		—	—	—	—	+	+	
Active exercises in CKC in the range of 0–60° with co-contraction		—	—	—	—	+	+	+
Vigorous muscle strength exercises in CKC, 0–90		—	—	—	—	—	+	+
Muscle strength exercises in OKC in extension (without range 30–0) and flexion (20–90)		—	—	—	—	—	+	+
Endurance exercises for the limb		—	—	—	—	—	+	+

Medi PTS orthosis worn for first 2 weeks (24 h), without the pad pushing the lower leg forward, and next (from the moment when load was introduced) Jack PCL orthosis worn over the day (with minimal pushing force) and Medi PTS worn at night.

Table 4.
The fourth stage of rehabilitation.

the isometric contractions with co-contraction of the hamstring muscles performed in full extension and in flexion of ca. 15°. Light flexion also allowed for proprioception exercises without load. Early introduction of the components of proprioceptive training (preferably already in the acute phase) accelerates regaining muscular control, which, with the knee extension, minimizes the risk of patellofemoral pain syndrome, and allows for maintaining the proper gait pattern [15]. Joint mobilization was started in the week 6. The large part of time was devoted to the improved proprioception: initially more in the sitting position and lying supine using balls and next in standing on the unstable ground (sensorimotor pads, mattresses with various softness, or platform for balance exercises) with both feet and then standing on one leg. Gait exercises were started after reaching the range of motion of 70° (ca. 2 weeks after mobilization started). Similar to the procedure following the PCL reconstruction, the focus was on gait symmetry and balance elements were added. Exercises of muscle force in closed kinematic chains were performed in the range of 0–60° excluding co-contraction of the hamstring muscles (half-squats with body forward inclination). In the 12th week, range of motion was 120°. After 12th week, new ligaments showed greater mechanical resistance [16], which allowed for introduction of muscle strength exercises with greater intensity: squats with load, mini-squats on one leg, and exercises with a stair stepper. Range of motion for the exercises in closed kinematic chain was 0–90°. In the open kinematic chain, the flexion movements were initially performed at 20–60°, whereas extension was 90–70° (the range was increased to 90–30° after ca. 4 months). No extension exercises were used in the range of motion of 30–0°, which leads to excessive tension of the graft [17]. Endurance training was also introduced (stair stepper, cycle ergometer) and components of proprioception training were extended by the components of various sports.

3.2 Subjective assessment of the effects of rehabilitation (Lysholm i IKDC 2000 questionnaires)

The patient was asked to evaluate the functioning of the knee joint twice: immediately after the completion of the fourth stage of rehabilitation (study 1) and then after 18 months (study 2). Two scales were used for the assessment: the knee joint assessment scale according to Lysholm and the IKDC 2000 knee assessment questionnaire (The International Knee Documentation Committee 2000). Both contain information about knee joint ailments and their impact on the functioning of the patient in daily life.

3.2.1 Lysholm knee scoring scale

The Lysholm scale contains eight points concerning pain and activity. In each point, the examined person is supposed to choose and check one of the statements which matches his or her pain or functions, each answer is a specific number of points. Maximal total score is 100 points, which means the highest subjective functional status possible (perfect level–over 90 points). The following functional levels are good: 84–90 points, satisfactory: 65–83 points and insufficient: below 65 points) [18].

3.2.2 IKDC 2000 questionnaire

The IKDC 2000 subjective knee evaluation form is composed of three blocks, which concern: pain, physical activity, and function during activity of daily living (ADL). Similar to filling the Lysholm form, the patient is expected to choose and check one of the statements that matches his or her complaints and abilities. For each answer, a certain number of points is assigned according to the principle that

0 means the greatest ailments or the most limited function. Highest final score that can be achieved being also 100 points.

The questionnaires with the instructions concerning the method of scoring and interpretation of the result were collected from the website of the American Orthopedics Society for Sports Medicine [http://www.sportsmed.org/research/IKDC_forms/].

3.2.3 Evaluation of the peak power and rate of power development

The examinations were performed in the laboratory of the Academy of Physical Education in Katowice, 18 months following the last stage of rehabilitation. Peak power (P_{peak}) of the knee flexors and extensors of operated limb was evaluated and the results were compared with the measurement for the healthy limb. Keiser A-300 Leg Curl/Leg Extension system was used for the examination.

The methodology consisted in maximal flexion and extension in the position that allowed for examination of only knee joint movements, that is, isolated work of the hamstrings in the case of flexion and quadriceps femoris muscles (more specifically, vastus muscles, excluding the rectus femoris) in flexion. The second limb rested relaxed on the device and was not stabilized. The examination was preceded by a short warm-up and several repetitions of the movement without load. Healthy leg was examined first. After receiving detailed instruction, the patient was asked to repeat the test of maximal knee flexion at the load of 10 kg twice at 5 s intervals. Next, the test was repeated with the load increasing to 20–30 kg. The tests were repeated in order to evaluate strength of knee joint extensors using the same loads. One-minute recovery break was used before the tests.

Rate of power development was measured by means of the force platform Accu Power. The measurement was preceded with accurate measurement of body mass and body composition analysis. After stepping on the platform, the patient adopted the test position: standing on one leg (the healthy leg was examined first) and then, at the signal of the test supervisor, the patient jumped up. After landing, the patient left the platform and repeated the procedure twice in consecutive tests. Next, the examination was repeated for the other limb.

4. Results

The results of the questionnaires are presented in **Table 5**.

In the power tests, differences in peak power of quadriceps femoris muscle were found between the operated and nonoperated limbs. With the increasing load, the differences in power in knee extension were 32, 17, and 61% (**Table 6**). Examination of the power in the hamstrings also revealed smaller differences at lower levels of load between the legs. The use of maximal tolerable load of 30 kg confirmed greater difference in power at the level of 15% (**Table 6**). **Tables 6** and **7** include better result of the two attempts performed during the test.

Scale	Points	
	Test number 1	**Test number 2**
Lysholm	85	95
IKDC 2000	78.2	81.6

Table 5.
The results of the questionnaires.

Intensity	Power [W]		Differences %
	Right lower limb (following the reconstruction)	Left lower limb (healthy)	
10 kg	128	169	32
20 kg	196	231	17
30 kg	156	251	61

Table 6.
Quadriceps femoris power (knee extension).

Intensity	Power [W]		Differences %
	Right lower limb (following the reconstruction)	Left lower limb (healthy)	
10 kg	77	78	1
20 kg	139	148	6
30 kg	137	157	15

Table 7.
Hamstring power (knee flexion).

Analysis of the jump height using the right (operated) limb and the nonoperated limb revealed differences in rate of power development achieved in consecutive tests. The highest power was recorded for the operated limb during the first jump (19.5 cm; 70.6 W/s/kg), with power reducing for consecutive tests to 18.7 cm, (67.9 W/s/kg) and 16.3 cm (59 W/s/kg), respectively. During the examination of the healthy limb, the values obtained in the first and second tests were lower compared to the operated limb, with 16.5 (62.7 W/s/kg) and 17 cm (64 W/s/kg), respectively. The power similar to that of the operated limb was obtained only for the third attempt, with its value reaching 19.5 cm (74 W/s/kg).

5. Discussion

5.1 Methods of surgical treatment

Knee joint dislocations account for fewer than 0.2% of all orthopedic injuries [19]. Collecting a numerous group of participants which would be homogeneous in terms of treatment methods in order to perform a detailed analysis is extremely difficult. Most studies have analyzed small groups of patients, which prevent from finding the best treatment options for knee joint displacement [20].

The doubts during the choice of the treatment method concern mainly the timing and stages of the interventions. Most studies that have demonstrated the advantage of sutures or ligament reconstruction in the acute phase (first 2–3 weeks following the injury) have examined only the anterior cruciate ligament. In the case of dislocation, Liow et al. [21] compared ACL and PCL stability and range of motion of the knee joint between two groups of patients: one group with the intervention in the acute phase (up to 2 weeks following the injury) and the other with the reconstruction performed following at least 6 weeks. The authors documented improved ACL stability for the intervention in the acute phase (first 2 weeks) and

no significant differences in PCL stability. No differences were also found in mobility between both groups. In light of general knee function, the levels of activity and anterior tibial translation, the results were better in the knees reconstructed within 2 weeks from the injury [21]. Another problem concerning the acute phase of the dislocation is the decision on suturing or reconstruction of the ligament. Sutures should be placed within 3 weeks following the injuries since scarring make the operation more difficult. It would seem that a torn ligament with preserved insertions can be more advantageous situation than a graft fixed in the bone tunnel. Furthermore, Mariani et al., in a study of 23 patients, demonstrated better outcomes in patients following total reconstruction of ACL and PCL compared to those after direct repair of the cruciate ligaments [22].

The attempt to perform a longitudinal analysis (12 years) of the results of treatment of knee joint dislocations and determination of prognostic factors for the results was started by Hirschmann et al. [23]. In a study of 68 patients, the researchers demonstrated a high effectiveness of the on-stage ligament reconstruction and indicated the correlation of the results with the demographic factors (e.g. age, education, and social status), body build (BMI), injury pattern (number of torn ligaments, damage to other structures), and operating timing. The factors that predispose to worse results include damaged fibular collateral ligament, combined reconstruction of ACL and PCL (according to the authors, most patients did not need PCL reconstruction), and delayed interventions > days [23]. Bin and Nam [11] presented very good results concerning the range of motion and stability in patients who underwent two-stage ligament reconstruction. The first stage involved reconstruction of medial and lateral ligament complexes within 2 weeks following the injury. The second stage, 3–6 month later, after regaining full range of motion, consisted in ACL reconstruction and/or PCL reconstruction if the substantial instability was found [11].

5.2 Rehabilitation proceedings

Fewer studies and, accordingly, fewer questions, were asked concerning postoperative procedures. The publications cited have discussed techniques of performing surgical interventions and final results concerning stability of ligaments and joint mobility. However, they failed to provide information about rehabilitation. Hirshmann et al. examined simultaneous reconstruction and emphasized the necessity of immediate mobilization in order to prevent arthrofibrosis. These authors recommended applying partial load to the orthosis with incomplete extension (10°) continued over 6 weeks. The limited passive and active movement was initiated immediately after the intervention, but the exercises of the first active flexion began following 6 weeks [23]. A very similar program was proposed by Robertson et al., who emphasized particular supervision and greater caution during knee mobilization following a complex reconstruction of several ligaments compared to that after isolated graft of a single ligament [19]. Ibrahim [24] encouraged to follow a more intensive rehabilitation program, recommending CPM movements in the rail within 0–30° and active knee flexion beginning as soon as 90° is reached. As emphasized by this author, this aggressive program, combined with early reconstruction of cruciate ligaments and repair of collateral ligaments, is highly effective in young and active patients [24].

The above examples suggest an overall idea of therapy following the complex reconstruction. However, there are no detailed protocols described after the interventions. It is known that some elements of therapy following ACL reconstruction differ extremely from those following PCL reconstruction. They suggest posterior

support of the lower leg after PCL reconstruction, with different ranges of motion, which must not be accessed during the exercises due to the highest shear forces in the joint or the necessity to evoke constant co-contraction of the hamstrings during exercises after ACL reconstruction. It seems to be impossible to develop an ideal therapeutic procedure to ensure protection of both ligaments following the simultaneous reconstruction. Therefore, an optimum is attempted to be found. However, it often leads to delayed onset of complications, for example, those concerning patellofemoral pain syndrome. If the patient's lower limb following the PCL graft is not adequately supported at the posterior part, the joint capsule contracture may occur in this region. Gravity force that acts on the lower limb during lying (e.g. sleeping) or activity of the hamstrings in the sitting position is among the causes of shrinking of the structures in the dorsal part of the joint. If the joint capsule shrinks, the lower limb will give way toward the posterior drawer, whereas fresh PCL graft will be unable to adapt to the new function in adequate conditions. Consequently, the biomechanical joint conditions will be changed and, despite the graft, the patella and its ligaments should overtake the function of preventing from posterior displacement of the tibia. This will lead to the progressing arthrosis of the patellofemoral and femorotibial joints, while efficiency of the quadriceps femoris muscle will be reduced [13]. Two-stage reconstruction that our patient underwent revealed differences in therapies following PCL and ACL reconstructions. The rehabilitation procedure discussed in detail takes into account the origin and quality of the graft (evaluated by the operating surgeon) and the gradual process of ligamentation (three periods: necrosis, collagen types I and II synthesis followed by collagen type III synthesis in the ligament, which is most similar to the primary ligament [25] and the meniscus which was additionally injured. Due to its damage, the first stage focused on creation of the conditions for the cartilage growth. As noted by Hwang and Kwoh, the best solution is to use less invasive methods, whereas correct rehabilitation leads to the desired treatment effects [26]. In turn, long immobilization of the limb in the third stage of rehabilitation was dictated by the force of the graft—determined by the thickness of the collected tendon, it was assessed as poor. It was recommended to immobilize the limb for 8 weeks in order not to apply load to the graft, because graft tissues are weaker during the first period (6–8 weeks) following the reconstruction. Infarction is observed, with the replacement tissue degenerated and disorganized. It is after 8 weeks (week 8–12) when the graft is revitalized and its mechanical value is improving. Therefore, in order to create optimal conditions for graft acceptance, the balance should be found between graft protection from the excessive tension and the movement that is needed for rehabilitation of any joint (it prevents arthrofibrosis, improves blood supply, and nutrition of the graft). It was demonstrated that insignificant joint tension is favorable since it stimulates formation of new collagen and arranges its fibers along the loading force, thus improving mechanical properties of the new ligament [16]. A large part of each rehabilitation stage was exercises in a closed kinetic chain. The characteristic pattern of CKC exercises is reflexive co-contraction of knee-flexing muscles and the quadriceps femoris muscle, with minimization of the shift of the tibia. Furthermore, during these exercises, the increase in the flexion in the knee joint leads to the increased contraction of the quadriceps femoris and higher contact surface of the patellofemoral joint, with the force acting on bigger surface, thus leading to lower pain in the joint [14]. Another typical element of rehabilitation after ligament reconstruction is proprioceptive training. Tearing the ligaments, which have numerous mechanical receptors, leads to substantial disturbances in proprioception. Only after reconstruction, the ligaments regain the sense of joint position (kinaesthesia) over the rehabilitation process, thus restoring the reflexive muscle stabilization [27].

5.3 Methods of joint functioning assessment

In practice, the most often tools used to assess the knee after rehabilitation are: functional tests, examination of the range of movement in the joint, questionnaires or, less often due to the required equipment, joint stability tests on the arthrometer. In this case on the week 15 after the intervention, the following functional tests were performed: jumps on one leg over an obstacle (different directions), long jumps on one leg, climbing a step, and running with directional changes. Apart from the test results, the quality was also evaluated (joint control during the movement, maintaining joint axis at landing). The examination was mainly aimed to subjectively evaluate joint functioning and was not analyzed in percentage values. Eastlack et al. [28] presented similar activities as tests of functional evaluation. They used maneuverability test, with the patient running across a flat surface on the 6.3 m square envelope, shuttle run (running over a short section with rapid directional changes on the operated leg to the opposite direction), crossover running over the short distance, jumping on one leg and triple jump. The measure of the dysfunction depending on the test is time difference in performing the task or asymmetry of the distance of the jump compared to the other side [28, 29]. Previous activities at the same level of intensity can be restored at 85–90% efficiency, at good proprioception, coordination and muscle balance, and without hydrarthrosis and pain during and after the exercise [17].

An important condition is also return to the full range of motion. After completion of the therapy, the patient was able to make full extension and 150° flexion (examination of passive motion) in the knee joint. The attention was attracted to substantial differences in circumferences. Long immobilization at individual stages led to muscle atrophy, whereas performing isometric exercises is insufficient to prevent this phenomenon. In this specific case, immobilization resulted from the simultaneous injury to the meniscus and the necessity of protecting the graft (evaluated as poor). The solution to the problems of protection of the grafted ligament is artificial grafts. Bielecki et al. [30] described simultaneous reconstruction of only the side complex and revision of ACL using polyester grafts (LARS) that allowed for an early and intensive rehabilitation. Active joint mobilization was used on the first day, with full loading and exercises that strengthen muscles of lower limbs. This procedure offered very good short-term effects (full range of motion, stable knee joint, no differences in circumferences), whereas differences were observed between the imaging examination (tibia displacement during MRI and positive score in the Lachman test) and subjective patient evaluation using forms [30].

To monitor the results of treatment, special scales are commonly used to assess subjective complaints of patients. In the discussed case, the patient submitted the knee joint to subjective evaluation of functioning. Both on the IKDC scale and Lysholm scale, higher (better) results were obtained in the later evaluations. On the IKDC scale, in the section of activities of daily living, the patient indicated some limitations due to the inability of performing the complete squat (squat position) or sitting on the heels. These activities were improved with gradual increase in the range of motion. On the Lysholm scale, the deducted points concerned, among other things, the knee giving way–the patient claimed that she experienced such problems during practising sports. Better result in the second evaluation was probably obtained due to the substantial (but still not enough) rebuilding the muscles in the operated limb.

Half a year after completion of the rehabilitation, the significant muscle deficit continued to have an effect on the evaluation of the peak power. The method proposed in this work is peak power test and the jump test on the force platform. Both in the case of flexion and extension, the value of peak power of the examined

muscles was greater for the left (nonoperated) limb. In the case of flexion, the difference was so small that it did not necessarily result from the injury and immobilization. In the case of extension, the power of the right limb muscles was significantly lower, accounting for 76% of the left lower limb power, whereas for the loads of 20 and 30 kg, this was 85 and 62%, respectively. The relatively good results for the load of 20 kg are likely to have resulted from the warm-up or increased patient motivation. However, overall tendency of the examination is the increasing disproportion between the value of peak power and the load: with the increasing load, the patient experienced more difficulty to achieve the result for the right leg similar to the left leg. The weakening of the quadriceps femoris muscle in the operated limb can be additionally confirmed by comparison of the first and second tests of the performed movement. Better result for the right and left limbs was achieved in the first test. Furthermore, the differences between the tests were substantially greater in the case of the operated leg. This means that the leg is not able to perform the extension movement twice with the same peak power, as it is the case with the left limb. Interestingly, the result of the jumping on the platform was better for the operated limb. This can be explained by the fact that, apart from the muscle strength, jumping ability is determined by such components as coordination and muscle balance, which may have resulted from the rehabilitation process which largely consisted in stabilization and working on the improved joint proprioception.

The proposed method of peak power test may turn out to be valuable information for both the physiotherapist and the patient himself. In the case of a significant deficit in the operated limb, it will be advisable to extend the therapy or individual work of the patient focused mainly on the muscle rebuilding. Then, the jump test seems to be a good tool for the functional assessment of the limb in players returning to the sporting activity.

6. Conclusions

Knee dislocation is quite a rare injury and therefore the choice of the treatment method raises many doubts. The choice of the method has an effect on the therapeutic treatment. The questions concerning the effectiveness of PCL reconstruction have been often raised among the authors of other studies due to frequent complications following the intervention. In our case, due to the age and athletic lifestyle of the patients, the necessity of restoring a complete stabilization apparatus seemed to be indisputable. A two-stage reconstruction allowed for different therapies following PCL and ACL reconstructions. Much attention was devoted to protecting of the PCL graft. The significant role in preventing complications was played by wearing an orthosis. The orthosis that pushed the lower limb forward (Jack PCL) following the injury and anterior cruciate ligament reconstruction seems to be necessary during therapeutic procedure: in certain private clinics, patients are refused to undergo the intervention until the orthosis is prepared. After completion of rehabilitation, the doctor evaluated the joint as stable in anterior-posterior direction (negative Lachman test, drawer test) with the first degree lateral instability. The patient was further recommended to gradually increase the load during training, care for maintaining muscle balance, perform exercises correctly, and continuously work to improve proprioception. The histological examinations demonstrated that the period of graft remodeling is 3 years and proprioception should be constantly stimulated in this period [16]. The power tests were expected to additionally evaluate the rehabilitation and point to the potential changes in the procedure (greater emphasis on strengthening of the limb following the periods of immobilization).

At the moment of the examinations, the subjective evaluation of the patient concerning joint functioning was positive, with the patient returning to full activity from the period before the accident. However, in order to fully confirm the positive final outcome of the used therapy, the examination with the evaluation of stability should be repeated after 5 and then after 10 years after rehabilitation is completed. It can be only stated that nowadays, the results of the tests with no pain symptoms and the lack of such symptoms during performance of the activities of daily living represent a good prognosis for a fast recovery.

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