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Single-stage revision anterior cruciate ligament reconstruction using bone grafting for posterior or widening tibial tunnels restores stability of the knee and improves clinical outcomes

Jason L. Dragoo[1] · Michael Kalisvaart[1] · Kevin M. Smith[1] · George Pappas[1] · Ray Golish[1]

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Abstract

Purpose Revision ACL surgery may be complicated by tunnel malposition and/or tunnel widening and often requires a staged treatment approach that includes bone grafting, a period of several months to allow bone graft incorporation and then definitive revision ACL reconstruction. The purpose of this study was to evaluate the results of a single-staged ACL revision reconstruction technique using a cylindrical dowel bone graft for patients who have existing posteriorly placed and/or widened tibial tunnels in the tibia at a minimum of 2 years follow-up.

Methods Between 2010 and 2014, patients undergoing single-stage revision ACL reconstruction with the described technique were prospectively enrolled and evaluated. At a minimum of 24 months, patients were evaluated by physical examination, multiple clinical outcome instruments including KOOS, Tegner and Lysholm, and preoperative and postoperative MRIs.

Results At a mean of 35.1 months, 18 consecutive patients had no revision surgery and no subjective knee instability. There were statistically significant improvements in the Tegner (median 2, interquartile range 2.25; $p<0.01$), Lysholm (20.0 ± 15.0; $p<0.01$), KOOS symptoms scale (12.9 ± 11.8; $p<0.01$), KOOS pain scale (15.4 ± 18.7; $p<0.01$), KOOS ADL scale (13.5 ± 19.0; $p<0.01$), KOOS sports scale (32.8 ± 26.4; $p<0.01$), and KOOS QoL scale (18.1 ± 16.9; $p<0.01$). Postoperative MRI demonstrated statistically significant anteriorization of the tibial tunnel and a statistically significant decrease in tunnel widening.

Conclusion Revision ACL reconstruction utilizing a single-staged tibial tunnel grafting technique resulted in improved knee pain, function, and stability at a minimum of 24-month follow-up.

Level of evidence IV.

Keywords Anterior cruciate ligament · ACL · Revision reconstruction · Single-stage · Tibial tunnel · Malposition · Bone grafting · Tunnel widening

Introduction

Reconstruction of the anterior cruciate ligament (ACL) is a very common surgical procedure with an incidence of greater than 200,000 annually with reported rates of success of 75–97% [21]. Regardless of the ACL reconstruction technique utilized, restoring the correct position of the ACL is paramount to achieving functional stability of the knee joint [4, 17]. However, if acceptable tunnel position is not achieved, there is an increased risk for graft failure.

Tunnel malposition is reported to be the most common mechanism for ACL graft failure and recurrent instability. It has been estimated that 70–80% of ACL graft failures are a result suboptimal tunnel placement [3]. Most often, this is a result of failure to restore the anatomic position of the femoral tunnel; however, establishing an anatomic tibial footprint is also critically important [17]. Placement of the ACL graft in a position too anterior on the tibia can result in graft impingement and subsequent limitations of motion and possible graft failure, while a graft placed too posterior

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✉ Jason L. Dragoo
jdragoo@stanford.edu

[1] Department of Orthopaedic Surgery, Stanford University, 450 Broadway Street, Pavilion C, 4th Floor, Redwood City, CA 94063-6342, USA

can lead to rotatory instability due to a vertical graft position [17].

As with primary ACL reconstruction, the goal of revision ACL surgery is to provide a stable and functional ACL that most accurately reproduces the kinematics of the native anatomic knee. A variety of factors dictate the surgical strategy in revision ACL reconstruction, including tunnel position, tunnel widening/bone loss, graft type, and fixation method [7, 9, 16]. In situations of significant tunnel malposition and/or tunnel widening, staged bone grafting followed by delayed reconstruction is often required [10]. However, a staged approach requires two separate surgical procedures, a period of several months to allow bone graft incorporation, and increased time to definitive revision ACL reconstruction, which could result in higher risk of cartilage and meniscus injury [13, 14]. As a result, several techniques have been described to perform revision ACL reconstruction in a single-stage procedure.

The purpose of this study was to report the prospective results of a consecutive series of patients with persistent instability following ACL reconstruction secondary to suboptimal tibial tunnel placement, with or without tunnel widening, treated with a single-stage revision ACL reconstruction technique. The hypothesis of this study was that patients would experience an improvement in clinical outcome scores and obtain results similar to two-stage revision for mal-positioned tibial tunnels.

Materials and methods

Eighteen consecutive patients were enrolled between 2010 and 2014. Patients were eligible if they met the following inclusion criteria: age less than 50 years, previous primary ACL reconstruction, persistent or recurrent instability since the primary reconstruction that limited daily and/or athletic activities, physical examination demonstrating instability with both positive Lachman and positive pivot shift testing, MRI imaging demonstrating a posteriorly placed tibial tunnel or tibial tunnel widening, and clinical follow-up greater than 24 months. Exclusion criteria were previous multi-ligamentous reconstruction or current multi-ligamentous instability or greater than or equal to grade 2 Kellgren–Lawrence tibiofemoral joint degenerative changes.

All patients completed standardized questionnaires including Knee Osteoarthritis Outcome Score (KOOS), Lysholm Knee Score, Tegner Activity Level and 12-Item Veteran Rand (VR-12) quality of life scale preoperatively and then again postoperatively at 6, 12, and 24 months.

Clinical and radiographic evaluation

The diagnosis of ACL graft failure was based on patient history, physical exam and a MRI documenting graft rupture. The onset of symptoms was noted and defined as follows: "acute" signified a well-defined event precipitating the acute onset of symptoms/instability or "insidious" meant absence of injury or precipitating event but a gradual onset of symptoms/instability. Subjective instability was noted and defined as follows: instability with activities of daily living and change-in-direction sports, instability with change-in-direction sports only, and no sense of instability with any activities. The type of graft used during the primary ACL reconstruction was recorded, as well as the time between the primary and revision surgeries.

ACL-specific physical examination was performed at each visit by a fellowship-trained orthopedic surgeon not involved with the study. The exam included the Lachman test, anterior drawer test, and pivot shift test. Preoperative radiographic examination included a standing posterior–anterior (PA) radiograph of bilateral knees, a lateral radiograph, a merchant view of the patella, and a full-length standing hip–knee–ankle radiograph to measure the mechanical alignment axis.

MRI of the knee was performed both preoperatively and at 12 months postoperatively. MRI measurements included preoperative and postoperative sagittal tibial tunnel position, maximum tibial tunnel width at the tibial aperture, and sagittal and coronal tibial tunnel angles. The reference line for all sagittal measurements was a line connecting the most proximal anterior and posterior aspects of the tibial plateau on the sagittal MRI slice containing the view with the widest part of the tibial tunnel aperture (Fig. 1).

Using a digital, metric scale, the total anterior–posterior (AP) size of the tibia, the anterior-most position of the tibial ACL tunnel (ATT), and the posterior-most position of the tibial tunnel (PTT) were measured from the posterior tibial cortex. Measurement accuracy was made to the nearest 1 mm. These distance measurements, as well as the tunnel center position, were expressed as percentages of the total tibial AP depth from the posterior tibial cortex as measured on the sagittal MRI slice containing the view with the most posterior tibial tunnel intra-articular aperture. In addition, tibial tunnel sagittal width (TW) at the aperture was calculated based on the difference between the anterior-most and posterior-most positions. As the ACL tunnel is typically positioned near 66% of the AP depth of the tibia from the posterior tibial cortex, patients were categorized as having a preoperative "posteriorized" tibial tunnel if the posterior-most aspect of the tibial tunnel was less than 55% of the AP depth of the tibia from the posterior tibial cortex. Patients were categorized as having

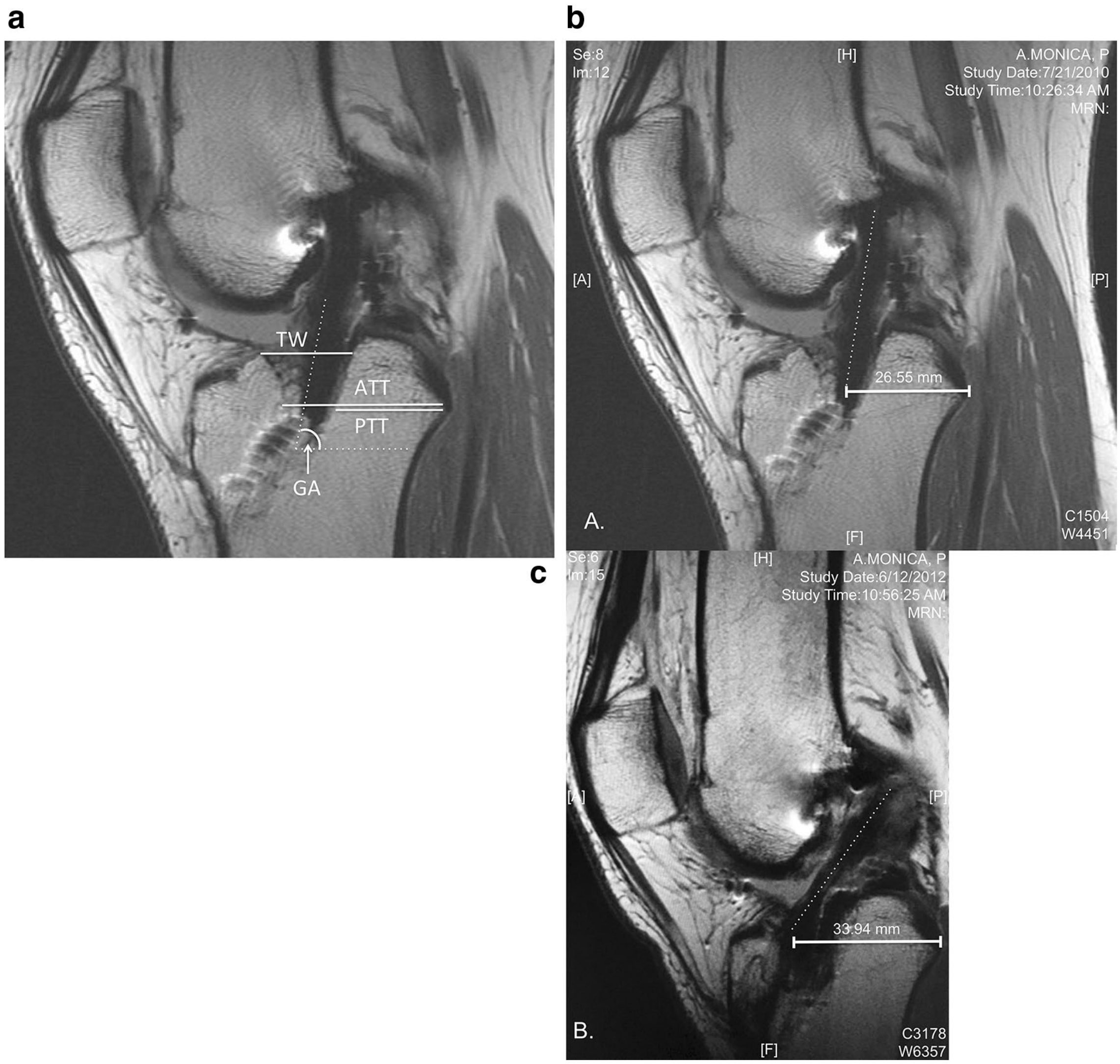

Fig. 1 Sagittal MRI measurements used for analysis of tibial tunnel position. **a** Method of measurement: *TW* tunnel width, *ATT* anterior-most position of the tibial ACL tunnel, *PTT* posterior-most position of the tibial tunnel, *GA* graft angle. **b** Graft angle measurement from posterior cortex pre-revision. **c** Graft angle measurement from posterior cortex post-revision

a preoperative "wide" tibial tunnel if the tibial tunnel sagittal width at the aperture was greater than 12 mm, and the original operative report described a less than or equal 10 mm tunnel diameter. Sagittal graft angle was defined as the angle measurement between the previously described reference line and a line directly through the center of the tibial tunnel (Fig. 1a).

Surgical technique

After induction of general anesthesia in the supine position, a diagnostic arthroscopy was performed and the remnant of the torn ACL graft was resected using a motorized shaver. Other intra-articular pathologies such as meniscus tears or cartilage lesions were addressed as indicated. A revision notchplasty was performed if necessary for femoral tunnel placement, along with removal of previously placed hardware as indicated.

On the back table, a fresh-frozen femoral head and neck non-irradiated allograft was fashioned into a cylindrical dowel bone graft with a slightly larger diameter than the reamer size used to ream the revised tunnel. The length of the bone graft was kept as long as possible, as it could be trimmed later in the procedure. The leading edge of the cylindrical graft was slightly bulleted for easier insertion. A 3.5 mm double-loaded suture anchor was then drilled and attached in the center of the cephalad end of the graft that will enter the joint. The sutures are then pulled down posteriorly, medially, and laterally, but not anteriorly, along the graft (Fig. 2).

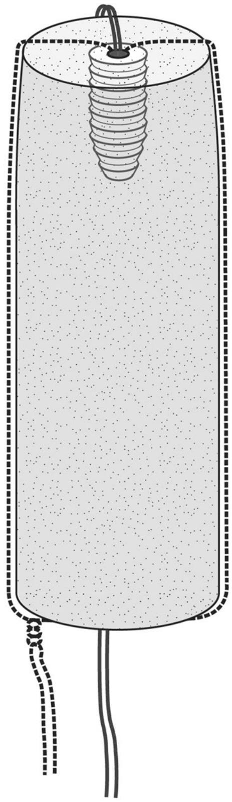

Fig. 2 This animated figure demonstrates the preparation of the graft with suture anchor in proximal end and sutures pulled posteriorly

The same incision for the primary ACL was used and lengthened as necessary for the revision procedure. Under arthroscopic visualization, an ACL tibial tunnel guide was used to drill a guide pin through the center of the previous tibial tunnel (see video). The selected fully fluted tibial reamer, chosen to match the original tunnel diameter on MRI, was then used to ream the original tunnel to a consistent diameter and to remove residual graft tissue (Fig. 3a).

The graft was then gently impacted into the tibial tunnel while the suture limbs were held posteriorly to avoid being later cut with the reamer. Proper graft positioning was confirmed under direct arthroscopic visualization. The graft was then trimmed flush with the cortical surface of the anterior tibial cortex as needed and the suture limbs were then fixed into the anterior tibia to prevent displacement using a suture anchor just distal to the bone grafted tunnel (Fig. 3b).

Upon completion of the bone-grafting portion of the procedure, a guide pin was positioned at the new desired position of the ACL tibial tunnel using an ACL tibial tunnel guide (Fig. 3c). The guide pin was visualized within the joint just anterior to the grafted tunnel in the tibial plateau. An appropriately sized cannulated fluted reamer was then carefully used to create the revised tunnel. While it was common for a small portion of the bone graft to be removed by the reamer, as long as the sutures remained posterior to the reamer and fixed in place, the bone graft remained stable (Fig. 3d).

The new graft was then positioned just along the anterior edge of the bone graft in the tibia and fixed with the surgeon's method of choice (Fig. 3e). A Lachman test was performed to ensure stability at the conclusion of the procedure.

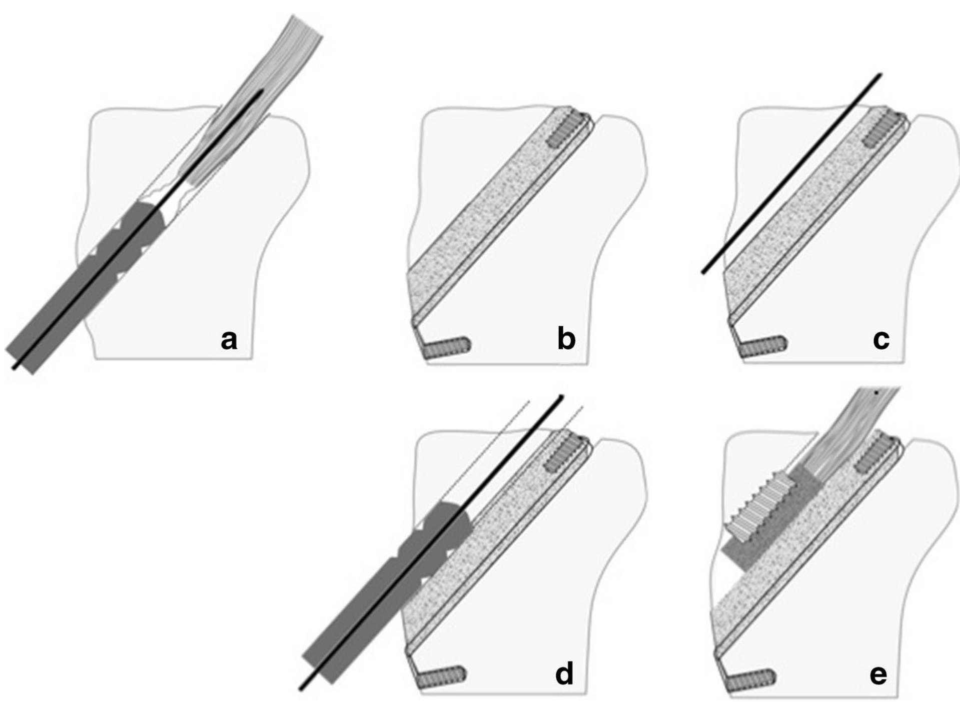

Fig. 3 Surgical technique. **a** Drill guide pin through the center of the previous tibial tunnel and ream original tunnel to a consistent diameter. **b** Graft is gently impacted into tibial tunnel under direct arthroscopic visualization while sutures are held posteriorly. Graft is then trimmed flush with anterior tibia and suture limbs are fixed to tibia with second suture anchor. **c** Position guide wire anterior to bone graft. **d** Gently ream new tunnel and perform revision ACL. **e** Completed revision ACL with anteriorized tibial tunnel

Institutional review board approval was obtained prior to initiation of the study.

Statistical analysis

Exploratory statistics were presented for all baseline preoperative measurements. For continuous variables, interval change at final follow-up was computed in a paired fashion rather than group-wise, and significance was tested with a paired t test. For all parameters, interval change was computed as last value—baseline value. This is because higher values indicate improvement for most physical exam, functional or MRI parameters. All statements of significance imply statistical significance with $p < 0.05$ after conservative, Bonferroni-type multi-test correction. Due to the limited sample size, no covariate analysis was performed, either to assess correlations among outcome measures, or to control for potential confounders. Functional outcomes were compared between patients with and without tunnel widening preoperatively for the purposes of exploratory statistics. The power of paired t tests is 82.1% for $N = 15$ samples with a large effect size (Cohen's $d = 0.8$).

Results

Eighteen patients (eight female, ten male) with an average age of 26.7 years (range 16–48 years) underwent single-stage ACL revision reconstruction with the described technique. Mean follow-up was performed at 35.1 months (range 24–68 months). There were no patients lost to follow-up. Table 1 presents demographics and baseline surgical characteristics. Concomitant procedures performed at the time of revision included meniscectomy ($n = 4$), meniscal repair ($n = 11$), synovectomy ($n = 3$) and removal of hardware ($n = 5$). The onset of symptoms was acute in 12 patients and insidious in 6 patients. Surgical time was increased by an average of 28 min compared with the senior author's standard primary ACL reconstruction procedure. There were no perioperative complications requiring revision surgery.

Physical examination

Tables 2 and 3 present physical examination findings at baseline and at final follow-up, respectively. No patients had an effusion. Seventeen of 18 patients (94.4%) had a negative Lachman test and negative pivot shift test at final follow-up. One patient had a grade 2A Lachman test and a grade 1 pivot shift test but experienced no subjective instability. In this one patient, postoperative MRI at 12 months demonstrated increased signal with intact ACL fibers suggestive of a high-grade partial tear. The patient experienced no limitations in his desired activities. Average postoperative knee flexion, extension and ROM were similar to preoperative values with no statistically significant difference.

Functional outcomes and sports

Table 4 presents functional measures preoperatively, and Table 5 presents changes in functional outcomes at final follow-up. At baseline, the Tegner score had a median of 3, interquartile range of 2, and range of 1–7. At final follow-up,

Table 1 Pre-revision demographic and surgical characteristics ($N = 18$)

	Mean	SD	Min.	Max.
Age (years)	26.7	7.6	16	48
Follow-up (months)	35.1	12.2	24	68
Onset (months)	2.4	0.8	1	3
Interval (months)	69.8	54.4	7	204

	Value	Frequency	%
Sex	F	8	44.4
	M	10	55.6
Side	L	12	66.7
	R	6	33.3
Prior surgeries	1	16	88.9
	2	2	11.1
Prior graft type	Allograft	6	33.3
	Autograft	12	66.7
Prior graft site	Achilles	1	5.6
	BTB	15	83.3
	HS	2	11.1

Table 2 Pre-revision physical examination ($N=18$)

	Mean	SD	Min.	Max.
Flexion (°)	132.8	5.5	120	145
Extension (°)	−2.1	3.7	−10	0
ROM (°)	134.9	7.1	120	145

	Value	Frequency	%
Pivot	1	3	16.7
	2	15	83.3
Effusion	0	14	77.8
	1	3	16.7
	2	1	5.6
Instability	1	5	27.8
	2	13	72.2
Lachman	2A	1	5.6
	2B	13	72.2
	3B	4	22.2

Table 3 Changes in physical examination at minimum 24-month final follow-up ($N=18$)

	Mean	SD	95% High	95% Low	*p* value
Flexion (°)	0.278	6.524	3.522	−2.967	n.s.
Extension (°)	0.500	2.662	1.824	−0.824	n.s.
ROM (°)	−0.222	7.780	3.647	−4.091	n.s.

	Value	Frequency	%
Pivot	0	1	5.6
	1	17	94.4
Effusion	0	18	100.0
Instability	0	18	100.0
Lachman	Normal	17	94.4
	2B	1	5.6

Table 4 Preoperative functional scores

	Mean	SD	Min.	Max.
Lysholm	65.6	12.8	35.0	88.0
KOOS symptoms	70.1	15.4	36.0	92.9
KOOS pain	75.5	16.7	39.0	97.2
KOOS activity	83.9	18.6	50.0	100.0
KOOS sports	48.9	27.2	0.0	100.0
KOOS QoL	35.1	25.3	0.0	87.5
VR-12 PCS	44.3	8.4	21.8	56.8
VR-12 MCS	49.8	10.5	25.7	64.0

Table 5 Changes in functional outcomes at minimum 24-month final follow-up ($N=18$)

	Mean	SD	95% High	95% Low	*p* value
Δ Lysholm	20.0	15.0	27.4	12.6	0.000
Δ KOOS symptoms	12.9	11.8	18.8	7.0	0.000
Δ KOOS pain	15.4	18.7	24.7	6.1	0.003
Δ KOOS ADL	13.5	19.0	23.0	4.0	0.008
Δ KOOS sports	32.8	26.4	45.9	19.7	0.000
Δ KOOS QoL	37.2	28.5	51.4	23.1	0.001
Δ VR-12 PCS	10.3	9.7	15.1	5.5	0.000
Δ VR-12 MCS	2.2	9.5	6.9	−2.5	n.s.

the Tegner score showed a statistically significant increase ($p<0.001$) with a median of 2, an interquartile range of 2.25, and a range of −1 to 6. All subscales of the KOOS (Fig. 4) and the Lysholm scale showed statistically significant improvements ($p<0.001$). The VR-12 physical component score was significantly improved, though the mental component score only showed a trend towards improvement.

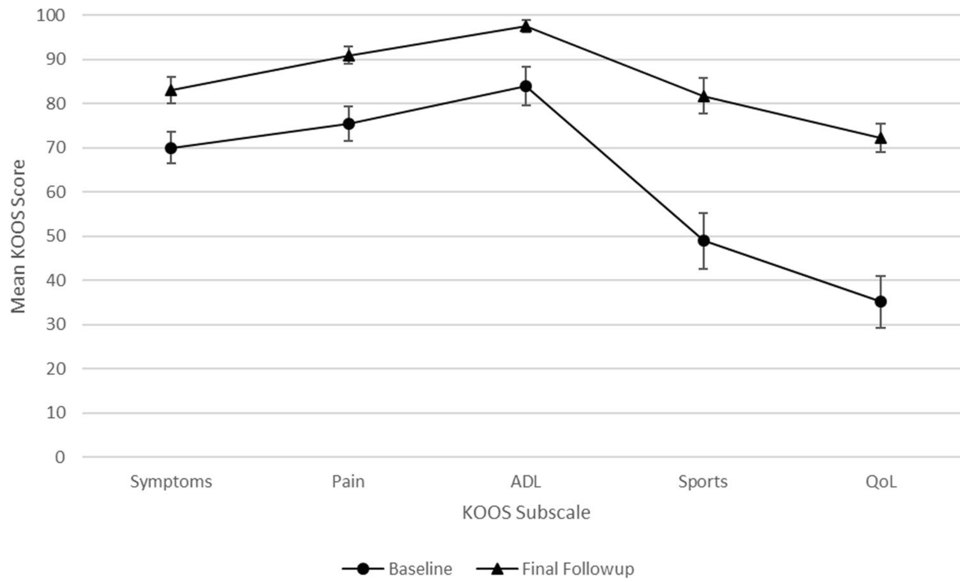

Fig. 4 Graphical representation of the mean KOOS subscale scores for $N=18$ patients preoperatively and postoperatively. Error bars represent standard error of the mean

Table 6 Preoperative MRI measurements ($N=15$)

	Mean	SD	Min.	Max.
Posterior tunnel (mm)	24.8	4.6	13.4	31.5
Posterior tunnel (%)	47.2	6.8	30.4	54.9
Anterior tunnel (mm)	37.2	6.3	22.5	45.9
Anterior tunnel (%)	70.8	9.2	51.0	83.2
Tunnel center (mm)	31.0	5.4	18.0	38.7
Tunnel center (%)	59.0	7.8	40.8	69.1
Tunnel width (mm)	12.3	2.3	9.1	15.6
Sagittal angle (°)	71.8	8.4	56.5	85.4
Coronal angle (°)	77.3	6.8	66.8	88.4
Tibia AP (mm)	52.4	4.6	44.1	60.4

Table 7 Change in MRI measurements at 12 months follow-up ($N=15$)

	Mean	SD	95% High	95% Low	*p* value
Δ Posterior tunnel (mm)	6.9	4.1	9.2	4.6	0.000
Δ Posterior tunnel (%)	13.5	8.4	18.1	8.9	0.000
Δ Anterior tunnel (mm)	5.2	5.0	8.0	2.5	0.001
Δ Anterior tunnel (%)	10.3	9.8	15.7	4.8	0.001
Δ Tunnel center (mm)	6.1	4.4	8.5	3.6	0.000
Δ Tunnel center (%)	11.9	8.9	16.9	7.0	0.000
Δ Tunnel width (mm)	− 1.7	2.0	− 0.6	− 2.8	0.005
Δ Graft angle (°)	− 11.6	8.6	− 6.9	− 16.4	0.000
Δ Coronal graft Angle (°)	− 3.4	6.9	0.4	− 7.3	n.s.

Preoperatively, four patients were collegiate athletes: two gymnasts, one basketball player, and one softball player. Two of the four patients (50%) who were collegiate athletes returned to their previous sport at or above the preoperative level of competition. Of the two patients who did not return, one played softball and the other was a gymnast. The softball player graduated from college and pursued a career outside of athletics. The gymnast elected to stop competing as a result of her knee injuries, although she denied any knee pain or subjective instability at final follow-up.

Imaging

For MRI assessment, three of 18 patients were not willing to obtain MRI at 12-month follow-up, though all participated in final clinical evaluation. Table 6 presents MRI measures of tunnel geometry and orientation at baseline preoperatively. All patients met the criterion for a posteriorized tibial tunnel, with the posterior aspect of the tibial tunnel less than 55% from the posterior cortex. Nine patients (50%) met the criterion for a wide tibial tunnel, with the tibial tunnel sagittal width at the aperture greater than 12 mm. Between patients with and without wide tunnels preoperatively, there were no significant differences in the postoperative improvement of KOOS symptoms KOOS pain, KOOS activity, KOOS sports, KOOS QoL, Tegner, Lysholm, VR12-PCS, or VR12-MCS. Table 7 presents the interval changes in MRI parameters at final follow-up. There are statistically significant changes in all parameters except for coronal plane angulation. The average postoperative posterior tunnel position was significantly anteriorized by 13.5% compared to preoperatively. There was a significant decrease in tunnel width in the nine patients with preoperative tunnel widening and a 1.7 mm decrease on average for all patients. There was a significant decrease in sagittal graft angle of 11.6° on average.

Discussion

The most important findings of this case series were that a single-stage ACL revision for posterior or widened tibial tunnels was an effective procedure at restoring knee stability and improving clinical outcome scores. There are clear advantages to a one-stage approach, assuming adequate placement and fixation of the graft can be achieved [18]. The two-stage approach necessitates multiple anesthetics as well as additional periods of activity modification. In addition, a period of several months is required between procedures that allow for adequate bone graft incorporation. During this time patients may experience periods of continued knee instability, which may result in further cartilage and meniscus damage. As a result, several authors have described techniques that reproducibly achieve secure graft fixation when bone grafts or other material is used to change tunnel position in a single-stage revision procedure [2, 4, 15, 19].

Comparing one-stage and two-stage techniques of revision ACL reconstruction, similar results have been reported by other authors. Wright et al. performed a systematic review of studies evaluating the outcome of revision ACL reconstruction with a minimum of 2-year follow-up and noted objective graft failure in 13.7% [20]. Mean Lysholm score was 82.1, and mean Tegner activity level was 6 [1]. Similar results were observed in this study with clinical evidence of graft compromise in one patient (7%), a mean postoperative Lysholm score of 90, and a mean postoperative Tegner activity level of 5.8. The authors of the systematic review did not describe the incidence of tunnel bone grafting or the results of one-stage versus two-stage procedures. The current study demonstrated that 50% of the patients who were competitive athletes were able to return to their previous sport at or above their preoperative level of competition. The current literature has reported similar figures, with approximately 60% of patients being able to return to sports after single-bundle revision ACL reconstruction, although this figure is not specific to collegiate or professional athletes or if bone grafting was required [6, 8].

The results of this new single-stage revision ACL reconstruction technique are also similar to reported outcomes following traditional two-stage methods for specifically managing mal-positioned tunnels. At a minimum follow-up of 3 years, Thomas et al. reported on 49 patients treated with two-stage revision ACL reconstruction and demonstrated that 6% of patients had a side-to-side difference of less than 5 mm, suggesting a failed reconstruction [18]. The current study showed clinical laxity in only one patient (7%) at final follow-up, but ligament arthrometry was not carried out so true comparison of laxity with other studies cannot be made.

The present study did not detect a difference in postoperative outcomes between patients with and without preoperative tunnel widening greater and lesser than 12 mm; however, this finding must be considered exploratory only as the study was not powered to test this hypothesis specifically. The correlation between tunnel widening and clinical outcome remains unclear. Multiple studies have demonstrated no significant correlation between tunnel widening and patient function or knee laxity [5, 7, 11], however, the 12 mm cut off for tunnel widening has also been shown to result in increased laxity between 5 and 15 year follow-up [22]. However, tunnel widening is thought to interfere with graft fixation and healing, and, when associated with large bone defects, can be a significant challenge in revision ACL reconstruction. As a result, a variety of surgical strategies exist for management of tunnel widening to allow for initial secure graft fixation in the revision setting [1, 12]. The single-stage tibial tunnel grafting technique described in this study resulted in improved clinical function in patients with preoperative tunnel width greater than 12 mm, with no significant difference in clinical outcome or knee stability compared with patients without preoperative tunnel widening at final follow-up.

Several recent publications have described techniques to address mal-positioned femoral tunnels and residual bone voids in a single stage [2, 4, 15, 19]. Battaglia et al. described a technique using freeze-dried allograft bone dowels to fill cylindrical bone defects measuring up to 16 mm in diameter resulting from mal-positioned and/or widened femoral tunnels [1]. Barrett et al. described a technique for treating femoral bone voids in revision ACL reconstruction with the use of a biocomposite synthetic dowel graft for isolated cylindrical defects of less than 11 mm [2]. Vaughn et al. performed a biomechanical cadaver study using bioactive moldable calcium phosphate cement for femoral bone defects [19]. They demonstrated excellent initial fixation strength and suggested that this technique may be a treatment option for contained femoral bone defects in a single-stage revision ACL reconstruction procedure.

The findings presented in this study have clinical significance when revision ACL reconstruction in the setting of posterior or widened tibial tunnels is encountered. The ability to improve knee stability and outcome scores in a single revision surgery is a tremendous advantage that avoids the additional costs and risks of a second surgery while expediting the patient's return to activities. Although there have been several described techniques for femoral-sided bone defects in revision ACL reconstruction, no previous investigations have been described for treatment of a mal-positioned tibial tunnel in a single-stage revision ACL reconstruction. The anteriorization technique described in this study allows for creation of a customizable graft for both width and length to accommodate any sized potential tibial defect, even those wider than 16 mm. This technique also allows for specific fixation of the graft through the length of the tibial tunnel and provides initial secure graft fixation to prevent migration or dislodging of the implanted graft while preparing a new tunnel and implanting the ACL revision graft.

This study has several limitations. First, there were a relatively small number of patients in the study cohort even though no patients were lost to follow-up. This smaller cohort is likely a result of relatively few patients meeting inclusion criteria requirements, especially compared to primary ACL reconstruction. Second, there was significant variation amongst the study group in the time between primary and revision surgeries, ACL grafts used, preoperative and postoperative activity level and arthroscopic treatment of meniscal tears. Third, the mean average follow-up of 35 months may not be adequate to provide perspective on longer-term clinical outcomes. Only longer follow-up can give us information on the durability of this single-stage technique. Last, this study lacks a control group and there are multiple potential confounding patient and operative variables. An attempt was made to minimize these variables by prospectively evaluating patients with strict inclusion and exclusion criteria.

Conclusion

Revision ACL reconstruction utilizing a single-staged tibial tunnel grafting technique resulted in improved knee pain, function, and stability at a minimum of 24-month follow-up.

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Compliance with Ethical Standards

Conflict of interest The authors report no conflicts of interest related to this article.

Ethical approval and informed consent IRB approval and informed consent was obtained for this investigation.

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