Tunnel widening prevention with the allo-Achilles tendon graft in anterior cruciate ligament reconstruction
Surgical tips and short term followup

Dong Won Suh, Seung Beom Han[1], Woo Jin Yeo, Won Hee Lee, Jae Ho Kwon, Bong Soo Kyung

Abstract

Background: Tunnel widening (TW) after anterior cruciate ligament (ACL) reconstruction can be a serious complication, and there is controversy over how to prevent it. This study aimed to suggest surgical approaches to prevent TW using an allo-Achilles tendon graft, and then to evaluate TW after these surgical tips were applied.

Materials and Methods: Sixty two patients underwent ACL reconstruction with an allo-Achilles tendon graft. Four surgical approaches were used: Making a tibial tunnel by bone impaction, intraarticular reamer application, bone portion application for the femoral tunnel, and an additional bone plug application for the tibial tunnel. After more than 1-year, followup radiographs including anteroposterior and lateral views were taken in 29 patients encompassing thirty knees. The diameter of the tunnels at postoperation day 1 (POD1) and at followup was measured and compared.

Results: In 18 knees (60%), there were no visible femoral tunnel margins on the radiographs at POD1 or followup. In the other 12 cases, which had visible femoral tunnel margins on followup radiographs, the mean femoral tunnel diameter was 8.6 mm. In the tibial tunnel, the mean diameters did not increase on all three levels (proximal, middle, and distal), and there was no statistically significant difference between the diameters at POD1 and followup.

Conclusion: The suggested tips for surgery involving an allo-Achilles tendon graft can effectively prevent TW after ACL reconstruction according to this case series. These surgical tips can prevent TW.

Key words: Allo-Achilles tendon graft, anterior cruciate ligament, anterior cruciate ligament reconstruction, tunnel widening

MeSH terms: Anterior cruciate ligament, anterior cruciate ligament reconstruction, achilles tendon, allograft

Introduction

After the first description of tunnel widening (TW) following anterior cruciate ligament (ACL) reconstruction in the 1990s,[1] the condition has been reported in many other studies.[2-8] The correlation between TW and the clinical outcomes of ACL reconstruction remains unclear; however, many researchers have investigated the causes of TW and methods of preventing it because TW can be a factor in graft failure after ACL reconstruction[9] and makes revision ACL reconstruction difficult.

The etiology of TW is still unclear as both mechanical and biological factors have been suggested to play roles.[10] The biological factors proposed include an antigenic immune response,[11] a toxic effect,[1] a nonspecific inflammatory response,[12] and cellular necrosis from drilling and graft remodeling,[13-15] and the mechanical factors proposed include local stress deprivation of the tunnel wall,[15] graft-tunnel motion,[12] aggressive rehabilitation,[16] and increased

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graft forces due to improper graft placement. Many recent studies have tried to prevent TW by modifying the surgical techniques used; strategies include the use of a bone plug application with press-fit,[17,18] bone impaction using a dilator,[19] proper tunnel positioning,[8] and a periosteal envelope.[5] It has been reported that these surgical procedures can effectively reduce the extent of TW; however, there is still controversy regarding the most effective method of preventing TW.

This study suggests surgical techniques to prevent TW by using an allo-Achilles tendon graft and to evaluate TW after ACL reconstruction with these techniques. We hypothesized that ACL reconstruction using an allo-Achilles graft with the suggested surgical tips would lead to less TW.

Materials and Methods

85 patients who underwent ACL reconstruction by a single surgeon (DWS) between September 2011 and June 2013 were included in this retrospectively study. Twenty three patients were excluded based on the following exclusion criteria: Age under 18 (n = 5), revisional ACL reconstruction (n = 13), and associated bony surgery such as high tibial osteotomy (n = 5). Among the remaining 62 patients, 29 patients with thirty knees (one patient underwent bilateral ACL reconstruction within a 2-month interval) were followed for more than 1 year. Ethical approval for the current study was obtained from the Public Institutional Review Board of country.

Operative procedure

All patients underwent single-bundle ACL reconstruction by a transtibial technique with careful targeting of the femoral insertion of the native ACL. After assessing the amount of remaining fiber and the tension of the injured ACL, the surgeon chose to perform an ACL reconstruction. Because of its advantages in ligament healing and proprioception, we preferred remnant-preserving ACL reconstruction with internal sutures between the remnant and reconstructed graft.[20,21]

To prevent TW after ACL reconstruction, we modified a few steps of procedure: First, we preferred bone-to-bone healing to bone-to-tendon healing.[22] Second, we used gradual reaming with bone impaction with a dilator to minimize bone loss during tunnel reaming. Third, to prevent undesired tibial tunnel reaming during femoral reaming, we applied a tibial tunnel-independent guide pin during the femoral reaming procedure. Fourth, to obtain bone-to-bone healing of the tibial tunnel, the tibial tunnel was fixed with a bone plug with a small interference screw.

We designed the allo-Achilles graft with a 10 mm diameter that preserved the bone-tendon junction as much as possible [Figure 1]. First, the bone block was cut and prepared into a cylindrical shape, 10 mm in diameter and 20 mm in length using a bone saw. To preserve the bone-tendon junction as much as possible, the bone block of the allo-Achilles tendon was prepared along the direction of the tendon fiber as shown in Figure 1, not perpendicular to the junction. We also prepared a free bone block from remaining allo-Calcaneus bone to be used as a bone plug for the tibial tunnel, which was 5 mm wide and 25 mm long.

Tibial tunnel reaming

During tunnel reaming, reamers can cause bone debris or thermal injury to the tunnel wall. These are known to cause TW. To prevent TW and to increase the compactness of the bone around the tunnel, a previous researcher had used a dilator with bone impaction.[19] However, bone impaction using a dilator could result in a cortical bone fracture on the articular side. Therefore, we modified the previous bone impaction technique by gradually reaming from 7 to 9 mm, then carrying out bone impaction with a dilator beneath the articular cortex, and finally reaming the articular cortical wall using a 10 mm reamer.

Femoral tunnel reaming

For femoral tunnel reaming, a guide pin was passed through the tibial tunnel and fixed on the distal femur. Usually, the reamer is applied to this guide pin extraarticularly. However, if the 10 mm diameter reamer passes through the same 10 mm diameter tibial tunnel within the rigid guide pin, the reamer can injure the tibial tunnel if there is a mismatch between the tibial tunnel and the fixed guide pin. To prevent tunnel damage via this mechanism, we recommend intraarticular reamer application [Figure 2]. Before the reamer was used, the guide pin was pulled

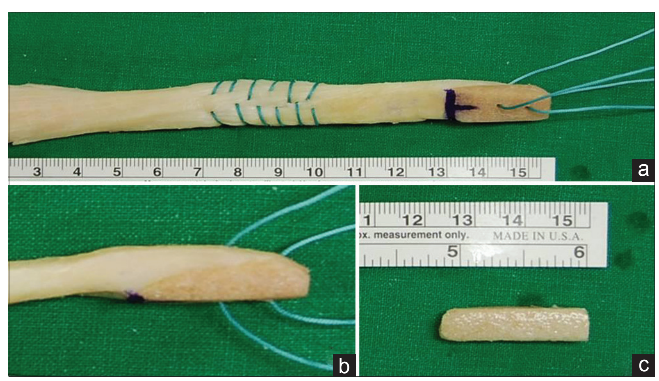

Figure 1: Preparation of the Achilles tendon allograft. (a) For anterior cruciate ligament reconstruction, the allo-Achilles graft is created to pass through the 10 mm diameter tunnel and to preserve the bone-tendon junction. (b) At the bone-tendon junction, a cylindrical tunnel 10 mm in diameter and 20 mm in length in the bone block is made along the direction of the tendon fiber and the tendon portion is prepared to pass through the 10 mm diameter tunnel. (c) An additional bone plug for the tibial tunnel is made using the remaining calcaneal bone; the tunnel is 5 mm in width and 25 mm in length

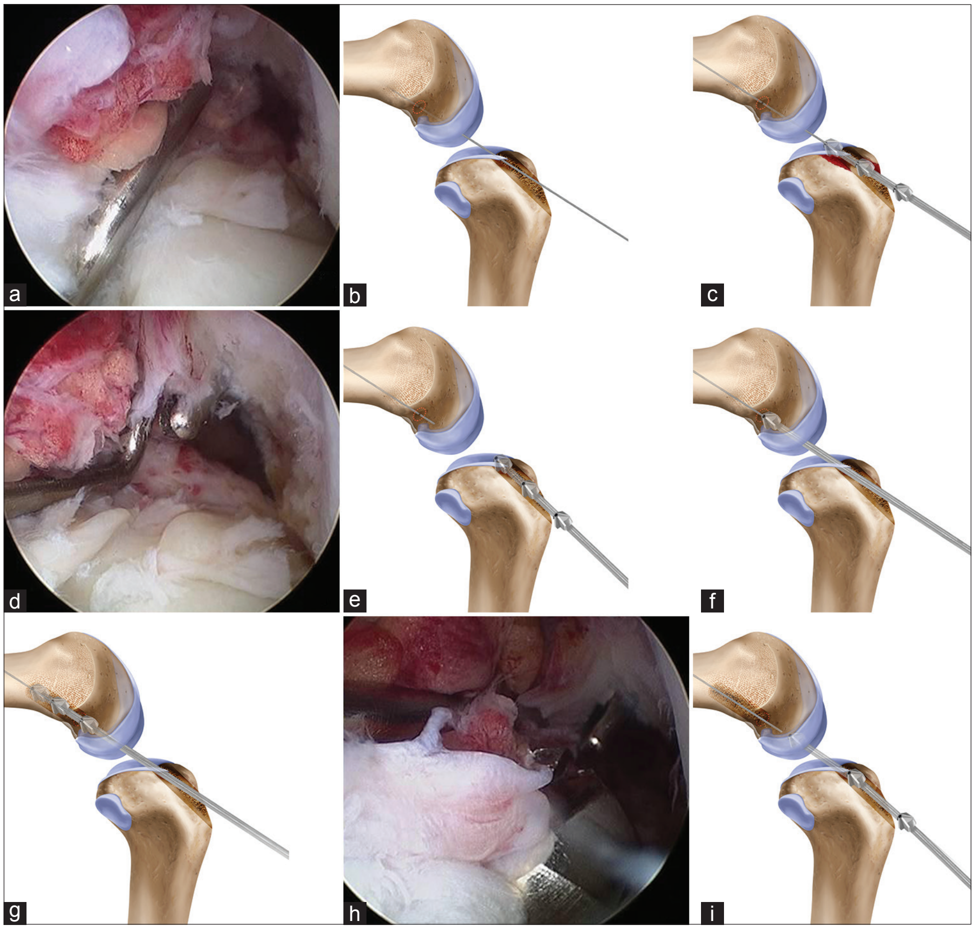

Figure 2: Intraarticular reamer application. (a and b) After targeting the anterior cruciate ligament femoral insertion, the guide pin is applied. Because the targeted anterior cruciate ligament femoral footprint is not equal to the advanced point of the tibial tunnel, axis of the guide pin for the femoral tunnel can be different to the tibial tunnel. (c) With these different axes, the reamer can violate and injure the tibial tunnel. (d and e) To prevent this injury, the guide pin is pulled proximally until the tip is located in the articular space. This allows the reamer to pass the tibial tunnel freely, without damaging the tibial tunnel. (f) On reaming, if the distance between the guide pin and the reamer is too short, then the direction of the reamer may be off causing improper and damaging tunnel reaming. Thus, the guide pin moves distally before reaming the femoral tunnel. (g) By using the 10 mm head reamer with a narrow shaft, femoral tunnel reaming can be completed without injuring the tibial tunnel. (h and i) To prevent similar tibial tunnel injury during reamer detachment, the guide pin is pulled proximally again, and the reamer is separated from the guide pin and knee joint. After that the guide pin is passed through the tibial tunnel using the cannulated guide

proximally until the tip of the guide pin which was located in the intraarticular space. Then, the reamer was passed through the tibial tunnel freely and attached to the tip. Before reaming, the guide pin was pushed distally about 2 cm to prevent axis mismatch between the guide pin and the reamer. After reaming, the guide pin was pulled again to prevent injury that can occur while the reamer is passed through the tibial tunnel for separating. After these procedures, the guide pin was pushed in again until the tip passed the tibial tunnel.

Bone plug application for tibial tunnel

The bony portion of the allo-Achilles tendon graft is applied to the femoral tunnel and that an 8 mm metal interference is used for fixation. With this fixation, the graft-tunnel motion may be absent. In addition, it provides a strong bone-to-bone union between the graft and the tunnel.

On the tibial side, the previous studies used the bone plug to reduce TW.[17,18] To obtain a strong bone-to-bone healing on the tibial side, we also recommended a bone plug. In our cases, a bone plug 5 mm wide and 25 mm long was prepared by using the remaining calcaneal bone of the allo-Achilles tendon graft. For stable fixation, dual fixation was recommended; the graft was fixed by a screw with a spike washer on the extratunnel part, and then intratunnel fixation was accomplished via the prepared bone plug. To prevent motion of the bone plug and to obtain a greater compression force on the graft-tunnel junction, we added a 7 mm bioabsorbable interference screw between the bone plug and the tibial tunnel [Figure 3].

Radiographic evaluation and analysis

On postoperative day 1 (POD1) and during the followup visit, patients underwent simple radiographs in both the anteroposterior (AP) and lateral views. The diameters of

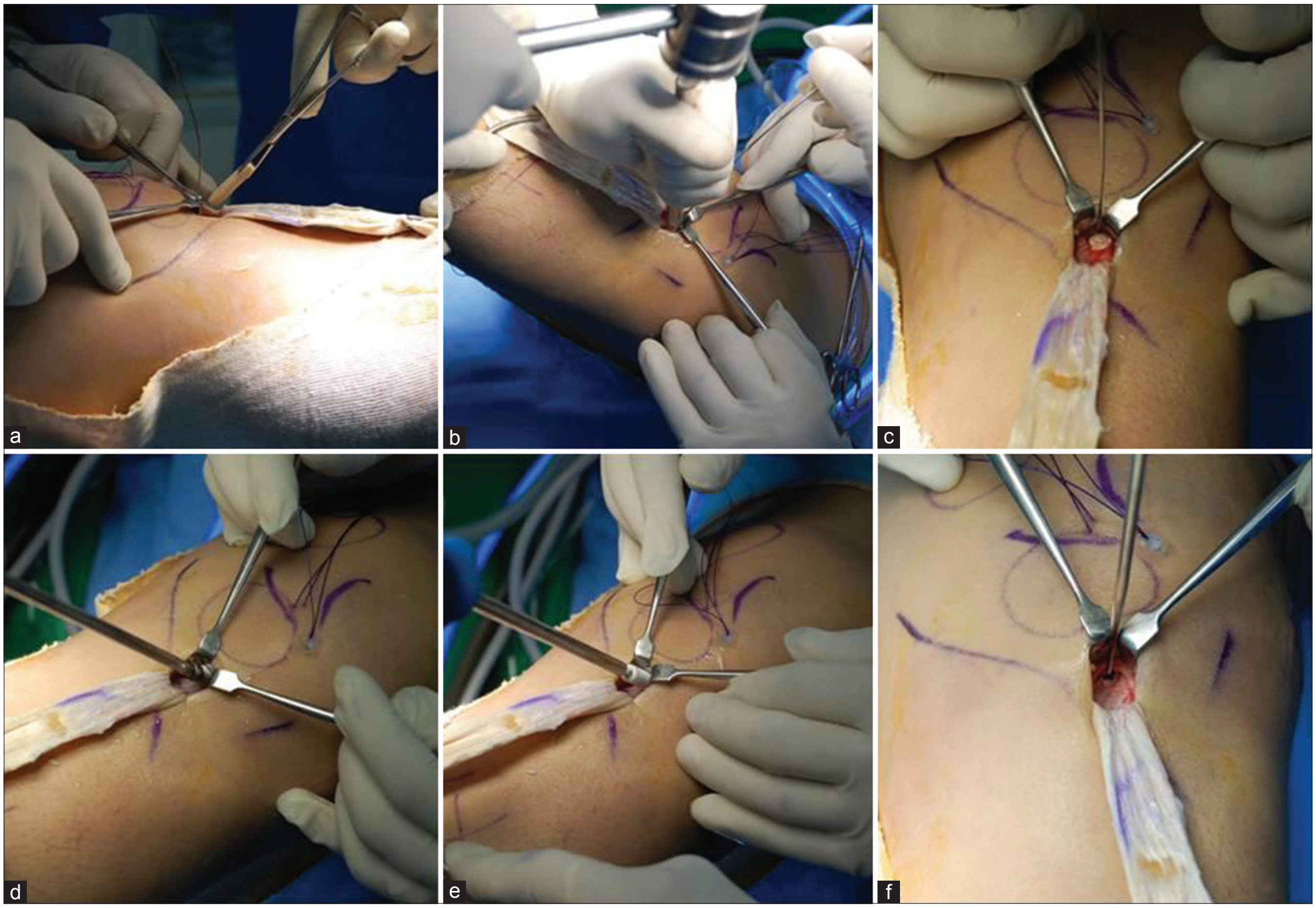

Figure 3: Peroperative photographs showing bone plug application in the tibial tunnel. After the graft passes through, it is fixed on the femoral tunnel and is fixed with a spike washer and screw, a bone plug and a bioabsorbable screw are applied for dual fixation. (a-c) A bone plug 5 mm in diameter and 25 mm in length from the bony portion of the allo-Achilles graft is passed between the allo-Achilles graft and tibial tunnel. (d-f) A guide pin is applied and a 7 mm diameter bioabsorbable screw is fixed after tapping between the bone plug and tibial tunnel

the femoral and tibial tunnels were measured on three levels (proximal, middle, and distal) as was described in previous studies.[23,24] The automatic distance measurement tool of the PiView STAR program (Infinitt Healthcare, Seoul, Korea), a type of picture archiving and communication system, was used to export all images and perform all measurements. Between the data obtained on POD1 and during followup, a difference of up to 1 mm was considered to be clinically relevant. Statistically, data on femoral tunnels were compared using the Mann–Whitney U-test and data on tibial tunnels were analyzed by paired *t*-tests. All statistical analyses were performed by the Statistical Package for the Social Sciences (SPSS) software version 12.0 (SPSS, Chicago, IL, USA) and a *P* value under 0.05 was considered statistically significant.

Results

The mean followup duration until the simple radiographs were taken was 16.2 months (range 12 to 31 months), and patients demographics are shown in Table 1.

Table 1: Patient demographics

	Mean value	Range
n	29 patients, 30 knees*	
Age (years)	30	18-51
Gender	18:11	Male:female
Followup duration (months)	16	12-31

*A male 25-year-old patient underwent bilateral ACL reconstruction within a 2 months interval. ACL=Anterior cruciate ligament

Femoral tunnel widening

Because the bone portion of the allo-Achilles graft was placed in the femoral tunnel, we could not identify the tunnel margin of the femoral tunnel in most of the simple radiographs. In eighteen of the thirty knees (60%), we could not see the femoral tunnel margin on either the POD1 or in the followup radiographs either in anteroposterior or lateral views [Figure 4]. In four cases, the radiographs taken on POD1 had a line showing the femoral tunnel margin, and in only one case, the visible femoral tunnel margin was available in the AP view alone. That case showed an increase of tunnel diameter in the followup radiographs [Figure 5]. It was also the case which had the

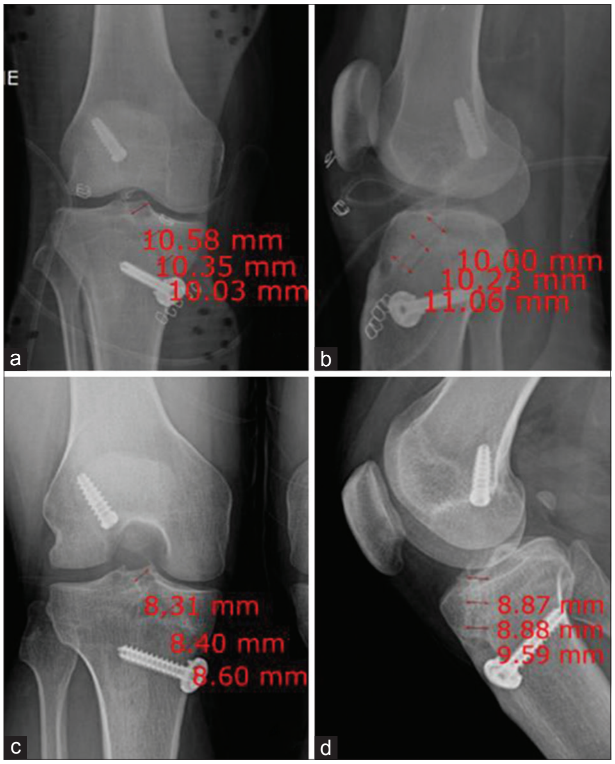

Figure 4: A 31-year-old male patient underwent anterior cruciate ligament reconstruction in our institution using the allo-Achilles graft. (a and b) X-ray of knee joint anteroposterior and lateral views showing the margins of the femoral tunnel could not be identified on postoperative day 1. The tibial tunnel diameters were 10.6, 10.4, and 10.0 mm (proximal, middle, and distal, respectively), and 10.0, 10.2, and 11.1 mm. (c and d) X-ray of knee joint anteroposterior and lateral views showing after 31 months, we could again not find the femoral tunnel margin and the diameters of the tibial tunnel had decreased (8.3, 8.4, 8.6, 8.9, 8.9, and 9.6 mm, respectively)

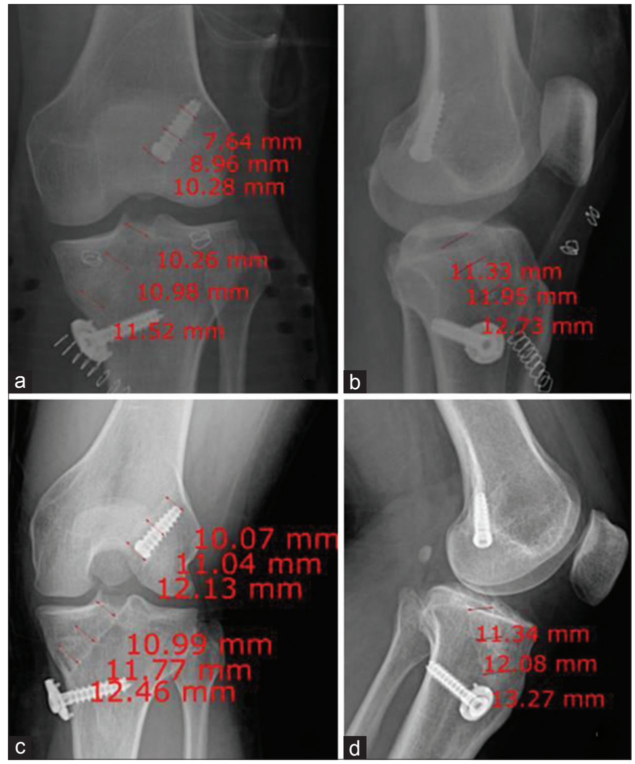

Figure 5: A case of femoral tunnel widening. A 29-year-old female patient underwent anterior cruciate ligament reconstruction with our surgical techniques (a) X-ray of knee joint anteroposterior view on postoperative day 1, the femoral tunnel margin was visible in the anteroposterior view and its diameters were 10.3, 9.0, and 7.6 mm (distal, middle, and proximal, respectively). (b) X-ray knee joint lateral view, the margin was not visible. (c) X-ray knee joint anteroposterior view showing nineteen months postoperatively, the femoral tunnel had increased in size to 12.1, 11.0, and 10.1 mm in the anteroposterior view (distal, middle, and proximal, respectively), and (d) X-ray knee joint lateral view showing the margin was invisible in the lateral view

largest femoral tunnel width in the present study. In eight other cases, the margins of the femoral tunnel could only be identified on the followup radiographs; however, the diameters at the three levels in both AP and lateral view were smaller than 10 mm, the reamer diameter for the femoral tunnel. The mean diameter of the femoral tunnels that could be identified on followup radiographs was 8.6 mm. According to the results of the Mann–Whitney U-test, there were no differences in tunnel diameter between POD1 and followup radiographs [Table 2].

Table 2: Mean diameter of tunnels (mm)

	Femur			Tibia		
	POD1	Followup	*P*‖	POD1	Followup	*P*¶
AP proximal	10.3*	10.0‖	0.433	10.2	9.9	0.325
AP middle	9.8*	8.8‖	0.089	10.7	10.5	0.414
AP distal	9.4*	7.5‖	0.117	11.3	11.1	0.597
Lateral proximal	9.2†	9.9§	0.197	10.4	10.3	0.798
Lateral middle	9.1†	8.8§	0.606	11.0	10.6	0.426
Lateral distal	8.8†	7.9§	0.302	11.6	11.1	0.316

*Data from four patients, †Data from three patients, ‖Data from 11 patients, §Data from 6 patients, ‖Result of Mann-Whitney U-test, ¶Result of paired t-test. POD1=Postoperation day 1, AP=Anteroposterior

Tibial tunnel widening

The mean diameters of the tibial tunnel in POD1 were 10.2, 10.7, and 11.3 mm in the AP view and 10.4, 11.0, and 11.6 mm in the lateral view (proximal, middle, and distal levels, respectively). On the followup radiographs, the mean diameters were decreased to 9.9, 10.5, and 11.1 mm in the AP view and 10.3, 10.6, and 11.1 mm in the lateral view (proximal, middle, and distal levels, respectively) [Table 2 and Figure 4]. Of the thirty knees, half (n = 15) showed an increase in mean tibial tunnel diameter and 4 (13.3%) had more than a 1 mm increment in mean tibial tunnel diameter; the increments were 1.4, 1.5, 2.0, and 2.8 mm [Figure 6]. Between POD1 and the followup, the paired *t*-tests showed no statistically significant differences in all three levels in both views.

Discussion

With our surgical tips using an allo-Achilles tendon graft, TW at least 1 year after surgery was effectively prevented

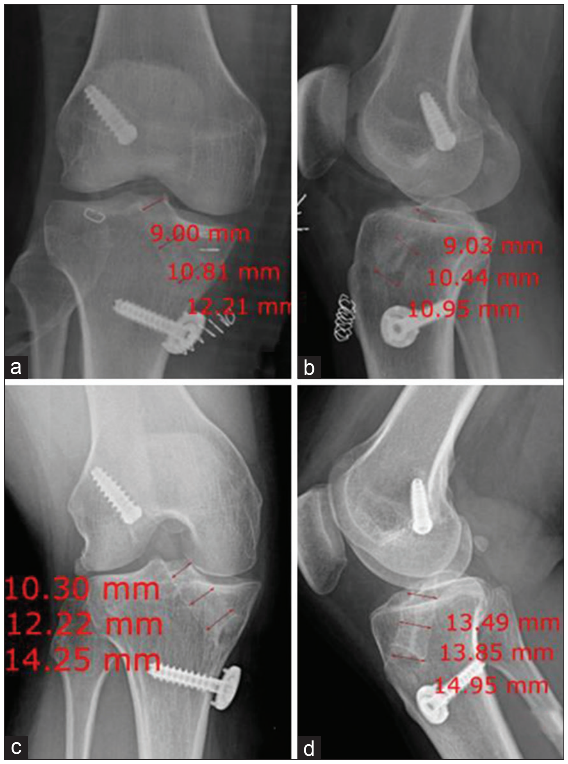

Figure 6: The case with the greatest extent of tibial tunnel widening. A 44-year-old female patient underwent anterior cruciate ligament reconstruction and was followed up for 21 months. (a and b) X-ray knee joint anteroposterior and lateral views on postoperative day 1 showing the diameters of the tibial tunnel were measured as 9.0, 10.8, 12.2, 9.0, 10.4, and 11.0 mm (distal, middle, and proximal, respectively). (c and d) X-ray knee joint anteroposterior and lateral views after 21 months, showing radiographs revealed that the tibial tunnel had widened as the tunnel's diameters increased to 10.3, 12.2, 14.3, 13.5, 13.9, and 15.0 mm. The mean diameter was 10.4 mm on postoperative day 1 and 13.2 mm at followup, which is a change of 2.8 mm

in this study. Although the clinical relevance of TW is not clear, the risk of revision after ACL reconstruction and the problems associated with revision ACL reconstruction from TW would be reduced by our surgical techniques.

Many studies have evaluated TW after ACL reconstruction based on the type of graft, fixation methods, or surgical techniques.[2-4,6-8,25-27] The mean extent of TW was 10–30% in those studies. According to the results of a previous study which used the same measurement methods as the present study, the mean amount of TW was about 7 mm.[23] On the other hand, the mean amount of TW was found not to increase significantly in the present study. Furthermore, there were only four cases (13.3%) of TW >1 mm. Given the results of this and other studies, we suggest that our surgical techniques are good options to prevent TW after ACL reconstruction.

As various types of grafts can be used for ACL reconstruction, many researchers have focused on which graft has the best clinical outcomes and the lowest morbidity rate. In particular, "autograft versus allograft" has been an important topic in orthopedic research.[28-30] Regarding TW, a previous study reported that a significantly higher amount of TW was observed in the allograft group compared to the autograft group,[26] but some studies have reported that there are no significant differences between autograft and allograft groups.[25,27,31] In the current study, though Achilles tendon allografts were used for ACL reconstruction, the results revealed no increase in tunnel diameter, which is better than the results of previous studies.[25-27] These results imply that the allo-Achilles tendon graft is a good option in ACL reconstruction to prevent TW.

For the junction between the graft and the tunnel, bone-to-bone healing may be better than bone-to-tendon healing. A previous study, which compared patellar and hamstring tendons, reported that TW occurred less in the patellar tendon, which allows for bone-to-bone healing on both the femoral and tibial sides.[32] Another study used the periosteal envelope to overcome the limitation of bone-to-tendon healing and reported minimal TW.[5] To obtain bone-to-bone healing in our ACL reconstructions without complications, we used the allo-Achilles tendon graft, which can provide bone-to-bone healing on the femoral tunnel. For the tibial tunnel, we used a bone plug from the remaining calcaneal bone of the previous allo-Achilles tendon graft. For fixation, we used an 8 mm metal interference screw for the femoral side and dual fixation for the tibial side, which was composed of the press fit by a bone plug and bioabsorbable interference screw, and the postfixation by a spike washer. The results of the present study showed no change after the 1st year, meaning that these techniques can be good options for obtaining stability after ACL reconstruction and to prevent TW.

During tunnel reaming, thermal injury or mechanical injury caused by the reamer and/or bone debris can occur. Such injuries can loosen the tunnel wall and cause TW or fixation failure. A previous study used a dilator to create more compact bone on the tunnel wall and reported less TW than with reaming alone.[19] We also used a bone dilator on the tibial tunnel to prevent TW, and our results also showed a successful reduction in TW. However, there is a risk that the dilator will negatively impact the articular cortical bone, possibly resulting in the development of a fracture on the tunnel aperture. Therefore, when performing bone impaction using a dilator, we recommend impacting just beneath the articular cortex and finalizing on the articular cortex with a 10 mm reamer. Using this technique, no fracture of the aperture occurred in our cases.

During transtibial ACL reconstruction, guide pin application and tunnel reaming for the femoral tunnel were performed through the tibial tunnel. Ideally, the guide pin and reamer for the femoral tunnel would be smaller or of an equal diameter to the tibial tunnel so that no injury would occur when constructing the femoral tunnel. However, the femur and tibia are not fixed to each other, and the axis of the femur and tibia can change during ACL reconstruction. Thus, an axis mismatch between the femoral and tibial tunnels can develop, potentially leading to an injury on the tibial tunnel wall. We recommend that the "intraarticular reamer application" method can be used to prevent this injury. This can minimize tibial tunnel injury during tibial tunnel-dependent femoral tunnel reaming ACL reconstruction.

The previous studies have had success using a bone plug in the tibial tunnel to improve bone-to-tendon healing and to prevent TW in ACL reconstruction.[17,18] Jagodzinski *et al*. reported that press-fit bone plug fixation decreases the amount of TW.[17] Another study used an autogenous bone plug for tibial press-fit fixation and also reported that autogenous bone plugs reduce tibial TW compared with bioabsorbable interference screws.[18] We also used a bone plug for the tibial tunnel; however, we were concerned about the limited expansive force of the cylindrical bone plug compared to the cone-shaped interference screw. Therefore, we added a smaller bioabsorbable interference screw between the bone plug and tunnel to increase the compression force between the graft and bone plug. With this method, there was no fixation failure 1-year postoperatively, and TW was effectively reduced.

There is a probable complication inherent in our surgical procedures due to a mismatch between the femoral tunnel and the metal interference screw. After passing the allo-Achilles graft through both tunnels, the metal interference screw cannot be applied through the tibial tunnel. Therefore, we applied the screw through the anteromedial portal after full flexion. With this modification, almost no cases had mismatches. However, among the 63 knees in the present study, the postoperative magnetic resonance images of eight cases (12.7%) showed mismatch [Figure 7]. Although there was no difference in TW or revision rate according to the occurrence of the mismatch, more studies on the modified methods, such as transportal tunnel reaming, and the clinical results of long term followup are needed to further bolster our present results.

There are certain limitations to the current study. First, there was no untreated control group, and it was not a prospective, randomized study. Second, there were no clinical results and the followup rate was small. Third, the followup period was relatively short. In the current study, some patients' followup radiographs were taken only 1 year after the operation. This period might be too short to prove the effectiveness of our surgical techniques. Fourth, we cannot prove which of our tips had the greatest effect in preventing TW. We need more prospective randomized multicentric studies to reach to conclusions.

Figure 7: A case of mismatch between the femoral tunnel and the metal interference screw. A postoperative magnetic resonance image of a 20-year-old male patient showing the same aperture between the femoral tunnel and the metal interference screw; however, the axes of the two were different

Conclusion

Our surgical techniques using an allo-Achilles tendon graft effectively prevented TW after ACL reconstruction in our case series. Therefore, these surgical tips are good options to prevent TW.

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Nil.

Conflicts of interest
There are no conflicts of interest.

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