Original Article

Both Adjustable and Fixed Loop Hamstring Tendon Graft Fixation Have Similar Clinical and Patient-Reported Outcomes in Anterior Cruciate Ligament Reconstruction

Christian Hwee Yee Heng, M.B.B.S., F.R.C.S.Ed. (Orth), Joel Yat Seng Wong, M.B.B.S., and Andrew Hwee Chye Tan, M.B.B.S., F.R.C.S.Ed. (Orth)

Purpose: This study aims to compare the outcomes of fixed-loop device (FLD) vs adjustable-loop device (ALD) graft fixation with up to 2-year follow-up in patients undergoing primary anterior cruciate ligament reconstruction (ACLR) in a predominantly Asian setting. **Methods:** Prospectively collected outcome measures as well as clinical records of patients who underwent primary ACLR using either FLD or ALD fixation of hamstring tendon autograft performed by a single surgeon were reviewed. The surgeon in this study used a fixed-loop device from 2018 to 2019 and then changed to adjustable loop from 2019 to 2020. Suspensory fixation was performed on the femoral side, and aperture (interference screw) fixation was performed on the tibial side. Outcome measures included knee range of motion, KT-1000 arthrometer testing, Lysholm knee score, and Tegner activity scale. Patients were assessed preoperatively and postoperatively at regular intervals of 6, 12, and 24 months. **Results:** A total of 105 patients were identified. Forty-six were excluded due to incomplete follow-up data, so 59 patients with full 2-year follow-up were included in the final study group. Both groups (FLD vs ALD) were similar in demographics except for age ($P = .042$). Out of 105, there were 59 patients remaining in the study group with 2-year follow-up data. No significant differences were observed between the 2 groups at all respective testing intervals. **Conclusions:** FLDs and ALDs for suspensory fixation of hamstring tendon autograft in ACLR had similar clinical outcomes with a minimum of 2-year follow up. There is no evidence of graft loosening from loop lengthening. **Level of Evidence:** Level III, retrospective comparative trial.

The goal of anterior cruciate ligament (ACL) graft fixation devices is to obtain secure stable fixation and optimal tendon-to-bone or bone-to-bone healing. ACL reconstruction (ACLR) fixation methods have long been the subject of frequent debate, and there is currently no gold standard.[1] Femoral suspensory fixation has gained favor as it provides stable graft fixation[2] while avoiding the problems associated with interference screw fixation such as damage to the graft during screw insertion and screw divergence contributing to loss of pullout strength.[3-5] Broadly speaking, there are 2 main types of femoral suspensory fixation devices based on the adjustability of the loop length: the fixed-loop devices (FLDs) and the adjustable-loop devices (ALD). (In our study, we used the EndoButton CL (Smith & Nephew) (EB) and the ToggleLoc with ZipLoop (Zimmer Biomet) respectively).[6-9] ACL fixation devices appear to be the most widely used graft fixation devices in clinical practice.[10] There are numerous studies reporting the clinical and biomechanical outcomes of these individual fixation devices.[11-14] FLDs such as the EB are extra-articular devices consisting of a fixed-loop (FL) that attaches the graft to a metallic button.[1] Second-generation ALDs were innovated to address the drawbacks of FLDs such as eliminating the need for overdrilling.[15] ALDs feature an adjustable 1-way locking mechanism that relies on friction between sutures to maintain a certain length.[3] The loop of ALDs can be

From the Department of Orthopaedic Surgery, Singapore General Hospital, Singapore (C.H.Y.H., J.Y.S.W., A.H.C.T.).

The authors report that they have no conflicts of interest in the authorship and publication of this article. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

Received November 27, 2022; accepted June 15, 2023.

Address correspondence to Christian Hwee Yee Heng, M.B.B.S., F.R.C.S.Ed. (Orth), Department of Orthopaedic Surgery, Singapore General Hospital, Academia Level 4, 20 College Rd, Singapore 169608. E-mail: heng.christian@gmail.com

2666-061X/221483
https://doi.org/10.1016/j.asmr.2023.100775

tightened and adjusted according to the tunnel length, thus reducing the possibility of bungee and windshield wiper effects, which are associated with a higher risk of tunnel widening.[16-18] Retensioning of the graft after tibial fixation is possible if there is excessive laxity noted after passive cycling of the knee as long as the graft is not bottomed out in the femoral tunnel. Reducing the length of the loop by advancing the graft to the femoral exit maximizes the amount of graft within the femoral tunnel,[19] resulting in a larger surface area for bone-tendon healing and optimizing graft incorporation.[20]

Several potential problems with adjustable-loop fixation have been described. A systematic review consisting of 6 studies amounting to a total of 76 FLDs and 120 ALDs concluded that cyclic displacement was higher in ALD compared to the EndoButton CL FLD.[21] However, the comparison of clinical outcomes arising from different fixation devices has not been well studied.[14,17] The available body of literature suggests a lack of sufficient evidence to recommend the use of fixed over adjustable suspensory fixation devices or vice versa.[15,19]

There may be significant differences between the biomechanical behavior or properties between different ethnic groups, such as those of Caucasians (where the bulk of the literature is from) and Southeast Asian knees. The purpose of this study was to compare the outcomes of FLD vs ALD graft fixation with up to 2-year follow-up in patients undergoing primary ACLR in a predominantly Southeast Asian setting. We hypothesize that the FLD and ALD of femoral cortical suspension ACL hamstring autografts provide equal results in restoring knee stability and patient satisfaction in patients undergoing primary ACLR.

Methods

Patients

Prospectively collected outcome measures from a database and clinical records of patients who underwent primary ACLR surgery from January 2018 to December 2020 with up to a 2-year follow-up were retrospectively reviewed.

Inclusion criteria were skeletal maturity, a magnetic resonance imaging—diagnosed ACL tear, and completion of 2 of 3 postoperative assessments. Exclusion criteria were multiligamentous injuries, prior knee pathology, and revision ACLR. Patients with concomitant injuries such as meniscus tear and chondral injury were not excluded. Data collected include patient demographics, patient-reported outcome measure scores (Tegner activity scale and Lysholm knee score), objective clinical outcome scores (KT-1000), and medical records review to identify complications.

Surgical Technique

All reconstructions were performed by a single sports surgeon (A.H.C.T.). Since there are no proven differences between the 2 methods of fixation, the primary surgeon chose the fixation device by surgeon preference. In this case, he used the FLD from 2018 to 2019 and then changed to ALD from 2019 to 2020. The graft fixation devices used were either an FLD (EB CL; Smith & Nephew) or an ALD (Zimmer Biomet TL Device with ZipLoop Technology). During the time of surgery, any other concomitant meniscus and cartilage pathologies were treated as well. A single-bundle ACLR via a transtibial approach was performed with autologous hamstring graft, which was fashioned into a quadruple strand to create a graft of at least 7.5 mm in diameter. Suspensory fixation was performed on the femoral side, and aperture (interference screw) fixation was performed on the tibial side. After insertion of the graft, the graft was tightened until taut and cycled.

Postoperative Rehabilitation

Patients were placed in a postoperative knee brace, which provided varus/valgus restraint, and range of motion was allowed until 90 degrees. Crutches were used for the first 4 weeks. Full weightbearing was allowed after 2 weeks if no meniscus repair was performed and after 6 weeks if meniscus repair was performed. Physiotherapy was started on the first postoperative day. Return to sports was not recommended earlier than 9 to 12 months postoperatively. Standardized rehabilitation protocol under the supervision of a sports physiotherapist was implemented.

Evaluation Methods

Clinical assessment was performed preoperatively and postoperatively by the operating surgeon at regular intervals of 6, 12, and 24 months. All patients were registered into an ACL injury database; all patients in the database would have patient-reported outcome measures as well as several clinical measures (such as KT-1000 scores) recorded in the database.

KT-1000 knee ligament arthrometer (MEDmetric) was used to test for anterior translational instability[22,23] at 30 lb. force, of which side-to-side difference was subsequently calculated; 30 lb. was used as a standardized measurement in our institution.

Questionnaires and scales were given to patients to assess clinical and functional knee outcomes: Tegner activity scale (TAS) was used to measure physical performance (1-10); Lysholm knee score (LKS) was used for subjective evaluation.

Statistical Analysis

Statistical analysis was conducted using Microsoft Excel 2019. Participants were grouped according to whether they had undergone ACLR surgery with the FLD or ALD

Table 1. Demographics

Characteristic	Fixed (EB) (n = 30)	Adjustable (TL) (n = 75)	*P* Value
Age, mean ± SD, y	26.0 ± 7.9	29.7 ± 8.5	.042*
Male/female, n (%)	20 (67.7)/10 (33.3)	50 (67.7)/25 (33.3)	.487
Ethnicity, n (%)			
Southeast Asian	28 (93.3)	67 (89.3)	NS
Non−Southeast Asian	2 (6.7)	8 (10.7)	NS
Time from first physiotherapy assessment to surgery, mean ± SD, mo	0.4 ± 0.5	0.5 ± 0.6	.478
Height, mean ± SD, cm	168.9 ± 7.0	167.8 ± 10.6	.596
Weight, mean ± SD, kg	70.7 ± 13.6	72.7 ± 19.3	.608
BMI, mean ± SD	24.7 ± 4.0	27.2 ± 20.0	.491
Follow-up rate, n (%)			
6 months	29 (96.7)	66 (88.0)	.300
12 months	26 (86.7)	45 (60.0)	
24 months	20 (66.7)	39 (52.0)	
Average follow-up, mo	19.2	15.2	.556

BMI, body mass index; EB, EndoButton CL; NS, not significant; TL, ToggleLoc with ZipLoop.
*Significant *P* value.

technique, and descriptive data (mean ± SD) were calculated for all variables. Unpaired 2-sample Student *t* test was used to compare primary outcomes: overall means for the KT-1000 test, Tegner, Lysholm scores, and knee range of motion. A confidence interval of 95% was considered statistically significant. With a power of 80% and a type I error rate of 5%, we calculated that we needed 28 patients for each group (56 patients in total).[24] Our sample size was larger than the minimum required since our study was a retrospective study analyzing 4 years of data (from 2018 to 2020).

Clinical significance was evaluated using minimal clinically important differences (MCIDs), the smallest change in outcome that a patient is able to perceive and appreciate.[25,26] The utility of the MCID is to determine the efficacy of a treatment by focusing on the clinical value rather than on statistical significance.[27] We consider a clinically significant difference as a change in the mean outcome score that exceeded a previously determined MCID for that particular outcome ($P < .05$). We determined maximal medical improvement by identifying the latest period where the change in singular outcome score did not exceed the MCID. In our study, we defined the MCID in alignment with the prevailing literature, where MCID for the Lysholm score was determined to be 10.[28,29]

Results

A total of 105 patients (mean follow-up was 16.7 months [range, 5 to 25 months]) underwent ACLR. The 105 patients do not all have a full 2-year follow-up. Mean age and body mass index at the time of surgery were 28.6 ± 8.1 years and 26.0 ± 10.0, respectively. There was a statistically significant difference in age ($P = .042$) (Table 1). The rest of the demographic parameters were comparable. There were 46 patients excluded due to lack of follow-up. There were 59 patients available for evaluation at the 2-year follow-up, 29 (66.7%) and 39 (52.0%) in the EB and TL groups, respectively. Thirty-six (34.3%) patients were lost to follow-up from 6 months to 2 years (Table 1). No statistical differences were observed between the groups except for age ($P = .042$) (Table 1).

Range of Motion

There was no statistically significant difference between the FLD and ALD in the knee range of motion (ROM) at the 2-year follow-up (Table 2).

Stability (KT-1000 Testing)

Preoperatively, all patients had positive Lachman's and pivot-shift tests. The mean preoperative manual KT-1000 arthrometer side-to-side laxity difference in both groups ranged from 3.4 to 3.5 mm. Clinical evaluation at 2 years indicated that the manual maximum side-to-side laxity difference was the lowest at a mean (SD) of 1.5 (4.0) mm in FLD. There was no statistically significant difference between the groups with regard to stability evaluation at the 2-year follow-up (Table 3).

Subjective Evaluation

Lysholm Knee Score

There were no significant differences between the 2 groups preoperatively. Higher LKS was found in ALD compared to the FLD group at all evaluation time points, but this did not reach statistical significance (Table 4).

The differences in the means of the Lysholm clinical outcome scores and progression toward becoming minimally clinically significant are depicted in Table 5. Clinical significance was reached from preoperatively to 6 months. This meant that at the time of final follow-up, the MCID was achieved by 90.5% of patients for the Lysholm score. Maximal medical improvement was detected during the 6- to 12-month follow-up period (Table 5).

Table 2. Comparison of Knee Range of Motion Between Fixed (EndoButton) and Adjustable (ToggleLoc) Loop Suspensory Fixation Devices

	Knee ROM, degrees					
	Extension			Flexion		
Characteristic	Fixed (EB) (n = 30)	Adjustable (TL) (n = 75)	*P* Value	Fixed (EB) (n = 30)	Adjustable (TL) (n = 75)	*P* Value
Preoperative	2.8 ± 6.7	1.7 ± 6.2	.428	123.1 ± 27.9	127.3 ± 23.6	.419
6 mo	0.1 ± 4.1	−0.3 ± 3.9	.659	137.7 ± 7.8	136.6 ± 9.4	.620
12 mo	0.1 ± 2.6	1.1 ± 3.4	.250	140.0 ± 8.2	137.5 ± 10.0	.354
24 mo	0.3 ± 2.8	−1.3 ± 3.8	.066	138.5 ± 9.3	138.0 ± 7.9	.852

NOTE: Data are presented as mean ± SD.
EB, EndoButton CL; ROM, range of motion; TL, ToggleLoc with ZipLoop.

Tegner Activity Scale

The differences in the TAS were not statistically significant (Table 4).

Complications and Additional Procedures

At the 24-month follow-up, there were no revision ACLRs and no postoperative surgical site infections.

Discussion

The most important finding of this study was that both FLD and ALD had similar patient-reported outcome measures and ROM up to 2 years after ACLR.

Our study has results comparable to another study in the literature that found that ALD compares similarly to FLD in terms of clinical outcomes.[3] However, in vitro studies suggest that ALDs are biomechanically weaker than FLDs. In the early rehabilitation period, Singh et al.[30] reported that while both FLD and ALD possess the necessary biomechanical properties for initial fixation of ACL grafts in the femoral tunnel, the FLD had least elongation and highest load at failure. Petre et al.[31] showed that device slippage in ALD resulted in higher displacement of the adjustable loop under testing during cyclic and pull to failure loads. Yet, while ALD appears to be biomechanically inferior to FLD, our results suggest that this does not appear to translate into clinical results. Likewise, Onggo et al.[32] revealed in a systemic review of 13 biomechanical, 2 prospective, and 6 retrospective studies that despite the superior biomechanical properties of FLDs, ALDs and FLDs yielded similar clinical outcome scores and graft rerupture rates.

Hovinga et al.[33] sought to characterize variations in mechanical knee alignment, tibial torsion, tibial width, and ACL laxity in a cohort size of 70 Japanese and Caucasian young adult subjects and found significant differences in tibial torsion and ACL laxity ($P < .01$) between Japanese and Caucasian participants, with the Japanese exhibiting lower tibial torsion (33.4° ± 10.0°) and higher ACL laxity (7.5 ± 0.4 mm) measurements compared to Caucasians (38.9° ± 9.5° and 5.7 ± 0.3 mm, respectively).

Most clinical outcomes comparing FLD and ALD to date have been centered on predominantly Western populations. Asif et al.[15] previously compared an adjustable- vs a fixed-loop device for arthroscopic ACLR femoral side fixation in a predominantly South Asian population. The current study also reports the outcomes comparing FLD and ALD in a predominantly Asian population, which is important considering the significant potential morphologic and functional differences between the Asian and Caucasian knee and its potential implications on outcomes.

ALDs have several advantages over FLDs. The tunnel size of ALDs is shorter, and drilling of exact tunnel length is not required as opposed to FLD,[34] resulting in a greater contract area (12% to 15%) between the superior tip of the graft (tendon) and the superior end

Table 3. Comparison of KT-1000 Arthrometer Testing Results at 30 Pounds for Stability Between Fixed (EndoButton) and Adjustable (ToggleLoc) Loop Suspensory Fixation Devices

	KT-1000 Measurement, mm					
	Mean			Side-to-Side Difference		
Characteristic	Fixed (EB) (n = 30)	Adjustable (TL) (n = 75)	*P* Value	Fixed (EB) (n = 30)	Adjustable (TL) (n = 75)	*P* Value
Preoperative	11.4 ± 3.8	10.6 ± 3.5	.321	3.5 ± 3.6	3.4 ± 3.0	.951
6 mo	9.8 ± 1.8	9.6 ± 3.2	.802	1.7 ± 2.4	2.0 ± 2.5	.739
12 mo	10.1 ± 4.0	10.4 ± 2.8	.737	1.8 ± 2.6	2.0 ± 2.2	.771
24 mo	10.8 ± 3.2	10.2 ± 2.2	.439	1.5 ± 4.0	2.2 ± 2.0	.464

NOTE: Data are presented as mean ± SD.
EB, EndoButton CL; TL, ToggleLoc with ZipLoop.

Table 4. Comparison of Outcomes Between Fixed (EndoButton) and Adjustable (ToggleLoc) Loop Suspensory Fixation Devices

	Lysholm Knee Score			Tegner Activity Scale		
Characteristic	Fixed (EB) (n = 30)	Adjustable (TL) (n = 75)	*P* Value	Fixed (EB) (n = 30)	Adjustable (TL) (n = 75)	*P* Value
Preoperative	60.0 ± 4.4	63.2 ± 4.3	.470	6.9 ± 2.3	6.5 ± 1.8	.381
6 mo	86.5 ± 15.6	87.2 ± 11.5	.822	3.9 ± 1.5	4.0 ± 1.6	.797
12 mo	88.0 ± 15.5	90.4 ± 8.4	.461	5.8 ± 2.5	5.0 ± 1.7	.156
24 mo	88.9 ± 11.5	92.8 ± 6.9	.171	5.0 ± 1.9	5.4 ± 2.0	.369

NOTE: Data are presented as mean ± SD.
EB, EndoButton CL; TL, ToggleLoc with ZipLoop.

of the tunnel wall in ALD than FLD. Kamitani et al.[34] suggest that this greater contact area allows greater blood flow to reach the superior end of the tendon graft in the femoral tunnel at 3 months post-ACLR, allowing for graft revascularisation and incorporation in the femoral tunnel to occur more readily after ALD than FLD postoperatively. ALDs possess the advantage of the "one size fits all" approach, conferring users the ability to readjust the tension (tighten) after fixation, thus maximizing the intratunnel graft length.[35] Retensioning of ALDs after tibial fixation also has been shown to improve biomechanical outcomes.[32] ALDs are technically easier to use because of the ability to tweak the graft tension after tightening. In comparison, the fixed loop length of FLD requires precise surgical planning and execution to achieve optimal graft fixation and minimize potential intraoperative complications such as the inability to flip/deploy the button, posterior wall blow-out,[36] insufficient intratunnel graft length, and postoperative complications such as amount of unused tunnel[37] and tunnel widening.[38]

Range of Motion

Our figures of no significant differences in postoperative knee ROM between FLD and ALD are comparable to Chandru et al.,[20] who reported mean ROM at 6 months (FLD: 125.38 ± 18.08 vs ALD: 130.53 ± 17.15) and at 1 year (FLD: 136.15 ± 8.70 vs ALD: 137.69 ± 8.32). At 2-year follow-up, Ahn et al.[39] also reported lack of significant difference between FLD (n = 41, EB) and ALD (n = 38, TR) at ROM figures of 135.2 ± 11.5 and 133.2 ± 13.6 (*P* = .834), respectively.

Stability, KT-1000 Arthrometer Testing

There was little change in mean from preoperative to postoperative KT-1000. A possible explanation could be that the KT-1000 is not an accurate measure of knee joint translation. It is also known that there may still be residual anterior-posterior translational laxity as picked up by the KT-1000 in ACL-reconstructed knees.

Biomechanical studies have suggested that ALD ACL graft suspension exhibits a greater likelihood of loosening with time compared to FLD, resulting in delay of graft incorporation and knee instability.[31] Yet, others suggest adjustable- and fixed-loop femoral cortical suspension devices can be used with similar mechanical properties during ACLR.[40,41]

Our results suggest that both FLD and ALD confer great stability to the knee, with both groups showing lower postoperative side-to-side difference in KT-1000 arthrometer testing compared to preoperative. In the postoperative period (6, 12, 24 months), our results revealed no significant difference between FLD and ALD in maximum side-to-side difference in KT-1000 testing (Table 3).

Similar to this study, Boyle et al.[42] revealed in 188 consecutive patients undergoing primary ACLR that adjustable-loop suspension does not clinically loosen after ACLR and found no significant difference in postoperative knee stability at 6, 12, or 24 months between FLD (n = 115, RetroButton; Arthrex) and ALD (n = 73, TightRope RT; Arthrex): 6 months (FLD: 1.79 vs ALD: 1.51; *P* = .23), 1 year (FLD: 1.64 vs ALD: 1.44; *P* = .48), and 2 years (FLD: 1.07 vs ALD: 1.44; *P* = .90).

Table 5. MCID for Lysholm at Different Postoperative Time Points

	Preoperative to 6 mo		6 to 12 mo		12 to 24 mo	
Characteristic	Fixed (EB)	Adjustable (TL)	Fixed (EB)	Adjustable (TL)	Fixed (EB)	Adjustable (TL)
Significant clinical improvement? (*P* = .05)	Yes	Yes	No	No	No	No
Difference between means	26.5	24.0	1.5	3.2	1.9	2.4
P value	<.001	<.001	>.99	>.99	>.99	>.99

EB, EndoButton CL; TL, ToggleLoc with ZipLoop.

Lysholm Knee Score

Our results reveal no statistically significant differences in LKS between FLD and ALD (Table 4). This contrasts with Ranjan et al.,[7] who reported better functional results at 6 months (FLD: 88.5 ± 3.48 vs ALD: 83.4 ± 2.52, $P < .001$) in FLD (n = 52, EB) compared to ALD (n = 50, TR).

Our findings are consistent with Asif et al.[15] (FLD: 91.4 ± 3.5 vs ALD: 91.0 ± 3.6; $P > .05$) and Schützenberger et al.[3] (FLD: 89.9 ± 11.0 vs ALD: 87.3 ± 12.1; $P = .380$), who both reported statistically insignificant LKS score differences between FLD and ALD in their patient cohorts of 43 and 67 patients, respectively. However, the exact device used in these 2 studies was from different manufacturers compared to those used in our study.

At 1-year follow-up, Sheth et al.[19] reported Lysholm scores of 94.23 ± 2.47 and 94.32 ± 2.1 in FLD (n = 31, EndoButton) and ALD (n = 31, TightRope RT; Arthrex) groups, respectively. In contrast, our LKS scores for FLD and ALD are 88.0 ± 15.5 and 90.4 ± 8.4, respectively.

In a systemic review for all-inside ACLR, de Sa D et al.[43] found that average LKS at 2 years postoperatively is 92.4 ± 11.4, while Connaughton et al.[44] reported a range of 90.9 to 93.1. In contrast, our study found that the LKS for FLD and ALD at 2 years are 88.9 ± 11.5 and 92.8 ± 6.9, respectively. A possible reason for this difference is that our cohort is predominantly Southeast Asian, whereas the above studies are predominantly Western, and these differences in ethnicity and body proportions may have contributed to the above differences in outcome scores.

Tegner Activity Scale

Significant differences between FLD and ALD were not found for TAS (Table 4). Our findings are largely consistent with various literature sources. At 1-year follow-up, no statistically significant differences were found for TAS, FLD (n = 22, EB) 7 vs ALD (n = 22, TR) 6.5.[45] At 2-year follow-up, Ahn et al.[39] reported that TAS in FLD (EB) was 5.1 ± 1.6, and ALD (TR) was 5.5 ± 2.1 ($P = .312$). In a retrospective study of 67 patients with a mean follow-up of 4 ± 1.5 years, the mean TAS was 6.2 ± 1.7 in the FL group and 5.5 ± 1.7 in the AL group ($P = .085$).[3] Interestingly, we obtained higher TAS scores at 2 years postoperatively (5.0 to 5.6) in our results compared to de Sa et al.,[43] who reported an average Tegner score (4.9 ± 2.3) at 2 years postoperatively in 526 patients.In contrast, our results were comparable to Connaughton et al.,[44] who reported a TAS of 5.2 to 6 at 2 years postoperatively.

Our results seem to agree with the existing literature that there are no statistically significant clinical differences between FLDs and ALDs.

The primary advantage of this study is its consistency in ACLR surgical technique. The ACLRs were performed by a single fellowship-trained orthopaedic surgeon, thus minimizing variations in surgical technique. Hence, any difference in postoperative outcomes would be less likely due to surgical technique.

Limitations

Our study has limitations to consider, including that of a small study population. With a power of 80% and a type I error rate of 5%, we calculated that we needed 28 patients for each group (56 patients in total).[24] This was a retrospective study with 34% of patients lost to follow-up at 2 years. Out of 105 patients, a study population of 20 and 39 patients for fixed and adjustable loops was available for analysis at the end of 24 months, respectively.

We acknowledge that there was a statistical difference in age between the 2 groups. However, we feel that this does not introduce significant bias into the study's result conclusions as the difference in age was minimal (mean age of 26 years in the FLD group vs 29 years of age in the ALD group). The difference of 3 years of age still places patients in approximately the same age group, and it can be argued that there should be no difference, biologically, functionally, or psychologically, between these 2 age groups that is relevant to this topic (of ACLR).

Finally, our study focused on clinical findings and did not include radiologic parameters such as tunnel position and tunnel widening. Tunnel widening is a potential issue with fixed-loop devices, but we did not obtain radiographs during follow-up to investigate this in our study. Our institutions do not routinely perform postoperative radiographs for post-ACLR patients.

Conclusions

FLDs and ALDs for suspensory fixation of hamstring tendon autograft in ACLR had similar clinical outcomes with a minimum of 2-year follow-up. There is no evidence of graft loosening from loop lengthening.

References

1. Colvin A, Sharma C, Parides M, Glashow J. What is the best femoral fixation of hamstring autografts in anterior cruciate ligament reconstruction? a meta-analysis. *Clin Orthop Relat Res* 2011;469(4):1075-1081.
2. Eguchi A, Ochi M, Adachi N, Deie M, Nakamae A, Usman MA. Mechanical properties of suspensory fixation devices for anterior cruciate ligament reconstruction: Comparison of the fixed-length loop device versus the adjustable-length loop device. *Knee* 2014;21:743-748.
3. Schützenberger S, Keller F, Grabner S. ACL reconstruction with femoral and tibial adjustable versus fixed-loop suspensory fixation: A retrospective cohort study. *J Orthop Surg Res* 2022;17(1):244.
4. Smith PA, Stannard JP, Pfeiffer FM. Suspensory versus interference screw fixation for arthroscopic anterior

cruciate ligament reconstruction in a translational large-animal model. *Arthroscopy* 2016;32(6):1086-1097.
5. Colombet P, Graveleau N, Jambou S. Incorporation of hamstring grafts within the tibial tunnel after anterior cruciate ligament reconstruction: Magnetic resonance imaging of suspensory fixation versus interference screws. *Am J Sports Med* 2016;44(11):2838-2845.
6. Özdemir G, Turan S, Aslan H, Bingöl O, Deveci A, Kılıç E. Anterior cruciate ligament reconstruction with ToggleLoc with ZipLoop system versus transfix system: A cost-effectiveness analysis. *Ulus Travma Acil Cerrahi Derg* 2021;27(2):231-237.
7. Ranjan R, Gaba S, Goel L, et al. In vivo comparison of a fixed loop (EndoButton CL) with an adjustable loop (TightRope RT) device for femoral fixation of the graft in ACL reconstruction: A prospective randomized study and a literature review. *J Orthop Surg (Hong Kong)* 2018;26(3): 2309499018799787.
8. Wise BT, Patel NN, Wier G, Labib SA. Outcomes of ACL reconstruction with fixed versus variable loop button fixation. *Orthopedics* 2017;40(2):e275-e280.
9. Milano G, Mulas PD, Ziranu F, Piras S, Manunta A, Fabbriciani C. Comparison between different femoral fixation devices for ACL reconstruction with doubled hamstring tendon graft: a biomechanical analysis. *Arthroscopy* 2006;22(6):660-668.
10. Runer A, Keeling L, Wagala N, et al. Current trends in graft choice for anterior cruciate ligament reconstruction—part I: Anatomy, biomechanics, graft incorporation and fixation. *J Exp Orthop* 2023;10(1):37.
11. Kim Y, Kubota M, Muramoto K, et al. Clinical and radiographic results after ACL reconstruction using an adjustable-loop device. *Asia Pac J Sports Med Arthrosc Rehabil Technol* 2021;26:32-38.
12. Colombet P, Saffarini M, Bouguennec N. Clinical and functional outcomes of anterior cruciate ligament reconstruction at a minimum of 2 years using adjustable suspensory fixation in both the femur and tibia: a prospective study. *Orthop J Sports Med* 2018;6(10): 2325967118804128.
13. Gürpınar T, Polat B, Eren M, Çarkçı E, Özyalvaç ON, Erdoğan S. The effect of soft tissue interposition of the Endobutton on clinical results and on its postoperative migration after single-bundle anterior cruciate ligament reconstruction. *Knee* 2020;27(6):1980-1987.
14. Asmussen CAP, Attrup ML, Thorborg K, Hölmich P. Passive knee stability after anterior cruciate ligament reconstruction using the Endobutton or ToggleLoc with ZipLoop as a femoral fixation device: A comparison of 1654 patients from the Danish Knee Ligament Reconstruction Registry. *Orthop J Sports Med* 2018;6(6): 2325967118778507.
15. Asif N, Khan MJ, Haris KP, Waliullah S, Sharma A, Firoz D. A prospective randomized study of arthroscopic ACL reconstruction with adjustable- versus fixed-loop device for femoral side fixation. *Knee Surg Relat Res* 2021;33(1):42.
16. Lubowitz JH, Ahmad CS, Anderson K. All-inside anterior cruciate ligament graft-link technique: Second-generation, no-incision anterior cruciate ligament reconstruction. *Arthroscopy* 2011;27(5):717.
17. Firat A, Catma F, Tunc B, Hacihafizoglu C, Altay M, Bozkurt M. The attic of the femoral tunnel in anterior cruciate ligament reconstruction: A comparison of outcomes of two suspensory femoral fixation systems. *Knee Surg Sports Traumatol Arthrosc* 2014;22(5):1097-1105.
18. Choi NH, Yang BS, Victoroff BN. Clinical and radiological outcomes after hamstring anterior cruciate ligament reconstructions: Comparison between fixed-loop and adjustable-loop cortical suspension devices. *Am J Sports Med* 2017;45(4):826-831.
19. Sheth H, Salunke AA, Barve R, Nirkhe R. Arthroscopic ACL reconstruction using fixed suspensory device versus adjustable suspensory device for femoral side graft fixation: What are the outcomes? *J Clin Orthop Trauma* 2019;10(1):138-142.
20. Chandru V, Santhosh MS, Sujana Theja JS, Nair RR. Comparison of fixed- and variable-loop button fixation in arthroscopic anterior cruciate ligament reconstruction. *Cureus* 2022;14(4):e24218.
21. Houck DA, Kraeutler MJ, McCarty EC, Bravman JT. Fixed-versus adjustable-loop femoral cortical suspension devices for anterior cruciate ligament reconstruction: A systematic review and meta-analysis of biomechanical studies. *Orthop J Sports Med* 2018;6(10):2325967118801762.
22. Arneja S, Leith J. Review article: Validity of the KT-1000 knee ligament arthrometer. *J Orthop Surg (Hong Kong)* 2009;17(1):77-79.
23. Kilinc BE, Kara A, Celik H, Oc Y, Camur S. Evaluation of the accuracy of Lachman and anterior drawer tests with KT1000 in the follow-up of anterior cruciate ligament surgery. *J Exerc Rehabil* 2016;12(4):363-367.
24. Suresh K, Chandrashekara S. Sample size estimation and power analysis for clinical research studies. *J Hum Reprod Sci* 2012;5(1):7-13.
25. Nwachukwu BU, Sullivan SW, Rauck RC, et al.; HSS ACL Registry Group. Patient-reported outcomes and factors associated with achieving the minimal clinically important difference after ACL reconstruction: Results at a mean 7.7-year follow-up. *JB JS Open Access* 2021;6(4):e21.00056.
26. Nwachukwu BU, Chang B, Rotter BZ, Kelly BT, Ranawat AS, Nawabi DH. Minimal clinically important difference and substantial clinical benefit after revision hip arthroscopy. *Arthroscopy* 2018;34(6):1862-1868.
27. Katz NP, Paillard FC, Ekman E. Determining the clinical importance of treatment benefits for interventions for painful orthopedic conditions. *J Orthop Surg Res* 2015;10: 24.
28. Agarwalla A, Puzzitiello RN, Liu JN, et al. Timeline for maximal subjective outcome improvement after anterior cruciate ligament reconstruction. *Am J Sports Med* 2019;47(10):2501-2509.
29. Mabrouk A, Nwachukwu B, Pareek A, et al. MCID and PASS in knee surgeries: Theoretical aspects and clinical relevance references. *Knee Surg Sports Traumatol Arthrosc* 2023;31(6):2060-2067.
30. Singh S, Ramos-Pascual S, Czerbak K, et al. Biomechanical testing of fixed and adjustable femoral cortical suspension devices for ACL reconstruction under high loads and extended cyclic loading. *J Exp Orthop* 2020;7(1):27.
31. Petre BM, Smith SD, Jansson KS. Femoral cortical suspension devices for soft tissue anterior cruciate ligament

reconstruction: A comparative biomechanical study. *Am J Sports Med* 2013;41(2):416-422.

32. Onggo JR, Nambiar M, Pai V. Fixed- versus adjustable-loop devices for femoral fixation in anterior cruciate ligament reconstruction: A systematic review. *Arthroscopy* 2019;35(8):2484-2498.
33. Hovinga KR, Lerner AL. Anatomic variations between Japanese and Caucasian populations in the healthy young adult knee joint. *J Orthop Res* 2009;27(9): 1191-1196.
34. Kamitani A, Hara K, Arai Y, et al. Adjustable-loop devices promote graft revascularization in the femoral tunnel after ACL reconstruction: Comparison with fixed-loop devices using magnetic resonance angiography. *Orthop J Sports Med* 2021;9(2):2325967121992134.
35. Turnbull TL, LaPrade CM, Smith SD, LaPrade RF, Wijdicks CA. Dimensional assessment of continuous loop cortical suspension devices and clinical implications for intraoperative button flipping and intratunnel graft length. *J Orthop Res* 2015;33(9):1327-1331.
36. Mitchell JJ, Dean CS, Chahla J, Menge TJ, Cram TR, LaPrade RF. Posterior wall blowout in anterior cruciate ligament reconstruction: A review of anatomic and surgical considerations. *Orthop J Sports Med* 2016;4(6): 2325967116652122.
37. Sabat D, Sehrawat R, Kumar V. A percutaneous technique to reposition the cortical button of adjustable-loop devices in anterior cruciate ligament reconstruction. *Arthrosc Tech* 2019;8(11):e1273-e1276.
38. Lind M, Feller J, Webster KE. Bone tunnel widening after anterior cruciate ligament reconstruction using EndoButton or EndoButton continuous loop. *Arthroscopy* 2009;25(11):1275-1280.
39. Ahn HW, Seon JK, Song EK, Park CJ, Lim HA. Comparison of clinical and radiologic outcomes and second-look arthroscopic findings after anterior cruciate ligament reconstruction using fixed and adjustable loop cortical suspension devices. *Arthroscopy* 2019;35(6):1736-1742.
40. Chang MJ, Bae TS, Moon YW, Ahn JH, Wang JH. A comparative biomechanical study of femoral cortical suspension devices for soft-tissue anterior cruciate ligament reconstruction: Adjustable-length loop versus fixed-length loop. *Arthroscopy* 2018;34(2):566-572.
41. Smith PA, Piepenbrink M, Smith SK, Bachmaier S, Bedi A, Wijdicks CA. Adjustable- versus fixed-loop devices for femoral fixation in ACL reconstruction: An in vitro full-construct biomechanical study of surgical technique-based tibial fixation and graft preparation. *Orthop J Sports Med* 2018;6(4):2325967118768743.
42. Boyle MJ, Vovos TJ, Walker CG, Stabile KJ, Roth JM, Garrett WE Jr. Does adjustable-loop femoral cortical suspension loosen after anterior cruciate ligament reconstruction? A retrospective comparative study. *Knee* 2015;22(4):304-308.
43. de Sa D, Shanmugaraj A, Weidman M, et al. All-inside anterior cruciate ligament reconstruction: A systematic review of techniques, outcomes, and complications. *J Knee Surg* 2018;31(9):895-904.
44. Connaughton AJ, Geeslin AG, Uggen CW. All-inside ACL reconstruction: How does it compare to standard ACL reconstruction techniques? *J Orthop* 2017;14(2):241-246.
45. Lanzetti RM, Monaco E, De Carli A, et al. Can an adjustable-loop length suspensory fixation device reduce femoral tunnel enlargement in anterior cruciate ligament reconstruction? A prospective computer tomography study. *Knee* 2016;23(5):837-841.