Computed Tomography Imaging Results of Single Band Anterior Cruciate Ligament Reconstruction: A Retrospective Study Comparing Fixed- and Adjustable-Length Loop Cortical Fixation on the First Day After Surgery

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Research article

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Abstract

Background: Cortical suspensory femoral fixation is commonly performed for graft fixation of the femur in anterior cruciate ligament (ACL) reconstruction using hamstring tendons. This study aimed to compare the morphology of femoral tunnel and graft insertion between fixed-length loop devices (FLD) and adjustable-length loop devices (ALD) using computed tomography (CT) images on the first day after hamstring ACL reconstruction.

Methods: Overall, 94 patients who underwent ACL reconstruction from January 2016 to January 2021 were included. For femoral graft fixation, FLD (Smith & Nephew, ENDOBUTTON) and ALD (DePuy Synthes, Mitek sports medicine, RIGIDLOOP Adjustable cortical system) were used in 56 and 38 patients, respectively (FLD and ALD groups). For evaluation of the morphology of the humeral tunnel and graft depth, CT scans were performed immediately on the first postoperative day. The gap distance between the top of the graft and the socket tunnel end, the length of lateral bone preservation, and the depth of graft insertion were measured on the CT images.

Results: The gap distance and bone preservation significantly differed between the two groups (1.90±1.81 mm and 14.35±4.67 mm in ALD groups; 7.08±2.63 mm and 7.35±3.62 mm in FLD groups, respectively; both P values < 0.01). The graft insertion depth did not significantly differ between the groups.

Conclusion: The ALD group had a smaller gap distance, better bone preservation, and a similar graft insertion length in the femoral tunnel when compared to the FLD group. Based on these findings, ALD might be better for bone preservation and tunnel utilization in patients with short femoral tunnels.

Trial registration: retrospectively registered

Background

Adequate filling of the graft in the bone tunnel is essential for treatment success after anterior cruciate ligament (ACL) reconstruction (ACLR) [1–4]. It provides initial stability of the graft and increases the contact between the graft and femoral interface. Additionally, it provides an opportunity for biological integration with the native bone. Several graft fixation techniques have been applied for graft fixation in the femoral side, all of which have demonstrated positive clinical outcomes. However, there is still no consensus regarding the best fixation technique to use in the femoral side [5, 6].

Cortical suspensory fixation devices are widely used due to their simplicity and because they do not require any additional incision on the femoral side [7–9]. Cortical suspensory fixation devices are divided into two types: fixed-length loop devices (FLDs) and adjustable-length loop devices (ALDs). FLDs have been chosen as the standard due to their good biomechanical properties and ability to handle high failure loads for graft fixation [8, 10, 11]. However, they require extra distance for plat flipping, which may create a gap distance between the top of the graft and the socket end, thus leading to over drilling on the lateral femoral condyle. Additionally, measurement error could also result in insufficient graft length in the femoral tunnel.

ALDs were designed to allow for adaptation of the graft to the different tunnel lengths without leaving excess space inside the tunnel [8]. Nowadays there are adjustable techniques mainly using finger trapping or one-way locking sliding knot technology [7], that allow doctors to tighten the loop after plate flipping is completed, thus eliminating the gap distance between the top of the graft and the socket end. Biomechanical studies have suggested that ALD could result in loop lengthening and subsequent graft slippage compared to the FLD [12, 13]. However, existing studies have not found a difference between the clinical outcomes using the two different devices.

Due to the recent emergence of ALD and the different technologies adopted by different manufacturers, the clinical effects of ALD are still poorly understood. The purpose of this study was to compare the postoperative morphology of the femoral tunnel and the graft filling condition between one selected ALD and one selected FLD using computed tomography (CT) as the postoperative imaging evaluation tool. To the best of our knowledge, few studies have reported on the CT results after ACLR using FLD or ALD fixed graft at the femoral tunnel. We hypothesized that the postoperative graft filling condition could also be measured using CT, and that ALD would lead to better graft filling with a smaller gap distance compared to FLD on the first day after reconstruction.

Methods

Participants

Ethics committee approval for this study was obtained from our institution (ID: 2016–178). Due to the retrospective nature of the study, the need for informed consent was waived. All the study participants underwent unilateral ACL reconstruction at our hospital between 2015 and 2020 and underwent CT scanning performed 1 day postoperatively. All surgical procedures were performed by the same surgeons using similar techniques.

Patients were included if they underwent single-bundle reconstructions with 4-strand or 6-strand autologous hamstring tendon bases on the length of tendons, using cortical suspensory devices for the fixed graft on the femoral side. Patients with a history of lower limb fracture, impaired kidney function, osteoporosis, revision surgery, or for whom drilling through the elliptical femoral tunnel was conducted were excluded. All enrolled patients were divided into two groups based on whether FLD (Smith & Nephew, ENDOBUTTON) or ALD (DePuy Synthes, Mitek sports medicine, RIGIDLOOP Adjustable cortical system) was used.

Surgical technique

First, a diagnostic arthroscopy was performed and ACL rupture was confirmed. Next, using an oblique incision measuring 3.5 cm in length, the semitendinosus and gracilis tendons were harvested over the pes anserinus. At the same time, the arthroscope was reinserted, and a femoral tunnel was made through an anteromedial (AM) portal. The femoral tunnel entrance was selected at the anatomical site of the ACL; tunnel preparation was conducted using standard instrumentation with a diameter corresponding to the graft. Then, a tibial tunnel was made by drilling at the ACL footprint using a drill guide fixed at 55°. The selected fixation devices were used to fix the pre-tensioned graft on the femoral side. Cyclic loading was conducted after evaluation for graft impingement, and the graft was manually tensioned at 30° of knee flexion. Thereafter, a bioscrew measuring 25–30 mm in length and a diameter 1 mm larger than the tunnel diameter was used to fix the tibial side. The use of additional materials for lateral tibial fixation is at the surgeon's discretion.

CT evaluation

For all patients, CT scanning (Siemens healthcare Erlangen, Germany) was performed on the first postoperative day before weight bearing was initiated. A non-contrast 2-D CT scan of the operated knee was obtained on a helical multi-detector scanner. To observe the graft tissue, images were acquired at the soft tissue window (130 KV and 65 mAs) and reformation was performed with 0.8 mm slice-thickness. During review of the multiplanar reformatted images, an oblique coronal image showing a total outline of the femoral tunnel was chosen (Fig. 1) [14, 15]. The distance between the top of the femoral tunnel and the top of the hamstring graft (tunnel-graft gap) was measured (Fig. 1). Meanwhile socket tunnel length, graft tissue length, and distance between the top of the femoral tunnel and the cortical button were also measured (Fig. 1) [16]. All measurements were performed on the picture archiving and communications system (PACS) using a mouse cursor with automated distance calculation. One musculoskeletal radiologist and one orthopedic resident doctor collected all the data.

Statistical analysis

Means and standard deviations were used to describe quantitative continuous data, while frequencies and proportions were used to describe qualitative data. Analysis was performed using SPSS software (SPSS 25.0; IBM, Armonk, NY), and statistical significance was assumed at $P < 0.05$. Two independent sample t-tests and χ^2tests were performed to evaluate differences between the ALD and FLD. The consistency between the two observers was evaluated by calculating inter-observer consistency (ICC) values.

Sample size

Post-hoc power analysis was performed using the power analysis sample size (PASS) software. For a total sample size of 94 and type I error (α) of .05, the study was expected to provide a power (1- β) of 0.90. The power of having a sample size large enough to obtain significant differences was greater than 99% in this study ($P < 0.05$).

Results

Of the 94 enrolled patients, 38 and 56 were included in the ALD and FLD groups, respectively. The average age of the patients at the time of surgery was 29.21 ± 8.74 and 30.43 ± 9.41 years in the ALD and FLD groups, respectively. Based on CT measurements, we found that the ALD group had a smaller gap distance (1.90 ± 1.81 mm, 7.08 ± 2.63mm,P < 0.01) and thicker lateral bone preservation (14.35 ± 4.67mm，7.35 ± 3.62mm,P < 0.01), but there was no significant difference between the length of the graft inserted in the tunnel (18.46 ± 4.93mm versus 19.75 ± 3.97mm，P > 0.05) when compared with FLD group. Differences between the two groups in terms of demographic characteristics, as well as the tunnel-graft gap distance, socket tunnel length, and the graft tissue insertion length measured on the CT images are described in Table 1, Fig. 2.

Table 1
Demographic data and main outcomes for the patients in the fixation-loop device and adjustable-loop device groups

	FLD	**ALD**	**P**
Number	56	38	NA
Age(years)	30.43 ± 9.41	29.21 ± 8.74	> 0.05
Sex: male	46 (82%)	28 (74%)	> 0.05
Female	10 (18%)	10 (26%)	
BMI (kg/m²)	23.99 ± 3.56	22.73 ± 3.28	> 0.05
Gap distance (mm)	7.08 ± 2.63	1.90 ± 1.81	**< 0.01**
Socket length (mm)	27.03 ± 4.07	20.21 ± 4.40	**< 0.01**
Bone preservation (mm)	7.35 ± 3.62	14.35 ± 4.67	**< 0.01**
Graft insertion length (mm)	19.75 ± 3.97	18.46 ± 4.93	> 0.05

Emboldened P-values indicate statistically significant differences between the groups (P < 0.05). ALD, adjustable-loop device; FLD, fixed-loop device.

Additionally, we found that CT can observe graft filling in the tunnel very well with good inter-observer consistency (ICC = 0.956, P < 0.001).

Discussion

This novel study highlighted the significant differences in the utilization of the femoral tunnel between the ALD and FLD. Additionally, it was the first study to our knowledge, to use CT to observe the filling of the femoral tunnel graft, making up for the lack of clinical data of on ALDs. Most importantly, this study found that the use of an ALD leads to better use of the lateral femoral tunnel with a smaller gap distance but does not completely eliminate the graft top gap or increase the length of graft insertion. Second, it found that CT can be effectively used, with good reliability, to evaluate graft filling in the femoral tunnel.

These findings were consistent with our hypothesis. Although the ALD has been reported to have no gap distance, our findings show that there was still a gap distance in the ALD group (1.90 ± 1.81 mm). One advantage of the ALD is that it may help clinicians to select a more suitable fixation device for patients, especially for patients with a short femoral tunnel. Our findings will enable clinicians to better understand the differences between the two devices and help them to make better decisions regarding the preferred device for use. However, the prolongation of the ALD still requires further investigation in future studies.

In previous studies, investigators used magnetic resonance imaging (MRI) to evaluate the femoral tunnel and graft [2, 3, 16, 17]. Ahmet.et al reported that the gap distance was 4.6 ± 0.3 mm and 9.5 ± 1.6 mm in the groups in which toggle loc with zip loop femoral fixation ALDs and ENDOBUTTON CL fixation loop devices were used, respectively [3]. These findings are similar to those obtained in our study; however, we found that the RIGIDLOOP had a smaller gap distance (1.90 ± 1.81 mm). This difference may be due to the use of different brands of ALDs. One biomechanical study showed that the stability of the RIGIDLOOP was closest to that of the fixed-loop device [18]. However, to our knowledge no clinical study has reported the postoperative tunnel filling of the RIGIDLOOP device. Moreover, recent studies have indicated that gap distances are positively correlated with postoperative femoral tunnel widening and that they may affect revascularization after ACLR based on CT and MRI image findings [2, 14, 16, 17, 19–21]. These findings suggest that the large space may affect the prognosis of patients. Although we only observed patients on the first day after surgery, these findings may provide a reference for future studies.

In this study, we decided to use CT for evaluation because all patients who underwent ACLR in our hospital required CT evaluation to determine bone tunnel position and the postoperative device position. MRI examinations require a longer wait time and cost more money, thus the use of CT was more viable. Given that CT was used for all patients, there was a big enough sample size to ensure the power of our results. Additionally, all radiograph measurements were conducted by one experienced radiologist who was specialized in musculoskeletal imaging. Finally, we tested the consistency of our measurements using CT images and found good consistency and repeatability between the two observers (ICC = 0.956, $P < 0.001$). Therefore, we believe that our results obtained using CT imaging were reliable.

Compared to the FLD, adjustable-loop femoral cortical suspension devices are relatively new. They offer various advantages: graft maximization in femoral tunnels, avoidance of the over drilling of the femoral tunnel, and obviation of the need to calculate the loop length [1, 5, 6]. Our study supports the findings from previous studies and provides more information for clinicians. A full understanding of these advantages of ALDs may help clinicians make more appropriate choices for patients, especially those with short femoral tunnels. The ALD allows for better use of the femoral tunnel and retains adequate thickness of the lateral femoral cortex.

There are several limitations of this study which merit a mention here. First, this was a retrospective study thus potentially limiting the validity of our findings. Second, we did not report on the prognosis for the two groups of patients. This study only provided information on the postoperative imaging parameters for the two kinds of suspension devices used. We did not provide data on postoperative follow-up observations, whether the ALD was relaxed, and whether the prognosis of patients differed. This requires evaluation in future studies. Third, we used CT rather than MRI to evaluate the graft filling conditions. This may have exposed patients to a certain amount of radiation. Finally, this study was only able to exhibit the difference between these two devices using our specific surgical approach, thus limiting the generalizability of our results. Different devices and surgical methods may produce different results.

Conclusions

This study found that the ALD was associated with a smaller gap distance, better bone preservation, and a similar graft insertion length in the femoral tunnel measured on CT images on the first postoperative day when compared to the FLD.

Abbreviations

ALD: adjustable length loop;

FLD: fixation length loop.

CT: computerized tomography

MRI: Magnetic Resonance Imaging

Declarations

- # Ethical approval and consent to participate:

Our research was approved by the Ethics Committee of the First Affiliated Hospital of Chongqing Medical University. Number: (ID: 2016–178).

- # Consent for publication:

Due to the retrospective nature of the study, the need for informed consent was waived

- # Availability of data and materials:

The datasets used and the analysis during the current study are available from the corresponding author on reasonable request.

- # Competing interest:

The authors declare that they have no competing interests.

- # Funding:

No funding supports this research.

- # Authors’ contribution:

LF. Y and XY. Z collected the data together. H. Z contributed to the research design and quality control. LF. Y and H. Z were major contributors in writing the manuscript. J. Z, JB. L and ZX. W helped with discussion of this article and the checking of language. All the authors read and approved the final manuscript.

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Figures

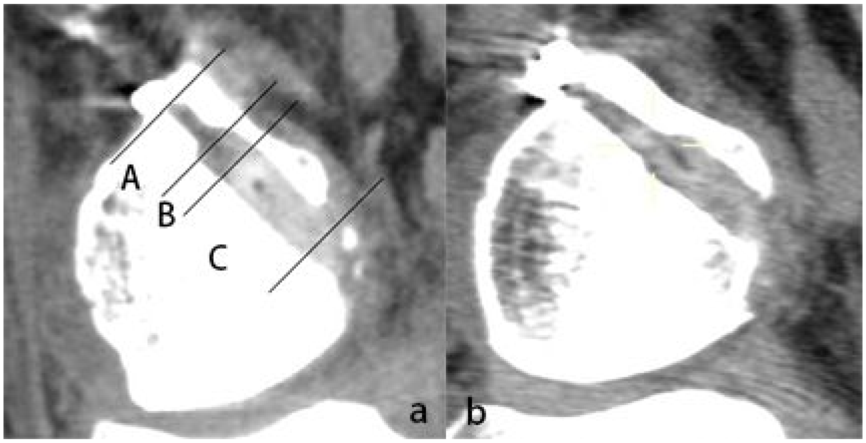

Figure 1

Postoperative computed tomography images (a) Fixed-length loop devices. Vertical to the longitudinal axial of the femoral tunnel, four parallel lines were made through the outer entrance of the tunnel, the end of the socket tunnel, the top of the graft tissue, and the central point of the inner entrance. The vertical distance between the parallel lines was measured as distance A (bone preservation), distance B (gap distance), distance C (graft inserted length), and socket length (add B and C). (b) Adjustable-length loop devices. The same methods were used for the measurements.

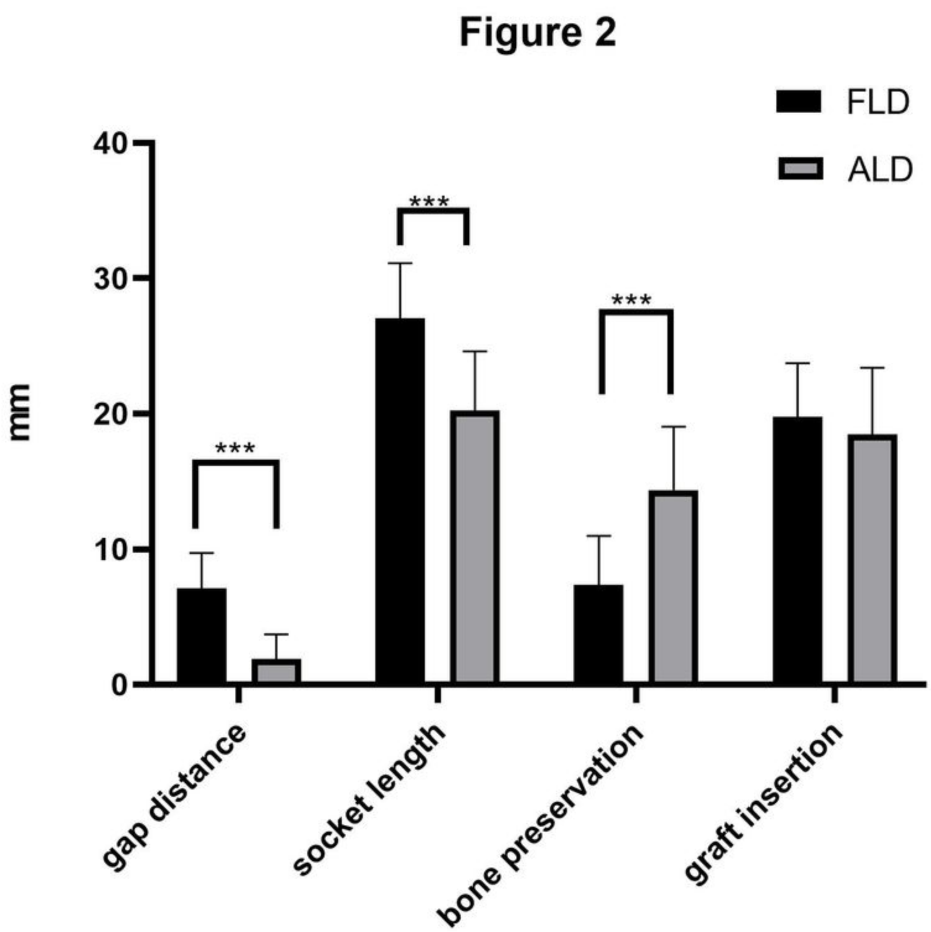

Figure 2

Differences between the two devices in mean distances for outcomes measured using computed tomography images

Supplementary Files

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- DATA.xlsx