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Original Research Article.

MRI Correlation with Functional Scores Following Anterior Cruciate Ligament Reconstruction Surgery

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ABSTRACT

Introduction: An anterior cruciate ligament tear is the most common ligament tear in the knee joint. Anterior cruciate ligament reconstruction is an accepted intervention for non-coping anterior cruciate ligament injured subjects. The torn ligament is removed from the knee before the graft is inserted in an arthroscopic procedure. Functional performance tests for assessing knee status is clearly evident in the literature, with each task seen to place different demands on the knee joint under controlled clinical conditions. MRI is able to asses graft signal intensity in a non-invasive way. The intra-articular graft undergoes a maturation and remodelling process lasting even beyond 24 months due to synovial proliferation, vascularization, and "neoligamentization" of the graft.

Materials & Methods: We did a descriptive cross-sectional study of 30 patients with 1.5-T magnetic resonance imaging of the knee who had undergone anterior cruciate ligament reconstruction six months after surgery. The amount of signal intensity changes in graft classified according to cross-sectional area in axial sections as <25%, 25-50%, and >50 %. Patients were subjected to functional testing, post-surgery.

Results: Of 30 cases examined increased intrasubstance graft signal intensity was found in 73.3% (22 of 30) of patients on T2-weighted and intermediate weighted MR images. There was an insignificant association between graft signal intensity and functional tests.

Conclusion: Graft signal intensity on can be seen after ACL reconstruction and not necessarily correlate with limitations in patients after ACL reconstruction surgery due to the process of remodeling.

Keywords: Anterior Cruciate Ligament Reconstruction Graft, Functional Performance Tests, Signal Intensity.

Abbreviations:

ACL: Anterior Cruciate Ligament; **IKDC:** International Knee Documentation Committee; **LSI:** Limb Symmetry Index; **MRI:** Magnetic Resonance Imaging.

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INTRODUCTION

The anterior cruciate ligament is the most frequently injured ligament in the knee[1] and it is the knee joint's primary restraint on the anterior translation of the tibia in regard to the femur and a secondary restraint on internal rotation of the tibia. Three major types of ACL injuries are described, Direct Contact: 30% of the cases, Indirect Contact and Non-Contact: 70% of the cases.[2]

Reconstruction of anterior cruciate ligament prevents further complications in the form of meniscal and cartilage lesions that could occur in complete anterior cruciate ligament tear.[3,4]

The reconstructions of anterior cruciate ligament performed arthroscopically and with the utilization of autografts or allograft constructs.[5,6] In our study reconstruction was done by semimembranosus and semitendinosus muscle tendons. MR can demonstrate an intact ACL reconstruction.[7] Postoperative magnetic resonance (MR) imaging of the knee following surgical intervention serves an important role in the diagnostic evaluation of patients with recurrent or residual symptoms following surgical intervention.[8] Synovial proliferation, vascularization, and "neoligamentization graft constructs cause increased intrasubstance signal intensity and complete resolution graft signal

changes take place by 18–24 months after surgery.[8] The functional tests relate to their ability in providing an objective indication of dynamic lower-extremity performance under simulated conditions, designed to mimic the greater demands imposed on the knee in the everyday environment.[9,10]

Functional performance tests for assessing knee status is clearly evident in the literature, with each task seen to place different demands on the knee joint under controlled clinical conditions.[11-18] Single-limb tasks, such as hopping tests, offer considerable benefits compared with 2-legged tasks because they provide between-limb, within-subject comparisons without the need to rely on population-specific normative data.

Hop tests are reliable and valid performance-based outcome measure for patients undergoing rehabilitation following ACL reconstruction surgery.[11]

To date, no other study demonstrated an association between anterior cruciate ligament reconstruction graft signal intensity and functional tests.

PURPOSE OF STUDY

We conducted a study to assess the intrasubstance signal intensity within ACL grafts and to compare it with functional test i.e. Hop tests (Single hop for distance, 6-meter timed hop, Triple hop for distance, Crossover hop for distance) six month after reconstruction surgery.

MATERIALS AND METHODS

A descriptive cross-sectional study done with the help of 1.5-T magnetic resonance imaging of the knee was done in 30 patients who had undergone primary anterior cruciate ligament reconstruction surgery six months back patients were identified from clinical record. All the subjects were between ages 15 to 60 years were included. Out of 30 patients, 3 were female and 27 male. MR imaging was performed with a 1.5 HD XT 16 channel 1.5T GE MRI machine by using a dedicated eight-channel extremity send-receive knee coil, with patients in a supine position and with a fully extended knee. Patients with concomitant ligamentous injury, bilateral lower limb involvement, irreparable meniscal damage, full thickness articular cartilage damage, patients with claustrophobia and patients with metal implants and cardiac pacemaker were excluded from the study. We took permission of institute ethical Committee prior to initiation of the study. The patient was explained about MR Imaging and clinical examination and informed consent taken prior to assessment.

Following MRI sequences were done:

1. Sagittal intermediate-weighted (repetition time msec/echo time msec, 2000/21.3) (slice thickness -4 mm).
2. Coronal intermediate-weighted (repetition time msec/echo time msec, 5117/33.9) (slice thickness -4 mm).
3. Axial T2-weighted (repetition time msec /echo time msec 3500/70) (slice thickness -4 mm).

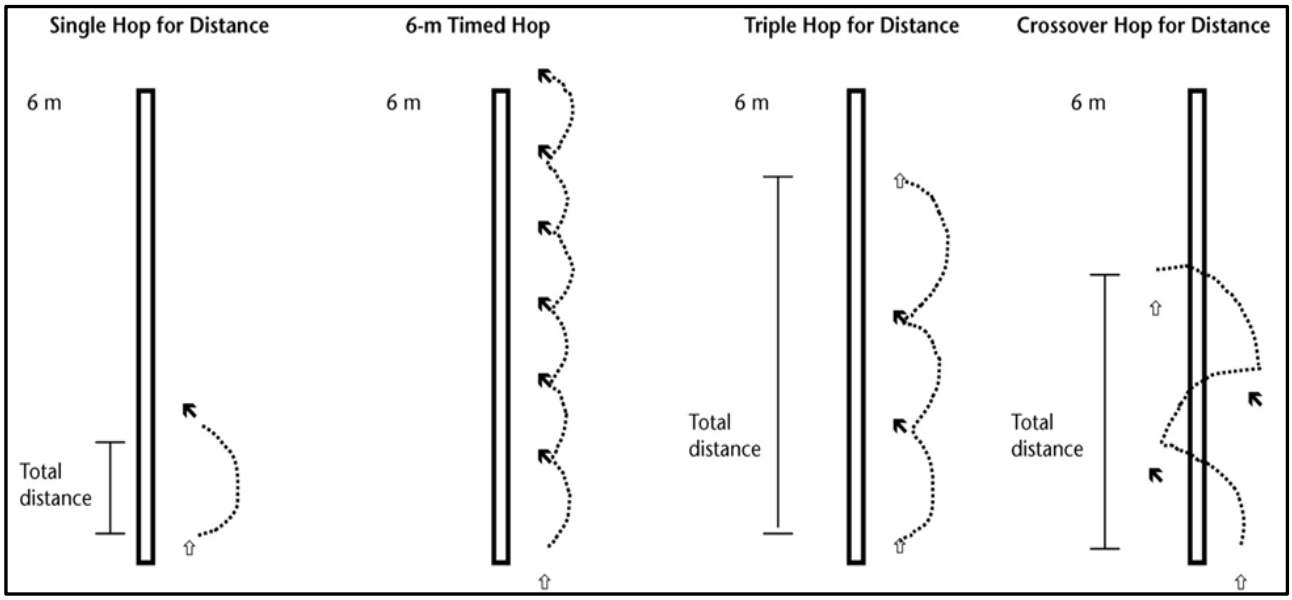

Figure 1: Diagrammatic representation of the series of 4 hop tests: single hop for distance, 6-m timed hop, triple hop for distance, and crossover hop for distance[12]

Functional Tests

Hop tests (Single hop for distance, 6-m timed hop, Triple hop for distance, Crossover hop for distance). (Figure 1)

MR imaging findings that were evaluated as follows

Signal intensity of the of the anterior cruciate ligament reconstruction graft was analyzed on intermediate-weighted and T2-weighted images in axial, coronal and sagittal planes as present (an increase of signal intensity within the substance of the graft) or absent (no increased signal intensity change).

All these scans were reported by the single radiologist to eliminate subject bias. The reader was blinded to findings functional score measurement at MR imaging evaluation.

Method of Scoring

For each hop test, the subjects performed one practice trial for each limb, followed by 2 measured trials. For each set of tests, the subjects were instructed to begin with the non-operative limb. To minimize fatigue, a rest period was offered between types of hop tests (up to 2 minutes) and between individual hop test trials if needed (typically less than 30 seconds was sufficient). For the hops for distance (single, triple, and crossover) to be deemed successful, the landing maintained for 2 seconds. An unsuccessful hop was classified by any of the following: touching down of the contralateral lower extremity, touching down of either upper extremity, loss of balance, or an additional hop on landing.

Single Hop

Subjects were instructed to stand on one leg and single hops as far as possible, landing on the same leg. The distance for hops was recorded.

Timed 6-meter Hop

Subjects were instructed to perform one-legged hops in series for a distance of 6-meter standard stopwatch was used to record the time. The stopwatch was started when a subject's heel was lifted from the starting position and stopped the moment when the tested foot passes the finish line.

Triple Hop for Distance

Subjects were instructed to stand on one leg and perform 3 consecutive hops as far as possible, landing on the same leg. The total distance for 3 consecutive hops was recorded.

Crossover Hop for Distance

The subjects with a hop forward 3 times while alternately crossing over a marking. The total distance hopped forward was recorded.

Statistical Analysis

Data were analyzed using SPSS version 21.0(Statistical Package for social sciences, Armonk, NY USA). The main outcomes for analysis were the number and proportion of patients who had undergone anterior cruciate ligament reconstruction surgery. The associations of radiological findings i.e. intrasubsatnce signal intensities with the functional score for categorical and continuous variables were obtained by using the Chi-square test and Unpaired t-test/ Paired t test respectively.

All p values were two-tailed and significant when values were less than 0.05.

Table 1: Comparison of single hop for distance, 6 meters timed hop, triple hop for distance and crossover hop for distance.[preoperative (assumed) vs. postoperative]

S. No.		Single hop for distance	Mean limb symmetry index of Single hop for distance	6 meter timed hop	Mean limb symmetry index of 6m timed hop	triple hop for distance	Mean limb symmetry index of triple hop for distance	Crossover hop for distance	Mean limb symmetry index of Cross over hop for distance
1	Operative limb	71± 42.9	62.83± 21.51	11.57± 12.5	64.13± 24.48	178.5± 87.3	61.70± 24.00	334.6± 209.2	82.76± 23.84
2	Non operative limb	108.87± 50.9	100	5.7± 2.13	100	300.4± 114.6	100	409.8± 208	100

Table 2: Frequency and percentage of intrasubstance signal intensity within an anterior cruciate ligament reconstruction graft.

S. No.	Signal intensity	Frequency	Percentage
1	Absent	08	26.7
2	Present	22	73.3
	Total	30	

Table 3: Comparison of single hop for distance, 6 meters timed hop, triple hop for distance and crossover hop for distance with signal intensity

S. No.	Signal intensity	p-values*			
		Single hop for distance	6 meter timed hop	Triple hop for distance	Crossover hop for distance
1	Absent	0. 807	0.509	0.829	0.372
2	Present	0.811	0.397	0.813	0.345

All p values were two-tailed and significant when values were less than 0.05.

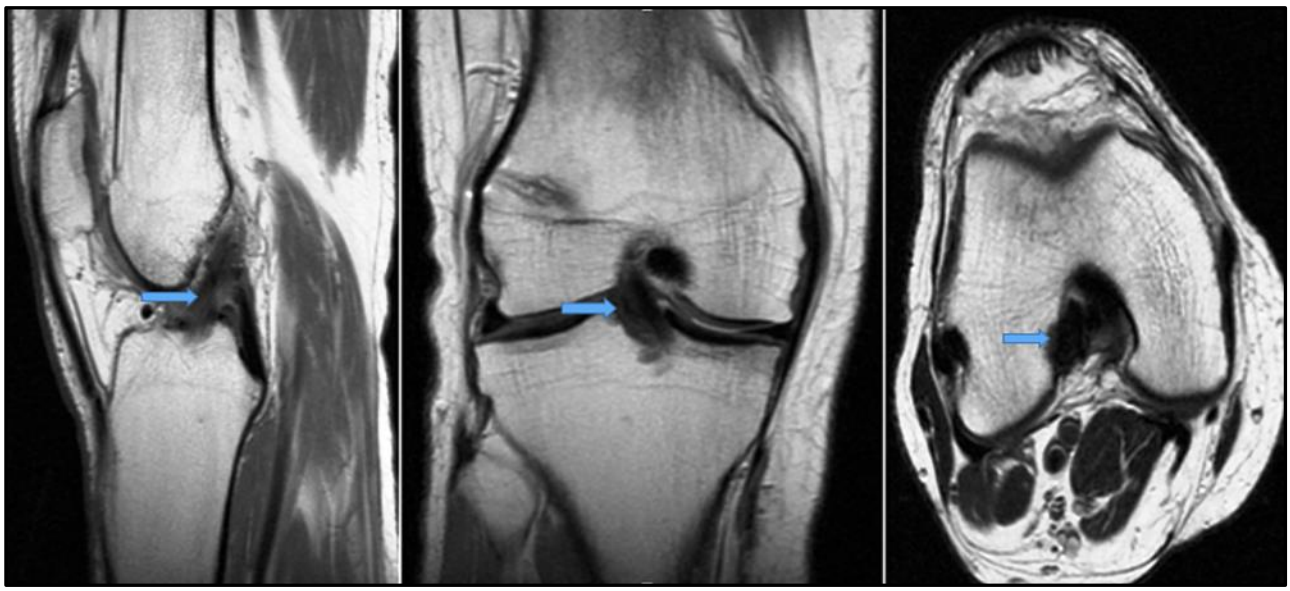

Figure 1: Sagittal intermediate-weighted, Coronal intermediate-weighted and axial T2-weighted MR Images, MR Image shows normal signal intensity within the ACL reconstruction graft(blue arrow).

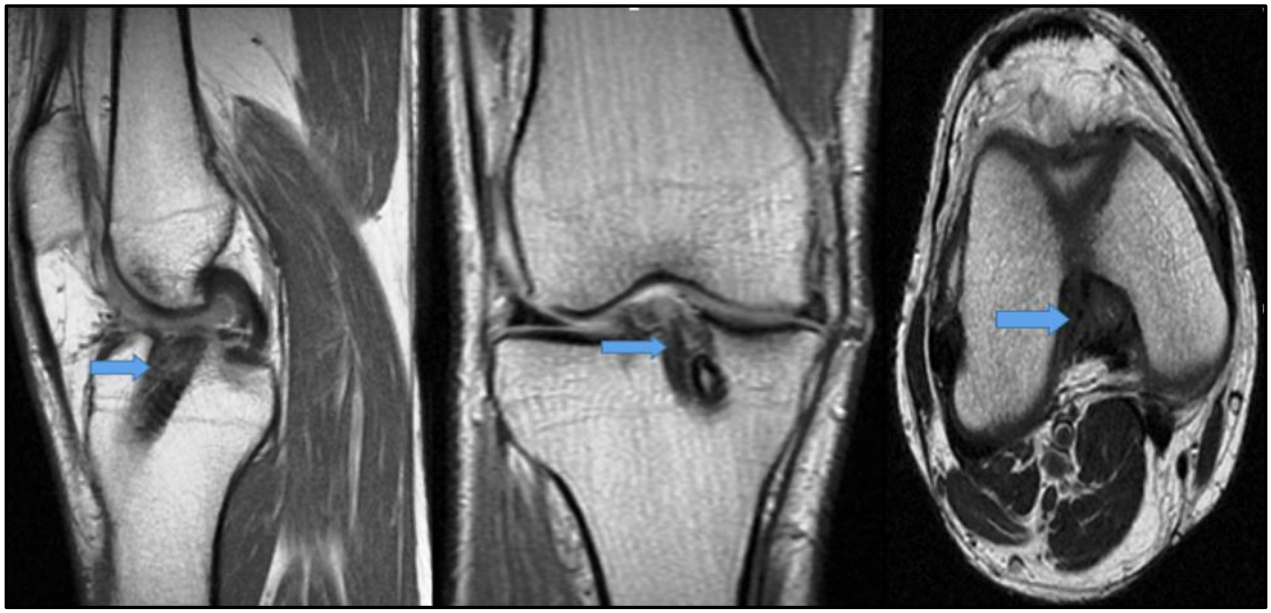

Figure 2: Sagittal intermediate-weighted, Coronal intermediate-weighted and axial T2-weighted MR Images, MR Image shows increased signal intensity within the ACL reconstruction graft(blue arrow).

RESULTS

In our study, a maximum number of patients between the age group of 15-30 years and 30-45 years 14/30(46.7%) in each group. Mean age of the study population was 32.07 years and male outnumbered female i.e. 90% male and 10% female observed in the study. We found that a maximum number of patients had knee injury due to fall from height 14(46.7%) and 12(40%) patients due to road traffic accident followed by trauma while working 2(6.7%), trauma while playing 01(3.33%) and twisting injury 01(3.33%). On mean comparison of single hop for distance, 6 meters timed hop, triple hop for distance and crossover hop for distance among non-operative limb and operative limb. We found that mean changes in the single hop for distance on the operative limb were (71±42.9), (11.57±12.5) (178.5±87.3) and (334.6±209.2) respectively. On comparison of normal contralateral limb symmetry index (LSI) with postoperative overall limb symmetry index, mean LSI of single hop for distance was 62.83±21.51,6 meter timed hop was 64.13±24.48, triple hop for distance was 61.70±24.00 and crossover hop was 82.76±23.84. (Table 1) Statistically, there is a significant difference ($P<0.05$) changes on the operative and nonoperative limb. Out of 30 patients, intrasubstance signal intensity was present within anterior cruciate ligament reconstruction graft, in 22 (73.33%) patients and intrasubstance signal intensity was absent within graft in 8 (26.7%) patients. (Table 2)

On comparison of signal intensity within anterior cruciate ligament reconstruction graft and Hop tests (Single hop for distance, 6-meters timed hop, Triple hop for distance, Crossover hop for distance) there was no significant ($p<0.05$) association between the presence of signal intensity and cross over hop for tests. (Table 3)

DISCUSSION

Different studies have shown that this 4 steps of maturation of graft and remodelling of graft lasts at least 4 to 6 months however it is possible to define the end of this phase because some changes occur even years after the reconstruction these changes can be demonstrated through an MRI[11] so we did our study 6 months after reconstruction surgery. There are subtle alterations in the collagen structure of the graft caused by instrumentation or mechanical stress that lead to focal increased ACL graft signal intensity on intermediate-weighted imaging. But on intermediate weighted imaging with shorter echo times focal increased signal intensity can be seen in tendons and ligaments because of variations in the density of the fiber bundles and the mobility of intrasubstance protons.[12] So we included T2 weighted imaging in our MR study protocol to delineate signal characteristics and integrity of reconstruction grafts.

In this descriptive cross-sectional study, we correlated signal intensity changes in anterior cruciate ligament reconstruction graft 6 months after surgery with functional score i.e. Hop tests (Single hop for distance, 6-meters timed hop, Triple hop for distance, Crossover hop for distance).

Earlier the cause of increased signal intensity in graft after surgery was unclear and it was assumed that increased intrasubstance signal intensity within graft is secondary to partial tear or impingement but now it is proven fact that intrasubstance signal intensity within graft is secondary to the process of maturation and remodeling of graft process.

In our study, it was observed that on a comparison of signal intensity within anterior cruciate ligament reconstruction graft with single hop for distance, 6 meters timed hop, triple hop for distance and cross over hop for distance there was a statistically insignificant association between the presence of signal intensity and single hop for distance. (Table 3)

LIMITATIONS

- We do not have any histopathological correlation with signal intensity changes so the exact cause of signal intensity could not be evaluated.
- Selection bias was there in the study as we have patients without any clinical symptoms.
- We do not have an equal number of patients in each group so signal intensity changes in each group could not be assessed separately.

CONCLUSION

MRI in the post-operative period detects postoperative changes in the form of the abnormal signal before its development. The functional tests showed different levels of imposed demands on the knee that could be used to assess functional recovery and readiness to resume work also. There is an insignificant correlation between intrasubsatnce signal intensity on MRI within anterior cruciate ligament reconstruction graft among three-fourths of patients showing increased signal intensity and functional scores.

With the increasing number of patients undergoing ACL reconstruction, it is important to be aware of the normal process of remodeling and maturation of graft and signal intensity changes during that process.

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