

Single-Bundle Anterior Cruciate Ligament Reconstruction with Semitendinosus Tendon Using the PINN-ACL CrossPin System: Minimum 4-Year Follow-up

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Purpose: This study evaluated mid-term results of anterior cruciate ligament (ACL) reconstruction using the PINN-ACL CrossPin system that allowed for short graft fixation.

Materials and Methods: Forty-three patients underwent single-bundle ACL reconstruction with a 4-strand semitendinosus tendon graft using the PINN-ACL CrossPin system. Femoral fixation was done using the PINN-ACL CrossPin system, and the tibial side was fixed with post-tie and a bioabsorbable interference screw. The mean follow-up period was 50 months. Evaluation was done using the Lachman test, pivot-shift test, International Knee Documentation Committee (IKDC) score and grade. Anterior displacement was assessed.

Results: There was improvement in the Lachman test and pivot-shift test at final follow-up, from grade II (n=40) or III (n=3) to grade I (n=3) or 0 (n=40) and from grade I (n=20) or II (n=10) to grade I (n=8) or 0 (n=22), respectively. The mean IKDC score was 88.7, and grade A and B were 93.0% at final follow-up. Side-to-side difference was improved from 6.7 mm to 2.1 mm at final follow-up. Complications occurred in 3 patients, a re-ruptured due to trauma at 2 years after surgery and a deep infection and a superficial infection.

Conclusions: The mid-term follow-up results of ACL reconstruction with the PINN-ACL CrossPin system were satisfactory. The PINN-ACL CrossPin can be considered as a useful instrument for short graft fixation.

Keywords: Anterior cruciate ligament, Reconstruction, Semitendinosus tendon, PINN-ACL CrossPin

Introduction

In anterior cruciate ligament (ACL) reconstruction, the use of bone patellar tendon bone graft (BPTB) has been decreasing due to increased anterior knee pain, weakness of extensor power and difficulty of kneeling position. Instead, the use of hamstring tendon has been increasing^{1,2}; however, the disadvantages of hamstring grafts include weaker fixation strength compared to

BPTB grafts and 24-week period for complete bone-to-tendon healing³. Adequate fixation has been considered essential for good outcomes of ACL reconstruction and a variety of graft fixation methods have been introduced. Fixation methods can be classified into compression, expansion, and suspension methods. The compression method allows for early firm fixation and healing with tight bone-tendon interface and enables close fixation to the ACL footprint, but it has low failure load and stability^{4,5}. The expansion fixation mechanism can be advantageous in obtaining secure fixation because two cross pins transversely inserted through a graft provides a centrifugal pressure on the femoral tunnel, but treatment results depend on the press-fit of the graft, bone density around the femoral tunnel, and correct placement of cross pins through the graft tendon⁶⁻⁸. The suspension methods are sub-classified into cortical, cancellous and, cortico-cancellous suspension methods⁹. The cortical suspension method provides good fixation strength, but it has a bungee cord effect¹⁰ and a windshield wiper effect¹¹ due to the long fixation point from the articular surface. The cortico-cancellous suspen-

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sion method has strong stability and stiffness due to the use of a metaphyseal crosspin. To et al.¹²⁾ reported that stiffness of the graft fixation complex was more affected by fixation method than the graft type in a cadaver study. Intercondylar cortico-cancellous fixation close to the articular surface is expected to offer better results than the EndoButton fixation.

Speirs et al.¹³⁾ reported that the cortico-cancellous suspensory fixation method required a short graft length due to fixation of the cross pin within the metaphysis, the lowest creep and cyclic elongation amplitude, and the highest strength and stiffness of all the tested devices. In particular, the PINN-ACL CrossPin (ConMed Linvatec, Largo, FL, USA) system was found to be the most rigid and strongest of all the tested reconstruction systems. Therefore, the cortico-cancellous fixation method seems to have the advantages of short graft, stability, and stiffness, and the PINN-ACL CrossPin implant features the proprietary self-reinforced poly-L-lactide acid polymer enabling it to be the strongest bioabsorbable implant. The cross pin absorption begins in vivo approximately within 15 to 24 weeks after insertion, the continuous loop is composed of high strength polyethylene fiber, and the ultimate pullout tensile strength is 1700N¹⁴⁾ (Fig. 1).

In this study, we analyzed the mid-term results of ACL reconstruction using the PINN-ACL CrossPin system, a cortico-cancellous suspension method device. We hypothesized that ACL reconstruction using the PINN-ACL CrossPin system would significantly improve manual stability, anterior-posterior laxity measured by instrument, and functional score.

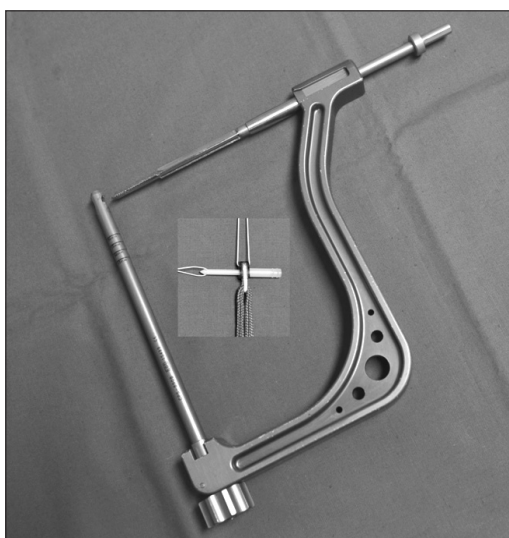


Fig. 1. The PINN-ACL CrossPin is composed of a CrossPin implant and a graft harness with a loop. The photograph also shows the CrossPin U-guide, a drill bit, a positioning rod, and a transverse cannula.

Materials and Methods

From June 2007 to July 2008, 43 of 46 patients with ruptured ACLs were evaluated. The patients underwent single-bundle ACL reconstruction using a 4-strand semitendinosus tendon (semi-T) with the PINN-ACL CrossPin system. Three patients were excluded due to conditions that might affect the results: articular cartilage damage and osteoarthritis in 1 patient, subtotal meniscectomy in 1 patient, and total meniscectomy in 1 patient. All included patients were male with a mean age of 28.7 years (range, 18 to 54 years). The ACL reconstruction was performed on the right knee in 24 patients and on the left knee in 19 patients. The mean follow-up period was 50 months (range, 48 to 61 months). Associated lesions were meniscal tear in 15 patients, which required meniscus repair in 5 and partial meniscectomy in 10, and medial collateral ligament injury in 2 patients, which was treated by conservative methods.

A 4-strand semi-T was used as a graft. A longer than 28 cm semi-T was harvested with an additional 2 cm of periosteum extension and was folded twice to be a 4-strand graft¹⁵⁾. The mean length of the graft was 7.2 cm and the diameter was 8.2 cm (Fig. 2). A modified trans-tibial method was used for femoral tunneling¹⁶⁾.

Depending on the diameter of the femoral tunnel, a positioning rod (8 mm or 9 mm) of appropriate size was selected and assembled onto the U-Guide. A disposable transverse cannula was slid onto the U-Guide body. With the U-Guide assembled, the positioning rod was inserted. When the U-Guide assembly was fully inserted, the laser etch marks on the positioning rod indicated the length of the femoral tunnel. After the U-Guide was fully inserted into the tunnel, the U-Guide body was rotated



Fig. 2. The photograph shows the PINN-ACL CrossPin-graft complex. A single 4-strand semitendinosus tendon was used as a graft. The minimum length of the semitendinosus tendon for the PINN-ACL CrossPin-graft complex was 28 cm, which resulted in a 4-strand graft with a length of 7 cm.

until the transverse cannula mounted on the U-Guide body was directed toward the lateral condyle. A transverse tunnel was drilled from the lateral to the medial condyle. Each cross pin had a cortical length designed to occupy the cortical side of the transverse tunnel. A cross pin of proper length was determined as the one whose cortical length was less than, or equal to, the measured cortical tunnel length. After selecting the proper size cross pin, the hamstring graft construct (i.e., Graft Harness and graft bundle assembly) was drawn into the knee using the graft passing guide pin. The lead suture was passed on the Graft Harness through the eyelet of the graft passing guide pin and, while maintaining lateral to medial alignment of the axis of the eyelet in the Graft Harness, the graft construct was passed into the tibial tunnel. It was firmly pulled on the graft construct until fully seated in the femoral socket. A sheathed scope could be placed into the Transverse Cannula to visualize the alignment of the axis of the Graft Harness eyelet with the axis of the transverse tunnel. The CrossPin Driver was inserted into the proximal end of the implant and tapped with a mallet to move the implant through the Transverse Cannula and into the transverse tunnels. The CrossPin implant, pressed into the lateral transverse tunnel, was advanced with the Driver and a mallet until it stops while pulling out the transverse cannula.

The position of the femoral tunnel was at the center of the footprint, directed 10:30 (or 1:30) o'clock position. Fixation of the femoral tunnel was done using the PINN-ACL CrossPin system. The position of the tibial was at the center of the footprint (Fig. 3).

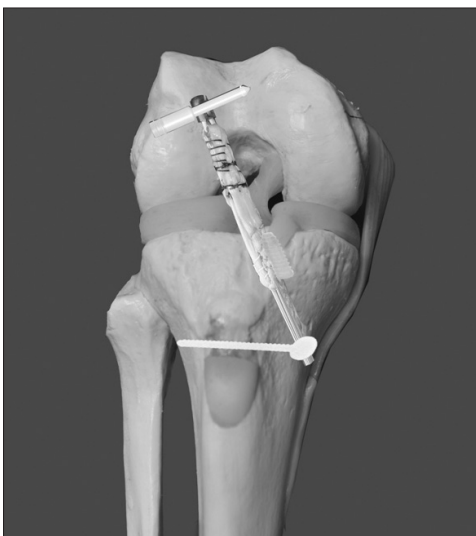


Fig. 3. Schematic drawing of anterior cruciate ligament reconstruction using the PINN-ACL CrossPin system.

We tried to preserve the remnants of ACL as much as possible. Tibial side fixation was done using a bioabsorbable screw and then post-tied with a washer and screw.

Postoperative rehabilitation started with quadriceps strength exercises immediately after surgery. Range of motion exercises were allowed at 2 weeks after surgery with extension locking braces applied. Weight-bearing was allowed as tolerated. At 2 weeks after surgery, up to 90° of active range of motion was permitted for 4 weeks and full range of motion exercise was performed thereafter. From 6 weeks after surgery, patients followed a usual rehabilitation program¹⁷⁾. In patients who had undergone concomitant meniscal repair, the rehabilitation program was delayed by 2 weeks.

Evaluation was done as follows. Anterior instability was evaluated on the day of admission using the Lachman test and the KneeLax3 arthrometer (Monitored Rehab Systems, Haarlem, Netherlands)¹⁸⁾. Rotational instability was evaluated using the pivot-shift test with the patient under anesthesia immediately before surgery. Functional knee score was evaluated using the International Knee Documentation Committee (IKDC) subjective score and objective grade. Data from both sides and pre- and postoperative data were compared.

Student's t-test was used to analyze parametric continuous data and chi-square test was used for non-parametric data. Statistical significance was accepted for p-values of <0.05, and SPSS ver. 21.0 (IBM Corp., Armonk, NY, USA) was used for all analysis.

Results

The range of motion was improved to normal without limitation at final follow-up. The Lachman test results were improved from grade II (n=40) or III (n=3) to grade I (n=3) or grade 0 (n=40) at final follow-up (p=0.001). The pivot-shift test results were improved from grade I (n=20) or II (n=10) to grade I (n=8) or grade 0 (n=22) at final follow-up (p=0.001). The IKDC subjective score was improved to 88.7 and the objective grades A and B were noted in 93% of the patients at final follow-up (p=0.039, 0.001). Anterior laxity measured by the KneeLax3 arthrometer was improved from 6.7±4.5 mm preoperatively to 2.1±1.0 mm at final follow-up (p=0.021) (Table 1). Three cases of complications occurred: a graft re-rupture was treated with revision reconstruction at 2 years after surgery; a superficial infection on the tibial side was improved after debridement; and a deep knee infection on the tibial side found at 2 weeks after surgery was identified as methicillin resistance *Staphylococcus aureus* and treated with thorough arthroscopic debridement, massive irrigation, and 4

Table 1. Clinical Results of Anterior Cruciate Ligament Reconstruction Using Hamstring Tendon with the PINN-ACL Crosspin System

Variable	Preoperative	Final follow-up	p-value
Lachman test grade			
0	0	40	0.001
1	0	3	
2	40	0	
3	3	0	
Pivot-shift test (+)			
0	13	35	0.001
1	20	8	
2	10	0	
3	0	0	
IKDC subjective score	70±9.2	88.7±6.1	0.039
IKDC objective grade			
A	0	27	0.001
B	0	13	
C	33	3	
D	13	0	
SSD by KneeLax3 arthrometer (mm)	6.7±4.5	2.1±1.0	0.021

Values are presented as number or mean±standard deviation.

IKDC: International Knee Documentation Committee, SSD: side to side difference.

weeks of antibiotic injection.

Discussion

In this study, anterior instability evaluated using the Lachman test and KneeLax3 arthrometer, and rotational instability evaluated by the pivot-shift test were significantly improved after surgery. The functional knee score evaluated using the IKDC score & grade was also remarkably improved after surgery.

Seo et al.¹⁹⁾ reported on 56 cases of ACL reconstruction using the PINN-ACL CrossPin system. In the study, the side-to-side difference measured by the KT-1000 arthrometer was 2.4 mm at a mean of 14.5-month follow-up and the mean IKDC score was 87.3. Kong et al.²⁰⁾ reported on 56 cases of ACL reconstruction using RigidFix, another CrossPin system. In their study, the mean side-to-side difference was 2.1 mm and 98.2% of the cases had IKDC grades A or B. Streich et al.²¹⁾ reported about 25 cases of single bundle ACL reconstruction with a single semi-T: the mean side-to-side difference was 0.94 mm, the pivot-shift test was grade 0 in 19 cases, more than grade 1 in 6 cases, and the mean

IKDC score was 88.6. The results of our study were comparable to those demonstrated in the abovementioned studies.

Seo et al.¹⁹⁾ reported that the incidence of CrossPin-femoral tunnel mismatch was high. To prevent this problem, they tried to firmly fix the drill guide sheath to the femur or create a short femoral tunnel to perform drilling at almost perpendicular direction to the cortical bone, but this technique requires further improvement of tools for minimization of complications. In our study, we encountered a mismatch between the harness hole within the femoral tunnel and the CrossPin tunnel caused by rotation of the harness in bone tunnel. We solved this problem by firmly fixing the guide assembly and switching from a small sized stick to a larger one of the same size of the harness hole to make 90% of the harness hole coincide with the CrossPin tunnel. Then, the CrossPin system was inserted.

Yamazaki et al.²²⁾ and Zantop et al.²³⁾ reported on the optimal length of the soft-tissue graft within a bone tunnel. They concluded that a graft length of over 15 mm does not influence the kinematic or structural properties of the knee joint. Although Lipscomb et al.²⁴⁾ indicated that slight or no deficits were observed in the knee flexor strength, most reports suggested that deficits of 10% to 20% in the knee flexor strength are common after ACL reconstruction using both semi-T and gracilis tendon autograft^{25,26)}. The single 4-strand semi-T tendon ACL graft was shorter but could be made thicker, had biomechanical benefits, and decreased donor site morbidity by not harvesting the gracilis tendon²⁷⁾. For a four-strand hamstring graft, at least a graft length of 7 cm is recommended¹⁵⁾ (Fig. 2). Thus, the minimum required semi-T tendon length is 28 cm for a four-strand semi-T graft. It is possible to obtain an additional 2 cm of semi-T tendon by including the periosteum¹⁵⁾. In this study the mean graft length was 7.2 cm, the mean diameter was 8.2 mm, which was thicker than the semi-T/gracilis 4-strand graft. So, we could expect less decrease of the knee flexor strength without harvesting of the gracilis tendon, enhanced tendon healing to the bone tunnel due to inclusion of the periosteum in the graft and a thicker graft²⁸⁾.

The PINN-ACL CrossPin instrument could be one of the useful cortio-cancellous suspensory devices for femoral fixation, allowing for easy fixation with a shorter graft (single semi-T 4-strand) and reducing donor site morbidity. The other CrossPin, RigidFix system, requires a 3-cm long graft in the femoral bone tunnel for adequate fixation. However, the PINN-ACL CrossPin needs a 1.5–2 cm graft for adequate fixation. So it is useful for shorter graft fixation.

In this study, one case of graft re-rupture occurred, but it was not related to the fixation method. Regarding the one case of

deep infection and another case of superficial infection, these two infections were improved after debridement. We suspect that the cause of infection might have been contamination of the guide assembly because the PINN-ACL CrossPin instrument was complex and composed of several small parts and guide assembly. So, we believe there is a need for thorough cleansing and sterilization including foreign body particle removal from the guide assembly before surgery. Maletis et al.²⁹⁾ evaluated the incidence of postoperative ACL reconstruction infections in the total 10,626 cases and concluded that graft choice would make a difference. The overall incidence of surgical site infection (SSI) was 0.48% (n=51), with 17 (0.16%) superficial infections and 34 (0.32%) deep infections. Hamstring tendon autografts (0.61%) had the highest incidence of deep SSIs of the total graft types (BPTB autograft 0.07% vs. allograft 0.27%). After adjusting for age, sex, and body mass index, the likelihood of a patient with a hamstring autograft having a deep SSI was 8.24 times higher than someone receiving a BPTB autograft. The risk of infections in allografts was not statistically significantly higher than BPTB autografts. Van Tongel et al.³⁰⁾ reported the incidence of septic arthritis after ACL reconstruction using semi-T/gracilis autograft was 0.51%. The graft can be retained during treatment of septic arthritis after ACL reconstruction.

The limitations of this study are no inclusion of a control group, retrospective study design, and no performance of radiologic evaluation.

Conclusions

This study demonstrated that good results can be obtained after single-bundle ACL reconstruction using 4-strand semi-T tendon with the PINN-ACL CrossPin system at a minimum follow-up of 48 months. We believe the PINN-ACL CrossPin system is a useful instrument for shorter graft fixation.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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