Revision Anterior Cruciate Ligament Reconstruction: Causes of Failure, Surgical Technique, and Clinical Results

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Revision Anterior Cruciate Ligament Reconstruction

Causes of Failure, Surgical Technique, and Clinical Results

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Background: Revision of an anterior cruciate ligament reconstruction is a complicated and delicate clinical procedure whose results, theoretically, are less satisfactory than those of the first operation.

Hypothesis: The outcome of a revised anterior cruciate ligament surgery is comparable to primary anterior cruciate ligament reconstruction, with a rate of success around 70% to 80%.

Study Design: Case series; Level of evidence, 4.

Methods: A total of 66 revisions of anterior cruciate ligament reconstructions were carried out from September 2000 to September 2004. Patients with concomitant instability and those with alterations in the weightbearing axis of the lower limbs were not included. Sixty patients were followed from 24 to 72 months: 50 clinically and 10 by a phone interview. Six patients were lost to follow-up due to changes of address.

Results: Lysholm scores were 57% excellent (95-100 points), 13% good (84-94 points), 22% fair (63-83 points), and 8% poor (<64 points). A total of 68% of patients had negative Lachman tests, 20% had positive tests with a hard end point, 10% had positive results, and 2% had very positive results. Stabilometric evaluation with the KT-1000 arthrometer at the maximum load showed that 56% of patients had <3 mm side-to-side difference, 34% had between 3 and 5 mm, and 10% had 6 to 10 mm. The International Knee Documentation Committee scores were 36% excellent (class A), 46% good (class B), and 18% fair (class C). The percentage of patients who resumed sport at the same level was 78%, compared with 58% after their primary reconstruction.

Conclusion: The results of these anterior cruciate ligament reconstruction revision surgeries are close to those achieved by other series of primary reconstructions with a little less satisfactory results. We attribute the high success rate to the strict application of the same technique and the confinement of revision to motivated patients. It should be noted, however, that follow-up is only at the midterm stage (mean, 41.9 months).

Keywords: anterior cruciate ligament; reconstruction; revision

The primary aim of anterior cruciate ligament (ACL) reconstruction is reestablishment of knee joint stability and function to allow normal relational life, participation in sport, to relieve pain and subjective sensations of instability, and slow the progression of arthritis. Current ACL reconstruction techniques secure good to excellent results in 75% to 90% of cases.[3,25,27,29,37,38,57] Failure, however, is not uncommon.[12,15,20,23]

Revision of ACL reconstruction is a complicated and delicate clinical procedure whose results are theoretically less satisfactory than those of the first operation because further intervention is required in an area where anatomical landmarks may have been altered by previous procedures.[1,4,5,19,35,42]

The purpose of this study was to evaluate the results of revision ACL reconstruction at a midterm follow-up.

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METHODS

Three authors performed 66 isolated revisions of ACL reconstruction failures from September 2000 to September 2004 (1268 primary reconstructions were performed in the same period) using the same technique. Patients requiring accessory surgery such as osteotomy or peripheral reconstructive surgery (for collateral ligament or posterolateral corner reconstruction) were excluded.

Sixty patients were followed up after 24 to 72 months (mean, 41.9 months): 50 (75.8%) clinically and 10 (15.2%) with a phone interview by an author not involved in the surgical procedures. Six patients were lost to follow-up due to changes of address.

Clinical examination comprised subjective and clinical evaluation, including the Lachman test with Lysholm score,[40] Tegner score,[60] International Knee Documentation Committee (IKDC) score,[26] and assessment with the KT-1000 arthrometer at the maximum load.[10] The phone interview was confined to a subjective evaluation and the Lysholm score.[40]

Sixty-one 1-stage revisions were performed. Five 2-stage operations were for arthrolysis (4 cases) and prior tibial and femoral bone grafting (1 case). The mean time between reconstruction and revision was 62.7 months (range, 3 months-15 years). There were 58 male and 8 female patients with a mean age of 31.2 (range, 16-55) years. The right limb was involved in 31 cases and the left in 35.

Causes of Failure

There were 3 different categories of reconstruction failure: 52% surgical (including 6 synthetic ligament failures), 35% traumatic, and 3% biological. Our criteria for defining a failure in each category were determined by history, imaging, and arthroscopic findings. Particularly, we classified a failure as surgical when, according to imaging and arthroscopy, the graft appeared to be positioned incorrectly; as traumatic when the described trauma could cause the graft lesion even though imaging and arthroscopy showed a correct graft position; and biological when the patient did not experience a trauma, and the graft appeared well positioned on imaging and arthroscopy.

Type of Graft

Preference was accorded to the doubled semitendinosus and gracilis tendon graft (37 revisions), as the patellar tendon had been almost exclusively employed for the initial reconstruction (Figure 1). The patellar tendon was used in 27 cases (in 13 cases it was the contralateral one for a high-demand sports activity or the patellar chondral status) and an Achilles allograft in 2 cases. The latter technique has been permitted only recently in our country. The previously harvested patellar tendon was never used.

Fixation was with bioabsorbable (Bio-Interference Screw; Arthrex Inc, Naples, Fla) and titanium (Soft Silk; Smith & Nephew Inc, Andover, Md) interference screws in patellar tendon revision ACL reconstructions. In doubled semitendinous and gracilis revision ACL reconstructions, fixation was achieved with femoral bioabsorbable cross-pins (RigidFix Cross Pin System, Mitek, Raynham, Mass) and a bioabsorbable interference screw (Bio-Interference, Arthrex Inc) at the tibia.

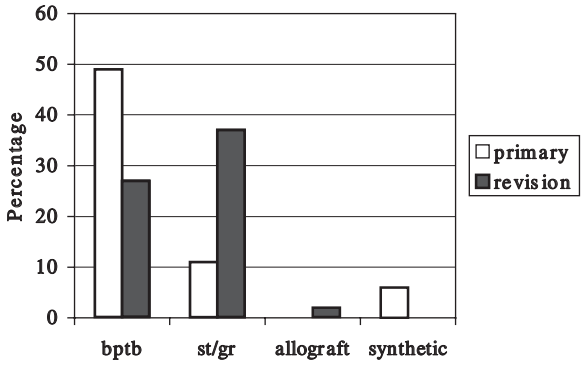

Figure 1. Type of graft used for primary ACL reconstruction and for revision. Bptb, bone-patellar tendon-bone; st/gr, semitendinosus and gracilis tendon.

Associated Management

A total of 43 treatments of associated disorders were carried out in 31 patients (20 single sites, 10 double sites, and 1 triple site) for 26 meniscal lesions, and 17 treatments for cartilage lesions. The authors performed 21 selective meniscectomies (13 medial, 8 lateral) and 5 meniscal repairs (4 medial, 1 lateral), 9 cartilage debridements, 6 microfractures, and 2 mosaicplasties.

Postoperative Management

The authors used accelerated rehabilitation,[57] but in patients with meniscal repair, microfracture, or mosaicplasty procedures, weightbearing was allowed at the third postoperative week. Statistical analysis was conducted using a simple descriptive analysis showing the percentage of the results obtained, while the comparison was calculated using the chi-square test (χ^2).

RESULTS

The Lysholm, Tegner, Lachman, IKDC, and KT-1000 arthrometer findings are detailed in Table 1.[10,26,40,60,62]

Lysholm scores[40] were a mean of 90.5 (range, 54-100). The mean Tegner score[60] was 6.7 points (range, 0-10), corresponding to recreational sports. The Lachman test was graded as negative, positive with a hard end point (1+), positive (2+), or very positive (3+). Stabilometric evaluation with the KT-1000 arthrometer was performed at the maximum load at 20°, and more than half of the patients had less than 3 mm side-to-side difference. The IKDC scores were 36% excellent (class A), 46% very good (class B), and 18% fair (class C). There were no significant differences

TABLE 1
Outcome Results by Percentage of Patients[a]

Test	Percentage
Lysholm score	
Excellent (95-100 points)	57
Good (84-94 points)	13
Fair (65-83 points)	22
Poor (<64 points)	8
Tegner score	
Competitive sports (8-10)	50
Recreational sports (5-7)	27
No sport but working (1-4)	17
Not working (0)	6
Lachman test	
Negative	68
1+	20
2+	10
3+	2
KT-1000 arthrometer	
<3 mm	56
3-5 mm	34
6-10 mm	10
>10 mm	0
IKDC score	
A	36
B	46
C	18
D	0

[a]IKDC, International Knee Documentation Committee.

between groups ($\chi^2 = 8.53$; $P = .074$). Table 2 compares the patellar tendon graft, the doubled semitendinosus and gracilis graft, and the allograft results.

The percentage of patients who resumed their previous sport at the same level was 78% compared with 58% after their primary reconstruction (Table 3).

DISCUSSION

The enormous increase in the number of ACL injuries and, hence, the crop of failures after primary reconstructions have made revision an ever more frequent item on a surgeon's agenda. The results published in the literature are less encouraging than those for initial reconstruction because repeated traumatic insults and multiple surgical procedures result in progressive damage that cannot always be repaired.[†]

Our revision results, however, proved to be comparable with those achieved by primary reconstruction, with only a little less satisfactory results. Their excellence is demonstrated by 3 findings: KT-1000 arthrometer results <5 mm in 90% of the series; negative Lachman results in 88%, and IKDC class A and class B scores in 82%. These scores are similar to those in a recent 2-step revision ACL reconstruction study.[61]

In a prospective study on our primary ACL reconstruction,[11] we noticed that the KT-1000 arthrometer 2-year

TABLE 2
Comparison of the IKDC and KT-1000 Arthrometer Revision ACL Reconstruction Results (n = 60) Between Bone Patellar Tendon Bone Graft, Doubled Semitendinosus and Gracilis Graft, and Allograft[a]

Scores	BPTB	St-Gr	Allog
IKDC A, n (%)	16 (59.3)	7 (22.6)	1 (50)
IKDC B, n (%)	8 (29.6)	17 (54.8)	1 (50)
IKDC C, n (%)	3 (11.1)	7 (22.6)	
KT-1000 arthrometer[b]			
<3 mm, n (%)	14 (51.9)	17 (54.8)	1 (50)
3-5 mm, n (%)	10 (37.0)	10 (32.3)	1 (50)
6-10 mm, n (%)	3 (11.1)	4 (12.9)	

[a]IKDC, International Knee Documentation Committee; ACL, anterior cruciate ligament; BPTB, bone patellar tendon bone; St-Gr, semitendinosus and gracilis; Allog, allograft.
[b]No significant statistical differences in the groups ($\chi^2 = .54$; $P = .97$).

TABLE 3
Comparison of Sport Level After Primary ACL Reconstruction and Revision ACL Reconstruction[a]

Sport	After Primary Reconstruction, %	After Revision, %	Difference, %
None	8	8	0
Lesser level	34	14	–20
Same level	58	78	+20

[a]ACL, anterior cruciate ligament.

follow-up evaluation was 5 mm or less in 94% of the patellar tendon ACL reconstructions and in 91% of the doubled semitendinosus and gracilis ACL reconstructions. After comparing the results of primary reconstruction[11,61] and revision, we can see that the resulting data of the latter are lower, although they are still a good standard (Figure 2).

Obviously the above can be explained in light of the multiple number of operations the patients have undergone and the long period of instability that eventually leads to a global knee laxity. We must also stress that the patients with a lower IKDC result were mainly those with cartilage damage or, to a lesser degree, those with a consequence of meniscectomies.[1,4,19,21,35,42,49,55] It must be stated that in any case, a stable knee is not always a pain-free knee.

Our success can certainly be ascribed to the application of a strict technique and the confinement of revision to motivated patients. It should be noted, however, that the follow-up is still at the midterm stage (mean, 41.9 months). We saw no significant differences regarding the type of graft used in terms of knee stability.

Determination of the real causes of reconstruction failures is an essential prelude to successful revision.[‡] When considering the causes of failure, account must be taken of the distinction between early failures due to surgical errors, nonintegration of the graft, or overly aggressive rehabilitation, and late failure due to injury after a period

[†]References 12, 13, 16, 17, 20, 28, 32, 45, 47, 49, 50, 59.
[‡]References 7-9, 18, 22, 33, 34, 41, 54, 66.

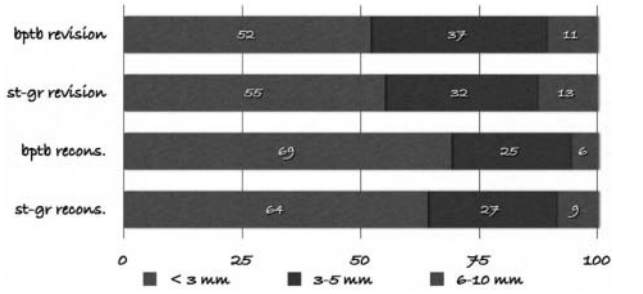

Figure 2. Comparison of KT-1000 arthrometer results (%) after our revision ACL reconstruction (revision) and our primary ACL reconstruction (recons)[11] with doubled semitendinosus and gracilis graft (st-gr) or bone-patellar-tendon-bone graft (bptb).

of joint stability. Particular attention must be paid to diagnostic inaccuracies on the part of the surgeon. These lead to failures caused by the presence of concomitant, for example, posterolateral instability, lesions or secondary conditions such as infection or arthrofibrosis. Graft damage may be caused surgically, biologically, or traumatically.

Surgical Causes

Surgical errors are evident in more than 70% of ACL reconstruction failures.[§] They include incorrect positioning of the tibial and/or femoral tunnel,[15,30,35,39,41,46] inappropriate graft selection, impingement of the graft in the intercondylar notch,[8,24,25,31,46] poor tensioning of the graft or insufficient fixation,[6,39,44,56,58,64] and incorrect diagnosis of concomitant peripheral lesions.[1,4] Incorrect tunnel placement is the main cause of failure as it eventually leads to stretching, weakening, and rupture of the graft and, thus, instability.[25,27,29]

The most common surgical mistake is excessive anterior positioning of the femoral tunnel with impingement and stressing of the graft during flexion to the point of rupture. The same is true with excessive posterior placement of the tibial tunnel, which leads to rupture due to excessive tension during extension.[35]

The type of graft, the means of fixation, and the quality of the bone are factors that determine the appropriate fixation of a graft, especially at the commencement of rehabilitation when it is not yet integrated with the bone.

Revision of ACL reconstructions is naturally related to the causes of their failure. Meticulous preoperative planning is needed to ensure that the operation will be performed as correctly as possible.

Biological Causes

The contribution of biology to the integration of a graft and its complete ligamentization[2,52,53] is often overlooked but is no less important than other factors. The patient's range of motion (ROM),[43,50] gait, and quadriceps tone must be considered. If the ROM is limited, an arthroscopic arthrolysis should be performed before revision (if this is indicated). The clinical diagnosis should be accompanied by radiography of the lower limbs during weightbearing, computed tomography, or magnetic resonance imaging, and bone scan in the event of infection.

Traumatic Causes

A fresh injury may damage a graft. Even so, one can never be certain whether it was the real cause or whether the graft was already weak and could not support the knee when required. Here careful sifting of the history is needed to determine how the injury was caused (intensity, type of movement, etc).

Other Factors

Patient motivation is an essential asset in revision ACL surgery, as a second operation is not always necessary. Revision of biologically caused failures or injury is more difficult as it must be carried out in the same anatomical position as the first reconstruction, whereas the correction of surgical errors is usually easier because there is more space available.

We prefer single-stage revisions because of the positive cost/benefit ratio for the patient. There are, however, some situations in which 2 stages may be preferred. Examples include joint movement deficits requiring rehabilitation for the complete recovery of ROM, arthrolysis to eliminate adherences and scar residues, axial deviations requiring corrective osteotomy at the same time as the revision, and widening of the tunnels needing bone grafts to fill gaps.[37] Two stages may also be advisable in the revision of synthetic ligaments in cases where residue in the joint could give rise to synovitis.

Several issues must be taken into consideration in revision ACL surgery: selection of the graft, type of incision, removal of the means of fixation, intercondylar notchplasty, placement of the femoral and tibial tunnels, type of fixation, and rehabilitation protocol.[50] Revision surgery must, in any event, be adapted to the technique (graft, fixation) previously employed.

Selection of the Graft

Graft candidates are semitendinosus and gracilis tendons, ipsilateral and contralateral patellar tendons, the quadriceps tendon, and allografts. We never use synthetic tendons for revision. When an autologous tendon is employed, it must be harvested as the last surgical step after determining if all the technical steps of the revision can be implemented.

Removal of the Means of Fixation

Means of fixation that could hinder surgery and impair the success of a revision must always be removed (Figure 3). In other cases, such fixation devices can be left in place so as not to lengthen the duration of the operation or make it more difficult. In some cases, indeed, they may improve the

[§]References 10, 33, 34, 36, 42, 48, 63, 65.

Figure 3. Correct revision demands the removal of some means of fixation.

Figure 4. Retention of the anterior screw allowed 1-stage revision with the contralateral patellar tendon and good fixation in this case.

firmness of the new tunnel (Figure 4). It is sometimes necessary to resort to special techniques such as coring to extract screws with stripped threads.

Preparation of the Tunnels

Tunnels should be placed in the same position as in the primary reconstruction unless the previous positions were incorrect. Bonoscopy (insertion of the arthroscope into the tunnels) must be undertaken to secure an exact assessment of the quality of the surrounding bone. One can then decide whether to plug any bone defects and also choose the most suitable means of fixation. If a tunnel is too wide, a larger bone block can be harvested with the patellar tendon. Bone grafting (Figure 5) can also be employed. Other alternatives are the "over-the-top" technique with 2 incisions or a 2-step operation.

Fixation of the Graft

The type of fixation used should be determined in accordance with the type of graft, the position of the tunnels, and the soundness of their surrounding bone. It is always best to use the means with which one feels most comfortable, although one must naturally be prepared to use whichever fixation type best suits the patient's needs.

Rehabilitation Protocol

If sound fixation is secured, the rehabilitation protocol followed after the first reconstruction should be repeated.[57]

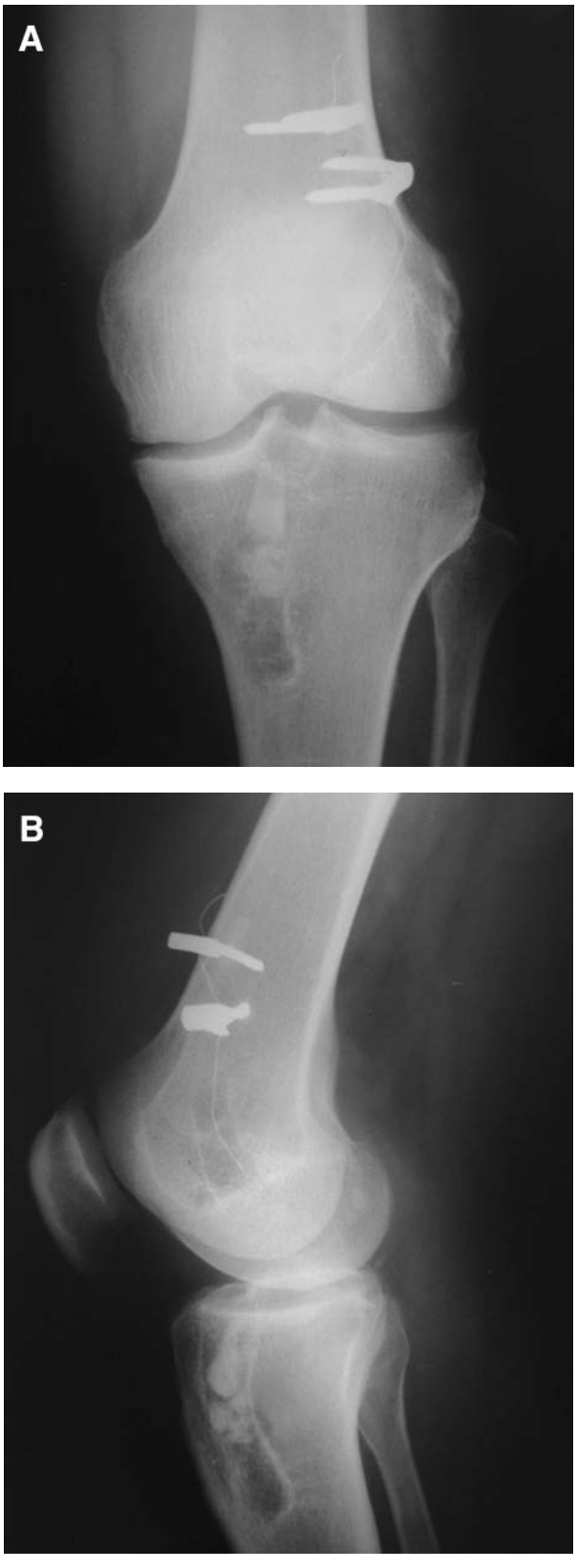

Figure 5. A, bone grafting during 1-stage revision with the semintendinosus and gracilis graft of a previous reconstruction with a synthetic ligament (the patient required a 1-step revision). B, usual fixation with femoral absorbable crosspins and an absorbable screw at the tibia.

CONCLUSION

We were surprised at the considerable number of patients (78%) who, after ACL reconstruction revision, returned to perform the same sport at the same level as *before their initial* knee injury compared to the only 58% who returned to the same sport at the same level after the primary reconstruction. This could be explained by the fact that, in our opinion, a large number among these patients did not have good knee stability after the first reconstruction. Therefore, as a consequence of the revision surgery, 20% more of the patients have been able to return to sport. This result is in conflict with the underlying belief that an ACL revision is a salvage operation meant to improve quality of life (activities of daily living) rather than to secure a return to sport, which more likely happens for professional athletes in case of a good result.[14,16,23,34,36,47,51] Obviously, when satisfactory knee stability is reached, most patients return to perform their favorite sport as before their initial injury.

REFERENCES

1. Allen CR, Giffin JR, Harner CD. Revision anterior cruciate ligament reconstruction. *Orthop Clin North Am.* 2003;34:79-98.
2. Amiel D, Kleiner J, Roux R, Harwood F, Akeson W. The phenomenon of ligamentization: anterior cruciate ligament reconstruction with autogenous patellar tendon. *J Orthop Res.* 1986;4:162-172.
3. Bach BR Jr, Tradonsky S, Bojchuk J, Levy ME, Bush-Joseph CA, Khan NH. Arthroscopically assisted anterior cruciate ligament reconstruction using patellar tendon autograft: 5- to 9-year follow-up evaluation. *Am J Sports Med*. 1998;26:20-29.
4. Brown CH Jr, Carson EW. Revision anterior cruciate ligament surgery. *Clin Sports Med*. 1999;18:109-171.
5. Brown HR, Indelicato PA. Complications of anterior cruciate ligament reconstruction. *Oper Tech Orthop*. 1992;2:125-135.
6. Burks RT, Leland R. Determination of graft tension before fixation in anterior cruciate ligament reconstruction. *Arthroscopy*. 1988;4:260-266.
7. Carson EW, Anisko EM, Restrepo C, Panariello RA, O'Brien SJ, Warren RF. Revision anterior cruciate ligament reconstruction: etiology of failures and clinical results. *J Knee Surg*. 2004;17(3):127-132.
8. Corsetti JR, Jackson DW. Failure of anterior cruciate ligament reconstruction: the biologic basis. *Clin Orthop.* 1996;325:42-49.
9. Cross MS, Purnell MB. Revision reconstruction of the anterior cruciate ligament. *Orthop Trans*. 1993-1994;17:931.
10. Daniel DM, Malcom LL, Losse G, Stone ML, Sachs R, Burks R. Instrumented measurement of anterior laxity of the knee. *J Bone Joint Surg Am*. 1985;67:720-726.
11. Denti M, Lo Vetere D, Bandi M, Volpi P. Comparative evaluation of knee stability following reconstruction of the anterior cruciate ligament with the bone-patellar tendon-bone and the double semitendinosus-gracilis methods: 1- and 2-year prospective study. *Knee Surg Sports Traumatol Arthrosc.* 2006;14(7):637-640.
12. Dye SF. The future of anterior cruciate ligament reconstruction. *Clin Orthop*. 1996;325:130-139.
13. Ferretti A, Conteduca F, Monaco E, De Carli A, D'Arrigo C. Revision anterior cruciate ligament reconstruction with doubled semitendinosus and gracilis tendons and lateral extra-articular reconstruction. *J Bone Joint Surg Am*. 2006;88(11):2373-2379.
14. Fox JA, Pierce M, Bojchuk J, Hayden J, Bush-Joseph CA, Bach BR Jr. Revision anterior cruciate ligament reconstruction with nonirradiated fresh-frozen patellar tendon allograft. *Arthroscopy*. 2004;20(8):787-794.
15. Fu FH, Safran MR. Revision anterior cruciate ligament reconstruction. Editorial summary. *Arthroscopy*. 1994;10:156-157.
16. Fu FH, Schulte KR. Anterior cruciate ligament surgery. 1996: state of the art? *Clin Orthop.* 1996:325:19-24.

17. Fules PJ, Madhav RT, Goddard RK, Mowbray MA. Revision anterior cruciate ligament reconstruction using autografts with a polyester fixation device. *Knee*. 2003;10(4):335-340.
18. Garofalo R, Djahangiri A, Siegrist O. Revision anterior cruciate ligament reconstruction with quadriceps tendon-patellar bone autograft. *Arthroscopy*. 2006;22(2):205-214.
19. Getelman MH, Friedman MJ. Revision anterior cruciate ligament reconstruction surgery. *J Am Acad Orthop Surg*. 1999;7(3):189-198.
20. Gillquist J. Repair and reconstruction of ACL: is it good enough? *Arthroscopy*. 1993;9:68-71.
21. Graf B, Uhr F. Complications of intra-articular anterior cruciate reconstruction. *Clin Sports Med*. 1987;7:835-848.
22. Greis PE, Johnson DL, Fu FH. Revision anterior cruciate ligament surgery: causes of graft failure and technical considerations of revision surgery. *Clin Sports Med*. 1993;12(4):839-852.
23. Harner CD. Failed ACL surgery: symposium. *Clin Orthop*. 1996;325:2-3.
24. 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.
25. Harter RA, Osternig LR, Singer KM, James SL, Larson RL, Jones DC. Long-term evaluation of knee stability and function following surgical reconstruction for anterior cruciate ligament insufficiency. *Am J Sports Med*. 1998;16:434-443.
26. Hefti F, Muller W, Jakob RP, Staubli HU. Evaluation of knee ligament injuries with the IKDC form. *Knee Surg Sports Traumatol Arthrosc*. 1993;1:226-234.
27. Holmes PF, James SL, Larson RL, Singer KM, Jones DC. Retrospective direct comparison of three intra-articular anterior cruciate ligament reconstructions. *Am J Sports Med*. 1991;19:596-600.
28. Houseworth SW, Mauro VJ, Mellon BA, Kieffer DA. The intercondylar notch in acute tears of the anterior cruciate ligament: a computer graphics study. *Am J Sports Med.* 1987;15:221-224.
29. Howe JG, Johnson RJ, Kaplan MJ, Fleming B, Jarvinen M. Anterior cruciate ligament reconstruction using quadriceps patellar tendon graft. Part I. Long-term follow-up. *Am J Sports Med*. 1991;19:447-457.
30. Howell SM, Clark JA. Tibial tunnel placement in anterior cruciate ligament reconstruction and graft impingement. *Clin Orthop*. 1992;283:187-195.
31. Jackson DW, Schaefer RK. Cyclops syndrome: loss of extension following intra-articular ACL reconstruction. *Arthroscopy*. 1990;6:171-178.
32. Jackson RW. The torn ACL: natural history of untreated lesions and rationale for selective treatment. In: Feagin Jr JA, ed. *The Crucial Ligaments: Diagnosis and Treatment of Ligamentous Injuries About the Knee*. 2nd Ed. New York, NY: Churchill Livingstone; 1994:485-493.
33. Jaureguito JW, Paulos LE. Why grafts fail. *Clin Orthop Relat Res.* 1996;325:25-41.
34. Johnson DL, Fu FH. Anterior cruciate ligament reconstruction. Why do failures occur? *Instr Course Lect.* 1995;44:391-406.
35. Johnson DL, Harner CD, Maday MG, Fu FH. Revision anterior cruciate ligament surgery. In Fu FH, Harner CD, Vince KG, eds. *Knee Surgery*. Baltimore, Pa: Williams & Wilkins; 1994:877-895.
36. Johnson DL, Swenson TM, Irrgang JJ, Fu FH, Harner CD. Revision anterior cruciate ligament surgery: experience from Pittsburgh. *Clin Orthop Relat Res.* 1996;325:100-109.
37. Kaplan MJ, Howe JG, Fleming B, Johnson RJ, Jarvinen M. Anterior cruciate ligament reconstruction using quadriceps patellar tendon graft. Part II. A specific sport review. *Am J Sports Med*. 1991;19:458-462.
38. Kornblatt I, Warren RF, Wickiewicz TL. Long-term follow-up of anterior cruciate ligament reconstruction using the quadriceps tendon substitution for chronic anterior ligament insufficiency. *Am J Sports Med*. 1998;16:444-448.
39. Lewis JL, Lew WD, Engebretsen L, Hunter RE, Kowalczyk C. Factors affecting graft force in surgical reconstruction of the anterior cruciate ligament. *J Orthop Res*. 1990;8:514-521.
40. Lysholm J, Gillquist J. Evaluation of knee ligament surgery results with special emphasis on use of a scoring scale. *Am J Sports Med*. 1982;10:150-152.
41. Maday MG, Harner CD, Fu FH. Revision ACL surgery: evaluation and treatment. In: Feagin JA, ed. *The Crucial Ligaments. Diagnosis and Treatment of Ligamentous Injuries About the Knee.* 2nd Ed. New York, NY: Churchill Livingstone; 1994:711-723.
42. Martinek V, Imhoff AB. Revision of failed anterior cruciate ligament reconstruction. *Orthopade*. 2002;31(8):778-784.
43. McCarthy DM, Tolin BS, Schwendeman L. Prosthetic replacement for the anterior cruciate ligament. In: Jackson DW, Arnoczky SP, Woo SLY, eds. *The Anterior Cruciate Ligament: Current and Future Concepts.* New York, NY: Raven Press; 1993:343-356.
44. Melby A 3rd, Noble JS, Askew MJ, Boom AA, Hurst FW. The effects of graft tensioning on the laxity and kinematics of the anterior cruciate ligament reconstructed knee. *Arthroscopy*. 1991;7:257-266.
45. Miyasaka KC, Daniel DM, Stone MD, et al. The incidence of knee ligament injuries in the general population. *Am J Knee Surg*. 1991;4:3-8.
46. Muneta T, Yamamoto H, Ishibashi T, Asahina S, Murakami S, Furuya K. The effects of tibial tunnel placement and roofplasty on reconstructed anterior cruciate ligament knees. *Arthroscopy*. 1995;11:57-62.
47. Noyes FR, Barber-Westin SD. Anterior cruciate ligament revision reconstruction: results using a quadriceps tendon-patellar bone autograft. *Am J Sports Med*. 2006;34(4):553-564.
48. Noyes FR, Barber-Westin SD. Revision anterior cruciate ligament surgery: experience from Cincinnati. *Clin Orthop Relat Res*. 1996;325:116-129.
49. Noyes FR, Barber-Westin SD. Revision anterior cruciate surgery with use of bone-patellar tendon-bone autogenous grafts. *J Bone Joint Surg Am*. 2001;83(8):1131-1143.
50. Noyes FR, Grood ES. Diagnosis of knee ligament injuries: clinical concepts. In: Feagin JA, ed. *The Crucial Ligaments*. New York, NY: Churchill Livingstone; 1988:261-285.
51. O'Neill DB. Revision arthroscopically assisted anterior cruciate ligament reconstruction with previously unharvested ipsilateral autografts. *Am J Sports Med*. 2004;32(8):1833-1841.
52. Oakes BW. Collagen ultrastructure in the normal ACL and in ACL graft. In: Jackson DW, ed. *The Anterior Cruciate Ligament: Current and Future Concepts*. New York, NY: Raven Press; 1993:209-217.
53. Rougraff B, Shelbourne KD, Gerth PK, Warner J. Arthroscopic and histologic analysis of human patellar tendon autografts used for anterior cruciate ligament reconstruction. *Am J Sports Med*. 1993;21:277-284.
54. Safran MR, Harner CD. Technical considerations of revision anterior cruciate ligament surgery. *Clin Orthop Relat Res*. 1996;325:50-64.
55. Salmon LJ, Pinczewski LA, Russell VJ, Refshauge K. Revision anterior cruciate ligament reconstruction with hamstring tendon autograft: 5- to 9-year follow-up. *Am J Sports Med*. 2006;34(10):1604-1614.
56. Sapega AA, Moyer RA, Schneck C, Komalahiranya N. Testing for isometry during reconstruction of the anterior cruciate ligament. Anatomical and biomechanical considerations. *J Bone Joint Surg Am*. 1990;72:259-267.
57. Shelbourne KD, Gray T. Anterior cruciate reconstruction with autogenuos patellar tendon graft followed accelerated rehabilitation: a 2- to 9-year follow-up. *Am J Sports Med*. 1997;25:786-795.
58. Steiner ME, Mizrahi J, Hecker AT, et al. Strength of graft fixation in anterior cruciate ligament reconstruction. *Trans Orthop Res Soc.* 1991;16:599.
59. Taggart TF, Kumar A, Bickerstaff DR. Revision anterior cruciate ligament reconstruction: a midterm patient assessment. *Knee*. 2004;11(1):29-36.
60. Tegner Y, Lysholm J. Rating systems in the evaluation of knee ligament injuries. *Clin Orthop Relat Res*. 1985;198:43-49.
61. Thomas NP, Kankate R, Wandless F, Pandit H. Revision anterior cruciate ligament reconstruction using a 2-stage technique with bone grafting of the tibial tunnel. *Am J Sports Med*. 2005;33:1701-1709.
62. Torg JS, Conrad W, Kalen V. Clinical diagnosis of anterior crucial ligament instability in the athlete. *Am J Sports Med*. 1976;4:84-93.
63. Uribe JW, Hechtman KS, Zvijac JE, Tjin-A-Tsoi EW. Revision anterior cruciate ligament surgery: experience from Miami. *Clin Orthop Relat Res*. 1996;325:91-99.
64. Vergis A, Gillquist J. Graft failure in intra-articular anterior cruciate ligament reconstructions: a review of the literature. *Arthroscopy*. 1995;11(3):312-321.
65. Wirth CJ**,** Kohn D. Revision anterior cruciate ligament surgery: experience from Germany. *Clin Orthop Relat Res*. 1996;325:110-115.
66. Wirth CJ, Kohn D. Revision surgery following failure of anterior cruciate ligament reconstruction. *Orthopade*. 1993;22:399-404.