Anterior Cruciate Ligament Reconstruction with a Four-Strand Hamstring Tendon Autograft

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Background: In this study, we analyzed the clinical outcomes at a minimum of two years following reconstruction of the anterior cruciate ligament with use of a four-strand hamstring tendon autograft in patients who had presented with a symptomatic torn anterior cruciate ligament.

Methods: One hundred and twenty-two consecutive patients who had an isolated, symptomatic anterior tibial subluxation associated with rupture of the anterior cruciate ligament were treated with reconstruction of the anterior cruciate ligament with a four-strand autologous semitendinosus-gracilis tendon graft. One surgeon performed all of the operations. Prior to surgery and at the follow-up examination, physical findings and functional scores were recorded and knee radiographs were analyzed. Following surgery, a six-month rehabilitation regimen was implemented.

Results: Eighty-five patients (70%) were available for follow-up, which included physical examination, scoring of function, KT-1000 arthrometric testing, and radiographs, at a mean of twenty-eight months. Seventy-six (89%) of the patients had negative Lachman and pivot shift tests. The mean Lysholm score improved from 55 points preoperatively to 91 points at the time of follow-up ($p < 0.01$). The mean Tegner score improved from 5 to 6 points ($p < 0.01$). Sixty-five patients had <3 mm of knee translation on arthrometric testing, but six patients with marked laxity were not tested. Three patients (4%) had a positive pivot shift test but had no history of additional trauma to the knee. Six patients (7%) had a traumatic rupture of the graft, occurring at a mean of 10.7 months postoperatively. Assessment of the follow-up radiographs demonstrated no evidence of progressive degenerative change compared with the appearance on the preoperative radiographs. However, tunnel expansion was noted in all patients. The tibial tunnel expanded a mean of 17% (range, 0% to 32%), and the femoral tunnel expanded a mean of 29% (range, 0% to 40%).

Conclusions: Reconstruction of the anterior cruciate ligament with use of a four-strand hamstring tendon autograft eliminated anterior tibial subluxation in 89% of patients who were examined at a minimum of two years postoperatively. The overall rate of failure was 11%. The functional knee scores were significantly increased at the time of follow-up, but these results did not correlate with the results of knee arthrometric testing.

Level of Evidence: Therapeutic study, Level IV (case series [no, or historical, control group]). See Instructions to Authors for a complete description of levels of evidence.

Reconstruction of the anterior cruciate ligament is an effective method of eliminating anterior tibial subluxation that is associated with rupture of that ligament[1-17]. Current techniques of anterior cruciate reconstruction employ a variety of autograft and allograft tissue to replace the injured native ligament. Reconstruction with an autologous bone-patellar tendon-bone graft is an effective method of treating anterior tibial subluxation due to a tear of the anterior cruciate ligament[1,4,5,7,16,18]. However, although this graft type remains the so-called gold standard and is typically used to reconstruct the anterior cruciate ligament, the potential morbidity of this procedure (patellofemoral pain, loss of motion, and patellar fracture)[4,5,16] has prompted continued investigation into the use of alternative graft sources that would yield

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clinical results equal to those observed after reconstruction with a bone-patellar tendon-bone graft.

Reconstruction of the anterior cruciate ligament with a hamstring (semitendinosus and gracilis) tendon autograft has been previously described[2,3,9,10,12-15,19-22]. The strength of the four-strand semitendinosus and gracilis construct has been shown to be equal to or greater than the strength of a bone-patellar tendon-bone graft of similar dimension at time zero[23] and with cyclical loading[24]. Most of the published reports on anterior cruciate reconstruction with autogenous hamstring tendon grafts have described the clinical outcomes in patients treated with a two or three-tendon construct[2,3,9,11-14,24], although more recently there have been studies of four-strand constructs[15,19,21,25].

We hypothesized that an arthroscopically assisted reconstruction of the anterior cruciate ligament with use of a four-strand hamstring tendon autograft would eliminate symptomatic anterior tibial subluxation and provide a good functional outcome for patients who have a torn anterior cruciate ligament. To test this hypothesis, we performed a clinical study to evaluate the effectiveness of a single-incision, arthroscopically assisted reconstruction of the anterior cruciate ligament with a four-strand, double-looped, semitendinosus and gracilis autograft.

Materials and Methods

Patients and Entry Criteria

The protocol for this study was approved by our institutional review board. Subsequently, all patients who presented to the senior author (T.L.W.) over a two-year interval, from 1996 to 1997, with symptomatic anterior tibial subluxation due to rupture of the anterior cruciate ligament underwent a standardized evaluation that included a physical examination (measurement of range of motion, the Lachman test, and the pivot shift test) and standing anteroposterior and lateral radiographs of the knee. Baseline knee function scores (the Lysholm score and Tegner score) were obtained at presentation. All patients who elected to undergo anterior cruciate reconstruction were treated with a single-incision, arthroscopically assisted reconstruction with a four-strand semitendinosus and gracilis tendon autograft. One hundred and twenty-two consecutive patients were treated in this fashion. The operating surgeon performed no other type of reconstruction for isolated symptomatic rupture of the anterior cruciate ligament during the study interval. At the time of surgery, the mean age of the patients was thirty-three years (range, fifteen to sixty-five years). There were sixty-six male patients and fifty-six female patients.

Patients who had undergone previous ligament surgery on the affected knee were excluded from the study. Nine patients (7.4%) had undergone prior partial medial or lateral meniscectomy in the ipsilateral knee, and two patients (1.6%) had previously undergone anterior cruciate reconstruction in the contralateral knee; all of these patients were included in the study group. However, patients who had had treatment for a symptomatic cartilage lesion (microfracture, abrasion arthroplasty, or cartilage resurfacing) were excluded from the study.

Preoperative Physical Examination

Prior to the reconstruction of the anterior cruciate ligament, the mean knee extension was approximately 0° and the mean knee flexion was 120° (range, 100° to 140°). All patients had a positive Lachman test (a grade of ≥2) and pivot shift test (a grade of ≥1+). Lachman grading was based on the relative tibial displacement at 30° of flexion, with grade 1 indicating 0 to 5 mm; grade 2, 6 to 10 mm; and grade 3, >10 mm[25]. No patient had a grade-1 result of the Lachman test, 110 patients had grade-2, and twelve had grade-3. Grading of pivot shift was based on the degree of tibial reduction during the maneuver, with normal indicating no shift; 1+, glide; 2+, a severe jump; and 3+, the tibia locked anteriorly[25]. The pivot shift phenomenon was rated as normal in no patients, 1+ in ten, 2+ in ninety, and 3+ in twenty-two.

Surgical Technique

The anterior cruciate ligament was reconstructed with a single-incision, arthroscopically assisted method. Antibiotics were given prior to the skin incision. The limb in which the operation was to be performed was preliminarily washed with Betadine Surgical Scrub (7.5% povidone-iodine) and subsequently washed with sponge-sticks containing Betadine solution (10% povidone-iodine). The leg was wrapped with an adhesive plastic barrier drape distal to the level of the tibial tubercle. The semitendinosus and gracilis tendons were harvested from the ipsilateral limb as described previously[26]. A tendon harvester was used in all operations. The graft was prepared by first removing all muscle fibers from the harvested tendons. The two tendons were passed through a closed-loop polyester tape that was attached to an Endobutton (Acufex Microsurgical, Mansfield, Massachusetts), forming four tendon strands, each with a free end. Each free tendon end was tethered with a nonabsorbable braided number-1 suture that was placed in an interlocking fashion.

Following preparation of the hamstring graft, diagnostic arthroscopy was performed. Any meniscal injury was treated prior to the anterior cruciate reconstruction. A lateral femoral notchplasty was performed in each patient to facilitate visualization of the posterolateral intracondylar portion of the lateral femoral condyle. Tibial and femoral tunnels were created on the basis of the measured diameter of the four-strand hamstring graft from each patient. Following creation of the femoral tunnel, a 4-mm tunnel was created between the proximal portion of the femoral tunnel and the anterior femoral cortex. Following a depth measurement, the Endobutton-polyester suture-loop complex was created to facilitate femoral fixation of the hamstring graft. In each patient, a minimum of 25 mm of tendon graft was placed within the femoral tunnel.

Following stable placement of the Endobutton on the exterior of the femoral cortex, the knee was flexed and extended while tension was applied to the graft. The individual graft limbs were tensioned manually prior to application of tibial fixation. Tibial fixation, which was performed with the

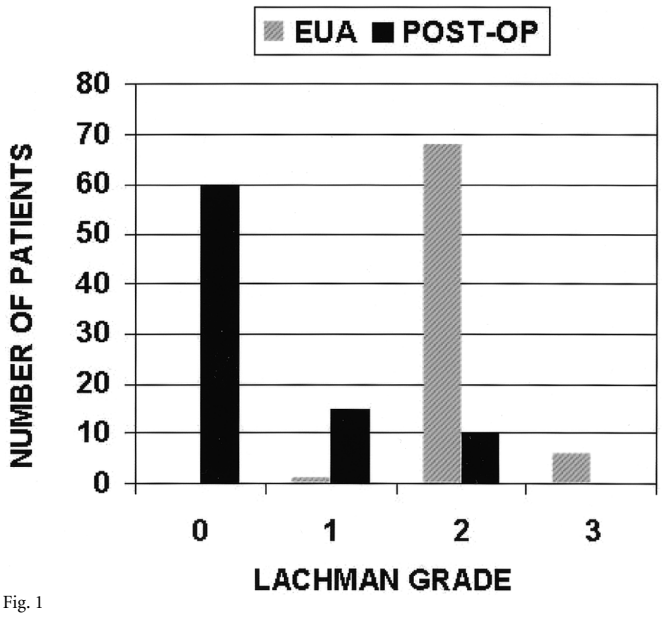

Fig. 1

Results of the Lachman examinations performed with the patients under anesthesia (EUA) and at the time of the latest follow-up.

knee in 20° of flexion, consisted of staples (fifty-seven patients), a washer and screw (fifty-seven patients), or an extracortical button (eight patients). The method of tibial fixation evolved from the washer-and-screw (post) construct to the anterior cortical staples. This change was implemented at the end of 1996, primarily in response to the dissatisfaction expressed by several patients early in the study, with the prominent bulge caused by the washer and screw-head. Buttons were used in operations in which the graft construct did not exit the tibial tunnel sufficiently for the surgeon to utilize a post or staple fixation reliably.

In nineteen patients, bioabsorbable polylactic acid interference screws (DePuy, Warsaw, Indiana) were inserted into the tunnels to provide additional fixation at the tunnel aperture. These screws were employed only when a graft-to-tunnel mismatch was apparent. The bioabsorbable interference screws were used in the femur only in five patients, in the tibia only in seven, and in both the tibia and the femur in seven.

Associated Procedures at Index Operation

At the time of the anterior cruciate reconstruction, six patients underwent partial medial meniscectomy and three patients underwent partial lateral meniscectomy. Ten patients underwent meniscal repair: eight of them had medial meniscal repair with use of the outside-in technique with number-0 PDS (polydioxanone suture) (Ethicon-Johnson and Johnson, New Brunswick, New Jersey)[27] and two had lateral meniscal repair with use of the inside-out technique with the Acufex meniscal suture repair system (Smith and Nephew, Andover, Massachusetts)[28].

Postoperative Rehabilitation Program

A six-month rehabilitation protocol, similar to a previously described protocol for anterior cruciate reconstruction[29], was employed for all patients. Patients began immediate active quadriceps isometric exercises and passive range-of-motion exercises. Continuous-passive-motion devices were not used. The patients who underwent surgery in 1996 were allowed to bear weight on the operatively treated limb, with the knee in a hinged brace that was locked in full extension, immediately after surgery. In the second year of the study, patients utilized a brace postoperatively but were restricted to toe-touch weight-bearing (<20 lb [9 kg]) with two crutches for the first three weeks after surgery. The remainder of the supervised rehabilitation protocol was the same in the two groups of patients.

Postoperative Assessment

At the time of follow-up, one examiner performed all of the examinations. Physical examination included assessment of the range of motion of the knee with a handheld goniometer, Lachman testing, and pivot shift testing. Arthrometric measurements of the knee were performed with use of a manual KT-1000 instrument. Standing anteroposterior and lateral radiographs of the operatively treated knee were also made, and all patients completed questionnaires to determine the Lysholm and Tegner outcome scores.

Statistical Methods

Preoperative, intraoperative, and postoperative data were collected and maintained in a central computer database. Descriptive statistics, the Student t test (paired or unpaired), chi-square analysis, Fisher exact tests, and Pearson correlations were appropriately applied. Statistical analysis was conducted with the SPSS software package (SPSS, Chicago, Illinois). Significance was established at $p < 0.05$.

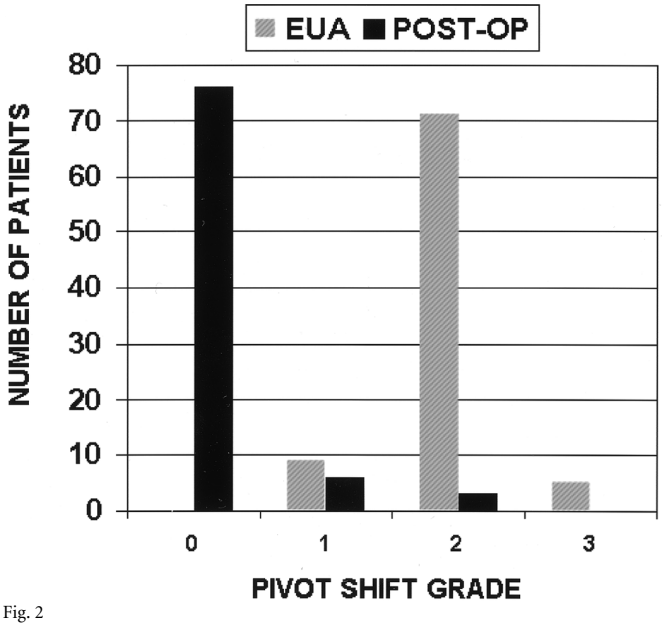

Fig. 2

Results of the pivot shift examinations performed with the patients under anesthesia (EUA) and at the time of the latest follow-up.

Results

Patient Follow-up

Eighty-five patients (forty-nine male and thirty-six female) were available for detailed physical examination at a mean of twenty-eight months (range, twenty-four to forty-two months). At the follow-up examination, functional scores were obtained with a questionnaire, and all but six patients who had marked laxity underwent radiographic examination and testing with the KT-1000 arthrometer (MEDmetric, San Diego, California).

Clinical Assessment

At the follow-up examination, seven (8%) of eighty-five patients had a flexion contracture of <5°. Mean extension was −0.2° (range, −3° to 0°), and mean flexion was 135° (range, 130° to 145°). Of the eighty-five patients, nine (11%), including six who sustained a traumatic tear of the hamstring graft postoperatively, had a positive (grade-2) Lachman test (Fig. 1).

Nine (11%) of the eighty-five patients had a positive pivot shift test (1+ or 2+) at the time of follow-up (Fig. 2). Three of these nine patients reported no episode of knee trauma, and the remaining six patients reported a recurrence of knee instability following a specific injury to the operatively treated knee.

The results of the Lachman and pivot shift tests were unaffected by the use of bioabsorbable screws (in nineteen patients) (Fisher exact test, $p = 0.67$).

Functional Scores

The Lysholm score improved from a preoperative mean (and standard deviation) of 55 ± 3 points (range, 15 to 100 points) to a postoperative mean of 91 ± 2 points (range, 55 to 100 points) ($p < 0.01$). The Tegner score improved from a preoperative mean of 5 ± 1 points (range, 2 to 10 points) to a postoperative mean of 6 ± 1 points (range, 3 to 9 points) ($p < 0.01$).

Arthrometric Testing

Seventy-nine patients underwent testing with the KT-1000 arthrometer at the follow-up examination. The six patients who had a traumatic rupture of the anterior cruciate graft were not retested with the KT-1000 arthrometer. Of the seventy-nine patients tested, sixty-five had ≤3 mm of laxity, nine had between 3.1 and 5.0 mm, and five had >5.0 mm. With the numbers available, the application of bioabsorbable screws (in nineteen patients) had no demonstrable effect on anterior tibial subluxation as measured with the KT-1000 arthrometer (Fisher exact test, $p = 0.55$).

The Pearson correlation coefficient showed a weak inverse correlation between the Lysholm score and the magnitude of tibial translation as determined with arthrometric testing ($r = -0.134$). There was no significant difference between the arthrometric measurements of the men and women ($p = 0.769$, Fisher exact test).

Rehabilitation Protocols

At the time of follow-up, the mean Lysholm and Tegner scores of the patients who had been permitted full weight-bearing in the immediate postoperative period were 91 ± 8 and 6 ± 1 points, respectively. The mean Lysholm and Tegner scores of the patients who had been permitted only toe-touch weight-bearing for three weeks after the operation were 91 ± 8 and 6 ± 1 points, respectively. There was no significant difference between the Lysholm ($p = 0.84$) and Tegner ($p = 0.68$) scores of these two groups (Student t test). There was also no significant difference in the results of the pivot shift tests ($p = 0.97$) or KT-1000 arthrometric measurements ($p = 0.48$) between the two rehabilitation groups.

TABLE I Tunnel Widening

	Mean Widening (and Standard Deviation) *(mm)*	Percent Increase in Width
Tibia		
Anteroposterior radiograph	1.4 ± 1.9	14
Lateral radiograph	1.7 ± 2.0	17
Femur		
Anteroposterior radiograph	2.9 ± 2.1	29
Lateral radiograph	0.8 ± 1.6	8

Radiographic Assessment

One radiologist analyzed the preoperative and follow-up knee radiographs. The mean Hospital for Special Surgery radiography knee score, which was used to assess the progression of degenerative changes[1], was 23.5 ± 1.5 points preoperatively and 22.5 ± 1.6 points at the time of follow-up. With the numbers available, this decrease in the score was not significant according to the Student t test ($p = 0.5$).

The femoral and tibial tunnels that were created during the anterior cruciate reconstruction were measured on anteroposterior and lateral radiographs made at the first postoperative visit, seven to ten days after surgery, and the measurements were compared with those on knee radiographs made at the follow-up examination. The maximum width of each tunnel was used to calculate the tunnel expansion over the follow-up interval. Radiographic magnification was considered. Expansion of the tibial tunnel (expressed as the percentage increase in the tunnel width on the follow-up radiographs compared with the width on the immediate postoperative radiographs) averaged 14% (range, −10% to 21%) on the anteroposterior radiograph and 17% (range, −5% to 40%) on the lateral radiograph. Expansion of the femoral tunnel averaged 29% (range, −10% to 70%) on the anteroposterior radiograph and 8% (range, −12% to 32%) on the lateral radiograph. Negative values for tunnel expansion reflect tunnel contraction—i.e., the tunnel size at the time of follow-up was smaller than that noted immediately postoperatively. A larger degree of tibial tunnel expansion was noted on the lateral radiographs, and a larger degree of femoral tunnel expansion was noted on the anteroposterior radiographs (Table I). The use of bioabsorbable screw fixation had no significant effect on widening of either the femoral or

TABLE II Analysis of Graft Failures

Age *(yr)*	Sex	Weight-Bearing During Rehabilitation	Time to Failure *(mo)*	Activity During Failure	Result of Lachman Test	Result of Pivot Shift Test	Tibial Fixation	Mode of Failure	Outcome
33	M	Limited	8	Basketball	2	2+	Staples	Trauma	Revision/tear of 2nd graft
19	F	Full	24	Softball	2	1+	Staples	Trauma	Brace/ patient active
18	F	Full	4	Basketball	2	1+	Post	Trauma	Revision
18	F	Full	12	Hockey	2	2+	Post	Trauma	Revision
38	M	Limited	9	Skiing	2	1+	Staples	Trauma	Revision
28	M	Full	7	Running	2	2+	Post	Trauma	Revision
34	M	Limited	25	None	2	2+	Post	Unclear	Patient considering revision
19	F	Full	30	None	2	1+	Staples	Unclear	Patient active
46	M	Full	32	None	2	1+	Post	Unclear	Patient active

the tibial tunnel ($p = 0.49$, Student t test).

Postoperative Complications

Two (2%) of the eighty-five patients had a deep infection of the knee in the postoperative period. These patients were treated with arthroscopic irrigation and débridement, intravenous and oral antibiotics, and resumption of physical therapy. In both patients, the hamstring graft was retained. At the follow-up examination, both reported subjective problems with the knee, and the objective functional scores were good. Another patient experienced disabling postoperative knee pain that persisted throughout the six-month rehabilitation period. During the seventh postoperative month, he was diagnosed as having reflex sympathetic dystrophy. This patient was subsequently referred for pain management and was treated with serial sympathetic blockade. Complete resolution of the pain and associated symptoms was noted at both the one-year and the two-year follow-up interval.

Additional Surgery

Sixteen patients had surgery on the involved knee following the anterior cruciate reconstruction: five were treated with revision anterior cruciate reconstruction; two, with arthroscopic irrigation and débridement; five, with partial meniscectomy; and four, with removal of tibial hardware (screw and washer). Four of the patients who had partial meniscectomy had sustained trauma to the knee that resulted in a new meniscal injury. The fifth patient who underwent subsequent partial meniscectomy had had a meniscal repair at the time of the anterior cruciate reconstruction. No patient who had staple fixation underwent hardware removal.

Graft Failure

Six patients (three men and three women) had a traumatic rupture of the anterior cruciate graft at a mean of 10.7 months (range, four to twenty-four months) following the surgery (Table II). Five patients subsequently had a repeat anterior cruciate reconstruction; the sixth patient tore the graft playing softball and remained active with use of a knee stabilization brace. One man, in whom the torn hamstring graft was replaced with a bone-patellar tendon-bone allograft, subsequently tore the revision graft while playing basketball.

A positive pivot shift (1+ or 2+) developed in the absence of discernible knee trauma in three patients. Arthrometric KT-1000 testing in each of these three patients demonstrated tibial translation of >5 mm at 30° of flexion. One of these three patients reported symptomatic knee instability at the follow-up examination; this patient was considering a revision anterior cruciate reconstruction. The remaining two patients did not think that the involved knee was unstable, despite the positive pivot shift, and had returned to activity as tolerated.

Discussion

Successful clinical outcomes following anterior cruciate reconstruction with a hamstring graft have been reported by many authors[2,3,6,9-15,17,20-22]. Despite these favorable results, concerns regarding the recurrence of atraumatic knee laxity, bone tunnel widening, the effect of rehabilitation, gender differences in outcome, and the appropriateness of hamstring grafts for certain types of athletic activity remain. In our study, anterior cruciate reconstruction with a four-strand hamstring graft resulted in a successful clinical outcome in 89% of patients who were available for follow-up. However, recurrent knee laxity (traumatic and atraumatic) resulting in clinical failure remains an important concern with this technique.

It is difficult to compare the results of existing studies because of the variations in the reported surgical techniques[2,3,6,9-15,20-22]. Marder et al. utilized a two-bundle semitendinosus construct and two femoral Endobuttons in sixty-two patients and reported improved anterior stability compared with that in patients who had been treated with a single semitendinosus bundle[10]. Hoffmann et al. reported the results, in

sixty-five patients, of anterior cruciate reconstruction with a doubled-semitendinosus-and-Endobutton construct that was augmented with an extra-articular lateral repair[8]. The authors reported a 78% rate of good or excellent results initially but noted that knee laxity increased over time. This observation induced the authors to switch to a four-strand hamstring construct for anterior cruciate reconstruction. Nebelung et al. reviewed the results of twenty-nine anterior cruciate reconstructions with a doubled autogenous semitendinosus tendon and a femoral Endobutton[14]. They graded 66% of the results as normal or nearly normal using the criteria of the International Knee Documentation Committee.

In the present study, we analyzed the effectiveness of a double-loop (four-strand) semitendinosus-gracilis graft in eliminating symptomatic anterior tibial subluxation caused by a torn anterior cruciate ligament. Anterior tibial subluxation was eliminated in 89% of the patients who were examined at a mean of 2.3 years postoperatively. The remaining 11% of the patients (nine) had a 1+ or 2+ pivot shift at the follow-up examination. Six of those nine patients had sustained a tear of the hamstring graft as a result of trauma to the knee, whereas a positive pivot shift developed postoperatively in the absence of a traumatic event in the remaining three (4% of the patients examined at the time of follow-up). The results in this study compare poorly with those in previously published outcome studies of hamstring tendon grafts[6,8-15,17,20-22] or bone-patellar tendon-bone grafts[4,5,7,16] used for anterior cruciate reconstruction.

Bach et al. reported a reoperation rate of 15% in a series of 103 patients evaluated two years after anterior cruciate reconstruction with a patellar tendon autograft[4]. They reported no traumatic failures but observed a 3% graft-failure rate on the basis of arthrometric criteria (>5 mm of laxity on testing with a KT-1000 device). None of those patients demonstrated a positive pivot shift test. Bach et al. also reported on ninety-seven patients followed for five to nine years after a two-incision anterior cruciate reconstruction with a patellar tendon autograft[5]. A positive pivot shift was observed in 16% of those patients, and 4% had translational differences of >5 mm on KT-1000 arthrometric testing. The reoperation rate was 26%. No traumatic failure was reported. The 7% prevalence of traumatic failure in the current study is high compared with the results reported with the use of patellar tendon autografts[4,5].

An analysis of all of the graft failures in our study (Table II) did not yield any insight regarding factors predisposing patients to graft rupture or attenuation. Patients without symptoms of instability but with objective anterior tibial subluxation and a positive pivot shift test may have had graft attenuation prior to the follow-up examination and remained athletically active by modifying their activity. This fact was reflected by the relatively low functional scores noted in this group of patients.

It has been suggested that expansion of the tunnels for the anterior cruciate graft may play a role in the development of atraumatic recurrent knee laxity following anterior cruciate reconstruction with soft-tissue grafts[30-34]. Tunnel expansion has been seldom described in reports on anterior cruciate reconstruction with bone-patellar tendon-bone grafts[35]. Conversely, tunnel widening has been extensively reported following anterior cruciate reconstruction with hamstring tendons[30-34]. Excessive motion of anterior cruciate grafts within the femoral tunnel has been demonstrated following fixation of the grafts within the tunnel[36]. However, the clinical relevance of this phenomenon following anterior cruciate reconstruction is unknown. In our series, the femoral and tibial tunnels widened a mean of 29% and 17%, respectively. These findings are consistent with those reported by other authors[30-34]. L'Insalata et al. reported widening of the femoral tunnel of 28% to 30% and widening of the tibial tunnel of 21% to 25% in a radiographic study of reconstructions of the anterior cruciate ligament with hamstring grafts; they found no correlation with functional outcome[32]. These results are similar to those recently reported by Simonian et al., more than one year after anterior cruciate reconstruction with a hamstring graft in forty patients[34]. Nebelung et al. found enlargement of at least 2 mm in 72% of femoral tunnels and 38% of tibial tunnels in patients examined two years after anterior cruciate reconstruction in which Endobuttons were used on the femur and staples were used on the tibia[14]. Thus, while the tunnel expansion observed in our study was similar to that in previous reports, the clinical implications of this phenomenon remain unclear.

In our study, the results of KT-1000 arthrometric testing did not correlate with the functional scores. The KT-1000 measurements reported here are consistent with those reported by several authors following reconstruction of the anterior cruciate ligament with a hamstring graft[11,14,33]. Aglietti et al. compared thirty knees in which a torn anterior cruciate ligament was replaced with a bone-patellar tendon-bone graft with thirty knees in which the ligament was reconstructed with a semitendinosus and gracilis tendon graft; they found translation of <5 mm in 13% and 20% of the knees, respectively[2]. Other authors have reported tibial translation of >5 mm in 10% to 18% of patients following anterior cruciate reconstruction with a hamstring graft[11,14,33]. We found tibial translation of between 3.1 and 5.0 mm in 11% of patients and of >5 mm in 6% of patients. Of the five patients in our series who had tibial translation of >5 mm, three had a positive pivot shift test and two did not. The grafts in the latter two patients were not considered failures. However, the six patients who had traumatic disruption of the anterior cruciate ligament graft were not tested with the KT-1000 arthrometer, so this report underestimates the knee laxity in the study group.

Gender did not play a significant role in the development of graft laxity or the occurrence of traumatic graft rupture in our series. Recently, however, Noojin et al. reported a significant difference ($p < 0.05$) between the clinical failure rates in women (23%) and men (4%) in a group of sixty-five patients who had undergone anterior cruciate reconstruction with a four-strand hamstring autograft[15].

With the rehabilitation protocol used in our study, the majority of patients returned to a high functional status after

six months. No motion deficits or clinically important knee pain was noted at the follow-up examination. Other authors have reported success with similar rehabilitation protocols following anterior cruciate reconstruction[12,29,37,38]. The use of protected weight-bearing for three weeks following surgery did not significantly affect the functional scores, findings on physical examination, or results of KT-1000 arthrometric testing. Therefore, we now allow full weight-bearing with the knee in terminal extension in a brace in the immediate postoperative period and employ immediate passive range of motion following the reconstruction.

Two patients had a deep infection of the knee following the anterior cruciate reconstruction, which is a high infection rate. In their study of 2500 consecutive arthroscopically assisted anterior cruciate reconstructions performed at our institution, Williams et al. reported an infection rate of 0.03%[39]. Both of the patients who had a postoperative infection in our study were treated effectively with a single arthroscopic knee lavage followed by a combination of parenteral and oral antibiotics for a total of six weeks. Most importantly, the hamstring graft was preserved in both patients, and a complete functional recovery was noted at the follow-up examination.

Clinically relevant patellofemoral pain or loss of knee motion has been reported following anterior cruciate reconstruction with the patellar tendon[4,5,39], but neither was observed in our study. The elimination of knee instability and the functional scores in our series were consistently good, but the rate of traumatic rupture of the graft (7%) is a cause for concern. The prevalence of traumatic rupture of bone-patellar tendon-bone grafts used for anterior cruciate reconstruction has been reported to be 0% to 2%[4,5,16]. The graft rupture rate in our study was markedly higher than those rates for patellar tendon autografts. As one of the goals of anterior cruciate reconstruction is the durable restoration of knee stability, the issue of rupture of hamstring grafts remains a concern. In a recent meta-analysis comparing outcomes of anterior cruciate reconstruction with either hamstring tendon or patellar tendon grafts, Yunes et al. reported significantly ($p < 0.01$) higher postoperative activity levels and greater static stability following the surgery with the patellar tendon grafts[40]. However, it is important to note that no graft that is currently used for anterior cruciate reconstruction is ideal. Although Yunes et al. noted better stability after the use of patellar tendon grafts, such grafts are associated with a higher prevalence of patellofemoral pain than are soft-tissue grafts[4,5,16]. We did not observe any clinically relevant knee pain or motion loss at the time of follow-up. The absence of such morbid findings following anterior cruciate reconstruction with a hamstring graft may make this method of reconstruction more desirable for certain patients (i.e., those with chronic patellofemoral pain or patellofemoral cartilage disorders) despite the somewhat increased risk of recurrent knee laxity noted in this study.

We found that a four-strand semitendinosus-gracilis autograft eliminated symptomatic anterior tibial subluxation associated with a torn anterior cruciate ligament in 89% of the patients who were available for follow-up. Significant improvements in functional scores were noted. Objective findings of knee stability were inferior to those reported after anterior cruciate reconstructions with bone-patellar tendon-bone autografts, but these findings did not correlate with functional scores. The prevalence of traumatic graft rupture was 7%, and the overall objective failure rate was 11%. Radiographs demonstrated tunnel widening in all patients; however, there were no progressive degenerative changes in the treated knees. ■

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