RESULTS AT MINIMUM FIVE YEARS FOLLOW-UP OF INTRA AND EXTRA-ARTICULAR ACL RECONSTRUCTION USING GRACILIS AND SEMITENDINOSUS TENDONS

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An original Hamstring technique that combines an intra and extra articular plasty was prospectively evaluated in 50 patients after 5 years follow-up.
The male/female ratio was 40/10, mean age at surgery was 28. 30 patients were soccer players at professional or college level. Partial weightbearing with no brace was allowed from the first week. Full return to sports was allowed at 4 months.
IKDC score and KT-2000 were used for assessing clinical outcome. Resumption of sport, Tegner Activity score and Isokinetic test were also used. The IKDC score gave 92% of normal or nearly normal knees. Extension deficit was never observed. KT evaluation was < 3 mm in 38 cases (76%), between 3 and 5 mm in 9 cases (18%) and more than 5 mm in 3 cases (6%). 90% of the cases resumed sport at the same level. The Tegner activity score had a mean value of 8.1 (min. 5 - max. 10). The Isokinetic test showed no deficit for both muscles groups. Removal of staples was necessary in 8 cases (16%) due to femoral lateral bursitis.
Acute reconstruction had significantly better manual stability, and KT value. Men had significantly better results then women (p.025).
This tecnique demonstrated a high reliability, low morbidity, low functional deficit and fast recovery using hamstring grafts. The outcomes of Hamstring ACL reconstrunction are now as good as patellar tendon reconstruction.

INTRODUCTION

Reconstruction of the anterior cruciate ligament is a procedure in which techniques continue to evolve. The basic principles of ACL reconstruction include graft selection and harvest, bone tunnel placement, graft fixation, and post-operative rehabilitation. Each technique has been shown to affect the clinical outcome of ACL surgery.(1,2,8,15,16,19,22,30,32,34,38,54,55,57,67)
The main purpose of ACL reconstruction is to provide an intrinsically stable knee with a full range of motion. The patient should be able to participate in unrestricted athletic competition. An optimal ACL reconstruction technique therefore uses graft material of sufficent strength and minimum harvest morbidity, accurate bone tunnel placement and strong reliable graft fixation, allows for immediate weight bearing and range of motion activities, to facilitate and accelerate the complete functional recovery after surgical management. Reconstruction of anterior cruciate ligament using one third of patellar tendon with bony attachments is recognized as being the optimum method because of its mechanical strength and bony fixation (5,6,7,41,45,62). Anterior knee pain, flexion contracture of the knee and delayed recovery of the strength of knee extension may occur after this procedure (29,32,34,41,43,56,58,64). To avoid these problems the semitendinosus tendon combined with that of gracilis has been used as an alternative procedure to improve its several disadvantages. However, some reports comparing the operative outcome of STG and BTB surgeries have indicated preferable results from BTB surgery with regard to knee stability and sporting activity recovery (1,11,18). Others showed no differences in clinical outcome between the two procedures (38,49). Recent studies showed an improvement in the outcome of ACL reconstruction using STG from subjective and objective points of view.(21,36)
In 1993 we developed an original Hamstring technique that would address the criteria necessary for modern ACL reconstruction that would still be technically simple enough for the occasional ACL surgeon to perform accurately. This technique combines an intra and extra articular plasty that guarantees high graft strength, reduces the risk of surgical errors using an over the top position, maintains the hamstring tibial insertion, and ensures a firm graft fixation to allow immediate full motion and aggressive rehabilitation with resumption of sport at 4 months. The purpose of this study was to prospectively evaluate after a minimum of 5 years follow -up the results of this technique in a very demanding sport population and evaluate if aggressive rehabilitation or other clinical factors could play a role in determination of residual laxity and final clinical outcome.

MATERIALS AND METHODS

Overview

From 1993 an arthroscopic intra and extra - articular ACL reconstruction using gracilis and semitendinosus tendons

was performed in prospectively selected patients. All young patients practicing sports at high level, that presented at first examination a frankly positive Lachman test and pivot - shift test, were selected for our combined ACL reconstruction. From 1993 to 1995 sixty patients were surgically treated. Of these sixty patients we were able to evaluate 50 at a minimum five years follow-up (mean. follow-up 6.4 months). The right/left ratio was 29/21, the male/female ratio was 40/10 and the age at surgery ranged from 21 to 40 years (mean. age 28 years). All subjects were athletically active. 30 patients were soccer players at professional (17) or college level (13). The other 20 cases included three professional basketball-players and 17 amateur athletes involved in high risk sports (4 skiing, 4 tennis, 4 martial arts, 5 volleyball).
No patients had previously undergone surgery on the involved knee.
Of these 50 cases 15 were treated in the acute phase (less than 3 weeks after injury). In the remaining 35 knees surgery was performed in the subacute phase (from 3 to 12 weeks after injury) in 11 cases, while chronic ACL lesions were present in the other 24 cases. In the chronic cases the original injury had occurred from 3 to 121 months (average 25 months) before the combined arthroscopic reconstruction was performed. At surgery associated lesions were not found in 19 cases. A single tear of the medial meniscus was found in 20 cases, a single tear of the lateral meniscus in 4 cases, a tear of both menisci in 6 cases. Ostoechondral defects were found only in 2 cases, and MCL tears were associated in 11 patients. Treatment for the associated injuries included partial meniscectomy and debridement of the osteochondral defect. No meniscal sutures were used and the MCL tear was never repaired in these cases.

Surgical technique.
The same technique was used in all operations which were performed by the senior author (M.M.). The technique described (37) involves the use of a single limb of gracilis and semitendinosus tendons that are sutured together. The tibial tendinous insertion is left intact. The tendons are then passed through the tibial tunnel and over the top and fixed to the lateral condyle with two barbed staples. The remnant part of the combined graft was then fixed in tension down to the Gerdy's tubercle as extra-articular lateral plasty.

Post-operative protocol.
The post-operative program consist of passive full extension and active flexion over a range of 0°-120° degrees from the third post-operative day. The patients were allowed partial weightbearing with no brace from the first week. Only patients with lack of extension had a knee brace locked in full extension for 1 week and during walking in the first 3 weeks. At the same time isometric and open chain proprioceptive exercises were performed as well as active and passive full range of motion. Full weightbearing was allowed from the third week. At 1 month isotonic and closed chain exercises were started. Running and quadriceps muscle resistive exercises were started at 2 months. Full return to sports including cutting sports were allowed at 4months after surgery.

Functional assessment.
At 5 years minimum follow-up, the difference in thigh girth between the operative leg and the contralateral leg 15 cm proximal to the supra patellar pole was calculated. The Lysholm (35) and IKDC (23) score were used for assessing clinical outcome. Knees were graded normal (A), nearly normal (B), abnormal (C) or severely abnormal (D). The categories evaluated included subjective assessment of function, symptoms (pain, swelling and giving-way), motion, stability, compartmental findings, harvest site pathology and one-legged hop test. According to IKDC recommendation the lowest grade in any category was used as the final outcome for that patient's knee. Stability was determined by the combined results of the manual Lachman test, pivot - schift test and varus-valgus rotation. Arthrometric laxity measurements were also performed with the KT-2000 knee arthrometer (Med metric Corporation, San Diego, CA) using the passive displacement test, manual maximum displacement test and quadriceps active test. A stable knee had all threeof the following findings: firm end-point, no pivot-shift or glide pivot-shift that was similar to the contralateral knee. The difference in anterior displacement for KT-2000 had to be less than three mm or between three and five mm. An unstable knee had either a soft end-point, an increased pivot-shift or more than five mm difference in anterior displacement compared to the contralateral knee. The functional capability of the knee was tested by the resumption of sport, time taken to resume sport, Tegner Activity score and Isokinetic test. All patients were tested on a Biodex Dynamometer which was calibrated before the testing period. The testing protocol was standardized to ensure reproducibility and validity (14,65). The patients were instructed on how to use the Isokinetic machine and allowed to become fully accustomed to the device before testing. They performed a five minute warm up on an exercise bicycle. The formal testing consisted of 5 maximal repetitions at 90°/sec and then 15 maximal repetitions at 240°/sec, using the healthy limb first and than the affected one.
Standard antero-posterior (AP) and lateral (L) X-rays were taken in weight-bearing X-ray at 30° flexion. The tibial

tunnel diametre was determined 1 cm distal to the ACL insertion on the AP and L X-ray (10). The shape of the tunnel was evaluated according to the Peyrache classification: cone, linear or cavitatory (50). Examination of postural defect and postero-lateral laxity was performed to evaluate any effect of surgical technique on the patient's gait. The number of reoperations was also recorded.

Statistical Analysis.
One way Anova was used to compare mean values between groups as well as the Mann Whitney non-parametric test. Linear regression analysis and correlation coefficents were used to evaluate if certain parameters could affect the final clinical outcome.
The minimum value of significance was p=0.05.

RESULTS
Thigh Atrophy
At five years 39 patients had no sign of muscle wasting. In 6 cases there was a difference of 1 cm. The remaining 5 patients had differences of 1.5 to 2 cm.
The Lysholm score gave a mean value of 94 (min. 78 - max. 100) with 1 case (2%) fair, 1 case (2%) good and 48 (96%) excellent results.
The overall IKDC score gave a high percentage of normal or nearly normal knees as shown in table 1. Subjective evaluation gave a mean value of 93.5% of the treated knee compared to the contralateral healthy knee. In particular 46 cases (92%) rated their knee as normal or nearly normal. The remaining 4 patients regarded their function as abnormal. Of these four patients one had failure of the graft, the other three experienced pain and effusion after moderate activity.

Range of movement
Extension deficit was never observed. Loss of flexion was less than 5° in 49 cases (98%) while flexion deficit between 6 and 15° was present in only 1 case (2%).

Ligament stability
Table 2 shows the results of the Lachman, anterior drawer, pivot shift test and valgus stress test. One case had increased laxity, and 30% of the cases had a residual valgus instability.
KT evaluation gave a mean side to side differrence of 2.1 mm, 1.7 mm and 1.2 mm for 30 libre, manual maximum and active displacement test respectively. In particular, the side to side difference was < 3 mm in 38 cases (76%), between 3 and 5 mm in 9 cases (18%) and more than 5 mm in 3 cases (6%).

FUNCTIONAL CAPABILITY OF THE KNEE
Resumption of sport was achieved before 4 months in 20 cases (40%), between 4 and 6 months in other 20 cases (40%) and between 6 and 8 months in the remaining 10 cases (20%). 90% of the cases resumed sport at the same level before surgery while 10% of the cases reduced their activity level.
The Tegner activity score had a mean value of 8.1 (min. 5 - max. 10).
The Isokinetic test showed a matching extensor mechanism performance in boths legs and a mean deficit of less than 10% for flexor muscle performance.

Radiological findings.
X-ray evaluation showed no medial compartment degeneration. Subchondral sclerosis was detected in 10 (20%) of the cases where a medial meniscectomy had been performed. Evaluation of the tibial tunnel showed a conic deformation of the tunnel of less than 2 mm in only 2 cases (4%).

Harvest site and Extensor apparatus.
Slight symptoms at the harvest site were recorded in 6 cases (12%). In particular 4 cases had paresthesia along the saphenous nerve irradiation, while 2 experienced pain after strenous activity.
Anterior knee pain after strenous activity was detected in 4 cases (8%), while no patients had discomfort on kneeling.

Complications.
Removal of staples was necessary in 8 cases (16%) due to femoral lateral bursitis.
Manipulation under anesthesia was never necessary. Medial meniscectomy became necessary later in 3 cases.

Statistical analysis
Analysis of results from statistical point of view have demonstrated that acute reconstruction had significantly better manual stability, and KT value (p.02 and p.018 respectively). The dominant leg had significantly better stability (p.0009).
Men had significantly better results then women (p.025).
Patients with positive valgus stress had the poorest results, although not significant.
However, patients with better stability and negative valgus stress had a significantly quicker resumption of sporting activity (p.025)

DISCUSSION

The overall results of our technique at a minimum of 5 years follow-up were highly satisfactory. Many important parameters as: subjective evaluation, knee laxity, resumption of sport activity and functional evaluation gave a high score; 92% of normal or nearly normal knee, according to the IKDC score.
Orthopaedic surgeons currently have a plethora of ACL reconstruction techniques from which they may choose. The hamstring tendons have been used as an ACL graft since 1939. Since then, numerous authors have described different methods of hamstring graft combinations(single, double, looped), graft fixation (distally based, free), and surgical approaches (open or arthroscopically assisted). (4,12,13,31,39,40,52,58,68) Our technique involves the use of a single semitendinosus and gracilis bundle intraarticularly and the residual part of the tendons is used as extraarticular plasty.
Laboratory analysis of graft strength has been ongoing since Noyes study in 1984 (45). Kennedy (28) and Noyes (45) have demonstrated that the maximum failure load of SMT and Gracilis is about 70% and 50% respectively of that of the normal ACL. A combination of these two tendons should, therefore, meet our strength requirements. These results have been confirmed in a recent study by Simonian(60), Brahmabhatt (3) and Hamada(17) that have shown that four bundles of hamstrings graft is sligthly stronger compared to patellar tendon and has a greater cross sectional area.
In our technique the intraarticular tendons, although thinner than the four bundle technique, are supported by the residual part of the tendons that is used as extraarticular plasty.
The role of extraarticular plasty is difficult to analyze separately from the ACL graft. Roth (55), Strum (63) and O'Brien (47) have found no beneficial effects regarding stability in adding an extraarticular plasty to an intraarticular ACL reconstruction.
Jensen (26) affirmed that the extraarticular plasty has no control on knee laxity but reduces the sensation of giving way. On the contrary, Noyes and Lerat (33,46), recently, have found a significant difference in knee stability when an extraarticular procedure is associated to ACL reconstruction. According to Wilson (66) we believe that a combination of intra and extra articular plasty helps to protect the intraarticular graft during the critical early phase of remodelling and maturation. Moreover the new techniques developed for the hamstring involve the detachment of tibial tendons insertion and the use of hamstring as a patellar tendon graft, which means the execution of a tibial and femoral tunnel and research and development of stable and safe femoral and tibial fixation. In our technique preservation of hamstring tibial insertion could mantain the blood supply to the tendons that could enhance the maturation process of the graft and at the same time solve the problem of tibial graft fixation, ensuring natural fixation of the graft.
Hamstring ACL reconstruction has been advocated as an alternative standard procedure to the use of bone patellar tendon bone graft to improve its several disadvantages such as slow recovery in quadriceps muscle strength, difficulties of full hyperextension, higher harvesting morbidity and anterior knee pain (29,56,58). However comparative outcome reports have indicated preferable results from BTB surgery with regard to knee stability and resumption of sporting activity. Aglietti (1,11,18) reported a more speedy return to athletic activity following the BTB procedure, Holmes (18) reported excellent and good results in only 50% of STG procedures five years after surgery. On the contrary, Marder and Otero (38,49) showed no differences in clinical outcome between the two procedures.
Recent studies showed an improvement in the outcome of ACL reconstruction with STG. Maeda described good results using multi strand semitendinosus tendon and had a better recovery of knee extension compared with BTB operation (36).
Muneta showed a preferable outcome for BTB reconstruction with regard to the recovery of knee stability. In this series with aggressive rehabilitation a greater number of patients with STG reconstruction had residual anterior laxity of more than 5 mm difference (10%) (41). On the other hand the subjective recovery was better for ACL reconstruction using STG than BTB reconstruction.

In other series, stability of less than 3 mm, using STG, has been found in 50% (2), 78% (59) and 83% (48). Pinzcewski (51) had stability restored in 72% of the knee 2 years after treatment.
Muneta and Howell (20,42) in a more recent series obtained greater stability with 90% of satisfactory results at KT evaluation at 2 years follow up.
Our results have shown, at a minimum of 5 years, a restored stability of less than 5 mm in 94 % of the cases. These results are similar to the ones obtained by Johma (27) in a sereis of BTB reconstruction at 7 years follow up.
The difference in the outcome of these numerous series certainly can be attributed to the graft choice, but especially in the last years, other factors such as tensioning of the graft, fixation method, timing of surgery, associated lesion, rehabilitation protocol and biological factors play an important role that is still difficult to estimate, verify and quantify.
In our series according to Johma (27) we found that acute reconstruction increases final clinical outcome compared to chronic reconstruction, reducing the risk of osteoarthritic degeneration.
Accelerated rehabilitation in our study did not influence stability as in the Muneta study (41). On the contrary, we found that patients with good A-P stability and negative valgus stress had significantly quicker resumption of sporting activity.
In agreement with Pinczewski (51) we found significantly better results for male patients: there was more laxity in female patients. An intrinsic different elastic modulus of tendons connective tissue as well as different integration method between gender could explain these findings.
Different surgical procedures certainly are responsible for different results. We fix the graft around 90 degrees as in the Maeda (36) study while other authors usually fix the graft around 30°. Our technique involves the preservation of tibial insertion and on the femur the staple fixation guarantees good stability. Extra- articular plasty can protect the graft in the early phase ensuring suitable mechanical stress to the graft. An indirect confirmation of our graft complex stability can be obtained analyzing our X-ray findings. Several authors such as Clatworthy, Jansson, Nebelung, Insalata (9,24,25,44) have documented tunnel enlargement especially using hamstring tendons. Many theories have been postulated and probably the origin of tunnel widening is multifactorial. The bungy cord effect with longitudinal pistoning of the graft or the wind shield wiper mechanism with graft complex oscillating from distant fixation point partly explain this effect. However, the inflammatary reaction at the bone tunnel interface with delayed remodelling process certainly is another component. In fact the widening is characteristic of the first 4-6 months.
In our cases a slight widening of the tibial tunnel was present in only 2 cases (4%) demonstrating a good biomechanical behaviour of our graft complex.
Another important factor is the muscular control of knee stability. In our cases dominant leg gave significantly better results than the contralateral one. Our isokinetic value at 5 years showed a comparable extensor value and a mean deficit of 6% for the harvested muscle.
Our results confirm Lipscomb's and Simonian's (34,60,61) data that showed good recovery of muscle strength after hamstring harvesting. These results confirm the lower morbidity of this graft compared to patellar tendon as documented in several papers. Natri, Sachs, Marder, Wilk (38,43,56,64) reported extensor muscle deficit in BTB group from 17 to 40% at different follow-up time.
We believed that especially in highly motivated athletes with good muscle strength pre-operatively, preservation of extensor mechanism of the knee allows a faster recovery of kinematic muscle control that could prevent elongation of the graft in the early phase.
Removal of hardware continues to be the most common reason for additional surgery using the hamstring tendons as a graft. Howell (20,21) reported required hardware removal in 21% of the subjects. Clark (8) and Siegel (59) reported 22 and 26 % respectively hardware removal in their series. In 16% of our cases it was necessary to remove staples from the femur due to irritation of ileotibial band probably related to early return to athletic activity. Removal was performed at least three months post-operatively with no influence on final clinical outcome.
In conclusion, according to Rosemberg (53) we believe that the outcomes of Hamstring ACL reconstruction are now as good as patellar tendon reconstruction, with lower global morbidity.
On the other hand, we agree with Clancy (7) that hamstring ACL reconstruction is not equaled in comparison to the patellar tendon in basic science research, long term follow up and overall consistently highly results. The results of this tecnique at a minimum of five years follow-up demonstrated a high reliability, low morbidity, low functional deficit and fast recovery using hamstring grafts. This study can contribute to decreasing the gap between patellar tendon and hamstring regarding long term studies. However, we believe that at the moment satisfactory clinical outcome do not depend by the graft choice but by a correct execution of the surgical technique.

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Table 1: IKDC score

Normal	21	42%
Nearly normal	25	50%
Abnormal	3	6%
Severely abnormal	1	2%

Table 2: Tests results

Test	Negative	1 +
Lachman	47 (94%)	3 (6%)
Anterior drawer	46 (92%)	4 (8%)
Pivot shift	38 (76%)	12 (24%)
Valgus stress	35 (70%)	15 (30%)