ISSN 2218-5836 (online)

World Journal of *Orthopedics*

World J Orthop 2018 March 18; 9(3): 14-59

Published by Baishideng Publishing Group Inc

W J O

World Journal of Orthopedics

Contents

Monthly Volume 9 Number 3 March 18, 2018

Contents

World Journal of Orthopedics
Volume 9 Number 3 March 18, 2018

ABOUT COVER

Editorial Board Member of *World Journal of Orthopedics*, Nigel Zheng, PhD, Professor, Center for Biomedical Engineering and Science, Department of Mechanical Engineering and Science, University of North Carolina at Charlotte, Charlotte, NC 28223, United States

AIM AND SCOPE

World Journal of Orthopedics (*World J Orthop*, *WJO*, online ISSN 2218-5836, DOI: 10.5312) is a peer-reviewed open access academic journal that aims to guide clinical practice and improve diagnostic and therapeutic skills of clinicians.

WJO covers topics concerning arthroscopy, evidence-based medicine, epidemiology, nursing, sports medicine, therapy of bone and spinal diseases, bone trauma, osteoarthropathy, bone tumors and osteoporosis, minimally invasive therapy, diagnostic imaging. Priority publication will be given to articles concerning diagnosis and treatment of orthopedic diseases. The following aspects are covered: Clinical diagnosis, laboratory diagnosis, differential diagnosis, imaging tests, pathological diagnosis, molecular biological diagnosis, immunological diagnosis, genetic diagnosis, functional diagnostics, and physical diagnosis; and comprehensive therapy, drug therapy, surgical therapy, interventional treatment, minimally invasive therapy, and robot-assisted therapy.

We encourage authors to submit their manuscripts to *WJO*. We will give priority to manuscripts that are supported by major national and international foundations and those that are of great basic and clinical significance.

INDEXING/ABSTRACTING

World Journal of Orthopedics is now indexed in Emerging Sources Citation Index (Web of Science), PubMed, PubMed Central and Scopus.

EDITORS FOR THIS ISSUE

Responsible Assistant Editor: *Xiang Li*
Responsible Electronic Editor: *Rui-Fang Li*
Proofing Editor-in-Chief: *Lian-Sheng Ma*
Responsible Science Editor: *Li-Jun Cui*
Proofing Editorial Office Director: *Xiu-Xia Song*

NAME OF JOURNAL
World Journal of Orthopedics

ISSN
ISSN 2218-5836 (online)

LAUNCH DATE
November 18, 2010

FREQUENCY
Monthly

EDITORS-IN-CHIEF
Quanjun (Trey) Cui, MD, Professor, Department of Orthopaedic Surgery, School of Medicine, University of Virginia, Charlottesville, VA 22908, United States

Bao-Gan Peng, MD, PhD, Professor, Department of Spinal Surgery, General Hospital of Armed Police Force, Beijing 100039, China

EDITORIAL OFFICE
Xiu-Xia Song, Director
World Journal of Orthopedics
Baishideng Publishing Group Inc
7901 Stoneridge Drive, Suite 501, Pleasanton, CA 94588, USA
Telephone: +1-925-2238242
Fax: +1-925-2238243
E-mail: editorialoffice@wjgnet.com
Help Desk: http://www.f6publishing.com/helpdesk
http://www.wjgnet.com

PUBLISHER
Baishideng Publishing Group Inc
7901 Stoneridge Drive,
Suite 501, Pleasanton, CA 94588, USA
Telephone: +1-925-2238242
Fax: +1-925-2238243
E-mail: bpgoffice@wjgnet.com
Help Desk: http://www.f6publishing.com/helpdesk
http://www.wjgnet.com

PUBLICATION DATE
March 18, 2018

INSTRUCTIONS TO AUTHORS
http://www.wjgnet.com/bpg/gerinfo/204

ONLINE SUBMISSION
http://www.f6publishing.com

World Journal of Orthopedics

Submit a Manuscript: http://www.f6publishing.com

World J Orthop 2018 March 18; 9(3): 24-34

DOI: 10.5312/wjo.v9.i3.24

ISSN 2218-5836 (online)

ORIGINAL ARTICLE

Retrospective Study

Complex knee injuries treated in acute phase: Long-term results using Ligament Augmentation and Reconstruction System artificial ligament

John Gliatis, Konstantinos Anagnostou, Pantelis Tsoumpos, Evdokia Billis, Maria Papandreou, Spyridon Plessas

John Gliatis, Konstantinos Anagnostou, Pantelis Tsoumpos, Department of Orthopaedic, University Hospital of Patras, Patras 25100, Greece

Evdokia Billis, Department of Physical Therapy, Technological Educational Institute of Western Greece, Aigion 25100, Greece

Maria Papandreou, Department of Physiotherapy, Technological Educational Institute of Athens, Aigion 25100, Greece

Spyridon Plessas, Department of Orthopaedic, General Hospital of Nikaia "Snt.Panteleimon", Piraeus 26504, Greece

ORCID number: John Gliatis (0000-0002-1216-354X); Konstantinos Anagnostou (0000-0001-7923-9732); Pantelis Tsoumpos (0000-0003-4773-5066); Evdokia Billis (0000-0002-5828-809X); Maria Papandreou (0000-0003-0353-4182); Spyridon Plessas (0000-0003-3695-0529).

Author contributions: Gliatis J has designed the research; Anagnostou K conducted the data collection, analysis and wrote the manuscript; Gliatis J and Plessas S were the senior surgeons; Billis E and Papandreou M were the senior physiotherapists of the team.

Institutional review board statement: The study was reviewed and approved by the Ethical Committee of University Hospital of Patras.

Informed consent statement: All study participants, provided informed written consent prior to study enrollment.

Conflict-of-interest statement: There are no conflicts of interest to report.

Data sharing statement: No additional data are available.

Manuscript source: Invited manuscript

Correspondence to: John Gliatis, PhD, Assistant Professor, Department of Orthopaedic, University Hospital of Patras Western Greece, Parodos Ipeirou, Agios Basileios, Patras 25100, Greece. igliat@upatras.gr
Telephone: +30-2610-999553
Fax: +30-2610-931025

Received: January 26, 2017
Peer-review started: February 7, 2017
First decision: December 18, 2017
Revised: December 21, 2017
Accepted: February 4, 2018
Article in press: February 5, 2018
Published online: March 18, 2018

Abstract

AIM

To present the long-term results of complex knee injuries, treated early using the Ligament Augmentation and Reconstruction System (LARS) artificial ligament to reconstruct posterior cruciate ligament (PCL).

METHODS

From September 1997 to June 2010, thirty-eight complex knee injuries were treated, where early arthroscopic PCL reconstructions were undergone, using the LARS (Surgical Implants and Devices, Arc-sur-Tille, France) artificial ligament. Exclusion criteria were: Late (> 4 wk) reconstruction, open technique, isolated PCL reconstruction, knee degenerative disease, combined fracture or vascular injury and use of allograft or autograft for PCL reconstruction. Clinical and functional outcomes were assessed with IKDC Subjective Knee Form, KOS-ADLS questionnaire, Lysholm scale and SF-12 Health Survey. Posterior displacement (PD) was measured with the Telos Stress Device.

RESULTS

Seven patients were excluded; two because of co-existing knee osteoarthritis and the remaining five because of failure to attend the final follow-up. The sample consisted of 31 patients with mean age at the time of reconstruction 33.2 ± 12.5 years (range 17-61). The postoperative follow-up was on average 9.27 ± 4.27 years (range 5-18). The mean average IKDC and KOS scores were 79.32 ± 17.1 and 88.1 ± 12.47% respectively. Average PD was 3.61 ± 2.15 mm compared to 0.91 ± 1.17 mm in the uninjured knees (one with grade 1 + and two with grade 2 +). Dial test was found positive in one patient, whereas the quadriceps active drawer test was positive in three patients. None was tested positive on the reverse-pivot shift test. The range of motion (ROM) was normal in thirty knees, in comparison with the contralateral one. There was no extension deficit. Osteoarthritic changes were found in three knees (9.6%).

CONCLUSION

Early treatment of complex knee injuries, using LARS artificial ligament for PCL reconstruction sufficiently reduces posterior tibia displacement and provides satisfactory long-term functional outcomes.

Key words: Complex knee injuries; Posterior cruciate ligament; Acute reconstruction; Ligament Augmentation and Reconstruction System

Core tip: Complex knee injuries pose a difficult problem while the treatment remains controversial. There are only few studies with long-term follow-up and with homogenous sample, regarding the timing of operation, the type of the graft and the type of reconstruction. In our study with a long-term follow-up, we have operated all the patients in the acute phase, using a standardized protocol regarding the technique, the type of the graft and the postoperative rehabilitation. Furthermore we have excluded the knee dislocations with vascular injuries, since these injuries have a different prognosis and they consist a separate category.

Gliatis J, Anagnostou K, Tsoumpos P, Billis E, Papandreou M, Plessas S. Complex knee injuries treated in acute phase: Long-term results using Ligament Augmentation and Reconstruction System artificial ligament. *World J Orthop* 2018; 9(3): 24-34 Available from: URL: http://www.wjgnet.com/2218-5836/full/v9/i3/24.htm DOI: http://dx.doi.org/10.5312/wjo.v9.i3.24

INTRODUCTION

Although most complex knee injuries are thought to occur due to a knee dislocation, in real practice a complete knee dislocation is very rare. Almost all complex knee injuries involve either the anterior cruciate ligament (ACL) and/or posterior cruciate ligament (PCL). This may be combined with injury to the medial knee structures and/or posterolateral corner structures of the knee. "Benign knee dislocation", described by Wascher *et al*[1] features isolated knee injury with mild or no neurovascular compromise and intact bony structure. Controversies also exist regarding various parameters, including early *vs* delayed surgery, type of reconstruction technique being chosen and postoperative rehabilitation program[2,3]. Very few studies exist with long term follow-up, whilst most of them include cases with complex injuries and true dislocations being classified within the same category.

Amongst the controversies regarding reconstruction of the multiple-injured knee is the choice of PCL graft tissue and the timing of the operation[4]. Posterior cruciate ligament is considered the primary restraint to posterior translation of the knee and the central stabilizer of the knee[5-8]. The incidence of PCL injuries is lower than that of ACL, occurring in approximately 3.4% to 20% of all knee ligament injuries[9]. PCL injuries are presented either as isolated tears or combined with other knee ligament injuries. Multiple knee ligament injuries usually need surgical treatment[10,11]. Despite the variety of operative techniques, PCL reconstruction still remains a challenge[10,12,13]. Autografts like Patella tendon (Bone-Tendon-Bone), Hamstrings and Quadriceps tendon or allografts like Achilles tendon, Anterior and Posterior Tibialis tendon are the most commonly used grafts[4]. Artificial grafts are rarely indicated because of their previous failure in ACL reconstruction[14-16]. The new generation artificial ligaments offer the advantages of less surgical time, absence of donor site morbidity, avoidance of possible spread of diseases (like Hepatitis C, HIV or knee infection), and faster postoperative rehabilitation[4,17-21].

As far as the timing of the operation is concerned, previous studies have stress out the risk of arthofibrosis after early treatment[22,23]. However in other reports, there is evidence that early reconstruction, in the first 4-6 wk usually provides better results compared to delayed reconstruction[2,24], which could be explained by the good healing capacity of the early ruptured PCL[25-29]. The limit of early treatment though arbitrary is considered 3 wk. Recently Fanelli *et al*[3] set the limit of early reconstruction in six weeks long.

In our retrospective study we have included patients with complex knee injuries being treated acutely and followed-up long-term, utilizing a standardized treatment protocol. Early (during 4 wk post injury) PCL reconstruction using an artificial ligament as a temporary restraint to posterior translation of tibia,

Table 1 Patients data

Patient	Gender	Age	Cause and time of Injury	Injury	Operation time after injury (wk)	Follow-up (yr)
1	Male	35	MVA (2007)	(R) PCL/MCL/MM	2	8
2	Male	46	MVA (2007)	(R)PCL/ACL/MCL part	4	8
3	Male	52	MVA (2003)	(L) PCL/ACL/LM	1	12
4	Male	19	MVA (2004)	(R) PCL/PLC/LM	4	11
5	Male	41	MVA (1997)	(L) PCL/ACL/LM	2	18
6	Male	36	MVA (2003)	(L) PCL/ACL	1	12
7	Male	25	MVA (2007)	(R) PCL/ACL/PLC	4	8
8	Male	20	MVA (2001)	(L) PCL/MCL/MM	4	14
9	Male	61	FALL (2006)	(R) PCL/ACL/MCL	1	9
10	Male	60	FALL (2007)	(R) PCL/ACL/PLC	3	8
11	Fem.	54	FALL (2000)	(R) PCL/ACL/	3	15
12	Male	37	MVA (2002)	(R) PCL/ACL	3	13
13	Male	25	MVA (2004)	(R)PCL/PLC/ACL/LM	1	11
14	Male	51	MVA (2007)	(L) PCL/MCL	4	8
15	Female	17	FALL (1999)	(L)PCL/ACL/LM	1	16
16	Female	28	FALL (2005)	(R)PCL/ACL/MCL part	1	10
17	Male	20	MVA (2000)	(L) PCL/MCL	4	15
18	Male	23	MVA (2003)	(R) PCL/PLC/LM	2	12
19	Male	38	MVA (2004)	(L) PCL/MCL	3	11
20	Male	37	MVA (2007)	(R) PCL/PLC	2	8
21	Male	27	FALL (2009)	(L) PCL/ACL	4	6
22	Female	36	MVA (2009)	(R) PCL/ACL/PLC	4	6
23	Male	33	MVA (2009)	(R) PCL/ACL/MCL/MM	4	6
24	Male	30	MVA (2010)	(L) PCL/ACL	1	5
25	Male	27	MVA (2010)	(L) PCL/ACL/PLC	3	5
26	Male	21	MVA (2010)	(R) PCL/ACL/MCL	2	5
27	Male	22	MVA (2011)	(R) PCL/ACL	1	6
28	Male	35	FALL (2010)	(R) PCL/ACL	4	5
29	Male	26	MVA (2010)	(R) PCL/ACL/MCL	2	5
30	Male	26	MVA (2010)	(R) PCL/ACL/MCL	4	5
31	Male	21	MVA (2011)	(R) PCL/ACL	4	7
Average ± SD		33.2 ± 12.5			2.67 ± 1.24	9.2 ± 4.27

allows the PCL remnants to heal[26,30-35] and can give satisfactory early and long-term results concerning posterior stability. In addition the augmentation of the posterolateral corner reconstruction allows the repaired soft tissues to heal in the correct position. We thus, retrospectively present the results of complex knee injuries treated in the early post-injury period using the artificial ligament LARS (Ligament Augmentation Reconstruction System)[36-38] to reconstruct PCL. The purpose of this study was to post-operatively assess the stability and clinical outcomes of the knee in mid-term to long-term follow-up, and to identify the progress of any degenerative changes in acutely operated knees.

MATERIALS AND METHODS

Sample

Multiple ligament knee injuries where PCL was reconstructed with LARS artificial ligament were retrospectively studied. The study period was from 1997 to 2010. Thirty-eight operations were undergone in this period. Inclusion criteria were the early arthroscopically-assisted, multiple ligament reconstruction, always including single bundle PCL reconstruction with LARS artificial ligament. Exclusion criteria were the open technique, the use of allografts or autografts such Hamstrings or Patella tendon for PCL reconstruction, the isolated PCL reconstruction, the presence of degenerative knee disease and the concomitant fracture or vascular injury that could influence the postoperative rehabilitation program. All patients were operated in the first four weeks after injury, which is the elapsed time to consider an injury as an acute one (Table 1).

Graft selection

The graft used for PCL reconstruction was the LARS (Ligament Augmentation and Reconstruction System, Surgical Implants and Devices, Arc-sur-Tille, France) artificial ligament, made of polyethylene terephthalate. LARS is a system of artificial ligament devices used for ACL, PCL, PLC (posterolateral corner) reconstructions and also Achilles tendon ruptures and acromioclavicular joint injuries[18,19,36,37,39]. We have used PC 80 in our cases.

Operative technique

All the operations were performed by the two senior authors, which were experienced in multiple ligament reconstructions. Under general anesthesia in supine position, a tourniquet was applied to the affected limb without being inflated. The foot of the operated leg was seated on a post over the operative table with a lateral support to maintain the knee in 90° of flexion. Leg position adjustments were possible. We used fluids with

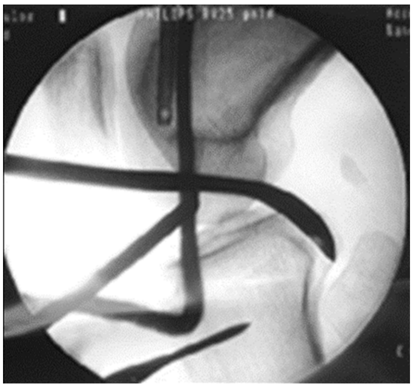

Figure 1 Tibial tunnel opening under image intensifier.

Figure 2 Proper position of tibia and femur for Telos Stress Device.

gravity flow and not a pump. An image intensifier was necessary in the theatre. In all cases, we performed a routine arthroscopic examination of the knee joint through the standard anterolateral and anteromedial portals. These portals were made immediately adjacent to the lateral and medial borders of the patellar tendon and 1 cm above the joint line to allow an easy passage of an arthroscope through the intercondylar notch to provide access to PCL tibial attachment. In PCL injuries, it is easier for the arthroscope to pass from the anterolateral portal to the posteromedial compartment through the intercondylar notch. In cases of meniscal or cartilage injury, if debridement was needed, the medial portal was used as well. Posteromedial portal was not used. Initial intra-articular bleeding was controlled with the aid of intermittent tourniquet inflation. A thorough evaluation of the intra-articular injuries was performed. The meniscal and cartilage injuries were treated first, either with fragments removal or meniscal repair. In all cases PCL was reconstructed, first of all injured ligaments, with LARS artificial ligament. The PCL remnants were always left intact and the tibial tunnel was created first, under image intensifier control (Figure 1). With the LARS instrument there was no need to debride the tibial PCL attachment. Then the femoral tunnel was created aiming just inferior to the native anterolateral bundle attachment of the PCL. The graft was passed afterwards through the tunnels with the aid of flexible wires, leaving the functional part of the graft inside the knee joint. The femoral side was fixed first and the normal step off was restored under image intensifier before the fixation of the tibial side with one screw and one staple. In cases of coexisting ACL rupture, we reconstructed the ligament in the early cases with LARS artificial ligament in the first 12 cases, while in the other 13 cases we used Hamstrings tendons. Posterolateral instability (PLI) was detected clinically with increased external rotation (Dial test) and arthroscopically with the "drive through sign" in 9 cases. We reconstructed posterolateral corner (PLC) addressing the popliteal and popliteo-fibular ligament (Warren procedure)[35,40]. In all cases we used Hamstrings tendons from the contralateral knee to augment the repaired PLC structures. In none of the cases MCL reconstruction was necessary[41]. Postoperatively we used continuous passive motion (CPM) from day one. The patients were allowed to partial weight-bear for 6 wk and gradually to full weight-bear up to two months. Postoperatively conventional functional braces were utilized[20,21].

Evaluation

All patients were assessed clinically and functionally in an outpatient office by an independent observer who was an appropriately trained senior resident. Clinical evaluation included Lachman and reverse-Lachman test, Anterior and Posterior Drawer tests (grading: 1 +: 0-5 mm, 2 +: 5-10 mm, 3 +: > 10 mm anterior or posterior translation respectively), Quadriceps Active Drawer test, Dial test for PLI and Varus-Valgus stress tests (grading Ⅰ: 0-5 mm, Ⅱ: 5-10 mm, Ⅲ: > 10 mm opening) for collateral ligaments' assessment[42]. The functional outcome was assessed with ROM evaluation, KOS-ADLS score and IKDC Subjective Knee Form, while Lysholm knee scoring, and SF-12 Health Survey completed the clinical outcomes[43-47]. The examiner used the Telos Stress Device to evaluate the posterior displacement of the injured knee in comparison to the contralateral healthy one[48,49]. A lateral x-ray imaging was performed in 90° of knee flexion under a standard anteroposterior force of 150N from Telos Stress Device (Figure 2). The standard force is widely accepted since 80N are adequate to induce posterior displacement of the tibia, while a greater than 180N force will cause pain and muscle contraction, influencing the reliability of measurements[50]. The total posterior tibial translation was measured and the side to side difference between normal and affected knee was compared during the force applied and not[50-53] (Figure 3). Arthritis was assessed by AP radiographs. Arthritis was rated as either present or absent based on joint space narrowing and/or the presence of osteophytes. This methodology is similar to that used in the Kellgren and Lawrence (KL) grading system[54]. Patients without evidence of osteoarthritis would be considered (KL) Grade 0 to 1, whereas patients with radiographic evidence of

Table 2 Functional scores

Patient code	KOS-ADSL/70 × 100%	IKDC/87 × 100	Lysholm/100	SF-12	
				Physical subscale (%)	Mental subscale (%)
1	94.2%	88.5	91	51.1	62.4
2	98.5%	79.3	100	54.8	59.8
3	88.5%	83.9	85	49.3	61.4
4	95.7%	98.8	91	56.6	60.8
5	92.8%	77.0	88	56.6	60.8
6	74.2%	65.5	83	48.7	61.5
7	98.5%	98.8	100	56.6	60.8
8	100%	94.2	100	57.2	33.8
9	88,5%	62.0	94	48.0	62.5
10	100%	98.5	100	56.6	60.8
11	77.1%	72.0	88	56.6	60.8
12	78.5%	80.4	90	53.1	59.9
13	88.5%	83.9	69	53.0	57.0
14	41.4%	24.1	48	30.8	40.5
15	90.0%	93.1	85	56.6	60.8
16	100%	95.4	100	56.6	60.8
17	80.0%	52.8	90	38.8	61.5
18	75.7%	60.9	58	47.6	48.6
19	85.7%	81.6	95	54.1	53.8
20	97.1%	95.4	99	56.6	60.8
21	90.0%	81.6	99	55.3	60.7
22	97.1%	95.4	99	55.3	60.7
23	58.5%	49.4	67	42.8	57.0
24	92.8%	81.6	94	55.3	60.7
25	98.5%	100	100	56.6	60.8
26	92.8%	86.2	85	53.2	49.8
27	95.7%	90.8	94	56.6	60.8
28	77.1%	55.1	81	36.0	60.4
29	98.5%	89.6	94	56.6	60.8
30	92.8%	85.0	94	56.6	60.8
31	92.8%	81.6	86	55.3	60.7
Average ± SD	88.1 ± 12.47	79.32 ± 17.1	88 ± 12.4		

osteoarthritis would be considered (KL) Grade 2 to 4.

RESULTS

Thirty-eight patients in total over the 17 years' period sustained a complex knee injury including PCL rupture and underwent a reconstruction of PCL with LARS artificial ligament. From these, two patients were excluded because of co-existing knee osteoarthritis, while five more did not manage to attend the final follow-up. So, the final sample consisted of 31 patients. From the 31 patients, 27 were males and 4 females. From the reconstructed knees 20 were right side and 11 left. The mean age at the time of reconstruction was 34.5 (± 12.5) years (range 17-61). The average time from injury to surgery was 2.67 (± 1.24) wk (range 1-4) and the mean time of postoperative follow-up was 9.2 (± 4.27) years (range 5-18), (Table 1). From the 31 cases, 24 were motor vehicle accidents (MVA) and 7 were sport injuries and falls (Table 1). All patients were examined clinically (clinical examination) functionally (with functional outcome questionnaires) (Table 2), and radiologically with the Telos stress device (Table 3).

Time interval between injury and operation

Three patients (8.8%) were operated during the first week (< 1/52); specifically two patients were operated three days post-injury and one patient on the accident day. Also five patients (17.6%) were operated 1 wk (1/52) after the trauma and six patients (17.6%) 2 wk (2/52) after their accident, respectively. Five patients (17.6%) underwent operation three weeks (3/52) post injury, while twelve patients (38.2%) were treated four weeks (4/52) after injury.

Functional scores and clinical findings

The mean KOS-ADLS score (Knee Outcome Survey - Activities of Daily Living Score) was 88.1% (± 12.47). Twenty-two patients (70.9%) had score greater than 60/70 and two of them (6.4%) reached the absolute 70/70, indicating excellent functionality. Only one patient (3.2%) had score of less than 35/70. The mean IKDC (International Knee Documentation Committee) Subjective Knee Form was 79.32 (± 17.1). Twenty patients (64.5%) reached 70/87 score and above but four patients (12.9%) pointed a score lower than 50/87.

The evaluation according to the Lysholm knee scoring revealed excellent (95-100) results for ten (32.2%) patients, good (84-94) for sixteen (51.6%), fair (65-83) for three (9.6%) and poor (< 64) for only two (6.4%) patients (Table 2). Regarding the SF-12 Health Survey, all patients except three declared very satisfied from

Table 3 Radiological results with Telos device

Patient code	Telos posterior displacement (mm) X-ray measured	
	Operated knee	Healthy knee (contralateral)
1	8	0
2	6	3
3	5	2
4	1	0
5	4	0
6	2	5
7	0	0
8	0	2
9	6	0
10	3	1
11	2	1
12	4	0
13	6	1
14	7	2
15	5	0
16	3	3
17	3	0
18	3	0
19	4	1
20	3	1
21	4	0
22	2	1
23	8	0
24	4	1
25	0	2
26	5	0
27	1	1
28	3	0
29	0	0
30	3	0
31	4	0
Average (SD)	3.61 (± 2.15)	0.91 (± 1.17)

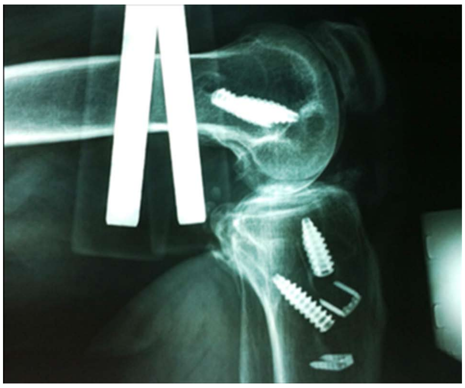

Figure 3 Anteroposterior force on tibia through Telos Device leading to posterior translation.

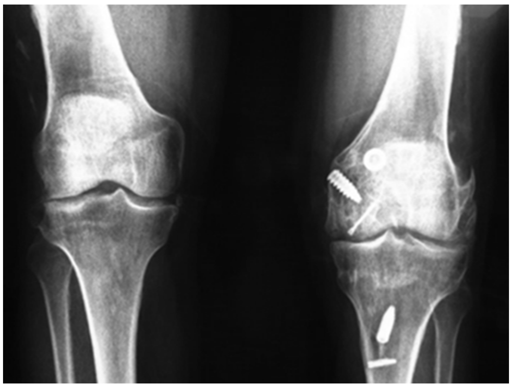

Figure 4 Anteroposterior knee x-rays for evaluation of arthritis progression (Kellgren and Lawrence grade 3).

the postoperative outcome in both physical and mental health fields (ranging from 30.8-56.6 and 33.8-62.5 respectively), and further indicated that if again needed, they would undergo the same procedure under the same circumstances (Table 3).

The posterior drawer test was positive (grade 2 +) in six (*n* = 6) patients, the anterior drawer test was positive in three (*n* = 3) (one with grade 1 + and two with grade 2 +), the varus stress test in five (*n* = 5) (three with grade Ⅰ and two with grade Ⅱ) and the valgus stress test in three (*n* = 3) patients (all with grade Ⅱ). The dial test was found positive (> 15° side to side difference) in one (*n* = 1) patient, whereas the quadriceps active drawer test was positive in three (*n* = 3) patients. None was tested positive on the reverse-pivot shift test. The range of motion (ROM) was normal in thirty knees, in comparison with the contralateral one, with a 0°-121.2° (± 10.14) average flexion arc and had no extension deficit. Only in one knee there was a limitation of ROM: 0°-90°.

Radiographic evaluation

The evaluation of knee X-rays (AP weight-bearing-standing) revealed a medial joint space narrowing (> 2 mm in comparison with lateral joint space) in three (*n* = 3) patients; in a 66 year old woman at the last follow-up, 15 years postoperatively with (KL) grade 3 (Figure 4), and in two men 64 and 54 years old, 8 and 15 years after operation, respectively both with (KL) grade 2. The remaining twenty-eight (*n* = 31) patients had no radiographic findings of joint space narrowing (KL grade 0 or 1). The mean tibial posterior displacement of the operated knees as measured with the Telos Stress Device was 3.61 (± 2.15) mm. The value for the normal contralateral knees was 0.91 (± 1.17) mm respectively. Twenty-five patients (80.6%) were found with posterior translation of less than 5 mm (Grade Ⅰ) and six patients (19.3%) with posterior displacement in the range 6-10 mm (Grade Ⅱ). No one patient was classified in the group of 11-15 mm or greater than 15 mm (Grades Ⅲ and Ⅳ, respectively) (Table 3).

DISCUSSION

In our study we treated complex knee injuries in the acute phase, at four weeks' time, reconstructing PCL with LARS artificial ligament in all our cases. The clinical outcome was satisfactory in most of the cases long-term. The rate of posttraumatic arthritis was very low, too. Most of our patients in this study maintained a good clinical outcome in the long-term follow-up. We assessed the stability with the Telos Stress Device postoperatively[48-53]. The posterior translation was more than 5 mm in only six patients, but none of them had an over 10 mm posterior displacement. The mean side-to-side difference was 2.7 mm, which is comparable with other series with long-term follow-ups. Hermans *et al*[55] found a 4.7 mm mean difference in their patients. Similar results have been reported in other studies using autografts or allografts[56]. The functional and clinical outcome was assessed through three knee-specific questionnaires: The IKDC Subjective Knee Form, the KOS-ADLS, the Lysholm scale, as well as a general health questionnaire, the SF-12 Health Survey[43-45]. More than 70% of our patients scored good to excellent results in all measures used. Only one patient yielded disappointing results even though the objective assessment was normal. In our study the rate of post-traumatic arthritis was low (three out of 34 patients) compared to other studies with similar follow-up time[3,57,58].

Very few studies underwent long-term follow-up[2,3,57-61] and only two studies exceeded the ten-year follow-up limit[3,59]. However most of these previous studies included both true dislocations and complex knee injuries together. Thus, making the sample heterogeneous, because the soft tissue injury is usually worse after a complete dislocation. In one of those, Engebretsen *et al*[58] also included patients with different type of injuries, where they concluded that high-energy injuries had significantly lower functional scores. Furthermore in some of these studies with long term follow-up the type of treatment was not consistent, either treating the patients in two stages[57] or conservatively[61]. Another issue, which was not consistent in these studies, was the timing of operative treatment. In some of those the operation was performed in a later stage[57], in others in an early stage[58,59] and some of these studies included patients, who had treatment both in early and late stage[58]. Recently, a study[2] presented good results after long-term follow-up in patients with traumatic knee dislocations. However they included patients with vascular injury requiring repair, as well as some patients with high-energy injuries. In these cases, soft tissues very rarely heal in the first three weeks after the injury making impossible reconstruction in early stage, thus influencing negatively the final outcome. Treatment regime was not the same for all the patients since they used various grafts for ligament reconstruction, especially for the PCL. The incidence of posttraumatic arthritis also, was not reported. Fanelli *et al*[3], presented the study with the longest follow-up (over 10 years) and the patients had a standardized treatment protocol, utilizing allografts in a delayed fashion in the majority of the cases. They reported that the knee stability was restored but one fourth of the patients had developed post-traumatic arthritis. Interestingly, the same authors in a previously reported study[62] with 10 years follow-up did not provide any information about post-traumatic arthritis. Engebretsen *et al*[58] on the other hand reported high incidence of arthritis in his patients but they included all high-energy traumatic complete knee dislocations.

Our treatment regime included several standardized procedures. Firstly, the requirement for operating was to have a "quiet" knee with no blisters or edema, and with smooth range of knee motion. In all of our cases we achieved this goal using early CPM and active quadriceps exercises, at the limits of the pain. Therefore, we excluded the cases of knee dislocations requiring revascularization, as in these cases the repair had to be protected with knee immobilization, using an external fixator. This is the reason we used the term "complex" knee injuries and not knee dislocations. In our experience, the latter is a different entity because of the severity of the soft tissue injury and the possible fasciotomies, associated with vascular reconstruction, which usually preclude early treatment of the knee ligaments. Secondly, our aim was to operate in an early stage, trying to preserve the remnants of both, the ruptured PCL and the ruptured collateral ligaments. There is debate in the literature regarding the timing for treating complex knee injuries. Two systematic reviews, published both in 2009[63,64] reported different conclusions regarding the timing of the operation. Levy *et al*[63] suggested that early operative treatment of the multi-ligament injured knee yields improved functional and clinical outcomes compared to non-operative management or delayed surgery. On the other hand, Mook *et al*[24] reported that delayed reconstructions of severe multiple-ligament knee injuries could potentially yield equivalent outcomes in terms of stability when compared with acute surgery. This is justified by the fact that acute surgery is highly associated with range-of-motion deficits. Hirschmann *et al*[59] reported in 12 years follow-up (average) study with early reconstruction very good results regarding knee stability, but one fifth of the patients had extension deficits and one third of the patients had not satisfactory clinical outcome. The authors did not include patients with vascular repair but the ligament reconstruction was performed with open surgery. Recently Khakha *et al*[2] reported a high level of overall knee function following acute surgical reconstruction with a 10-year average follow-up. However, the treatment protocol was not consistent, since they used different grafts for PCL and PLRI reconstruction. They also included patients requiring vascular repair, who needed postoperative immobilization; they however, have reported immediate knee motion postoperatively.

We have used also the artificial LARS ligament to reconstruct PCL. The artificial graft acts as a scaffold for the PCL remnants. The stable joint environment and the scaffold function of the LARS ligament promotes the healing procedure[25,27,29,31,32,39,51]. Its use in ACL reconstruction as an isolated graft is contraindicated because it has failed in the majority of the cases even though it seemed successful in the short-term[14-17,26,37,41,64]. The difference in PCL reconstruction is that the function of the graft in the acute phase is to acts as the central support system, allowing the PCL remnants to heal in the correct position with minimal posterior laxity in the knee[30,31,34,65]. Another advantage of the artificial graft is that there is no need for intensive postoperative rehabilitation using sophisticated devices. In all the cases we did not restrict the range of motion postoperatively. The surgical technique also is simpler than the conventional PCL reconstruction techniques, because the posterior portals are not needed, since the posterior exit of the tibial tunnel is assessed fluoroscopically, using the special guide of the LARS system. The risk of synovitis was reduced as we did not notice any case of synovitis in our sample and we are aware of only one case in the literature[14,15]. Another benefit of this reconstructive procedure is that it permits fast return to daily activities and sooner to sports. In contrast to this fast return, hamstrings or other autografts require a period of graft revascularization, where activities are limited and rehabilitation program is extended. In addition, allografts always pose the risk of disease transmission[18,20,21]. The advantage of preserving the PCL remnants was stressed out in two studies. Both Ahn *et al*[32] and Zhao *et al*[66] reported a preserving reconstruction method for chronic, however PCL injuries. The only study available to describe the results of remnant-preserving PCL reconstruction in the acute and sub-acute stage was presented by Jung *et al*[31] but the authors have included patients in the sub-acute phase (3 mo post-injury). They also used hamstrings grafts, which require protection in the early postoperative period. Recently various reports have published good results after PCL reconstruction using LARS artificial ligaments[19,37]. However only in one study the operation was performed in an early stage[19] and the follow-up was relatively short (less than 5 years), which is considered a limitation when artificial grafts are used, because of their tendency to fail in a later phase[15,16].

Despite our efforts, there are limitations in our study. It is a retrospective study, but the majority of similar studies are also retrospective, since the incidence of these injuries is very rare. A second limitation is the sample size, which seems rather small, however it is considered a homogenous sample, since we used a standardized protocol regarding the timing of surgery and the treatment method. We have also excluded patients with vascular injuries, which require different treatment protocol and they also have different prognosis. The follow-up was long enough, compared to other similar studies, reported in the literature. Therefore, we believe that our proposed treatment protocol to treat complex knee injuries, operating in an early fashion and reconstructing PCL with LARS artificial ligament may restore knee stability and provide satisfactory long term clinical outcome.

ARTICLE HIGHLIGHTS

Research background

Complex knee injuries pose a difficult problem across the literature in terms of diagnostic classification while the treatment remains controversial. In particular, there is conflict regarding: (1) Their classification (as benign knee dislocations with intact neurovascular status and knee dislocations with arterial injury are not well classified); (2) their postoperative rehabilitation (as knee dislocations with arterial injury require a period of knee immobilization, whereas “benign” knee dislocations can be treated with aggressive postoperative rehabilitation); (3) the timing of the operation; (4) the graft type; and (5) the lack of long term follow-up. In our study we have tried to address all these issues, because we present a homogenous sample, with a long-term follow-up, using LARS artificial ligament to reconstruct PCL and all patients had the operations in the acute phase. Therefore, we feel that the results presented here are reliable since our study, although retrospective has a clear and robust methodology.

Research motivation

In medicine and in any other research processes, the researcher first he observes a phenomenon, secondly he tries to explain it with a theory, and lastly, he has to reproduce it, to confirm the theory. Taking this into account, we have observed that early reconstruction of these injuries provide better outcomes, because the injured soft tissues, have a better healing potential in the acute phase. There is also always a fear for knee arthrofibrosis, when operating early these injuries; we have therefore, allowed (in all our cases) the inflammation to settle down with the help of intensive physiotherapy after the injury. The artificial ligament also provides the scaffold, necessary for the tissue healing in the appropriate position. Furthermore, it allows early rehabilitation because primary stability is achieved during the operation and no need for further protection is needed during the early postoperative period. The satisfactory outcome after this study’s long-term follow-up is supporting the theory of early intervention following our treatment protocol.

Research objectives

The main objective of our study was to present a standard treatment protocol to manage complex knee injuries, taking into account parameters which have not been clearly elaborated in previous studies, such as postoperative rehabilitation, timing of the operation, follow-up *etc*. The various parameters of the protocol have been well defined and we suggest this protocol, since we have found very promising outcomes for our patient sample.

Research methods

In this retrospective study, we have used a range of clinical outcome measures and radiological parameters. Clinical measures included three knee-specific measures; the Knee Outcome Survey for Activities of Daily Living (KOS-ADLS), the Lysholm scale, the Knee Osteoarthritis Outcome Survey (KOOS) as well as a generic health measure, the SF-12 Health Survey, all of which present as the most commonly used self-reported outcomes in similar type of studies. In addition, for detecting any anteroposterior (AP) instability we have used the Telos devise. We have also used plain radiographs to detect any possible remaining instability and post-traumatic arthritis. However, we believe that the main advantages of our methodology is (1) Our homogenous sample selection (not including patients with vascular injury or major fracture around the knee); (2) the fact that the sample were all treated with the same standardized protocol; and (3) that postoperative rehabilitation was also intensive with no serious precautions regarding sophisticated and expensive braces.

Research results

Authors study we have found satisfactory clinical outcomes after a long period of time. The functional scores, which have been used in our study yielded very good results. The remaining instability was minimal in most cases and the rate of posttraumatic arthritis was not detectable in most of our cases, given the long follow-up. In future, we may have to include an MRI to detect any occult meniscal or cartilage injuries.

Research conclusions

The new findings of this study support the theory of early intervention following complex knee injuries (without concomitant serious vascular or bony injuries) as clinical, functional and radiological outcomes have all been satisfactory during our long follow-up. We propose to treat early these injuries, providing that the patient has achieved a good range of motion preoperatively. We also suggest augmenting PCL remnants with LARS artificial ligament, which has been proven adequate in the long-term follow-up. In summary, the proposed treatment protocol is efficient in complex knee injuries, providing there is no concomitant serious vascular or bony injuries. The new hypothesis proposed by this study is the reconstruction of complex knee injuries in the acute phase. The cornerstone of our approach is to start early intensive physiotherapy, to operate as soon as the inflammation settles down and to repair all tissues in one stage. We augment the PCL with LARS artificial ligament and we also augment the repair of collateral ligaments. Based on these findings, we feel that all these injuries should be treated in the acute phase. The new methods are the use of LARS artificial ligament, only for PCL reconstruction and the repair of all the injuries in one stage. With this approach the patients may return earlier to their previous functional level. We feel that this is a major achievement because these injuries may be disabling when they are not treated appropriately.

Research perspectives

The experience learnt from this study was to proceed for proper classification of complex knee injuries. We cannot classify them all in the same category since the prognosis and the treatment protocol is different in injuries complicated with vascular or serious bony injuries. The direction of the future research should be oriented towards the better classification of these injuries and to determine the use of the various available grafts. The methods for future research, is either biomechanical or clinical. The problem with clinical studies, is the rarity of the injury, therefore multicenter studies are required.

REFERENCES

1 **Wascher DC**, Becker JR, Dexter JG, Blevins FT. Reconstruction of the anterior and posterior cruciate ligaments after knee dislocation. Results using fresh-frozen nonirradiated allografts. *Am J Sports Med* 1999; **27**: 189-196 [PMID: 10102100]

2 **Khakha RS**, Day AC, Gibbs J, Allen S, Hill P, Hull J, Perry A, Chissell H. Acute surgical management of traumatic knee dislocations--Average follow-up of 10 years. *Knee* 2016; **23**: 267-275 [PMID: 26545616 DOI: 10.1016/j.knee.2015.09.019]

3 **Fanelli GC**, Sousa PL, Edson CJ. Long-term followup of surgically treated knee dislocations: stability restored, but arthritis is common. *Clin Orthop Relat Res* 2014; **472**: 2712-2717 [PMID: 24898528 DOI: 10.1007/s11999-014-3707-6]

4 **Höher J**, Scheffler S, Weiler A. Graft choice and graft fixation in PCL reconstruction. *Knee Surg Sports Traumatol Arthrosc* 2003; **11**: 297-306 [PMID: 12942234 DOI: 10.1007/s00167-003-0408-1]

5 **Harner CD**, Höher J. Evaluation and treatment of posterior cruciate ligament injuries. *Am J Sports Med* 1998; **26**: 471-482 [PMID: 9617416]

6 **Wang D**, Berger N, Cohen JR, Lord EL, Wang JC, Hame SL. Surgical treatment of posterior cruciate ligament insufficiency in the United States. *Orthopedics* 2015; **38**: e281-e286 [PMID: 25901620 DOI: 10.3928/01477447-20150402-55]

7 **Voos JE**, Mauro CS, Wente T, Warren RF, Wickiewicz TL. Posterior cruciate ligament: anatomy, biomechanics, and outcomes. *Am J Sports Med* 2012; **40**: 222-231 [PMID: 21803977 DOI: 10.1177/0363546511416316]

8 **Papannagari R**, DeFrate LE, Nha KW, Moses JM, Moussa M, Gill TJ, Li G. Function of posterior cruciate ligament bundles during in vivo knee flexion. *Am J Sports Med* 2007; **35**: 1507-1512 [PMID: 17376856 DOI: 10.1177/0363546507300061]

9 **Miyasaka KC,** Daniel DM, Stone ML. The incidence of knee ligament injuries in the general population. *Am J Knee Surg* 1991; **4**: 3-8

10 **Lee BK**, Nam SW. Rupture of posterior cruciate ligament: diagnosis and treatment principles. *Knee Surg Relat Res* 2011; **23**: 135-141 [PMID: 22570824 DOI: 10.5792/ksrr.2011.23.3.135]

11 **Apsingi S**, Nguyen T, Bull AM, Unwin A, Deehan DJ, Amis AA. The role of PCL reconstruction in knees with combined PCL and posterolateral corner deficiency. *Knee Surg Sports Traumatol Arthrosc* 2008; **16**: 104-111 [PMID: 18060383 DOI: 10.1007/s00167-007-0444-3]

12 **Kohen RB**, Sekiya JK. Single-bundle versus double-bundle posterior cruciate ligament reconstruction. *Arthroscopy* 2009; **25**: 1470-1477 [PMID: 19962075 DOI: 10.1016/j.arthro.2008.11.006]

13 **Kim SJ**, Kim TE, Jo SB, Kung YP. Comparison of the clinical results of three posterior cruciate ligament reconstruction techniques. *J Bone Joint Surg Am* 2009; **91**: 2543-2549 [PMID: 19884425 DOI: 10.2106/JBJS.H.01819]

14 **Li H**, Yao Z, Jiang J, Hua Y, Chen J, Li Y, Gao K, Chen S. Biologic failure of a ligament advanced reinforcement system artificial ligament in anterior cruciate ligament reconstruction: a report of serious knee synovitis. *Arthroscopy* 2012; **28**: 583-586 [PMID: 22361004 DOI: 10.1016/j.arthro.2011.12.008]

15 **Klein W**, Jensen KU. Synovitis and artificial ligaments. *Arthroscopy* 1992; **8**: 116-124 [PMID: 1532312]

16 **Viateau V**, Manassero M, Anagnostou F, Guérard S, Mitton D, Migonney V. Biological and biomechanical evaluation of the ligament advanced reinforcement system (LARS AC) in a sheep model of anterior cruciate ligament replacement: a 3-month and 12-month study. *Arthroscopy* 2013; **29**: 1079-1088 [PMID: 23726110 DOI: 10.1016/j.arthro.2013.02.025]

17 **Batty LM**, Norsworthy CJ, Lash NJ, Wasiak J, Richmond AK, Feller JA. Synthetic devices for reconstructive surgery of the cruciate ligaments: a systematic review. *Arthroscopy* 2015; **31**: 957-968 [PMID: 25620500 DOI: 10.1016/j.arthro.2014.11.032]

18 **Smith C**, Ajuied A, Wong F, Norris M, Back D, Davies A. The use of the ligament augmentation and reconstruction system (LARS) for posterior cruciate reconstruction. *Arthroscopy* 2014; **30**: 111-120 [PMID: 24290790 DOI: 10.1016/j.arthro.2013.09.081]

19 **Shen G**, Xu Y, Dong Q, Zhou H, Yu C. Arthroscopic posterior cruciate ligament reconstruction using LARS artificial ligament: a retrospective study. *J Surg Res* 2012; **173**: 75-82 [PMID: 20888585 DOI: 10.1016/j.jss.2010.08.015]

20 **Lee YS,** Kim NK. Rehabilitation after posterior cruci¬ate ligament reconstruction. *Minerva Ortop Traumatol* 2011; **62**: 291-295

21 **Edson CJ**, Fanelli GC, Beck JD. Postoperative rehabilitation of the posterior cruciate ligament. *Sports Med Arthrosc* 2010; **18**: 275-279 [PMID: 21079508 DOI: 10.1097/JSA.0b013e3181f2f23d]

22 **Harner CD**, Irrgang JJ, Paul J, Dearwater S, Fu FH. Loss of motion after anterior cruciate ligament reconstruction. *Am J Sports Med* 1992; **20**: 499-506 [PMID: 1443315]

23 **Jari S,** Shelbourne KD. Non-operative or delayed surgical treatment of combined cruciate ligaments and medial side knee injuries. *Sports Med Arthrosc Rev* 2001; **9**: 185-192

24 **Mook WR**, Miller MD, Diduch DR, Hertel J, Boachie-Adjei Y, Hart JM. Multiple-ligament knee injuries: a systematic review of the timing of operative intervention and postoperative rehabilitation. *J Bone Joint Surg Am* 2009; **91**: 2946-2957 [PMID: 19952260 DOI: 10.2106/JBJS.H.01328]

25 **Bray RC**, Leonard CA, Salo PT. Vascular physiology and long-term healing of partial ligament tears. *J Orthop Res* 2002; **20**: 984-989 [PMID: 12382963 DOI: 10.1016/S0736-0266(02)00012-8]

26 **Woo SL**, Vogrin TM, Abramowitch SD. Healing and repair of ligament injuries in the knee. *J Am Acad Orthop Surg* 2000; **8**: 364-372 [PMID: 11104400]

27 **Akisue T**, Kurosaka M, Yoshiya S, Kuroda R, Mizuno K. Evaluation of healing of the injured posterior cruciate ligament: Analysis of instability and magnetic resonance imaging. *Arthroscopy* 2001; **17**: 264-269 [PMID: 11239346]

28 **Shelbourne KD**, Jennings RW, Vahey TN. Magnetic resonance imaging of posterior cruciate ligament injuries: assessment of healing. *Am J Knee Surg* 1999; **12**: 209-213 [PMID: 10626911]

29 **Scapinelli R**. Comment on W. Petersen and B. Tillmann, "Blood and lymph supply of the posterior cruciate ligament". *Knee Surg Sports Traumatol Arthrosc* 1999; **7**: 337, author reply 338 [PMID: 10525706 DOI: 10.1007/s001670050174]

30 **Trieb K**, Blahovec H, Brand G, Sabeti M, Dominkus M, Kotz R. In vivo and in vitro cellular ingrowth into a new generation

of artificial ligaments. *Eur Surg Res* 2004; **36**: 148-151 [PMID: 15178903 DOI: 10.1159/000077256]
31 **Jung YB**, Jung HJ, Song KS, Kim JY, Lee HJ, Lee JS. Remnant posterior cruciate ligament-augmenting stent procedure for injuries in the acute or subacute stage. *Arthroscopy* 2010; **26**: 223-229 [PMID: 20141985 DOI: 10.1016/j.arthro.2009.07.017]
32 **Ahn JH**, Yang HS, Jeong WK, Koh KH. Arthroscopic transtibial posterior cruciate ligament reconstruction with preservation of posterior cruciate ligament fibers: clinical results of minimum 2-year follow-up. *Am J Sports Med* 2006; **34**: 194-204 [PMID: 16303881 DOI: 10.1177/0363546505279915]
33 **Yoon KH**, Bae DK, Song SJ, Cho HJ, Lee JH. A prospective randomized study comparing arthroscopic single-bundle and double-bundle posterior cruciate ligament reconstructions preserving remnant fibers. *Am J Sports Med* 2011; **39**: 474-480 [PMID: 21098819 DOI: 10.1177/0363546510382206]
34 **Jung HJ**, Kim JH, Lee HJ, Koo S, Chang SH, Jung YB, Lee SH. The isometry of two different paths for remnant-preserving posterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc* 2013; **21**: 1029-1035 [PMID: 22763568 DOI: 10.1007/s00167-012-2111-6]
35 **Fanelli GC**, Giannotti BF, Edson CJ. Arthroscopically assisted combined posterior cruciate ligament/posterior lateral complex reconstruction. *Arthroscopy* 1996; **12**: 521-530 [PMID: 8902124]
36 **LARS**. Accessed June 2013. Available from: URL: www.lars-ligaments.com
37 **Huang JM**, Wang Q, Shen F, Wang ZM, Kang YF. Cruciate ligament reconstruction using LARS artificial ligament under arthroscopy: 81 cases report. *Chin Med J* (Engl) 2010; **123**: 160-164 [PMID: 20137364]
38 **Tzurbakis M**, Diamantopoulos A, Xenakis T, Georgoulis A. Surgical treatment of multiple knee ligament injuries in 44 patients: 2-8 years follow-up results. *Knee Surg Sports Traumatol Arthrosc* 2006; **14**: 739-749 [PMID: 16602025 DOI: 10.1007/s00167-006-0039-4]
39 **Xu X**, Huang T, Liu Z, Wen H, Ye L, Hu Y, Yu H, Pan X. Hamstring tendon autograft versus LARS artificial ligament for arthroscopic posterior cruciate ligament reconstruction in a long-term follow-up. *Arch Orthop Trauma Surg* 2014; **134**: 1753-1759 [PMID: 25376713 DOI: 10.1007/s00402-014-2104-7]
40 **Wiley WB**, Askew MJ, Melby A 3rd, Noe DA. Kinematics of the posterior cruciate ligament/posterolateral corner-injured knee after reconstruction by single- and double-bundle intra-articular grafts. *Am J Sports Med* 2006; **34**: 741-748 [PMID: 16382008 DOI: 10.1177/0363546505282615]
41 **Shelbourne KD**, Carr DR. Combined anterior and posterior cruciate and medial collateral ligament injury: nonsurgical and delayed surgical treatment. *Instr Course Lect* 2003; **52**: 413-418 [PMID: 12690868]
42 **Rubinstein RA Jr**, Shelbourne KD, McCarroll JR, VanMeter CD, Rettig AC. The accuracy of the clinical examination in the setting of posterior cruciate ligament injuries. *Am J Sports Med* 1994; **22**: 550-557 [PMID: 7943523]
43 **Kapreli E**, Panelli G, Strimpakos N, Billis E, Zacharopoulos A, Athanasopoulos S. Cross-cultural adaptation of the Greek version of the Knee Outcome Survey--activities of Daily Living Scale (KOS-ADLS). *Knee* 2011; **18**: 424-427 [PMID: 20869875 DOI: 10.1016/j.knee.2010.09.001]
44 **Koumantakis GA**, Tsoligkas K, Papoutsidakis A, Ververidis A, Drosos GI. Cross-cultural adaptation and validation of the International Knee Documentation Committee Subjective Knee Form in Greek. *J Orthop Traumatol* 2016; **17**: 123-129 [PMID: 26093603 DOI: 10.1007/s10195-015-0362-y]
45 **Kontodimopoulos N**, Pappa E, Niakas D, Tountas Y. Validity of SF-12 summary scores in a Greek general population. *Health Qual Life Outcomes* 2007; **5**: 55 [PMID: 17900374 DOI: 10.1186/1477-7525-5-55]
46 **Zayni R**, Hager JP, Archbold P, Fournier Y, Quelard B, Chambat P, Sonnery-Cottet B. Activity level recovery after arthroscopic PCL reconstruction: a series of 21 patients with a mean follow-up of 29 months. *Knee* 2011; **18**: 392-395 [PMID: 21144755 DOI: 10.1016/j.knee.2010.11.005]
47 **Hammoud S**, Reinhardt KR, Marx RG. Outcomes of posterior cruciate ligament treatment: a review of the evidence. *Sports Med Arthrosc* 2010; **18**: 280-291 [PMID: 21079509 DOI: 10.1097/JSA.0b013e3181eaf8b4]
48 **Margheritini F**, Mancini L, Mauro CS, Mariani PP. Stress radiography for quantifying posterior cruciate ligament deficiency. *Arthroscopy* 2003; **19**: 706-711 [PMID: 12966377]
49 **Stäubli HU**, Noesberger B, Jakob RP. Stressradiography of the knee. Cruciate ligament function studied in 138 patients. *Acta Orthop Scand Suppl* 1992; **249**: 1-27 [PMID: 1529706]
50 **Jung TM**, Reinhardt C, Scheffler SU, Weiler A. Stress radiography to measure posterior cruciate ligament insufficiency: a comparison of five different techniques. *Knee Surg Sports Traumatol Arthrosc* 2006; **14**: 1116-1121 [PMID: 16799824 DOI: 10.1007/s00167-006-0137-3]
51 **Mariani PP**, Margheritini F, Christel P, Bellelli A. Evaluation of posterior cruciate ligament healing: a study using magnetic resonance imaging and stress radiography. *Arthroscopy* 2005; **21**: 1354-1361 [PMID: 16325087 DOI: 10.1016/j.arthro.2005.07.028]
52 **Schulz MS**, Russe K, Lampakis G, Strobel MJ. Reliability of stress radiography for evaluation of posterior knee laxity. *Am J Sports Med* 2005; **33**: 502-506 [PMID: 15722285 DOI: 10.1177/0363546504269723]
53 **Wirz P**, von Stokar P, Jakob RP. The effect of knee position on the reproducibility of measurements taken from stress films: a comparison of four measurement methods. *Knee Surg Sports Traumatol Arthrosc* 2000; **8**: 143-148 [PMID: 10883424 DOI: 10.1007/s001670050204]
54 **Kellgren JH**, Lawrence JS. Radiological assessment of osteo-arthrosis. *Ann Rheum Dis* 1957; **16**: 494-502 [PMID: 13498604]
55 **Hermans S**, Corten K, Bellemans J. Long-term results of isolated anterolateral bundle reconstructions of the posterior cruciate ligament: a 6- to 12-year follow-up study. *Am J Sports Med* 2009; **37**: 1499-1507 [PMID: 19451096 DOI: 10.1177/0363546509333479]
56 **Cooper DE**, Stewart D. Posterior cruciate ligament reconstruction using single-bundle patella tendon graft with tibial inlay fixation: 2- to 10-year follow-up. *Am J Sports Med* 2004; **32**: 346-360 [PMID: 14977658]
57 **Bin SI**, Nam TS. Surgical outcome of 2-stage management of multiple knee ligament injuries after knee dislocation. *Arthroscopy* 2007; **23**: 1066-1072 [PMID: 17916471 DOI: 10.1016/j.arthro.2007.05.008]
58 **Engebretsen L**, Risberg MA, Robertson B, Ludvigsen TC, Johansen S. Outcome after knee dislocations: a 2-9 years follow-up of 85 consecutive patients. *Knee Surg Sports Traumatol Arthrosc* 2009; **17**: 1013-1026 [PMID: 19609504 DOI: 10.1007/s00167-009-0869-y]
59 **Hirschmann MT**, Zimmermann N, Rychen T, Candrian C, Hudetz D, Lorez LG, Amsler F, Müller W, Friederich NF. Clinical and radiological outcomes after management of traumatic knee dislocation by open single stage complete reconstruction/repair. *BMC Musculoskelet Disord* 2010; **11**: 102 [PMID: 20507623 DOI: 10.1186/1471-2474-11-102]
60 **Plancher KD**, Siliski J. Long-term functional results and complications in patients with knee dislocations. *J Knee Surg* 2008; **21**: 261-268 [PMID: 18979926]
61 **Roman PD**, Hopson CN, Zenni EJ Jr. Traumatic dislocation of the knee: a report of 30 cases and literature review. *Orthop Rev* 1987; **16**: 917-924 [PMID: 3333596]
62 **Fanelli GC**, Edson CJ. Arthroscopically assisted combined anterior and posterior cruciate ligament reconstruction in the multiple ligament injured knee: 2- to 10-year follow-up. *Arthroscopy* 2002; **18**: 703-714 [PMID: 12209427]
63 **Levy BA**, Dajani KA, Whelan DB, Stannard JP, Fanelli GC, Stuart MJ, Boyd JL, MacDonald PA, Marx RG. Decision making in the multiligament-injured knee: an evidence-based systematic review. *Arthroscopy* 2009; **25**: 430-438 [PMID: 19341932 DOI: 10.1016/j.arthro.2009.01.008]

64 **Gao K**, Chen S, Wang L, Zhang W, Kang Y, Dong Q, Zhou H, Li L. Anterior cruciate ligament reconstruction with LARS artificial ligament: a multicenter study with 3- to 5-year follow-up. *Arthroscopy* 2010; **26**: 515-523 [PMID: 20362832 DOI: 10.1016/j.arthro.2010.02.001]

65 **Lessim S**, Migonney V, Thoreux P, Lutomski D, Changotade S. PolyNaSS bioactivation of LARS artificial ligament promotes human ligament fibroblast colonisation in vitro. *Biomed Mater Eng* 2013; **23**: 289-297 [PMID: 23798650 DOI: 10.3233/BME-130753]

66 **Zhao J**, Xiaoqiao H, He Y, Yang X, Liu C, Lu Z. Sandwich-style posterior cruciate ligament reconstruction. *Arthroscopy* 2008; **24**: 650-659 [PMID: 18514108 DOI: 10.1016/j.arthro.2008.01.005]

P- Reviewer: Ohishi T **S- Editor**: Cui LJ **L- Editor**: A
E- Editor: Li D

Baishideng®

Published by **Baishideng Publishing Group Inc**
7901 Stoneridge Drive, Suite 501, Pleasanton, CA 94588, USA
Telephone: +1-925-223-8242
Fax: +1-925-223-8243
E-mail: bpgoffice@wjgnet.com
Help Desk: http://www.f6publishing.com/helpdesk
http://www.wjgnet.com