The cross-sectional shape of the four-fold semitendinosus tendon graft is not round

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Background: The looped side of the semitendinosus tendon (ST) graft, i.e., the side that is inserted into the femoral tunnel in ACL reconstruction, appears to be oval rather than round. To the best of our knowledge, there are no studies published in the literature that present scientific evidence concerning the cross-sectional shape of the ST graft. Furthermore, we hypothesize the ST graft fits better to the rounded rectangular tunnel than to round femoral tunnel. The purpose of this study was to investigate the cross-section of four-fold ST graft and the contact pressure between the ST graft and the rounded rectangular femoral tunnel or round femoral tunnel.

Materials and Methods: Seven semitendinosus tendons were harvested from fresh-frozen cadaveric knees. After both ends of the double-fold ST were sutured with a Baseball stitch using no.2 FiberWire (Arthrex Co., Ltd., Naples, USA), the graft was looped over TightRope (Arthrex Co., Ltd., Naples, USA) to make four-fold ST graft. The graft tension was set to 30 N. Aluminum cubes with two types of tunnels containing four-way pressure-sensitive conductive rubber sensors (vertically and bilaterally) were used to measure the pressure. One was round (8.16 mm diameter) and another was rounded rectangular (6×10 mm). The area of both cross-sections was the same (52.3 mm²). The graft was inserted into the tunnels 15 mm from the lapel edge and its crease accorded with bilateral sensors. After measuring the pressure, the ST graft was set in place using UV-curing acrylic resin and UV lump with 30 N tension. The graft was cut at 7.5 mm and 15 mm from the lapel edge. Photographs of the cross-sections were analyzed using a computer software to measure the area of the cross-section, the major and minor axis for the best fitting ellipse of the cross-section and ellipticity (major axis/minor axis).

Results: In the round tunnel, the mean contact pressure was 287.0 ± 136.7 gf at bilateral sensor. However, there was no contact pressure detected by vertical sensor. In the rounded rectangular tunnel, the mean contact pressure was 260.9 ± 186.4 gf at bilateral sensor and 352.9 ± 49.5 gf at vertical sensor. The cross-section of the graft was not round but oval. Elasticity was 1.25 ± 0.13 at 7.5 mm, and 1.17 ± 0.07 at 15 mm from the lapel edge of the graft.

Conclusion: The cross-sectional shape of the four-fold ST graft was not round but oval. The rounded rectangular femoral tunnel was more fitted for the graft than round femoral tunnel.
Background: There are multiple sources of grafts for ACL reconstruction, bone-patellar tendon-bone and hamstring autografts and also allograft. The gold standard for ACL reconstruction has been bone-patellar tendon-bone, but recently enthusiasm has arisen for harvesting semitendinosus and gracilis tendons to avoid the potential complications of bone-patellar tendon-bone harvesting, such as patellar fracture and extensor mechanism damage. It is essential to obtain a prepared harvested graft thickness of at least 7 mm for ACL reconstruction. If the semitendinosus tendon is thick enough (minimum 7 mm), it can be used alone without harvesting the gracilis which would reduce the adverse effects on knee.

The aim of this study was to compare the thickness of a triple fold semitendinosus tendon versus quadrupled semitendinosus and gracilis autograft. Our hypothesis was that triple fold semitendinosus tendon have the same thickness as quadrupled semitendinosus and gracilis tendon.

Material: One hundred and twenty patients (110 males and 10 females) with documented ACL tears were enrolled in our study.

Method: In the first (case) group, semitendinosus tendon autograft and in the second (control) group, semitendinosus and gracilis tendon autografts were used for arthroscopic ACL reconstruction. Inclusion criteria were complete ACL tear in adult patients, full range of motion of the knee without effusion and edema before surgery (at least 4 weeks after trauma). Exclusion criteria were multiple ligamentous injuries requiring allograft, revised ACLR, partial ACL tear, previous hamstring tendon injury, or harvest in ipsilateral leg. All surgeries were performed by a senior surgeon (HRY) with the same equipment and surgical technique. The thicknesses of the grafts were measured using a tendon thickness tester (Karl Storz, Tuttlingen, Germany).

Results: The mean age of the case group was 34±12.6 years (21 to 47 years) and of the control group was 35.5±11.3 years (17 to 48 years). There were no significant differences in age, male-to-female ratio, height, and BMI between the groups. Mean graft thicknesses were 7.89±0.59 mm in the control group and 7.87±0.50 mm in the case group. An analytical study using the independent T test showed no significant difference in graft thickness between the two groups (p value=0.87).

Discussion: In this study, we found that there is no significant difference between the thickness of triple fold semitendinosus tendon auto graft and quadrupled semitendinosus and gracilis tendon autograft. But using semitendinosus tendon alone would result in less graft harvesting time, less donor site morbidity, and fewer adverse effects on leg internal rotation and knee flexion force.

Conclusion: This study showed that a triple ST tendon graft has the same thickness as a quadrupled ST and G graft.
Prediction of Hamstring Tendon Graft Size for ACL Reconstruction from Preoperative MRI and Patient Height

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Abbreviations: GT – gracilus tendon, ST – semitendinosus tendon, CSA – cross sectional area

a) Background: Small diameter hamstring tendon autograft size has been reported as a possible cause of failure of anterior cruciate ligament (ACL) reconstructions. The ability to accurately predict the diameter of an individual’s hamstring pre-operatively using magnetic resonance imaging (MRI) and anthropometric patient height would enable surgeons to identify patients at risk of small hamstring graft size and consider alternative graft constructs. Hence, the purpose of this study was to comparatively examine the predictive relationship of 1) cross-sectional area (CSA) measurements of hamstring tendons on preoperative MRI and 2) patient height, with the intraoperative hamstring autograft diameter retrieved at the time of ACL reconstruction (ACLR) and to assess the accuracy and reliability of the MRI CSA measurement method.

b & c) Materials and Method: A series of 238 subjects who underwent quadrupled-strand hamstring tendon autograft ACLR with available preoperative MRI studies and heights, were identified from a prospective database of knee surgery over a four year span from 2011 to 2014. The total CSA of the semitendinosus and gracilus hamstring tendons (ST +GT) was measured using the OsiriX MD region-of-interest tool by two raters blinded to each other. MRI-estimated CSA and patient height was correlated with the intraoperative hamstring autograft. This was a retrospective diagnostic study (Level II).

d) Results: Using a predictive model, in order to determine with greater than 90% confidence that the graft diameter will be greater than 7mm, the measured CSA needs to be greater than 18mm². In order to have greater than 90% confidence that the graft diameter will be greater than 7.5mm, the measured CSA needs to be greater than 23mm². The Pearson correlation coefficients for 1) MRI CSA of ST + GT and 2) patient height to the intraoperative hamstring autograft diameter was 0.64 (P <0.001) and 0.42 (P <0.001), respectively. In an ANOVA F Test, both predictors gave an F value of 93.585 (P < 0.001), with MRI CSA of ST + GT, giving a 17.2% (P<0.001) increase in predictability and patient height giving a 7.5% (P<0.001) increase in predictability, when compared to the null model. An intraclass correlation coefficient of 0.814 (P<0.001, 95% CI 0.760 to 0.856) was obtained for both raters.

e) Discussion: MRI CSA of ST+GT was found to be a stronger predictor of intraoperative hamstring tendon autograft diameter compared to patient height, whilst the MRI measurement method was found to be highly accurate and reliable. The use of preoperative MRI CSA measurements of hamstring tendons can enhance pre-surgical planning & identify
patients at risk of diminutive autografts, allowing surgeons to consider alternative graft constructs and lower rates of ACLR failure.

**f) Conclusions:** There is a strong, positive correlation and a significant predictive relationship between using both MRI CSA ST + GT measurements and patient height in determining intraoperative hamstring autograft diameter. Our protocol has the future potential to be added as universally-applied routine aspect of preoperative planning for ACL reconstruction.
Graft Diameter Matters in Hamstring ACL reconstruction

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Introduction
Recently techniques have been developed to increase graft diameter in hamstring ACL reconstruction with the hope to decrease graft failure. To date there is limited evidence to show that a smaller graft diameter results in a higher ACL failure rate.

Method
The factors for failure in 1480 consecutive single surgeon hamstring ACL reconstructions were evaluated prospectively. Patients were followed for 2-15 years. A multivariate analysis was performed which looked at graft size, age, sex, time to surgery, meniscal integrity, meniscal repair and ACL graft placement to determine whether graft diameter matters in determining the failure of hamstring ACL reconstruction.

Results:
Graft diameters ranged from 6-10mm. The mean graft diameter for all patients was 7.75mm. 83 ACL reconstructions failed. The mean size of graft failures was 7.55mm.

ACL reconstructions that failed had a significantly smaller hamstring graft diameter p=0.001

The Hazard Ratio for a smaller diameter graft is 0.517 p=<0.0001
For every 1mm decrease in graft diameter there is a 48.3% higher chance of failure

The multivariate analysis showed a hazard ratio of 0.543  p=0.002
For every 1mm decrease in graft diameter there is a 45.7% higher chance of failure
If the graft ≤ 7.5mm the failure rate is 7.6%
If the graft ≥ 8mm the failure rate is 3.8%

**Conclusion:**
Smaller diameter hamstring grafts do have a higher failure rate. Grafts ≤ 7.5mm had twice the failure rate of grafts ≥ 8mm. Using a multivariate analysis for every 1mm decrease in graft diameter there is a 45.7% higher chance of failure.
Regression modelling combining MRI measurements and patient anthropology to predict graft diameter in ACL reconstruction

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Background
Graft diameter has been shown to influence the risk of graft failure. Graft preparation techniques used in anterior cruciate ligament reconstruction (ACLR) are variable and may affect graft diameter. Previous studies have correlated anthropometric data and MRI tendon measurements to intraoperative graft diameter and suggested that these singular factors can be used to predict graft diameter. However, none have investigated these together in an integrated model. Our study aimed to investigate the prediction of intraoperative graft diameter in quadrupled semitendinosus (4-ST) and doubled semitendinosus-gracilis (4-STG) graft constructs, using anthropology and MRI measurements, with a goal of providing practical guidelines for orthopaedic surgeons.

Materials & Methods
Hamstring autograft, arthroscopic ACL reconstructions using four-strand gracilis + semitendinosus (4-STG) and quadrupled semitendinosus grafts (4-ST) between April 2009 and June 2015 were retrospectively reviewed. Cross-sectional areas (XSA) of the semitendinosus and gracilis tendons were measured in the axial slice of a T2 weighted MRI image using a region-of-interest tool. Measurements were taken at the slice with the widest trans-epicondylar distance, and repeated at one slice above and below. The median was recorded. Patient anthropometric data (height, weight and gender) were extracted from patient clinical notes. Pearson’s correlation coefficients with 95% prediction intervals (PI) were used to replicate previously reported correlations. Ordinal logistic regression models were established using all data, as well as sub-group models of those receiving 4STG grafts and 4ST grafts with graft diameter categorised into an ordinal response variable (>8mm, 8mm, <8mm). Partial least squares regression (PLSR) using the nonlinear iterative algorithm (NIPALS) was used to develop a refined predictive model for graft diameter. The model was validated using leave-one-out cross validation (LOOCV).

Results
A cohort of 108 ACL reconstructions in 107 patients was examined, 75 of which were performed with the 4-STG construct, and 33 which employed the 4-ST construct. The mean graft diameter in the 4-ST group (8.6±0.8 mm) was significantly (p < 0.001) greater than the 4-STG group (7.9±0.7mm). Intra-observer reliability was high for MRI measurements. MRI XSA sum of ST and gracilis tendons and height demonstrated statistically significant correlations with graft diameter in both 4-STG (r = 0.48, r = 0.45 respectively) and 4-ST (r = 0.71, r = 0.67 respectively) constructs. Ordinal logistic regression of the overall cohort showed that female gender and the 4-STGT preparation technique were associated with increased odds of receiving grafts <8mm, while every 1mm² increase in ST XSA reduced the log odds of receiving a graft <8mm by 0.39 (87.2% concordance). PLSR regression of the overall cohort identified median ST XSA and height as key predictors of graft diameter. The 95% prediction error for the overall model for a single future patient was 0.9mm. That is, predicted graft diameters of 8.92mm or above would have a 2.5% chance of being <8mm in theatre.

Discussion
The ability to predict graft diameter prior to surgery may improve surgical efficiency for ligament reconstruction, particularly if a minimum graft diameter threshold is to be achieved. Previous studies have correlated patient anthropology and MRI XSA to intra-operative graft diameter,
however this study is the first to present a validated predictive model. The results identify females receiving 4-STGT constructs at-risk of producing grafts <8mm, and this can be screened with MRI-based measurements of tendon geometry. More accurate predictive models that are easy to use provide surgeons with a useful clinical tool for surgical planning. With a future prospective study incorporating a range of intraoperative variables, this model can be further refined to increase its clinical applicability.

**Conclusion**
Patient height, gender and MRI cross-sectional measurements are significant predictors of graft diameter. Whilst the actual graft diameter required for each patient is a decision for the treating surgeon, this study confirms previous correlations, and proposes a novel method of stratifying and accurately predicting the likely graft diameter for each patient.
Abstract

PURPOSE: The gold standard in ACL reconstructions has been the bone-patellar tendon-bone autograft fixed with interference screws. This prospective, randomized clinical trial aimed to compare two methods of fixation for BPTB grafts: press-fit fixation vs. interference screw, over a 12-month follow-up interval.

METHODS: 158 patients with an average age of 29.8 years, between 2011 and 2012, were treated for torn ACL. 82 patients underwent reconstruction with BPTB autograft with a press fit fixation technique, and in 76 cases an interference screw was used. At the time of final follow-up, 71 patients in press-fit group and 65 patients in interference screw group were evaluated in terms of return to pre-injury activity level, pain, knee stability, range of motion, IKDC score and complications.

RESULTS: At 12-month follow-up, 59 (83 %) and 55 (85 %) in press-fit and screw group, respectively had good-to-excellent IKDC score (p > 0.05). The mean laxity assessed using a KT-1000 arthrometer improved to 2.7 and 2.5 mm in press-fit and screw group, respectively. Regarding Lachman and pivot shift test, there was a statistically significant improvement in the integrity of the ACL in both the groups, but no significant differences was noted between groups. There were no significant differences in terms of femur circumference difference, effusion, knee range of motion, pain and complications.

CONCLUSIONS: The press-fit technique is an efficient procedure. Its outcome was comparable with the interference screw group. Furthermore it has unlimited bone-to-bone healing, no need for removal of hardware, ease for revision and cost effectiveness.

KEYWORDS: Anterior cruciate ligament reconstruction Bone-patellar tendon-bone graft Press fit fixation Interference screw Outcome
Biomechanical Comparison of Two ACL Reconstruction Methods: Semitendinosus and Gracilis Construct versus Quadrupled Semitendinosus and Tape Construct.

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Background: A Quadrupled Semitendinosus (QSt) for Anterior Cruciate Ligament Reconstruction has a number of potential advantages compared to a doubled Semitendinosus and Gracilis (StG) graft. Preservation of Gracilis may reduce post-operative pain, swelling and later loss of knee flexor strength. In addition, a Quadrupled construct is of greater diameter than the doubled St/G. The main disadvantages of the QSt tape construct is the tibial fixation biomechanics and the shorter length of graft in the tibial tunnel for ingrowth. We investigated the biomechanical properties of using an Endobutton Tape (Smith & Nephew, USA) loop held with an interference screw for tibial fixation of a QSt graft compared to a doubled St/G graft held with an interference screw. We hypothesized that the biomechanical performance of QSt and St/G tibial fixation would be similar. Our second hypothesis was that the QSt grafts would be of greater average diameter.

Method: Six matched pairs of cadaveric tibiae were dissected from surrounding soft issue tissue. The bone mineral density (BMD) of the tibiae was measured using DEXA (Lunar Prodigy Advance Bone Densitometer, GE Healthcare). The tibiae were potted in PVC pipe using PMMA cement. The matching Semitendinosus and Gracilis tendons were preserved from each side. Two ACL constructs were tested: a Semitendinosus and Gracilis (StG) construct and a Quadrupled Semitendinosus - Endobutton Tape (Smith & Nephew, USA) (QSt-ET) construct. The two constructs were evenly distributed between the left and right sides of the matched pairs. The ST/G constructs were fixed with a Biosure PK interface screw (Smith & Nephew, USA) on the tibia. In the QSt-ET construct, the Endobutton tape was help in the tibial tunnel by a Biosure PK screw, then the tape was tied over the screw head in a square knot. During Tape construct preparation, the QSET was loaded to 500N on a modified Grafmaster (Smith & Nephew, USA) device. All graft dimensions were measured prior to insertion. In both constructs the proximal graft was held with a 20mm closed loop Endobutton CL (Smith & Nephew, USA). Tibial tunnel diameter was matched to the graft diameter. Biosure Screw diameter was matched to the tibia tunnel or upsized if the tunnel was between sizes. Both grafts were inserted retrograde into the tibial tunnel, with the distal 15mm of the QSt-ET in the tunnel. Each tibia was mounted on the base of the tension testing machine (ElectroPuls E10000, Instron) so that the tibial tunnel was coaxial with the line of pull of the linear actuator. Each construct was subjected to cyclic loading as follows: preconditioning cycling from 10N to 50N for 10 cycles at a frequency of 0.5Hz, followed by cyclic loading from 50N to 220N for 500 cycles at a frequency of 1Hz, followed by cyclic loading from 50N to 500N for 500 cycles at a frequency of 1Hz. The following results were captured: number of cycles, initial displacement, residual displacement after 500 cycles for each load case, peak displacement at failure (where relevant), peak displacement at 10, 100 and 500 cycles for each load case, and failure load. The mode of failure was also recorded for each test. Results were analysed using a two-tailed, paired t-test where possible. Where insufficient paired results were available, a standard t-test was used to compare results.

Results: The QSt grafts were of greater mean diameter (9.5mm +/- 0.42mm 95% CI), compared to the St/G grafts (8.6 mm +/- 0.51mm 95% CI) (p=0.0004). All twelve constructs failed during cyclic testing; no load-to-fail tests were conducted. Most constructs failed on the first cycle at 500N, so a
comparison of displacement results has only been conducted for the first phase of cyclic loading, with a peak load of 220N. The ST/G construct survived 353 cycles (SD 239.7) and the tape construct survived 274 cycles (SD 254.6). Four ST/G and three tape constructs survived 500 cycles at 220N, with only one from each group surviving more than one cycle at 500N.

The displacement results for the ST/G and tape constructs, respectively, were: initial displacement - 2.26mm (SD 3.58mm) and 4.32mm (SD 3.73mm); residual displacement after 500 cycles at 220N – 3.77mm (SD 2.05mm) and 3.15mm (SD 1.94mm); peak displacement at failure – 19.59mm (SD 9.58mm) and 16.94mm (SD 8.89mm); peak displacement at 10/100/500 cycles – 0.71mm (SD 0.49mm)/1.24mm (SD 0.80mm)/3.52mm (SD 2.36mm) and 2.28mm (SD 2.46mm)/4.3mm (SD 5.70mm)/2.63mm (SD 1.45mm).

The failure loads from cyclic load data were 396.2N (SD 128.9N) for the ST/G construct and 332.5N (SD 136.9N) for the tape construct. Displacement results and failure loads show a strong or very strong correlation with BMD for the tape construct, respectively (r<-0.6, r>0.7). The opposite is true for the ST/G construct (-0.5<r<0.3). This reflects the less predictable influence of friction along the graft/bone tunnel interface. There was no significant difference between any of the results reported above for the different constructs (p>0.05 for each parameter). The modes of failure for the two grafts were very consistent. For the ST/G, failure was due to the graft pulling past the interference screw. The screw was typically left in place in the cortical bone. For the QSt-ET graft, failure occurred when the screw was pulled in enough for the knot to slip around the screw and pull through the cancellous bone.

**Discussion:** The results show no significant difference in biomechanical performance between the tibial fixation of the two techniques despite the graft diameter differences. A Quadrupled Semitendinosus – Endobutton tape graft may be an alternative graft option for ACLR. Each graft exhibited different failure mechanisms. The fixation of the QSt – ET graft depends entirely on the interference between the cortical bone and the interference screw.

**Conclusion:** A Quadrupled Semitendinosus – Endobutton tape graft may be an alternative graft option for ACLR.
Comparison of clinical outcomes and second-look arthroscopic findings after ACL reconstruction using a hamstring autograft or a tibialis allograft

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Abstract

Background The purpose of this prospective randomized clinical study was to compare the clinical and radiological outcomes, including tibial tunnel widening and the progression of osteoarthritis after ACL reconstruction using a hamstring autograft or a tibialis allograft. In addition, we compared the graft tear, and synovial coverage of grafts in patients that underwent the second-look arthroscopy.

Material and Method Among 184 patients with an ACL injury underwent ACL reconstruction, 68 patients of autograft group and 64 patients of tibialis allograft group were included for this study after minimum of 2-year follow-up. The Lachman and pivot-shift tests, Tegner activity score, Lysholm knee score, and IKDC score were compared between the two groups. The quadriceps and hamstring isokinetic strengths using dynamometer were also compared. Degree of OA was determined using the Kellgren-Lawrence grading system on the weight-bearing radiographs. 51 patients (26 patients in autograft group and 25 in the tibialis allograft group) underwent the second-look arthroscopy, in which we compared the apparent tear of graft and synovial coverage of grafts.

Results At the final follow-up, there were no statistical significances in the two groups in Lachman and pivot-shift tests (n.s.). The Tegner activity, Lysholm knee score, and IKDC scores were similar in the two groups. Moreover, no significant differences were observed in the muscle powers (n.s.). Some patients showed the progression of OA (5 in autograft and 4 in allograft groups) without intergroup difference (n.s.). Regarding the findings of second-look arthroscopy, although there was no significant difference in graft tear, synovial coverage was better in autograft group than in allograft group.

Conclusions Even though hamstring autografts and tibialis allografts provided good functional outcomes without significant differences, the second-look arthroscopy revealed that hamstring autografts produced better synovial coverage than tibialis allograft.
Preoperative measure of individualized anatomic ACL reconstruction in west Chinese patients: correlation between preoperative MRI and intra-operative measurements

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Abstract

Purpose: This study was to identify coronal and sagittal length of tibial insertion, tibial insertion site area, length and inclination angle of ACL of patients undergoing ACL reconstruction. The secondary aim was to evaluate the correlation of the measurements between gender, age, BMI, Height and weight.

Methods: Sixty nine patients undergoing ACL reconstruction, a preoperative measurement on MRI and intra-operative measurements using a specialized ruler were going to detected the coronal and sagittal length of tibial insertion, tibial insertion site area, length and inclination angle of ACL. Additionally, correlation among gender, age, BMI, Height, weight, BMI and the measurements was analyzed.

Results: The tibial insertion site coronal length of ACL had a mean length of 9.7±1.0 mm (7.7-12.8 mm) as measured by MRI, and 9.5±1.0 mm (7.5-12 mm) as measured intra-operatively. The tibial insertion site sagittal length was 11.5±1.5 mm (8.5-14.9 mm) by MRI and 11.1±1.6 mm (8.5-14.5 mm) in arthroscopic. The tibial insertion site area was 87.5±16.0 mm² (59.3-149.8 mm²) by MRI and 83.2±16.5 mm² (53.4-136.6 mm²) in arthroscopic, and intercondylar notch width was 13.2±1.9 mm (7.5-16.6 mm) and 13.3±2.0 mm (8-18 mm), ACL length was 34.0±4.5 mm (25.2-46.1 mm) and ACL inclination angle was 45.9±5.9° (32.4-56.8°) by MRI. Then, the male and female date was also measured, and there was no significant different between the measurements and gender, height, weight, BMI or age of the patients besides the intercondylar notch width correlated with the height, weight and BMI, and ACL length have correlation with height.

Conclusion: The results of this study confirmed the bone morphology and ACL characters of our patients, and found the tibial insertion size and intercondylar notch width is less than other published in the West, besides the length and inclination angle of ACL. Our date also suggest that MRI preoperative measurement can be confidently used in operative planning and our patients could just perform SB ACL-R, and the intercondylar notch width has the correlation with the weight and height.
LARS reconstruction of anterior cruciate ligament with remnant preservation: a prospective randomized control study

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Background:
To compare the short term clinical outcomes of remnant preserving anterior cruciate ligament (ACL) reconstruction with ligament advanced reinforcement system (LARS) artificial ligament and standard ACL reconstruction.

Methods:
A prospective randomized controlled study was performed in 40 eligible consecutive patients with ACL rupture who were equally assigned into 2 groups from August 2011 through April 2013. Group A (n=20) received ACL reconstruction with remnant preservation technique and group B (n=20) the standard ACL reconstruction. LARS artificial ligament was used for all Cases. The Lysholm score, International Knee Documentation Committee (IKDC) grading and stability assessments (Lachman test, pivot shift test and KT-1000 side-to-side differences) were evaluated pre-and post-operatively. Synovial coverage of the graft and proprioception evaluation were estimated post-operation.

Results:
All patients were followed up for at least 2 years (mean, 25.7 months). At the last follow-up, the mean Lysholm score was 96.0±6.0 in group A and 93.0±7.5 in group B; there were 18 cases of IKDC grading A or B in group A and 14 in group B; 97.4% in group A and 97.6% in group B had negative Lachman test results; 94.9% in group A and 87.8% in group B had negative pivot-shift tests; the KT-1000 side-to-side differences averaged 1.64-1.7 mm in group A and 1.8±1.8mm in group B; the synovial coverage of grade A or B was 71.4% in group A and 70.4% in group B; the passive angle reproduction test at 15° was 3.6°±1.8° in group A and 3.9°±2.2° in group B.

Conclusion:
In the LARS ACL reconstruction, compared with standard technique, remnant preserving may result in significant improvements in postoperative stability, and proprioceptive recovery of the knee joint.

Key words:
anterior cruciate ligament reconstruction; remnant preserving; ligament advanced reinforcement system
Local delivery of controlled-release simvastatin to improve the biocompatibility of polyethylene terephthalate artificial ligaments for reconstruction of the anterior cruciate ligament

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Abstract:

Background: The Ligament Advanced Reinforcement System (LARS) has recently been widely used as the primary graft of choice in ACL reconstruction. But the biological graft–bone healing still remains a problem. Previous studies have shown that simvastatin (SIM) stimulates bone formation.

Purpose: The objective of this study was to investigate whether surface coating with collagen (COL) containing low-dose SIM microsphere could enhance the surface biocompatibility of polyethylene terephthalate (PET) artificial ligaments to accelerate graft-to-bone healing.

Methods: The in vitro studies demonstrated that BMSCs on the SIM/COL/PET scaffolds proliferated vigorously. Compared with the PET group and the COL/PET group, simvastatin could induce BMSCs’ osteoblastic differentiation, high alkaline phosphatase activity, more mineralization deposition and more expression of osteoblast-related genes such as osteocalcin, runt-related transcription factor 2, bone morphogenetic protein-2 and vascular endothelial growth factor growth factor in the SIM/COL/PET group. In vivo, rabbits received ACL reconstruction with different scaffolds.

Results: Histological analysis demonstrated that graft–bone healing was significantly greater with angiogenesis and osteogenesis in the SIM/COL/PET group than the others groups. In addition, biomechanical testing at the eighth week demonstrated a significant increase in ultimate failure load and stiffness in the SIM/COL/PET group.

Conclusion: The low dose of simvastatin sustained released from SIM/COL/PET promoted the graft–bone healing via its effect on both angiogenesis and osteogenesis. This study suggested that collagen containing low-dose SIM microsphere coating on the surface of PET artificial ligaments could be potentially applied for ACL reconstruction.

Keywords: simvastatin, controlled release, graft–bone healing, biocompatibility, ligament reconstruction
Effects of Remnant Tissue Preservation on the Tendon Autograft in Anterior Cruciate Ligament Reconstruction: Biomechanical and Histological Study with a Sheep Model

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Background: No studies using an ACL reconstruction model with large animals have been conducted to clarify the effect of remnant tissue preservation on outcome after ACL reconstruction. We have hypothesized that, remnant preservation may accelerate revascularization and reinnervation in the graft, and significantly improve the anterior translation of the knee at 12 weeks after surgery. The purpose of this study was to test these hypotheses.

Methods: Forty-two sheep were randomly divided into 2 groups of 21 animals each. In group I, the ACL was completely removed. In group II, the ACL was transected at the midsubstance. Then, ACL reconstruction was performed using a semitendinosus tendon autograft in each group. Histological changes of the grafted tendon and the preserved remnant tissue were observed at 4 and 12 weeks after surgery. Biomechanically, the anterior translation and the stiffness of the knee under an anterior drawer force and the structural properties of the femur-graft-tibia complex were evaluated.

Results: The remnant preservation significantly accelerated revascularization in the grafted tendon, and significantly increased the number of mechanoreceptors in the reconstructed ACL at 4 and 12 weeks. The remnant preservation significantly improved the anterior translation and the initial stiffness of the ACL-reconstructed knee in drawer testing at 12 weeks.

Discussion: Preservation of the remnant tissue in ACL reconstruction not only enhanced cell proliferation, revascularization, and regeneration of proprioceptive organs in the reconstructed ACL, but also improved the knee stability.

Conclusion: Preservation of the remnant tissue may be beneficial in improving the clinical outcome of ACL reconstruction.
Effects of Remnant Tissue Preservation on Tunnel Enlargement after Anatomic Double-Bundle Anterior Cruciate Ligament Reconstruction

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Background: Bone tunnel enlargement is a problem that has been observed after reconstruction of anterior cruciate ligament (ACL) [Höher 1998, Robert 2004, Wilson 2004]. Tunnel enlargement and coalition could cause problems during revision surgery and necessitate staged procedures [Järvelä 2008, Siebold 2007]. Recently, preservation of the ACL remnant tissue has been expected to have several potential advantages, such as preservation of proprioceptive cells [Adachi 2002, Lee 2008] stability preservation [Kondo 2015, Muneta 2013] and graft revascularization and ligamentization [Ahn 2010, Gohil 2007]. In addition, remnant preservation may inhibit tibial tunnel enlargement in a single-bundle ACL reconstruction [Demirag 2012, Zhang 2014]. However, the effect of remnant tissue preservation on tunnel enlargement in anatomic double-bundle (DB) ACL reconstruction has not yet been established. We hypothesized that the incidence and the degree of tunnel enlargement of remnant-preserving procedures will be significantly less than that of remnant-resecting procedures after anatomic double-bundle ACL reconstruction. In addition, the incidence of tunnel coalition in remnant-preserving procedures will be less than in remnant-resecting procedures. The purpose of this study was to test these hypotheses.

Material and Method: A prospective study was conducted between 2009 and 2013 using patients who had an isolated ACL injury in the unilateral knee. A total of 80 patients underwent anatomic DB ACL reconstruction using hamstring tendon autografts. Based on the Crain classification of ACL remnant tissue [Crain 2005], 40 patients underwent the remnant-preserving procedure (group P) [Yasuda 2012] and the remaining 40 patients underwent the remnant-resecting procedure (group R) [Yasuda 2004]. After surgery, patients underwent the same rehabilitation. All patients were informed that they would undergo a 2-dimensional (2D) and 3 dimensional (3D) CT at 2 weeks and 1 year after surgery. Then the images were processed by using a work station (ZioTerm 2009, Ziosoft, Tokyo). The oblique axial (OA), sagittal (OS), and coronal (OC) views were reconstructed based on the direction of the longitudinal axis of the femoral and tibial tunnels from CT data using multi-planar reconstruction. The tunnel measurement was taken at 10 mm from the intra-articular outlet of the femoral and tibial tunnels in OA, OC, and OS views, respectively. The tunnel area measurement was taken digitally at the same level of both the femoral and the tibial tunnels in OA views using ImageJ software (ver. 1.48, National Institutes of Health). The percentage change in the
diameter and area between the images at 2 weeks and 1 year was defined as the degree of tunnel enlargement. The incidence of tunnel enlargement was determined by the number of femoral or tibial tunnels that tunnel area enlarged more than 30%. The position of the femoral and tibial tunnel was evaluated by observing the AM and PL tunnel outlets on the intra-articular bone surface of 3D CT images using the Quadrant method [Bernard 1997]. Tunnel coalition was determined by observing the AM and PL tunnel outlets on the intra-articular bone surface and 10 mm from the intra-articular outlet of the femur or the tibia using OA, OC, and OS views, and measuring the width of the bony septum between the 2 tunnels [Hantes 2010]. When the width was zero, we defined it as ‘tunnel coalition’. Intra-observer variability for tunnel measurement was satisfactory (mean intraclass correlation coefficient, 0.84; range, 0.81 to 0.92). A priori power analysis was performed. A sample size was calculated to have 74–85% power to test the hypothesis.

**Results:**
(1) There were no significant differences in the femoral and tibial tunnel positions between the groups.
(2) Concerning the femoral AM tunnel, the degree of tunnel enlargement in OC and OA views in group P was significantly less than those of group R. Concerning the femoral AM tunnel area, the degree of tunnel enlargement in group P was significantly less than those of group R. The incidence of femoral AM tunnel enlargement was significantly less in the group P than in the group R.
(3) Regarding the tibial tunnel enlargement, there were no significant differences between the groups.
(4) There were also no significant differences in the tunnel coalition between the groups.
(5) Regarding knee laxity, we divided the patients’ side-to-side laxity values into 2 categories, ≤ 2mm and > 2mm; the chi-square test showed that anterior laxity in group P was significantly better than in group R. Postoperative the Lysholm knee score, IKDC evaluation, and mean isokinetic peak torque of the quadriceps and hamstring muscles, there were no significant differences between the 2 groups.

**Discussion:**
The degree of femoral AM tunnel enlargement of group P were significantly less than those of group R. The incidence of femoral AM tunnel enlargement was significantly less in group P than in group R. Then regarding the patients’ side-to-side laxity values, anterior laxity in group P was significantly better than in group R. Preservation of the ACL remnant tissue in ACL reconstruction is expected to have several potential effects to improve the clinical results. Some study reported that remnant tissue preservation resist bone tunnel enlargement, because of remnant tissue may restrict synovial fluid propagation within the tunnel [Berg 2001]. And previous studies showed preservation of the ACL remnant tissue improve knee stability [Wu 2013, Kondo 2015]. We consider that preservation of the ACL remnant tissue inhibit tunnel enlargement because of prevent biological factors such as proinflammatory cytokines of synovial fluid and biomechanical factors such as micromotion at the tunnel by graft.

**Conclusion:**
The degree of tunnel diameter and area enlargement of remnant-preserving procedure are significantly less than those of the remnant-resecting procedure in the femoral AM tunnel. These results indicated that remnant-preserving anatomic double-bundle procedure may have potential to inhibit incidence of the tunnel enlargement.
Double Bundle Anterior Cruciate Ligament Reconstruction Preserving Antero-medial Aspect of Remnant Tissue

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Background
Preserving remnant tissue during anterior cruciate ligament (ACL) reconstruction have been reported to have advantages. However, preserving large amount of remnant tissue sometimes makes precise decision of tunnel position more difficult. Hence, the author have tried to preserve only antero-medial aspect of remnant tissue continuously from tibial attachment to close to proximal attachment if there is sufficient remnant tissue. Lateral part of remnant and soft tissue around femoral footprint were debrided for better direct observation of femoral attachment and tunnel positions. In this study, we present our surgical technique, and report short term results of this technique.

Materials and Methods
Twelve patients ( 5 males, 7 females) who received antero-medial remnant preserving double bundle ACL reconstruction using hamstrings tendon between January 2013 to December 2014, and were examined at 12 month after surgery were included in this study. Side to side differences of anterior laxity using KT-2000 and MRI findings were evaluated.

Results
Mean side to side differences of anterior laxity was 1.75 ± 1.80mm. MRI examination of antero-medial bundle showed good graft position resembling native ACL.

Discussion
Although reconstructed ACL showed good resemblance to native ACL in scopic view and MRI, anterior laxity was similar to our previous results of double bundle ACL reconstruction.

Conclusion
We believe double bundle ACL reconstruction preserving only antero-medial aspect of remnant tissue is precise and safe technique to preserve continuous remnant tissue, however regarding anterior laxity we could not prove its predominance.
Quantitative Evaluation of Three-dimensional Dynamic Knee Laxity with Isolated Anteromedial- or Posterolateral-bundle Anterior Cruciate Ligament Deficient Knees

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Background: Anterior cruciate ligament (ACL) consists of the anteromedial bundle (AMB) and posterolateral bundle (PLB). The purpose of this study was to clarify how these bundles contribute to the knee joint stability during the Lachman test and the pivot shift test.

Materials & Methods: Twelve fresh-frozen hemi-pelvis lower limbs (6 paired) were used. Each bundle was determined arthroscopically and the AMB or PLB was cut first and subsequently the remained bundle was cut. The Lachman test and the pivot-shift test were performed under the following conditions; (1) ACL-intact (n=12), (2) AMB-cut/PLB-intact (n=6), (3) PLB-cut/AMB-intact (n=6), and (4) ACL-deficient (n=12). Each knee went through the conditions, either (1)-(2)-(4) or (1)-(3)-(4). The anterior tibial translation (TT) during the Lachman test and the acceleration of posterior tibial translation during the pivot-shift test (APT) were measured using an electromagnetic measurement system.

Results: The mean TT during the Lachman test in the ACL-deficient condition was significantly larger than those in other three conditions. No significant differences were observed among the conditions, (1), (2) and (3). The mean APT in the ACL-deficient condition was significantly larger than those in other three conditions. In addition, the mean APT was significantly increased in the PLB-cut (only AMB intact) condition compared with the ACL-intact group, whereas, no significant difference was observed between the AMB-cut (PLB intact) condition and the ACL-intact condition.

Discussion & Conclusions: These results suggested that both AMB and PLB contribute to the control of TT and PLB may play a more dominant role in the control of the pivot-shift phenomenon than AMB.
AUGMENTATION OF TENDON GRAFT ANTERIOR CRUCIATE
LIGAMENT RECONSTRUCTION OUTCOME USING A SILK BASED
OSTEOCONDUCTIVE SHEATH

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BACKGROUND

With increased longevity in the global aging population, joint health remains critical as the quality of
life is increasingly associated with human mobility. Coupled with the growing focus on an active
lifestyle, intervention procedures performed on the knee have been gaining popularity, particularly the
Anterior Cruciate Ligament (ACL) reconstruction. Such surgical intervention often involves the use of
tendon autografts, with semitendinosus and gracilis tendons being popular choices. Nevertheless, less
than optimal healing of the tendon graft within the surgically created bone tunnel remains a
fundamental problem in this procedure. The proposed solution involves the application of a novel silk
fibroin (SF) based sheath, embedded with nanoparticles of low crystallinity hydroxyapatite (nHA), to
complement the use of tendon autografts and promote enthesis formation. This SF-nHA sheath
configuration is tested against SF sheaths with incorporation of bone morphogenetic protein 2 (BMP-2)
only (SF-BMP2), a blend of BMP-2 and nHA (SF-BMP2-nHA) and pure silk sheaths (pure SF) to
evaluate their potential in osteointegration of tendon grafts. The optimal sheath type was subsequently
put through an in depth assessment for biocompatibility and also in vivo study in a small and large
animal model for up to 9 months to evaluate the efficacy of the sheath in promoting osteointegration of
tendon grafts.

MATERIALS AND METHODS

Knitted SF scaffolds (240 fibroins, L30 × Ø5 mm) were first fabricated from raw Bombyx mori silk
(Chul Thai Silk Co. Ltd) and subsequently degummed. The nHA precipitates were synthesized by a co-
participation method of aqueous (NH4)2HPO4 with aqueous Ca(NO3)2. Hydrothermal treatment of the
precipitates' aqueous solution was carried out at 140 °C under a pressure 0.3 MPa for 2 h in an
autoclave to form the nanograde rod HA crystals. SF sponges, made from a blend of aqueous SF
solution (2% w/v) and synthesized nHA (12.9 mg/ml), were incorporated to the knitted structures via a
lyophilization process in a customized mould. This SF-nHA group was compared with pure SF, SF-
BMP2 (19.3 µg/ml BMP-2) and SF-BMP2-nHA (19.3 µg/ml BMP-2 and 12.9 mg/ml nHA) via static
culture of 10 × 10 mm specimens (Fig. 1A) with seeded porcine bone marrow derived MSCs (P2, 0.5 ×
10^6/scaffold) over 28 days. Ex vivo static culture of the four groups of SF sheaths with tendon
autografts (porcine Flexor Digitorum Profundus sections, L10 × Ø5 mm, Fig. 1B) and porcine bone
marrow derived MSCs (P2, 2 × 10^6/scaffold) was then conducted over 28 days. In these assessments,
the cellular viability, proliferation, gene expression, collagen deposition levels, scanning electron
microscopy (SEM) and histological analyses were performed (n = 3). Consequently, the most
efficacious group for osteointegration of tendon grafts was selected for the in depth biocompatibility
assessments and in vivo tests.
The complete optimized sheath was then tested through a series of biocompatibility assessment for cytotoxicity, sensitization, intracutaneous reactivity, acute systemic and 14 days sub-chronic repeated dose toxicity, genotoxicity (Ames test, chromosome aberration assay, mouse lymphoma assay) and 12-weeks implantation in rabbit femur. A preclinical trial was conducted in the porcine ACL reconstruction model using tendon autograft harvested from the flexor digitorium profundus and SF-based sheath sutured onto both ends of the graft (Fig. 1C). Graft integration in the presence of SF-based sheaths within the bone tunnels and tendon integrity within the intra-articular space were assessed via imaging (CT and MRI), histomorphometrical and histopathological methods at 1, 3, 6 and 9 months time points. All animal experiments were approved by the respective institutional IACUC.

RESULTS

The SF sheaths were observed to be porous with interconnected pores. nHA and BMP-2 were observed to be securely incorporated in the lyophilized SF sponges. BMP-2 bioactivity was ascertained after the fabrication process and was shown to be eluting with an initial burst release, followed by a lowered sustained release.

MSCs were observed to be viable and proliferative in all four groups of the \textit{in vitro} study. Increased proliferations were observed in SF-nHA, SF-BMP2 and SF-BMP2-nHA at the early phase (days 1-7) with an accelerated differentiation phase beginning from day 14. Consequently, there was an upregulation of osteogenic related genes (Collagen I (Coll I), Collagen III (Coll III), osteonectin (ON) and osteopontin (OPN)) (Fig. 2), leading to a significantly increased deposition of collagen by day 21. However, it was further noted that between SF-nHA, SF-BMP2, and SF-BMP2-nHA, the presence of BMP-2 did not improve upon a persistent (beyond 21 days) upregulation of osteogenic genes and increase in collagen production.

When cultured with excised tendon sections, it was observed that cells from within the tendon tend not to participate in interfacial tissue regeneration, while seeded MSCs were viable and produced ECM for bridging the tendon-scaffold interface after 2 weeks in SF-nHA, SF-BMP2, and SF-BMP2-nHA (Fig. 3A-H) as observed via SEM and H&E staining images. SF sheaths with nHA stimulated osteogenesis from seeded MSCs as observed by the presence of calcium deposits in SF-nHA and SF-BMP2-nHA via alizarin red staining (Fig. 3I-P). Ossification was thus observed with the presence of nHA, with or without the presence of BMP-2.

Consequently, the SF-nHA sheath configuration was selected for further biocompatibility assessment and \textit{in vivo} testing. The SF-nHA sheath was found to induce discrete intracytoplasmic granules with no cell lysis or reduction in cell growth in the tested mouse connective tissue cell line (NCTC clone 929), indicating non-cytotoxicity. Sensitization tests indicated limited erythema and oedema at challenged skin site over the 48 hours. There were also no significant biological reactivity findings compared to the respective negative control groups in the acute systemic and sub-chronic repeated dose toxicity assessments. Genotoxicity (Ames test) showed that the sheath was non-mutagenic in the tested bacterial strains of \textit{Salmonella typhimurium} and \textit{Escherichia coli}, while \textit{in vitro} chromosome aberration test indicated that the sheath did not induce structural chromosome aberration in the cultured mammalian somatic cells. Histopathological assessments of the extracted femurs of the 12 weeks implantation study indicated absence of inflammatory cells with presence of neovascularization and bone ingrowth.

At 1 month post ACL reconstruction using the SF-based sheath with tendon autografts in the
preclinical porcine model, the reconstructed ACL became taut, when initially the tendon graft was implanted slack. This indicated that there was simultaneous growth and graft remodeling during this period. Regenerated epiligament was also formed, which provided vascularization to the graft (Fig. 4A). It should be noted that the cartilage of the ACL reconstructed knee remained pristine and clear of cartilage erosion, which was indicative of accelerated and enhanced joint stability soon after the ACL reconstruction. The enhancement in osteointegration of tendon autograft was evident as multiple small foci of mineralization were identified within the femoral and tibial ends of the graft from as early as one month post ACL reconstruction (Fig. 4B). By 3 months, bone tissue infiltration into the interfacial space was evident from the increase in bone mineralization and vascularized neotissue formation, indicating improved graft to bone integration comparing to control (tendon autograft ACL reconstruction without SF-based sheath).

DISCUSSION

Prompt osteointegration of the tendon graft within the bone tunnel post ACL reconstruction was difficult with conventional therapies due to the lack of biochemical precursors. These precursors are provided by the SF-based sheath, which also includes a temporary scaffolding material that helps to provide a snug fit to the bone interface. It will prevent micromotion resulting in early inflammatory reactions, which can lead to the onset of fibrosis. The sheath will also serve a delivery platform for cellular and bioactive components. Progenitor cells, either seeded or attracted from the host into the porous sheath, will reconstitute the native cellular environment of the enthesis by differentiating into chondrocytes and osteoblasts. They will not only deposit the necessary ECM but also cytokines that elicit regenerative responses at the integration site. The delivery of osteogenic factors via the SF-based sheath will accelerate tissue restoration by triggering a migration of host reparative cells. These bioactive agents will also induce cellular differentiation required for the formation of fibrocartilage and bony tissue at the anchorage site.

Results from the in vitro study indicated that although BMP-2 led to earlier upregulation of osteogenic genes, the expression of Coll I and ON were not significantly higher in SF-BMP2-nHA by day 28 when compared with SF-nHA. In terms of protein production, collagen synthesis between SF-nHA and SF-BMP2-nHA were not significant throughout the study, indicating that even though SF-BMP2-nHA might have stimulated the targeted genotypic behavior, the phenotypic outcome was not significantly improved. This was further substantiated when the silk sheaths were cultured with excised porcine tendons, whereby mineralized ECM could be found after 4 weeks of culture in SF-nHA and SF-BMP2-nHA.

Balancing clinical needs and our in vitro and ex vivo findings, the SF-nHA sheath was selected for further development. It was found that nHA stimulated tissue infiltration of host bone tissue, resulting in bone tunnel narrowing with new mineralized tissues observed in both the small and large animal models. Consequently, there was enhanced graft-to-host integration progressively over the 9 months implantation period, which potentially resulted in overall mechanical properties closer to that of the native bone-ACL-bone construct.

CONCLUSION

Based on our knowledge, this study is the first to investigate a SF-based device to augment ACL reconstruction with tendon autografts. With minimal disruption to current surgical practice, the SF-
based sheath exhibits clinical potential in accelerating healing to allow earlier and more aggressive rehabilitation.
Objective: To observe the anatomical morphology of the tibial insertion of the anterior cruciate ligament (ACL) in Chinese adults so as to offer theoretical guidance for ACL reconstruction and meniscus transplantation.

Methods: Fifteen adult cadaveric knees (8 left knees and 7 right knees) were dissected, including 10 males and 5 females, with an age ranged from 25 to 47 years (mean, 32.4 years). All knees were generally observed through standard medial parapatellar approaches, then the ACL midsubstance and the tibial insertion (direct and indirect insertions) were anatomically measured.

Results: In all specimens, the ACL was flat with a lot of fine fibers. The anteromedial bundle and posterolateral bundle could be observed in 13 of 15 knees. However, no obvious bundles were found in 2 knees. The arcshaped tibial direct insertion started at the medial tibial eminence and ended at the anterior horn of the lateral meniscus. The width of the arc was (11.2±2.4) mm; the thickness was (3.0±0.3) mm; and the cross-sectional area was (28.8±7.8) mm². And the left-right diameter of the whole insertion was (9.5±1.8) mm; anteroposterior diameter was (11.9±0.6) mm; and the cross-sectional area was (117.8±12.5) mm². The width of the anterior horn of lateral meniscus was (12.3±2.0) mm. The anterior horn of lateral meniscus was surrounded by arc-shaped direct insertion in the middle, and its fibers were partly intertwined with indirect insertion of ACL.

Conclusions: Anatomical ACL reconstruction may therefore require a arc-shaped tibial footprint. There are overlap covering relationship between the attachment location of anterior horn of the lateral meniscus and tibial insertion of ACL. It should pay more attention to protecting tibial insertion of ACL in lateral meniscus transplantation.
Repair of Anterior Cruciate Ligament with Internal Brace technique - early results

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Background: Concept of the ACL repair is not new, however it was abandoned for years due to unsatisfying results. The main problem was that sutured ligament wasn’t strong enough to carry regular loads and therefore elongated. This problem was solved with new generation of synthetic tapes, providing mechanical support and protecting healing ligament.

Material: We present group of 35 patients, (16 female, 19 male), medium age 35.2 y.o. (19 to 52). Medium follow up - 8.6 months (3 to 21). All patients had ACL tear confirmed on MRI. Only patients with well preserved ligament stump were qualified for the procedure. As a matching group we are presenting cohort of 25 patients (9 female, 16 male), medium age 37.4 (14 to 45) in which we performed double bundle ACL reconstruction using ST tendon.

Method: In all studied group we performed the same procedure of suturing the ACL stump to femoral insertion. The stump was sutured with FiberWire, and reinforced with FiberTape stabilized with endobuttons on Tibia and Femur. We also repaired all others damages found in operated knees.

Results: We assessed results with clinical examination, MRI three to six months post surgery, and clinical scales (Lysholm, IKDC and KOOS). Clinical results according to stability and function were generally similar to double bundle ACL group, but patients after Internal Brace needed shorter rehabilitation and presented less postoperative swelling, comparing to DB group.

Discussion: Internal bracing is a new approach to ACL repair, so there are no publications containing its results. However our observations are promising, we jet don’t know how the ligaments rebuild over time and how the body will react at FiberTape in long term. Therefore we will continue our research for mid and long time results.

Conclusions: It seems that Internal Bracing repair of the torn ACL is promising and safe method to repair ligament in selected cases. Results show that it may be better tolerated by patients than classic reconstruction.

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Introduction

In order to determine the rehabilitation course, it is important to understand the biological processes that occur during graft remodeling and maturation. Autograft quadriceps tendon with a bone block might have a better remodeling process given that bone-to-bone healing at the tunnel is superior to tendon-to-bone healing; however, little is known about the remodeling process of quadriceps tendon graft including the healing effects of ACL remnant bundle.

Objectives

The purposes of this study were 1) to confirm graft maturity & revascularization of quadriceps tendon graft through serial evaluation by contrast enhanced MRI and 2) to compare graft maturity & clinical outcome between remnant preserving group and non-preserving group.

Methods

Twenty-one patients who underwent an ACL reconstruction with quadriceps tendon between January 2012 and September 2014 were studied and evaluated by MRI at 3 days, 3, 6 and 12 months after surgery. 12 of 21 patients were evaluated by MRI at 12 months. In 15 cases, remnant bundles were preserved and in 6 cases, they were not. The MRI evaluation focused on 4 measurements as follows: (1) Signal-to-noise quotient (SNQ) was calculated for 3 graft sites (proximal, middle and distal region) on oblique coronal MRI scan before gadolinium administration to evaluate graft maturity (2) SNQ(enhanced) was calculated for 3 graft sites on subtraction image (post - precontrast image) to evaluate graft revascularization more clearly by facilitating enhancement demonstration. (3) The orientation of the ACL ligament was measured using sagittal and coronal ACL angle, ACL-blumensaat angle and tibial tunnel placement. IKDC score, Lysholm score, Tegner activity scale and KT-2000 arthrometry were also evaluated.

Results

In the proximal and middle region, SNQ was increased between 3 days and 3 months and
decreased between 3 and 6 months. The middle region showed a significant increase between postoperative 3 days and 3 months (p=0.008). In the distal region, SNQ continued to increase until 6 months and showed a significant increase between postoperative 3 days and 3 months (p=0.049). SNQ of 12 patients were decreased at 12 months in all site. SNQ(enhanced) in all site continued to increase over time and the proximal region showed a higher SNQ(enhanced) value compared with middle and distal region. Comparing remnant bundle preservation group and non-preservation group, it showed similar changing pattern of SNQ to that of quadriceps tendon graft; SNQ was increased between 3 days and 3 months and decreased between 3 and 6 months in the proximal and middle region. In the distal region, SNQ continued to increase until 6 months. In the remnant preservation group and non-preservation group, SNQ(enhanced) continued to increase for 6 months postoperatively. In the preservation group, SNQ(enhanced) at the distal region was significantly lower compared to SNQ(enhanced) at the proximal and middle region on 3 months period (proximal vs distal : 0.028, middle vs distal : 0.049). Remnant preservation group showed higher SNQ(enhanced) value compared with remnant non-preservation group at the middle and distal region. The two groups did not differ significantly in the orientation of ACL and clinical outcome.

**Conclusion**

SNQ representing graft maturity demonstrated faster recovery of proximal portion of the graft. Proximal portion near bone to bone contact area showed faster revascularization compared to distal portion and revascularization process continued until six months. And there was overall tendency of remnant preserving group having higher vascularity than non-preserving group.
Influence of initial tension on the postoperative tibiofemoral relationship after anatomic anterior cruciate ligament reconstruction

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Background:
The initial tension at graft fixation is one of the keys for successful outcomes after ACL reconstruction. Mae et al. previously reported good clinical outcomes after anatomic double-bundle (ADB) ACL reconstruction with a total initial tension of 20 N (Mae T, et al. Arthroscopy 2010). Recently, anatomic triple-bundle (ATB) procedure was developed in order to mimic the closer morphology of the native ACL and provided the better immediate postoperative stability than the ADB procedure with the same initial graft tension of 20 N (Mae T, et al. Arthroscopy 2013). Thus, we hypothesized that the ATB procedure might provide good postoperative outcomes with the smaller initial tension. The aim of this study was to prospectively compare the tibiofemoral relationship after the ATB ACL reconstruction with 10 N of initial tension to that with 20N.

Materials and Methods:
The ATB ACL reconstruction using a hamstring tendon graft via 2 femoral and 3 tibial tunnels was performed in 27 patients with unilateral ACL injury. After graft passage, grafts were fixed with Endobutton-CLs on the femur. Then the patients were divided into 2 different pre-tensioning groups (a total graft tension of 10 N (13 knees) and 20 N (14 knees)), and the grafts were finally fixed at 20 degree of knee flexion with Double Spike Plates (Meiraco, Nagoya, Japan) on the tibia. After knee immobilization for 2 weeks in both groups, range of motion exercise was started. Full weight bearing was allowed at 4 weeks, followed by a return to sports at 6 to 8 months. Computed tomography scans were obtained preoperatively, 3 weeks, and 6 months postoperatively. The patients lay in a prone position at 15° of knee flexion, in which the tibia caught an anterior load by the calf weight. The imaging data were constructed to 3-dimensional computer models. The anterior-posterior translation and the internal-external rotation of the tibia relative to the femur were measured. Then the side-to-side difference of tibial position was compared between the 2 groups. Likewise, the side-to-side difference at a maximal anterior load with KT-2000 Knee Arthrometer was calculated 6 months after surgery. Wilcoxon rank sum test was used for the statistical analysis with a significant value of P < 0.05.
**Results:**
Preoperatively, the tibia located anteriorly and rotated internally in the ACL-deficient knee in both groups. At 3 weeks postoperatively, the tibia in 10-N group / 20-N group located 1.2 ± 1.0 mm / 2.3 ± 1.4 mm posteriorly and externally rotated 1.7 ± 1.5° / 4.4 ± 2.5°. The posterior shift and external rotation were significantly smaller in 10-N group than in 20-N group. The tibia at 6 months located quite close to the normal position in both groups. The side-to-side difference of KT value was 0.3 ± 1.0 mm in 10-N group and 0.2 ± 1.0 mm in 20-N group, with no significant difference.

**Conclusion:**
Excessive initial tension led to the abnormal tibiofemoral relationship and increased the tibiofemoral joint load. As the difference from the normal tibial position in 10-N group was smaller at 3 weeks in this study, an unnecessary load to tibiofemoral joint might be less at 3 weeks. Thus, the smaller initial tension prevented the tibial over-constrained position, while it provided a favorable tibiofemoral relationship as well as anterior knee laxity 6 months postoperatively.