# All-Inside Anterior Cruciate Ligament Reconstruction Using an Anterior Half of the Peroneus Longus Tendon Autograft

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**Background:** The peroneus longus tendon (PLT) has been used as a graft in many orthopaedic surgical procedures because of its comparable biomechanical strength with the native anterior cruciate ligament (ACL). Despite its potential, few studies have been performed to investigate the clinical reliability of ACL reconstruction using a PLT autograft.

**Purpose:** To assess the clinical outcomes and donor-site morbidity of ACL reconstruction using an anterior half of the PLT (AHPLT) autograft in patients with an isolated ACL injury.

**Study Design:** Case series; Level of evidence, 4.

**Methods:** Between January 2016 and January 2017, a total of 21 patients with an isolated ACL injury underwent all-inside single-bundle ACL reconstruction using an AHPLT autograft. Knee stability was assessed using the Lachman test, pivot-shift test, and KT-2000 arthrometer (side-to-side difference) with 134-N anterior force and at 30° of knee flexion. Knee function was evaluated using the International Knee Documentation Committee score, Lysholm score, and Tegner score. Donor-site morbidity was assessed using ankle eversion and plantarflexion strength as well as the American Orthopaedic Foot & Ankle Society scoring system and the Foot and Ankle Disability Index.

**Results:** At a mean final follow-up of 40.1 months (range, 36-48 months), the KT-2000 arthrometer side-to-side difference was significantly lower compared with preoperatively (1.1 ± 0.62 vs 7.0 ± 2.18 mm, respectively; $P < .001$). The mean preoperative International Knee Documentation Committee, Lysholm, and Tegner scores were 52.0 ± 8.27, 50.9 ± 8.50, and 1.8 ± 0.87, respectively, increasing significantly to 94.2 ± 2.61, 95.2 ± 2.64, and 6.8 ± 1.50, respectively, at final follow-up ($P < .001$ for all). All patients had grade 5 muscle strength in ankle eversion and plantarflexion at the donor site, with mean American Orthopaedic Foot & Ankle Society and Foot and Ankle Disability Index scores of 96.8 and 97.6, respectively. No complications or reoperations occurred.

**Conclusion:** All-inside ACL reconstruction using an AHPLT autograft produced good functional scores and stability without obvious ankle-site morbidity.

**Keywords:** anterior cruciate ligament; all-inside; peroneus longus tendon

Graft selection is important for satisfactory outcomes after knee ligament reconstruction. The most commonly used autografts include hamstring tendon (HT) autografts[22,27] and bone–patellar tendon–bone (BPTB) grafts.[10,32] Other common sources of autografts include the quadriceps tendon,[15] fascia lata,[3] and Achilles tendon.[12] Some authors favor HT autografts for anterior cruciate ligament (ACL) reconstruction because of lower anterior knee pain, donor-site morbidity, extensor strength deficits, and osteoarthritis development.[6,11,29] However, others have

suggested that the BPTB autograft is the most favorable graft choice, with the advantages of faster graft incorporation,[21] a higher proportion of patients returning to pre-injury activity levels,[34] and potentially a lower risk of graft ruptures.[19] Although there are many theoretical autograft choices, shortages in the supplies of grafts are often experienced, especially after considering the drawback of a potentially insufficient graft size using the HT in patients with shorter heights, lower weights, and variable thigh and shank lengths[16,31] as well as the shortcomings of anterior kneeling pain and loss of extension[6,10] using the BPTB, especially for double-bundle ACL reconstruction, posterior cruciate ligament reconstruction, multiligament

reconstruction, or revision. When one of these occurs, alternative autologous tendons are urgently needed.

The prerequisites for a donor site to be an ideal source of autografts should be that the autograft has an acceptable amount of strength and that it can be safely and easily harvested with no obvious functional impairment after its removal from the donor site. The peroneus longus tendon (PLT) may represent a good choice as a potential autograft, as it has good biomechanical properties of high failure loading and stiffness.[37] More recently, the PLT or anterior half of the PLT (AHPLT) autograft has been described as a potential autograft option for its strength, predictable clinical outcomes, and low donor-site morbidity.[13,24,25] The ultimate tensile strength of the native ACL has been reported as 1725 N.[26] Previous biomechanical studies have reported the tensile strength of the PLT as $446.16 \pm 233.28$ N[1] and its ultimate tensile strength as 2500 N.[26] Zhao and Huangfu[37] reported that the failure load of the AHPLT was comparable with that of the semitendinosus tendon and approximately 1.5 times that of the gracilis tendon.

PLT or AHPLT autografts are commonly used in many orthopaedic surgical procedures.[4,33,35] Because of its superficial location, the PLT can be easily and quickly exposed compared with the HT. Unlike the complicated anatomic structure of the semitendinosus and gracilis tendons, there is no fiber connection between the PLT and deep fascia or other nearby tendons. Donor-site morbidity is a topic of concern for some authors because the PLT plays an important role in plantarflexion of the ankle, eversion of the sole of the foot, and maintenance of the transverse arch.[5,7,8] Total removal of the PLT may result in ankle-site morbidity.[1] Thus, we only use the AHPLT to avoid the possible loss of ankle function. Based on our experience, the graft has a mean length of 65 mm when quadrupled, with a mean diameter of 7.9 mm. This is very close to the limits of what surgeons will accept using classic techniques and thus requires an all-inside technique.[17]

The purpose of this study was to assess the clinical outcomes and donor-site morbidity of ACL reconstruction using AHPLT autografts in patients with an isolated ACL injury. The hypothesis was that patients treated via ACL reconstruction using AHPLT autografts would obtain good knee function and stability and that there would be little donor-site morbidity after harvesting the AHPLT.

## METHODS

This study was approved by the local ethics committee, and all participating patients provided informed consent. A total of 27 patients were treated via arthroscopic single-bundle ACL reconstruction using AHPLT autografts between January 2016 and January 2017. A retrospective case series was conducted to evaluate the clinical outcome of AHPLT autografts in ACL reconstruction. Magnetic resonance imaging (MRI) was performed preoperatively to confirm ACL injuries and evaluate concomitant intra-articular structure injuries. Before surgery, the basic information of every patient including sex, age, injured side, time from injury to surgery, smoking status, and body mass index was recorded. Clinical assessments examined knee function using the International Knee Documentation Committee (IKDC), Lysholm, and Tegner scores as well as stability using the Lachman test, pivot-shift test, and KT-2000 arthrometer (MEDmetric).

We harvested AHPLT autografts in athletes who needed dominant hamstring power or patients who were predicted to produce an inadequate length and diameter of the HT graft using preoperative anthropometric measurements. The inclusion criteria were an isolated rupture of the ACL and an age between 18 and 45 years. The exclusion criteria were (1) grade >2 osteoarthritis according to the Kellgren-Lawrence classification on plain radiographs,[28] (2) revision cases, (3) multiple ligament injuries, (4) chronic synovitis diseases (gout, pigmented villonodular synovitis), and (5) grade >2 chondral lesions according to the Outerbridge classification.[20] Patients with concomitant reparable meniscal injuries were also excluded because of potential effects on outcomes.

### Surgical Procedures

For AHPLT harvesting, the location of the skin incision was marked 1 cm behind and 2 to 3 cm above the lateral malleolus. A 2-cm incision was made through the skin, subcutaneous tissue, and superficial fascia. A vessel clamp was used to separate the subcutaneous tissue from the retinacular tissue of the peroneal tendons. Care was taken to differentiate the PLT from the peroneus brevis tendon. The PLT was exposed using an orthogonal clamp, and then it was split longitudinally into 2 equal parts, anterior and posterior, using a mosquito hemostat. The distal part of the AHPLT was sutured 1 to 2 cm above the level of the lateral malleolus using No. 1 Vicryl suture (Ethicon). With the tendon pulled proximally, the AHPLT was cut at its most distal section about 0.5 to 1 cm distal to the Vicryl suture. Then, a tendon stripper was used to harvest the AHPLT in a proximal direction (Figure 1). The graft was symmetrically folded over an adjustable-length looped cortical button device (ACL TightRope RT; Arthrex), and both free ends were whipstitched. Subsequently, the doubled graft was passed through the second cortical button loop, and the

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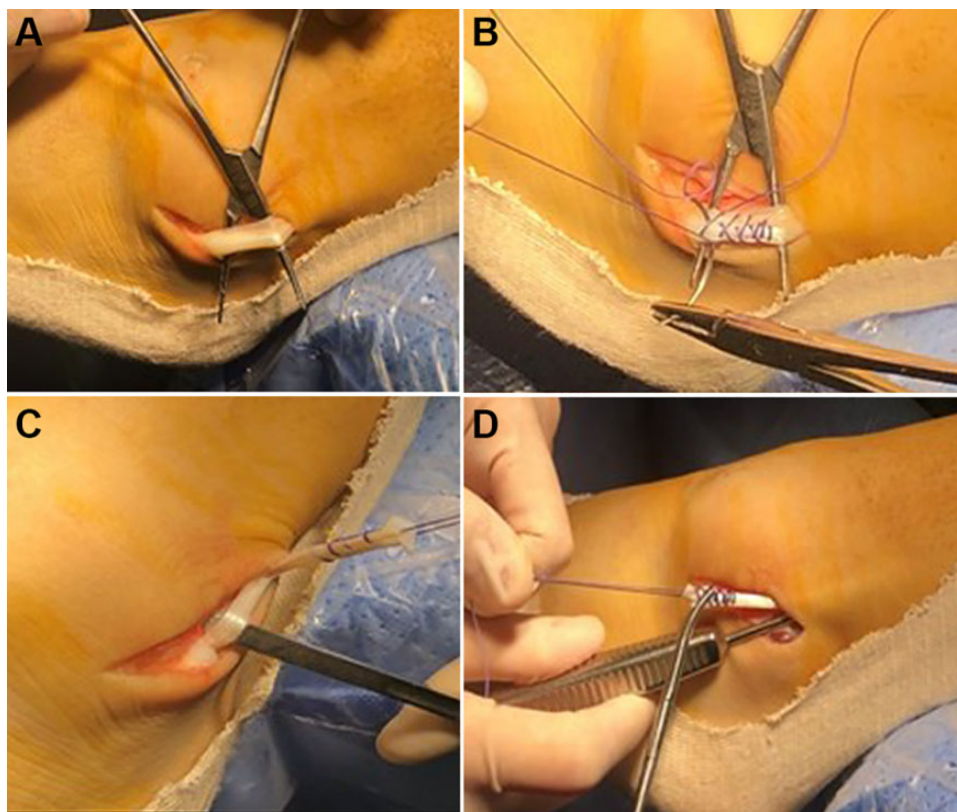*Ningbo Medical Center, Lihuili Hospital, Ningbo University School of Medicine, Ningbo, China.
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**Figure 1.** Harvesting of the anterior half of the peroneus longus tendon (PLT). (A) A 2-cm skin incision over the posterior border of the lateral malleolus was made to expose the PLT. The anterior half of the tendon was split anteroposteriorly using a vessel clamp. (B) The distal part was stitched using suture. (C) The anterior part of the PLT was freed, and (D) the posterior half was saved using a tendon stripper to harvest the PLT.

whipstitched graft ends were inserted into the graft apex on the first cortical button loop. A 4-bundle AHPLT autograft was produced, and the graft ends were secured via sutures using the "buried-knot" technique[17] (Figure 2, A and B). The mean diameter of the graft was 7.9 mm (range, 7-10 mm), and the mean length was 6.5 cm (range, 6-7 cm).

Different from classic anatomic ACL reconstruction techniques, the all-inside technique used the RetroConstruction System (Arthrex) to create tunnels via retrograde drilling.[27] The femoral tunnel was drilled based on identified ACL footprint sites and the lateral intercondylar ridge (resident's ridge) through the accessory medial portal. Both the femoral and tibial tunnels were placed in the center of the anteromedial bundle footprint. The Dual RetroCutter (Arthrex) was used for the creation of tibial and femoral sockets, while the TightRope (Arthrex) was used to fix the grafts at both the femoral and tibial sites (Figure 2).

## Postoperative Analgesia and Rehabilitation

An ice compress with a nonsteroidal anti-inflammatory intravenous injection was used immediately to decrease postoperative swelling and pain. The knee was kept in full extension in a brace for 3 days. During the immobilization period, ankle pump exercises, isometric quadriceps contractions, and straight-leg lifts were encouraged and continued through the passive motion phase. The passive motion program was initiated at 3 days postoperatively by using a passive exercise device. Cycling at 7 days postoperatively was allowed to improve range of motion and knee stability. Full range of motion was obtained within 4 to 6 weeks. Full weightbearing was allowed in at least 4 weeks. Jogging was allowed after 3 months, but contact sports were not recommended until 9 months after surgery. For the ankle and foot, range of motion exercises and partial weightbearing were allowed immediately after surgery. Ankle eversion and heel lifting began at 6 weeks postoperatively. Return to normal activities was allowed when the ankle exhibited painless range of motion or the patient exhibited normal or improved muscle strength that was comparable to that of the contralateral healthy side while also considering the functional status of the knee.

## Follow-up and Outcome Evaluation

Radiography and 3-dimensional computed tomography were performed immediately after surgery to evaluate tunnel placement (Figure 3). We requested that patients have postoperative clinical visits at 1 month, 3 months, 6 months, 1 year, and then annually at which the IKDC,
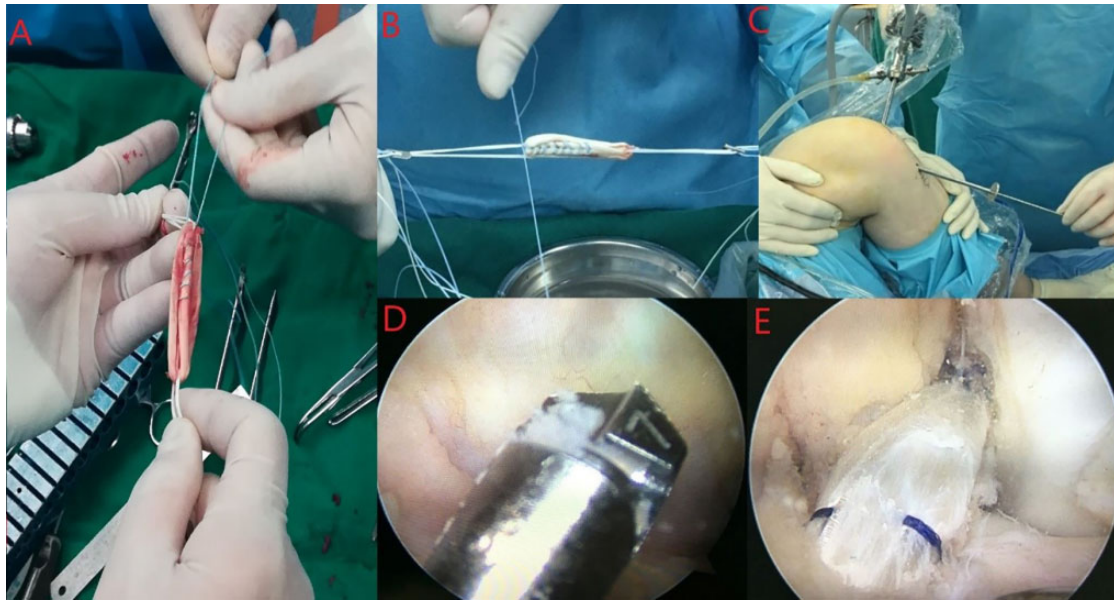
**Figure 2.** All-inside single-bundle anterior cruciate ligament (ACL) reconstruction. (A, B) Preparation techniques for an ACL cortical button graft. (C, D) Retrograde drilling of a socket from inside out. (E) Reconstruction using an anterior half of the peroneus longus tendon autograft under arthroscopic examination.
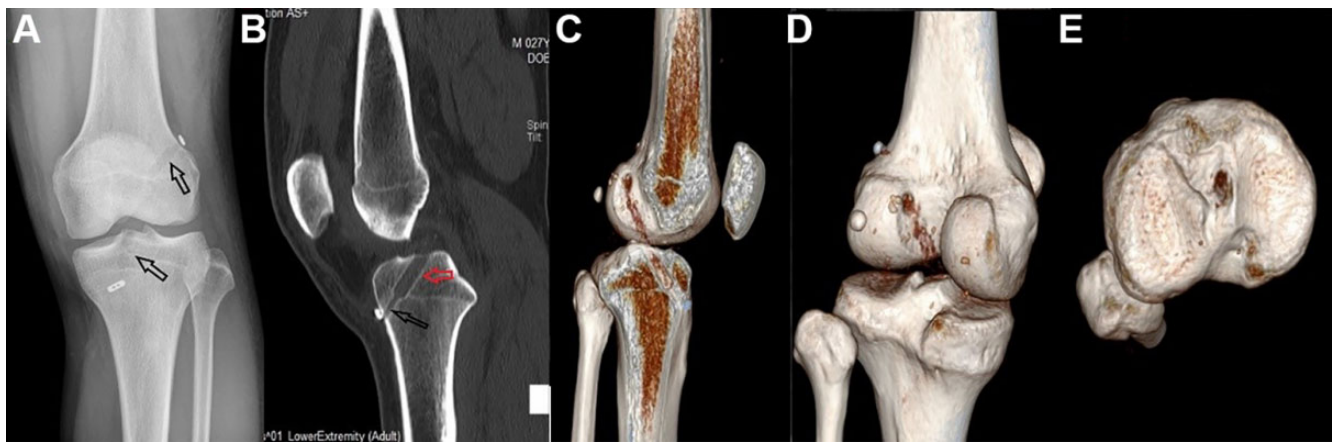


**Figure 3.** Postoperative radiography and 3-dimensional computed tomography findings. (A) Bone tunnels (black arrows) were revealed on the anteroposterior radiograph using TightRope devices (Arthrex) on both the tibial and the femoral sides. (B) The sagittal computed tomography scan showed the establishment of a tibial bone tunnel from inside out: a thick tibial bone tunnel was inside (thick red arrow), and a thin tunnel with a guide pin was outside (thin black arrow). (C) Anatomic footprint of the bone tunnels. (D) Femoral tunnel from an oblique coronal view. (E) Tibial tunnel from an axial view.

Lysholm, and Tegner scores were recorded. During this period, postoperative MRI was performed to assess graft morphology, reshaping, or retearing. The Lachman test was performed to investigate anterior tibial translation, and findings were graded as negative, slight (1+; <5 mm), moderate (2+; 5-10 mm), or severe (3+; >10 mm) compared with those of the healthy knee.[30] A KT-2000 arthrometer examination of the side-to-side difference was performed using 134-N anterior force and at 30° of knee flexion to evaluate anterior displacement of the knee. The pivot-shift test was used to assess rotational stability, and findings were

graded as negative, slight (1+), moderate (2+), or severe (3+). All clinical results were documented by 2 independent observers (C.-Z., L.-C.). We compared ankle eversion and plantarflexion strength between the donor site and its contralateral site after AHPLT harvesting.[25] We determined PLT muscle strength using manual muscle testing on a scale from 0 to 5,[18] where 0 = no muscle contraction, 1 = the presence of contractions in the muscle without joint motion, 2 = the ability to move the segment through its range of motion but not against gravity, 3 = the ability to move the segment (the arm) through its range of motion

against gravity, 4 = resistance between grades 5 and 3, and 5 = the normal amount of resistance to applied force. Donor-site morbidity was assessed before surgery and at 1 year, 2 years, and then annually after surgery using the American Orthopaedic Foot & Ankle Society (AOFAS) scoring system and the Foot and Ankle Disability Index (FADI) for the ankle and hindfoot.

## Statistical Analysis

Statistical analysis mainly focused on the improvement in clinical outcomes from before to after surgery and was performed using SPSS Version 17.0 for Windows (SPSS, Inc) and Excel (Microsoft Corp). Data were expressed as the mean, standard deviation, and range. The paired $t$ test was applied to compare the basic quantitative data of the preoperative and postoperative clinical scores, whereas the qualitative data of the pivot-shift test and Lachman test were analyzed using the chi-square test or Fisher exact test. A 2-sided $P$ value <.05 was considered significant for all tests.

## RESULTS

### Patient Characteristics

A total of 21 of 27 consecutive patients were enrolled for final analysis. Overall, 4 patients with meniscal repair were excluded, 1 with multiple ligament injuries was

excluded, and 1 was lost to follow-up at 6 months postoperatively. There were 13 male and 8 female patients with a mean age of 28.9 years (range, 21-43 years). The cohort included 17 patients who were young athletes or sports enthusiasts with a mean preinjury Tegner score of 7.3 ± 1.0.

All patients completed at least 3-year follow-up with a mean follow-up of 40.1 months (range, 36-48 months). The descriptive data of these patients are summarized in Table 1.

### Function

The IKDC and Lysholm scores significantly improved at 1 year after ACL reconstruction using AHPLT autografts. They increased from 1 to 2 years but plateaued at this level at 3 years postoperatively. At the last follow-up, the mean IKDC and Lysholm scores were 94.2 ± 2.61 and 95.2 ± 2.64, respectively, which were significantly different from the preoperative scores of 52.0 ± 8.27 and 50.9 ± 8.50, respectively ($P < .001$) (Table 2).

### Stability

According to the Lachman test, preoperatively, 16 patients had anterior instability of 2+ or 3+; this decreased significantly to 2 patients at 1-year follow-up and to 1 patient at 3-year follow-up. Before surgery, the KT-1000 arthrometer showed that the mean side-to-side difference was 7.0 ± 2.18 mm, while it significantly decreased to 1.1 ± 0.62 mm at the last follow-up. Moreover, 8 patients had a 2+ pivot shift preoperatively, while 1 patient had a traumatic 2+ pivot shift at 1 year postoperatively. Although this situation did not change at 3 years postoperatively, the patient reported having instability in his daily life activities (Table 2).

### Assessment of the Ankle Donor Site

No pain, instability, reduced range of motion, or decreased muscle strength in plantarflexion and eversion was found at 3 years after surgery. All patients had grade 5 muscle strength in ankle eversion and plantarflexion at the donor site, with similar results to those at the contralateral healthy site. The mean AOFAS score was 96.8 ± 3.01, and the mean FADI score was 97.6 ± 2.66 (Table 3).

### TABLE 1
Descriptive Data of the Patients[a]

|  | Value |
| --- | --- |
| Sex, male/female, n | 13/8 |
| Age, y | 28.9 ± 5.95 |
| Time from injury to surgery, d | 5.9 ± 3.45 |
| Injured side, left/right, n | 12/9 |
| Smoker, yes/no, n | 11/10 |
| Body mass index | 22.1 ± 2.38 |
| Follow-up period, mo | 40.1 ± 3.74 |

[a]Data are reported as mean ± SEM unless otherwise indicated.

### TABLE 2
Preoperative and Postoperative Clinical Outcomes[a]

|  | Preoperative | 1 y | 2 y | 3 y | Statistic[b] | P Value |
| --- | --- | --- | --- | --- | --- | --- |
| Tegner score | 1.8 ± 0.87 | 4.4 ± 1.28 | 6.1 ± 1.31 | 6.8 ± 1.50 | $t = 13.18$ | <.001 |
| IKDC score | 52.0 ± 8.27 | 90.4 ± 3.67 | 94.1 ± 3.14 | 94.2 ± 2.61 | $t = 22.29$ | <.001 |
| Lysholm score | 50.9 ± 8.50 | 91.2 ± 3.94 | 94.9 ± 2.88 | 95.2 ± 2.64 | $t = 22.78$ | <.001 |
| KT-2000 arthrometer, mm | 7.0 ± 2.18 | 2.0 ± 1.02 | 1.2 ± 0.83 | 1.1 ± 0.62 | $t = 11.84$ | <.001 |
| Lachman, negative/1+/2+/3+, n | 2/3/13/3 | 15/4/2/0 | 18/2/1/0 | 18/2/1/0 | FE = 24.43 | <.001 |
| Pivot shift, negative/1+/2+/3+, n | 7/6/8/0 | 10/10/1/0 | 12/8/1/0 | 11/9/1/0 | FE = 1.55 | >.050 |

[a]Data are reported as mean ± SD unless otherwise indicated. FE, Fisher exact test; IKDC, International Knee Documentation Committee.
[b]$t$ and FE are the corresponding statistics for the paired $t$ test and Fisher exact test, respectively; results are from comparing 3-year postoperative outcomes with preoperative outcomes.

TABLE 3
Preoperative and Postoperative Clinical Outcomes at the Ankle Donor Site[a]

|  | Preoperative | 1 y | 2 y | 3 y | Statistic[b] | P Value |
|---|---|---|---|---|---|---|
| FADI score | 97.9 ± 2.19 | 93.5 ± 4.11 | 97.0 ± 2.85 | 97.6 ± 2.66 | $t = 0.44$ | >.05 |
| AOFAS score | 98.4 ± 2.01 | 91.6 ± 3.61 | 96.2 ± 2.88 | 96.8 ± 3.01 | $t = 1.99$ | >.05 |

[a]Data are reported as mean ± SD. AOFAS, American Orthopaedic Foot & Ankle Society; FADI, Foot and Ankle Disability Index.
[b]Results are from comparing 3-year postoperative outcomes with preoperative outcomes.

## Complications

No fixation failure, infection, or graft rupture was found on MRI scans and clinical follow-up.

## DISCUSSION

The main finding of this study was that all-inside single-bundle ACL reconstruction using an AHPLT graft was an effective and safe technique to improve knee function and symptoms in patients with ACL tears. The activity level at 3 years was close to the preinjury level, with no reruptures at follow-up. One patient had clinical failure, as he had a 2+ pivot shift and reported knee instability with strenuous activities in his daily life. Compared with the high risk of functional loss after segmental removal of the PLT, ankle eversion and plantarflexion strength at the donor site were comparable with those at the contralateral healthy site after harvesting the anterior half, with no donor-site morbidity.

Anatomic and biomechanical studies have shown that the ACL consists of the anteromedial bundle and posterolateral bundle.[36] The aim of anatomic single-bundle reconstruction is to restore the anteromedial bundle. There are several advantages to using the PLT as an autograft for single-bundle ACL reconstruction. First, the normal ACL strength is 1725 ± 269 N,[26] while the PLT has comparable biomechanical properties, with an ultimate tensile strength of 1950 N reported by Kerimoglu et al[9] or even better and a strength of 2500 N reported by Rudy et al.[26] In addition, the PLT autograft has a large diameter, with a reported mean diameter of 8.8 mm (range, 8-10 mm).[24] This indicates that the PLT can be used as an ACL substitute from a biomechanical perspective. Subsequently, clinical studies of ligament reconstruction, such as medial patellofemoral ligament reconstruction, double-bundle ACL reconstruction, posterior cruciate ligament reconstruction, multiligament reconstruction, and ankle ligament reconstruction, have reported excellent postoperative function of the knee joint and the ankle.[13,23] In addition, because of its superficial location, the PLT can be more easily and quickly exposed than can the HT. Donor-site morbidity after tendon harvesting can be categorized as structural failure and functional impairment. We made a 2-cm incision to expose the PLT with more soft tissue around the lateral malleolus to protect it. We only harvested the anterior half and kept intact the posterior half, where the blood supply enters. Compared with patellar tendon ruptures after BPTB harvesting, structural failure, such as tendinopathy, tenosynovitis, and delayed tendon ruptures, was not found in our study possibly because of the small sample size. Compared with total removal of the PLT, resulting in functional impairment of the peroneus longus muscle, harvesting the AHPLT was safer.[37] Although Kerimoglu et al found signs of regeneration after total removal, the quality and function of the reported regenerated PLT are still unknown. We are reluctant to completely remove the PLT in vivo for fear of causing irreversible functional impairment.

In addition to graft factors, surgical factors also contributed to the final results. A new method called the all-inside technique has been developed for 20 years with many advantages, such as improving cosmesis,[27] being minimally invasive,[2] and saving the graft.[17] The all-inside technique is suitable for numerous graft options and can be used in primary reconstruction, revision augmentation, or multiligament reconstruction. As reported,[37] the usable length of the AHPLT was 23.7 cm; it was more suitable for all-inside ACL reconstruction after it was folded to produce a 6 cm–long graft when quadrupled. Similar studies using the semitendinosus tendon have been widely reported. Schurz et al[27] performed a study using the semitendinosus tendon to evaluate the functional outcomes of all-inside ACL reconstruction. They found a significant improvement in the IKDC score between baseline and the final clinical follow-up (44.6 vs 89.7, respectively). Lubowitz,[14] in a prospectively comparative study between the all-inside technique and a full tibial tunnel technique, found a good IKDC score and lower pain score in the all-inside group at 2-year follow-up. Benea et al[2] found that the pain level was lower in the all-inside group than in the classic group at 1 month after surgery.

There were several limitations in our study. First, we only summarized clinical experiences by analyzing the data of 21 patients using the AHPLT in a retrospective fashion. Although good clinical outcomes were found after surgery, a well-designed randomized controlled trial should be performed in the future to compare the AHPLT autograft with commonly used autografts, such as the HT, to make the conclusion more reliable. The length of the AHPLT averages 65 mm when quadrupled, which may be an insufficient length for the classic technique and thus requires an all-inside technique. Second, we used the pivot-shift test to evaluate rotational stability; although no difference was found, to the best of our knowledge, the pivot-shift test is a subjective instrument that is prone to interexaminer variations. A more objective test needs to be applied to reflect the true function of the knee. Third, a more objective

method should be used to assess donor-site morbidity after harvesting the peroneus longus muscle.[23] Fourth, selection bias may have excluded patients with reparable meniscal injuries. Fifth, return to sports was not examined.

## CONCLUSION

In our pilot study, all-inside ACL reconstruction using an AHPLT graft showed satisfactory subjective and objective results and minimal donor-site morbidity. We believe that the AHPLT is safe and could be considered as a graft option for ACL reconstruction.

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