Short Socket ACL Reconstruction Reduces Tunnel Widening While Preserving Graft Maturation and Achieving Comparable Clinical Outcomes Compared to Conventional Technique: A 2-Year Prospective Quantitative MRI Study

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INTRODUCTION: Tunnel widening following anterior cruciate ligament reconstruction (ACL-R) is associated with suboptimal graft-to-bone healing and increased complexity during revision procedures. To address these concerns, short socket ACL-R techniques utilizing all-inside approaches have gained popularity, with studies demonstrating comparable clinical outcomes to conventional techniques while offering potential advantages of preserved bone stock and reduced donor site morbidity. However, their biological healing characteristics and tunnel preservation effects remain unclear, particularly regarding sustained 2-year outcomes using quantitative MRI (qMRI) metrics. This prospective study investigated whether short femoral and tibial bone sockets during ACL-R result in sustained tunnel preservation, favorable graft maturation characteristics as assessed by qMRI, and maintained clinical outcomes compared to conventional full tunnel technique at 2-year follow-up. To our knowledge, this is the first prospective study to evaluate both clinical and qMRI-based biological healing outcomes of short socket ACL-R over a 2-year period.

METHODS:

Forty-four patients undergoing primary ACL-R with hamstring autografts between 2021 and 2024 were prospectively enrolled. The short socket group (n = 25) underwent all-inside ACL-R with retrograde drilling of femoral and tibial sockets to 7-10 mm and 10-15 mm depth, respectively, with suspensory fixation. The normal socket group (n = 19) received 15-20 mm femoral tunnel via anteromedial portal and full tibial tunnel using outside-in technique, with suspensory femoral fixation and interference screw tibial fixation. Groups were comparable in baseline characteristics including age (normal socket vs short socket: 35.6 vs 37.5 years), BMI (23.8 vs 24.5), and injury-related factors (Table 1). Clinical outcomes were assessed at 6, 12, and 24 months using KOOS, IKDC, ACL-RSI, and Marx Activity Scale. All patients underwent 3T MRI including T1ρ, T2 sequences. Manual segmentation of intra-articular grafts was performed. Bone tunnel cross-sectional area (CSA) was measured at 5 mm from aperture using 3D reconstruction from MRI CUBE sequences. The percentage of tunnel widening was determined by dividing the measured CSA by the initial CSA according to the diameter of tunnel or interference screw during surgery. Statistical analysis was performed using Student's t-test for continuous variables and Fisher's exact test for categorical variables, with significance set at $p < 0.05$.

RESULTS:

Of the 44 enrolled patients, all completed 6-month follow-up MRI (normal socket vs short socket: 19 vs 25). At 12 months, MRI data were available for 14 vs 18 patients (4 vs 1 dropouts). At 24 months, MRI was completed by 8 vs 9 patients (2 vs 1 dropouts). Some patients had not yet reached the 12- or 24-month timepoint at analysis. Dropouts were mostly due to relocation or pregnancy. Both groups showed clinical improvements over time (Fig. 1). At 6 months, KOOS and IKDC scores showed no significant differences between groups. At 12 months, the short socket group demonstrated superior outcomes with higher KOOS-QOL scores (62 vs 72, $p = 0.04$) and IKDC scores (77 vs 84, $p = 0.04$) compared to the normal socket group, while other KOOS subscales, ACL-RSI, and Marx scores showed no significant differences. At 24 months, all clinical outcome measures showed no significant differences between groups. Intra-articular graft T1ρ and T2 values showed no significant differences between groups at all time points, with both groups demonstrating decreasing trends over time (24 months: T1ρ 39.8 vs 38.6 ms; T2 26.5 vs 27.4 ms) (Fig. 2). Tunnel widening (% of original CSA) was significantly less in the short socket group at all timepoints (Fig. 3). Femoral tunnel: 6 months (154.3% vs 105.2%, $p=0.001$), 12 months (152.1% vs 99.4%, $p<0.001$), 24 months (136.3% vs 113.1%, $p=0.03$). Tibial tunnel: 6 months (145.6% vs 113.7%, $p=0.003$), 12 months (157.1% vs 117.7%, $p=0.002$), 24 months (178.7% vs 121.4%, $p=0.04$).

DISCUSSION AND CONCLUSION:

Short socket ACL-R achieved significantly reduced tunnel widening with equivalent clinical outcomes and comparable graft maturation compared to conventional technique at 2-year follow-up. Although quantitative MRI provides objective graft assessment, limitations include advanced imaging constraints requiring smaller cohorts, 24-month patient attrition, single-center design, mixed fixation techniques, and insufficient follow-up for long-term evaluation. Extended studies with larger cohorts are warranted to determine long-term clinical significance. In conclusion, short socket ACL-R provides effective tunnel preservation while maintaining clinical equivalence to conventional techniques.

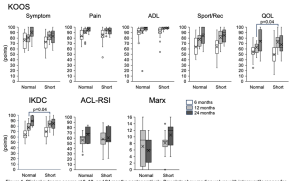

Figure 1. Clinical outcome scores at 6, 12, and 24 months postoperatively. Box plots show median values with interquartile ranges for KOOS subscales (Symptom, Pain, Activities of Daily Living [ADL], Sport/Recreation, and Quality of Life [QOL]), International Knee Documentation Committee (IKDC) subjective score, ACL Return to Sport after Injury (ACL-RSI) scale, and Marx Activity Scale comparing normal socket and short socket groups. Outliers are shown as individual points.

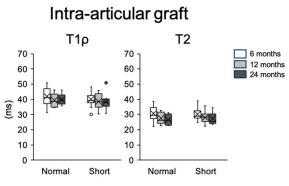

Figure 2. Figure 2. Intra-articular graft T1ρ and T2 relaxation times at 6, 12, and 24 months. Data presented as box plots with median and interquartile ranges. No significant differences observed between groups at any time point.

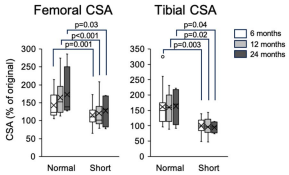

Figure 3. Tunnel cross-sectional area (CSA) measurements at 6, 12, and 24 months postoperatively. Box plots show median values with interquartile ranges for femoral and tibial tunnel CSA expressed as percentage of original tunnel diameter, comparing normal socket and short socket groups. Outliers are shown as individual points.

Table 1. Baseline characteristics of patients in the Normal socket and Short socket groups

	Normal socket (n = 19)	Short socket (n = 25)	*P* value
Lost to follow-up compared with last evaluation	6/19	2/25	
Age, y	35.6±8.3	37.5±9.1	.48
Sex			.51
Female	12 (63%)	19 (76%)	
Male	7 (37%)	6 (24%)	
Height, cm	171.0±11.1	168.7±10.5	.50
Weight, kg	69.7±10.5	70.2±11.3	.89
BMI	23.8±2.5	24.5±2.4	.32
Time from injury to surgery, mo	2.3±2.0	3.3±2.3	.16
Knee			.12
Right	5 (26%)	13 (52%)	
Left	14 (74%)	12 (48%)	
Lachman test			.68
2A	2 (12%)	4 (19%)	
2B	17 (88%)	21 (81%)	
Pivot shift test			.36
I	10 (53%)	9 (36%)	
II	9 (47%)	16 (64%)	
Medial Meniscus injuries	3 (16%)	3 (12%)	1.00
Partial meniscectomy	2	1	
Meniscal repair	2	2	
Lateral Meniscus injuries	4 (21%)	3 (12%)	1.00
Partial meniscectomy	1	2	
Meniscal repair	2	1	

Values are presented as mean ± standard deviation or number (%). P values calculated using Studentfs t-test for continuous variables and Fisher's exact test for categorical variables. Lost to follow-up represents patients who had not yet reached the respective follow-up timepoint at the time of analysis.