Studying effect of tunnel expansion on functional outcome in anterior cruciate ligament reconstruction using CT scan: A prospective study

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Abstract

Background: Tunnel expansion in anterior cruciate ligament reconstruction (ACL-R) is a well-accepted phenomenon, still its effect on functional outcome is little known.

Purpose: To study prospectively the effect of change in the tunnel volume as observed with computed tomography (CT) on functional outcome after ACL-R.

Materials and Methods: This study conducted for a follow up of 24 months of time period between June 26th 2017 to 31st December of 2019, after approval from ethical committee 31 patients with complete ACL tear with or without the meniscal injury were treated with single bundle arthroscopic reconstruction using hamstring tendon graft. With common post-operative rehabilitation protocol, all patients were followed up clinically and radiologically for two years. Tibial and femoral tunnel volume were measured and correlated with the clinical parameters. Radiological parameters were summarized as mean, standard deviation and proportions as applicable.

Results: Total number of 31 patients with the average age 27.13±5.89 and pre-operative lysholm score average of 64.26±8.93 were included in the study. At the end of 2years follow up of each patient, 32.2% and 35.5% of patients showed grade 1 anterior drawer and lachman test positive respectively and mean lysholm score averaged to be 86.58±5.32. Significant difference of tunnel volume noted at the end of 2 years with a 0.837 cm^3 and 0.545 cm^3 of tibial and femoral tunnel volume respectively.

Conclusion: Noted a significant expansion of both tibial and femoral tunnel volume postoperatively when compared to the intra-operative tunnel volume. Both the femoral and tibial tunnel volume showed negative correlation with the functional outcome.

Keywords: Anterior cruciate ligament, Tunnel volume, lysholm score, functional outcome

Introduction

Anterior cruciate ligament (ACL) tear is one of the common sports injuries and arthroscopic reconstruction is now a routine surgical procedure. Proper tibial and femoral tunnel placement is considered critical for the success of anterior cruciate ligament reconstruction (ACLR) surgery [17]. Bone tunnel enlargement is an early change in ACLR. Tunnel lysis or expansion may occur which complicates the graft placement and fixation. It may also complicate the revision surgery if required.

The highest percentage of change in femoral and tibial tunnel size occurs within the first 6 weeks after surgery, though, tunnel enlargement has been reported up to 2 years postoperatively. Biologic and mechanical factors play an important role in the enlargement of tunnel.

However effects of this tunnel widening on patients' functional recovery have not been widely documented in literature. Hence an attempt has been made to study the effects of changes in volumes femoral and tibial tunnels post-operatively on functional outcome after ACLR.

Methods

Thirty-one patients with ACL injury with or without associated meniscal injury who underwent ACLR were included in this prospective study. Patients with posterior cruciate ligament or collateral ligament injury, preexisting arthritis or skeletally immature patients were excluded from the study.

All patients underwent functional assessment as per lysholm scores. Hamstring graft was harvested through anteromedial incision and prepared in a standard fashion and final diameter and length of the prepared graft was measured. Femoral tunnel was drilled through trans portal Tanique. We used flip technique with Indian style Endo button ,intra operatively calculated the tunnel and graft length and noted for example in figure one patient intra operatively femoral tunnel length was 30 mm used Endo button used was 15 mm so we need drill of 25 mm of tunnel length where extra 10 mm required for Endo button to flip outside so intra operatively tunnel length was 25 mm and diameter was calculated highest size use to drill tunnel which is decided by graft sizer which is 9 mm, same way tibial tunnel length and highest size of drill used to make the tunnel were calculated which was decided by the graft sizer instrument and noted down ,later mathematically using the formula $\pi r^2 h$ both tunnel volumes are calculate and noted down in the registry.

The tibial tunnel was placed in line with the inner margin of the anterior horn of the lateral meniscus, just posterior to the center of the ACL footprint lying about 6 mm anterior to the posterior cruciate ligament and 2-3 mm anterior to the peak of the medial tibial spine. The intraoperative length and diameter of the femoral and tibial tunnels were noted.

Graft was fixed with endobutton suspensory device on femoral side and bioscrew on the tibial side. Meniscal injuries were suitably dealt when present with balancing or repair. All patients were rehabilitated with common written rehabilitation protocol.

Knee swelling was managed with rest, ice, non-steroidal anti-inflammatory drugs and partial weight bearing. Muscle strengthening exercises were started on the first postoperative day with isometric quadriceps contractions and progressed to active closed-chain exercises by 4-6 weeks postoperatively. Patients were allowed full weight-bearing three weeks postoperatively and returned to running after three months.

Tibial tunnel and femoral tunnel volume were calculated with highest size of drill and length of the tunnel was calculated with formula $\pi r^2 h$. At 24 months post operatively, CT scan with multiplanar reconstruction (MPR) sections was done in all patients. Where we can accurately measure the tunnel length with these sections by deleting the Endo button loop length or measuring only the drilled tunnel length Fig no.1 shows the measurement of the length of the femoral tunnel.

Fig no. 2 shows coronal axial section of femoral tunnel with its diameter. Fig no. 3 shows the length of the tibial tunnel in its axis. Fig no. 4 shows the measurement of the diameter of the tibial tunnel. Using these values tunnel volume is calculated. Functional assessment done and lysholm score documented. The final score was categorized into one of the four groups

(Excellent: 95-100, Good: 84-94, Fair: 65-83 and Poor: < 64).

Results

The average age of thirty-one patients was around 27.13± 5.89. The Statistical software namely, SPSS 18.0 and R environment ver.3.2.2 were used for the analysis of the data. A comparison of the differences between the groups was done using the student's t -test, with one-way analysis of variance for the continuous variables while the chi-square test was applied to compare differences among the categorical variables. A multivariate analysis of variance was used to study the effect of all the compounding variables. In all the tests, an alpha level of 0.05 was considered to be significant. Incidence of associated injuries such as ACL with meniscal injury was 48.4%. In the pre-op, lysholm score (baseline) ranged from 44-77. Post operatively mean lysholm score was 86.58+/-5.32.
Table 1 shows the assessment of the clinical stability test at presentation and two years follow up. We used a Lysholm score to assess functional outcome.
Table 2 with the lysholm score at the presentation and final follow up, pre-operatively most of the patients belongs to fair group, post operatively 80.6% of the patient showed statistically significant improvement in the lysholm score, grading which is showed in table 3.
We measured tunnel volume intra operatively and post operatively. Intra-operatively average tibial tunnel volume was 1.44±0.32, femoral tunnel volume was 1.33±0.29. We noted a significant expansion of both tibial and femoral tunnel volume postoperatively. Table 4 shows the statistically significant expansion of the tunnel volume. The values are plotted in the graph. Fig no. 5 bar diagram shows the depiction of the tibia tunnel volume expansion. Figure no 6 shows the bar diagram of intra and post-operative volume the femur tunnel. We also correlated the volume changes with the lysholm score with Pearson's correlation. Table 5 depicts the correlation of the lysholm score and changes in the volume. And the values are depicted in the scatter plot diagram in the figure no 7. Both the femoral and tibial tunnel volume showed negative correlation with the functional outcome here tibial tunnel expansion showed a statistically significant negative correlation with the functional outcome.

Fig 1: Femoral tunnel length

Fig 2: Femoral Diameter in the axial section

Fig 3: Tibial tunnel length

Fig 4: Diameter in axial section

Table 1: Assessment at baseline and 2 years of patients studied

Variables	Baseline	24 months	% difference	P value
Anterior drawer test				
Negative	0(0%)	21(67.7%)	67.7%	<0.001**
Positive	31(100%)	10(32.3%)	-67.7%	
Posterior drawer test				
Negative	0(0%)	31(100%)	100.0%	<0.001**
Positive	0(0%)	0(0%)	-100.0%	
Lachman test				
Negative	0(0%)	20(64.5%)	64.5%	<0.001**
Positive	31(100%)	11(35.5%)	-64.5%	
Pivot shift test				
Negative	0(0%)	31(100%)	100.0%	<0.001**
Positive	(0%)	0(0%)	(.0%)	

Chi-Square test/Fisher Exact test

Table 2: Assessment of LYSHOLM SCORE at baseline and 24months (student t test-paired)

LYSHSCO	Min-Max	Mean ± SD	difference	t value	P value
Baseline	46.00-77.00	64.26±8.93	-	-	-
24 months	76.00-95.00	86.58±5.32	-22.323	-12.143	<0.001**

P<0.001**, Significant, Paired proportion test, 80.6% improvement over 24 months

Table 3: Lysholm Score

Lysholm Score	Baseline	24 months	% difference
Poor	9(29%)	0(0%)	-29.0%
Fair	22(71%)	6(19.4%)	-51.6%
Good	0(0%)	21(67.7%)	67.7%
Excellent	0(0%)	4(12.9%)	12.9%
Total	31(100%)	31(100%)	-

Table 4: Difference of tibial and femoral tunnel volume

Variables	Min-Max	Mean ±SD	Difference from Intra-op	P value
TB VOL(cubic cm)				
Intra-op	1.07-2.28	1.44±0.32	-	-
24 months	1.47-3.84	2.28±0.64	0.837	<0.001**

FM vol(cubic cm)				
Intra-op	0.96-2.22	1.33±0.29	-	-
24 months	1.03-3.86	1.88±0.52	0.545	<0.001**

Student t test (Paired)

Table 5: Pearson correlation of volume with lysholm score

Pair	r value	P value
INTRA-OP		
LYSHOLMSCORE **vs.** TIBIAL volume (cubic cm)	-0.056	0.765
LYSHOLMSCORE **vs.** FEMORAL volume (cubic cm)	-0.133	0.476
24 MONTHS		
LYSHOLM SCORE **vs.** TIBIAL volume (cubic cm)	-0.579	0.001**
LYSHOLM SCORE **vs.** FEMORAL volume (cubic cm)	-0.378	0.036*

Discussion

Many studies have proved early tunnel expansion and its effect on the functional outcome. Various causes of this widening of the tunnels have been proposed. A possible explanation could be drill-related bone necrosis, which theoretically is less marked at the femoral site, as the femoral bone-reamer contact area is irrigated with arthroscopic fluid in contrast to the tibial site. Also, the femoral condylar bone has a higher density than proximal tibial bone, which could make femoral bone more resistant to tunnel enlargement after ACL reconstruction. Furthermore, tibial tunnel enlargement may be related to the biomechanical stress caused by the interference screw, which theoretically may be more distinct in smaller bone-tendon interfaces. However, a multifactorial etiology of tunnel enlargement must be assumed.

We studied the tunnel volume post operatively at 2 years and compared it with the largest size drilled during surgery and we found significant expansion of the tunnels. The amount of change of tunnel volume was more on the tibial side compared to femoral side in our study.

Tunnel expansion is due to loss of bone, which is caused by an imbalance between osteoclastic resorption and osteoblastic formation. One of the many proposed biologic mechanisms of tunnel expansion after ACLR is a deleterious effect on bone of intra-articular cytokine release after ACL reconstruction. It is known that inflammatory mediators such as tumor necrosis factor-affect osteoclast activity. Using a rabbit ACLR model, the authors found increased osteoclastic activity at sites with increased graft tunnel motion. This finding could be due to mechanical factors such as stress deprivation or biologic factors such as increased cytokine production. Furthermore, it is known that persistent elevations in cytokine levels occur in ACL-injured knees [8].

The enlargement occurs particularly within the first 6 weeks after operation and no further increase in bone tunnel diameter was observed thereafter up to 2-3 years after operation [9].

The majority of studies regarding tunnel enlargement after ACL reconstruction surgery have focused on the correlation between bone tunnel enlargement and surgical technique, graft choice, fixation method, and aggressiveness of rehabilitation. Biologic factors like synovial fluid-derived cytokines and inflammatory mediators, quality of patients bone, the graft choice, bone necrosis from drilling [2, 6, 8, 19, 23, 24, 26]. The excessive graft tunnel motion in early post-operative day or deprivation of local stress are considered as mechanical factors, graft position, tension, aggressive physiotherapy also contribute to the tunnel widening and many studies have proved early enlargement of tunnel [3, 11, 20, 25].

A biologic response to bioabsorbable screws leading to sequelae from an inflammatory response and osteolysis has been reported [7, 18]. However, a large body of literature has demonstrated satisfactory clinical outcomes and comparable results with poly-L-lactic acidbased screws compared with metal screws [4, 9, 13, 14, 16].

In daily practice, measuring bone tunnel diameter has been subjective with the use of conventional radiographs. They are widely used as the primary modality, but they cannot show the bone tunnel consistently because they only provide two-dimensional images. Although CT imaging has been regarded as a reliable imaging modality for evaluating ACL bone tunnels, as proven by superior intra-and inter observer agreement compared with radiographs, MPR for the axis of each bone tunnel is mandatory for exact measurement. Alexander weber *et al*. [1] showed in study a significant expansion and concluded that Tunnel expansion after ACLR occurs early and primarily at the tunnel apertures. He opined expansion may not affect clinical outcome. Younger age, male sex, and delay from injury to ACLR may be potential risks for enlargement. We have used MPR sections on CT images taken at 24 months post-operatively for accurately measuring the increase in tunnel volumes.
Soo Jeong Yoon *et al*. [24] compared correlation between bone tunnel diameter after anterior cruciate ligament (ACL) reconstruction measured by computed tomography (CT) using multiplanar reconstruction and stability or clinical scores. The expansion in diameter did not correlate with the clinical outcome in their study.
However in the present study, we found that both femoral and tibial tunnel volume increased significantly at 24 moths postoperatively and this tunnel widening had negative correlation with functional outcome as measured with pre and post-operative lysholm scores. This needs to be confirmed by studies with larger pool of patients as also the effects of this tunnel expansion on revision ACLR.

Conclusion

Tunnel widening is an inevitable consequence after anterior cruciate ligament reconstruction using hamstring graft on both femoral and tibial side. This change in tunnel volume may have negative effect on the functional recovery of the patients, in our study more than femoral tunnel tibial tunnel expansion has a statistically significant effect on functional outcome.

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