The Knee 21 (2014) 80–85

Contents lists available at ScienceDirect

The Knee

Mid-term results of transphyseal anterior cruciate ligament reconstruction in children and adolescents

Sandro Kohl [a], Chantal Stutz [a], Sebastian Decker [a], Kai Ziebarth [b], Theddy Slongo [b], Sufian S. Ahmad [a], Hendrik Kohlhof [a], Stefan Eggli [c], Matthias Zumstein [a], Dimitrios S. Evangelopoulos [a,*]

[a] Department of Orthopaedic Surgery, Inselspital, University of Bern, Bern, Switzerland
[b] Division of Paediatric Trauma and Orthopaedics, Department of Paediatric Surgery, University Children's Hospital, Bern, Switzerland
[c] Sonnenhof Orthopaedic Clinics, Bern, Switzerland

ARTICLE INFO

Article history:
Received 25 June 2012
Received in revised form 6 July 2013
Accepted 10 July 2013

Keywords:
Anterior cruciate ligament
Children
Growth plate
Quadriceps tendon reconstruction
Rupture
Skeletally immature
Transphyseal reconstruction

ABSTRACT

Background: Optimal therapy for anterior cruciate ligament (ACL) rupture in the paediatric population still provokes controversy. Although conservative and operative treatments are both applied, operative therapy is slightly favored. Among available surgical techniques are physeal-sparing reconstruction and transphyseal graft fixation. The aim of this study was to present our mid-term results after transphyseal ACL reconstruction.
Methods: Fifteen young patients (mean age = 12.8 ± 2.6, range = 6.2–15.8 years, Tanner stage = 2–4) with open physis and traumatic anterior cruciate rupture who had undergone transphyseal ACL reconstruction with unilateral quadriceps tendon graft were prospectively analyzed. All children were submitted to radiological evaluation to determine the presence of clearly open growth plates in both the distal femur and proximal tibia. Postoperatively, all patients were treated according to a standardized rehabilitation protocol and evaluated by radiographic analysis and the Lysholm–Gillquist and IKDC 2000 scores. Their health-related quality of life was measured using the SF-12 PCS (physical component summary) and MCS (mental component summary) questionnaires.
Results: Mean postoperative follow-up was 4.1 years. Mean Lysholm–Gillquist score was 94.0. Thirteen of the 15 knees were considered nearly normal on the IKDC 2000 score. The mean SF-12 questionnaire score was 54.0 ± 4.8 for SF-12 PCS and 59.1 ± 3.7 for SF-12 MCS. No reruptures were observed. Radiological analysis detected one knee with valgus deformity. All patients had a normal gait pattern without restrictions.
Conclusion: Transphyseal reconstruction of the anterior cruciate ligament shows satisfactory mid-term results in the immature patient.

1. Introduction

The prevalence of anterior cruciate ligament (ACL) ruptures in children and adolescents is unknown. They are estimated to occur primarily during contact sport activities [1–9]. Among soccer players aged 5 to 18 in the United States, ACL ruptures constitute 30.8% of all symptomatic knee injuries and 6.7% of all injuries [10].

Besides isolated ACL ruptures, additional injuries such as damage to collateral ligaments and associated meniscal tears may occur. The prevalence of such additional injuries is mostly double-digit, ranging up to 100% depending on the study [11–16]. Both conservative and operative treatment options are available for the paediatric population. However, because this patient group is characterized by the presence of an open physis, ACL ruptures provoke some controversy as to optimal treatment strategy, conservative or operative. This controversy is further exacerbated by the scarcity of data regarding long-term sequellae [17]. Only a few studies have so far examined the long-term results of transphyseal ACL reconstruction in children and adolescents [11,12,14,18–22].

Conservative treatment can be difficult because of noncompliance and may cause secondary meniscal tears due to shearing forces [11,18,19,23]. Moreover, a high rate of degenerative changes may occur, as observed by Mizuta et al. [24] after a mean follow-up of 51 months.

As in adults, a number of surgical techniques are available for repair of ACL ruptures in children and adolescents, including ligament repair, nonanatomic extra-articular tenodesis procedures, physeal-sparing reconstruction and transphyseal fixation using hamstrings, bone–patella–bone, quadriceps and fascia lata autografts [17,25–27]. However, a major concern in the treatment of these injuries in children is the integrity of the growth plate. Injury to the growth plate can cause limb malalignment and limb length discrepancy, including both growth arrest and overgrowth [28–30]. Since 65% of the leg length leads from the distal femur and the

* Corresponding author at: Department of Orthopaedic Surgery, Inselspital, University of Bern, 3010 Bern, Switzerland. Tel./fax: +41 313813411.
E-mail address: ds.evangelopoulos@gmail.com (D.S. Evangelopoulos).

0968-0160/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.knee.2013.07.004

proximal tibia, transphyseal reconstruction techniques are regarded with concern in patients with open growth plates [31]. In a recent meta-analysis, transphyseal ACL reconstruction is reported to offer a lower risk of growth disturbances compared to physeal-sparing techniques. Growth disturbances leading to differences in leg length and axis deviation were seen after a median follow-up of 40 months in approximately 1.8% of cases treated operatively with suture repair or graft reconstruction. The mean risk of rerupture was 4.8% [32].

In the present study, we report a series of 15 children and adolescents treated with transphyseal autologous quadriceps tendon graft reconstruction for intraligamental ACL ruptures, with a mean follow-up of 4.1 years. The objective is to assess quality of life, function and risk for posttraumatic deformity after transphyseal ACL reconstruction.

2. Patients and methods

Fifteen children and adolescents with open growth plates (12 boys, 3 girls) and normal contralateral knees underwent transphyseal autologous quadriceps tendon graft reconstruction of the ACL to treat traumatic ACL rupture. All children were classified according to Tanner's criteria [33]. Radiological evaluation with anteroposterior and lateral x-rays revealed clearly open growth plates in both the distal femur and proximal tibia at the time of surgery. Nine of the patients suffered from a right ACL rupture, six from a left ACL rupture. Only six patients had isolated ACL ruptures, the other nine also had meniscal tears. Two menisci had to be resected, seven menisci underwent suture repair (all by inside technique using anchors). Patient details are listed in Table 1.

In all 15 patients, the ACL was replaced by a quadriceps tendon graft. Briefly, the middle part (7–9 mm × 8.0 cm) of the autologous unilateral quadriceps tendon was harvested without any bone plug through a small ventral incision under general anesthesia. A transphyseal tibial tunnel like that used in adults was then drilled at the centre of the native ACL footprint followed by a femoral tunnel for which the knee was flexed to at least 100°. Both tunnels were drilled transtibially using an Arthrex aiming device (Arthrex Medizinische Instrumente GmbH, Germany). Drilling diameters were determined by the size of the one-stranded quadriceps tendon graft. Each end of the graft was transfixed by two FiberWire sutures (Arthrex Medizinische Instrumente GmbH, Germany). The graft was positioned with the necessary preload and both ends were fixed extra-articularly by 3.5 mm screws with peek washer (Synthes GmbH, Germany) (Figs. 1 and 2). The femoral end of the graft was fixed first and then the knee was placed at 30° of flexion for tensioning and fixation of the tibial end of the graft.The total intraosseous graft length was 25 mm for the femur and 25–30 mm for the tibia. No patient required subsequent surgery.

Postoperative care followed a standardized rehabilitation protocol. This included optional initial immobilization followed by a functional knee brace for the first six weeks, a CPM splint (Kinetec S.A., France), physiotherapy or functional rehabilitation [34]. The timing of the post-operative treatment depended on the course and the level of function of the affected knee.

To test for growth disturbances, leg length discrepancy and extremity alignment were measured with orthoradiograms. To evaluate the clinical results of transphyseal reconstruction, each of the 15 patients was asked to complete the SF-12 questionnaire, a 12-item downsized subset of the SF-36 health survey [35,36]. Two components were assessed, the physical health component summary (SF-12 PCS) and the mental health component summary (SF-12 MCS) [37]. All patients underwent physical examinations, including x-ray. To facilitate accuracy of comparison, results of the physical examination and x-rays were converted to the IKDC 2000 Knee Examination Form [38]. This instrument evaluates the following aspects: knee effusion, passive motion deficits, ligament stability, compartment findings, harvest side pathology, x-ray findings and a functional test. Results are graded from A (normal) to D (severely abnormal), each patient's worst grade determining that patient's final assessment [39]. The Lysholm–Gillquist score was used to register symptoms of knee instability, which besides pain has the greatest impact on daily living [40]. Leg length and extremity alignment were determined by means of orthoradiograms.

This study was performed according to the guidelines of the Ethics Committee of the University of Bern, Switzerland, and informed consent was obtained from all 15 patients.

3. Results

The mean age of the study group was 12.8 ± 2.6 years, range 6.2–15.8 years. Six children were evaluated to be at Tanner stage 2, 7 at Tanner stage 3 and 2 at Tanner stage 4 of physical development at the time of surgery (Table 1). Average graft diameter was 8.2 ± 0.77 mm while average anteroposterior laxity measured with the KT-1000 was 5.9 ± 1.2 mm. Average follow-up was 4.1 ± 2.2 years (range 1.9–9.7 years). None of the patients experienced a rerupture. Functional tests were normal in 10 patients.

4. IKDC 2000, Lysholm–Gillquist score, SF-12(PCS + MCS)

On clinical examination, applying the IKDC 2000, one knee was assessed as IKDC grade A, thirteen as IKDC grade B and only two as IKDC grade C due to harvest side pathology and ligament instability. Overall, 13 patients had either grade A or B scores at the final follow-up. The mean Lysholm–Gillquist score was 94.0 (range 68–100). The

Table 1
Patient data: mid-term results (mean 4.1 years) after transphyseal ACL reconstruction with an autologous quadriceps tendon graft. PCS: physical health component summary; MCS: mental health component summary; M: male; F: female; R: right; L: left; LM: lateral meniscus; MM: medial meniscus; LMM: lateral and medial meniscus; B: nearly normal; C: abnormal.

Patient	Sex	Tanner stage	Age at follow-up	Years since surgery	Side of injury	Additional injury	KT 1000 Post op (mm)	KT 1000 healthy (mm)	Graft Diameter (mm)	SF-12 PCS	SF-12 MCS	IKDC 2000	Lysholm & Gillquist score	Alignment Helthy Valgus(°)	Alignment Post op (°)	Gait pattern	Leg length operated/ healthy (mm)
1	M	II	19.5	9.7	R	—	7	4	8	55.8	61.3	B	94	0	6	Normal	−18
2	M	II	15.4	3.9	L	—	6	4	7	56.1	57.2	B	100	2	3	Normal	−4
3	M	II	12.1	3.1	R	LM	4	4	8	56.7	62.4	B	100	−2	0	Normal	9
4	F	III	17.0	2.8	L	LM	7	3	8	55.1	62.5	C	99	4	5	Normal	0
5	M	III	15.3	1.8	R	LMM	5	4	9	53.5	63.4	B	99	−1	0	Normal	−9
6	M	II	15.8	3.6	R	MM	5	4	8	53.2	61.0	B	99	−2	−3	Normal	0
7	F	II	14.2	1.6	L	LM	7	5	7	57.6	59.2	B	91	6	4	Normal	7
8	M	IV	18.2	2.9	R	MM	4	6	9	57.2	51.8	B	100	−3	−2	Normal	−4
9	M	III	16.4	3.8	R	—	6	4	9	53.5	63.4	B	99	−1	0	Normal	−9
10	M	III	18.4	3.1	R	—	6	4	8	54.8	54.4	B	95	2	2	Normal	−10
11	M	III	17.4	2.1	L	—	8	4	9	37.3	62.4	C	68	2	1	Normal	−1
12	M	III	20.1	6.7	L	LM	5	3	9	56.4	59.5	B	95	−1	0	Normal	−20
13	M	III	22.7	7.4	L	MM	6	3	8	54.8	54.4	B	100	−2	−1	Normal	9
14	F	II	10.6	4.4	R	—	8	6	7	50.9	60.0	B	71	4	6	Normal	2
15	M	IV	19.6	3.8	R	LMM	5	3	9	57.5	54.2	B	100	−3	−2	Normal	4