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Original Research Article

Prospective Study of Assessment of Proprioception Recovery Post Anatomical Anterior Cruciate Ligament Reconstruction with Remnant Retention

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Conflict of interest: Nil

Abstract

Background: Most of proprioception receptors of anterior cruciate ligament (ACL) for somatosensory reflex arc are present in tibial footprint. These receptors start disappearing after tear and degenerate by the end of a year. Retaining these receptors can help in early rehabilitation, graft ligamentization and reducing postoperative graft re-ruptures.

Objectives: To evaluate proprioception post ACL reconstruction between remnant retaining and remnant non retaining group by Lysholm knee score and clinical propriception assessment.

Methods: Participants between age 15-45 years within 6 months of ACL injury presented to our hospital between January 2021 to December 2021 were randomised and divided into two groups of remnant retaining (RR) and non-Remnant retaining surgery (NRR), were evaluated by joint position sense weight bearing (WB) and non-weight bearing (NWB) tests, followed by functional scoring with Lysholm knee score at 6weeks, 3 months, 6 months, 1 year and 2 years.

Result: 31 patients (M-18, F-13) were enrolled in RR (n-17) and NRR (n-14) depending upon surgical technique with mean age 34.1±7.6 years and 32.2±4.8 years respectively. Preoperative mean scores were 53±4.4 and 52±5.7 in each group. Mean of preoperative NWB test were 42±2.7 (RR) and 40.7±3 (NRR) respectively. Mean score of the preoperative WB test were 44.3±3.3 (RR) and 44±3.3 (NRR) respectively. At 6 weeks, RR group had score 63±3.4, NWB 40.4±2.8, WB 42.3±3. NRR group had similar picture (Score 66±2.8, NWB 42.5±2.4, and WB 46.3±2.6). There was significant difference in score and proprioception test between groups at the end of 6 months and thereafter till 2 years. In RR group, numbers were following (score- 85±7, NWB -33±3, WB-35±3.7) as compared to NRR group (score 73±4, NWB -39±3, WB-41±3.4). Patients of RR group were followed till end of 2 years had mean score 98.

Conclusion: Remnant retaining anatomical ACL reconstruction using hamstring graft have better proprioception recovery compared to non-remnant retaining group in short period of time which can avoid serious complication post-surgery like re-rupture of graft due to frequent falls.

Keywords: Remnant Retaining Anterior Cruciate Ligament Reconstruction, Proprioception, Tibia Remnant Sparing Method.

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Introduction

Anterior Cruciate ligament (ACL) injury is most common sports related injury [1-5]. ACL reconstruction is the definitive treatment. Goal of treatment is to return to pre-injury activity level in young patients. In past decades, main focus was on stable fixation and early rehabilitation of patient. However difficulty lies in achieving pre-injury activities in high demanding young patients [5]. Proprioception recovery reduces chance of re-tear in ACL reconstruction patients [2,5]. ACL deficient knee are 30-40 times more prone to injury [6]. These receptors provide necessary afferent information to CNS for processing and relay to muscle, tendons, ligaments and skin around the joint to balance the body [4,5]. Histological, it is proven that ACL stump has mechanoreceptors [1-4]. Purpose of our study is to evaluate proprioception recovery post ACL reconstruction in Remnant retaining group as compared to Non-remnant retaining group. Our hypothesis is Remnant retaining ACL reconstruction patients will have better functional outcome, early proprioception recovery and early return to pre-injury level activities than patients underwent Non remnant retaining ACL reconstruction.

Material and Methods

Population: Patients with ACL injury who presented in our hospital during November 2020 to April 2021 were included. Patients were divided into two groups Remnant retaining (RR) and Non-Remnant retaining (NRR) ACL reconstruction. Randomization was done with coin flipping method by other than operating surgeon to avoid bias. All cases were operated by same team. Human Ethical Committee clearance was obtained from the institute.

Inclusion and exclusion criteria: Patients were included 1) Age 15-45 yrs, 2) isolated ACL injury with intact tibia footprint attachment, 3) contra-lateral normal knee, 4) Injury within 6 months. Exclusion criteria were: 1) previous H/o knee surgery 2) associated neurovascular deficit 3) injury associated with fractures and poly-trauma 4) h/o autoimmune disorder.

Study design –It is prospective study design which compare two groups over a follow-up period of 2 years. Procedure: Patient diagnosed with isolated ACL injury with informed consent, pre-anaesthesia fitness underwent arthroscopy knee with anatomical ACL reconstruction with quadruple hamstring graft by Remnant retaining and non-remnant retaining method. Under combined spinal and epidural anaesthesia, tourniquet control, using standard anterolateral and far medial portal was done. Initially diagnostic arthroscopy was done. Hamstring graft was harvested after confirming MRI findings. (Fig: 1, 2) – Tibia ACL remnant identified and protected. Tunnels were made by Transportal technique. While making tibia tunnel, remnant protected with intent of retaining more than one third of footprint. Amount of remnant was measured with use of 5 mm probe before trimming of remnant. There is always some damage to tibia remnant while making tunnel. Shaver with suction was used to just remove debris in the joint around tunnels and loose ligament tissue to avoid future Cyclops lesion and graft impingement around tunnels. Depending upon the size of remnant and notch impingement, trimming of remnant can be done. In our study, in 2 cases, where notch was impinging against ligament even after minimal trimming of remnant, minimal notchplasty was done with an electronic burr to avoid impingement and future extension loss.

Non Remnant retaining – Shaver was used to remove tibial footprint completely to expose underlying bone with petechial spots and tunnels were made Fig: 3, 4). In all cases,

on table graft tensioning was done. Graft diameter was more than 7 mm in all the cases. Graft fixation was done with variable loop endo-button on femur side. Knee cycling was done 20 times to remove the slack. Tibial fixation was done with headless interference screw. Transosseous secondary fixation of tibial graft suture ends was done in all the cases. Postoperative management - Pain was managed with epidural infusion till 24hrs after surgery. Patient was mobilized with full weight bearing with walker support and knee brace.

Rehabilitation protocol – Supervised physiotherapy, as per protocol, was started (Table: 1). Clinical and Functional assessment – Clinical assessment with Lachman and anterior drawer test was done preoperatively, intraoperatively and postoperatively at 6weeks, 3, 6 months, 1 year and 2 years respectively. The Lysholm score was used to evaluate the functional outcome. Inference includes 91 to 100 (excellent); 84 to 90 (good); 65 to 83 (fair); and 64 or less (poor). Measurement of the Lysholm score was done preoperatively and postoperatively at 6 weeks, 3 months, 6 months, 1 year and 2 years.

Proprioceptive assessment – Joint Position sense assessment was done with Weight bearing and Non weight bearing method, as described in literature [7]. In Non weight bearing method, patients were blind folded and in lateral decubitus position with affected limb kept upside (Fig: 3, 4). Patient was instructed regarding procedure.

Bony landmarks of Greater trochanter, lateral knee joint line and lateral malleolus were marked. Goniometer was fixed to lateral side of leg with sticking tape firmly. Affected knee was flexed passively by examiner till preset angle of 30 degree and kept for 5 seconds. Patient was told to remember the position. Later, limb brought to the initial position. Now patient was told to bring the limb to similar position actively. Angle discrepancy was measured. Three sets were done and mean was calculated to remove any error. In weight bearing method, with eyes open, patient guided to bend till 30 degree actively in single leg stance and remember the position. After taking rest for few seconds, patient was advised to flex knee again till 30 degree without any guidance. Angles were measured in three sets again to remove any error. It was done at 6 weeks, 3 months, 6 months, 1 year and 2 years postoperatively. Single leg hop test was performed on each patient at 6 months and thereafter.

Statistical analysis: IBM SPSS version 29 was used to analyze whole data using T test to compare means of quantitative data. Pearson's correlation was used to compare qualitative and quantitative data. Demographic data was evaluated with means and standard deviation. P value <0.05 was considered significant.

Results

31(Male-18, Female-13) patients with isolated ACL injury were subdivided into RR (n-17) and NRR (n-14) group after undergoing ACL reconstruction by two different techniques. Mean time interval between injury to surgery in RR and NRR group was 11±6 and 10±5 weeks respectively (Table: 2). At 6 weeks, there was almost similar pictures on comparing functional score, NWB and WB tests between two groups (RR score -63±3.4, NWB-40.4±2.8, WB- 42.3±3; NRR score -66±2.8, NWB-42.5±2.4, WB-46.3±2.6). There was significant difference with increasing correlation at 3 months and 2 years between our study groups (Table: 3, 4 and 5). RR group is having better outcome as per functional score and proprioception assessment at end of 2 years. There was significant negative correlation between variables like Lysholm Score, NWB and WB

test at end of 2 year follow up (Table: 6). There is negative correlation between time interval and WB test at end of two years but not significant (-0.206, p –0.266).

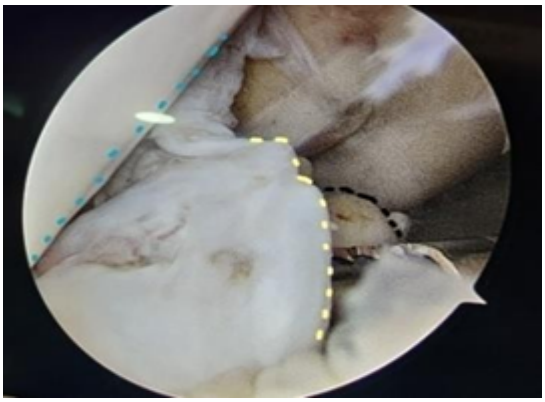

Figure 1: Arthroscopic view of Knee showing Left to right lateral femoral condyle, medial side in blue, middle yellow color of tibial remnant and medial tibial spine visualized after trimming remnant to the right.

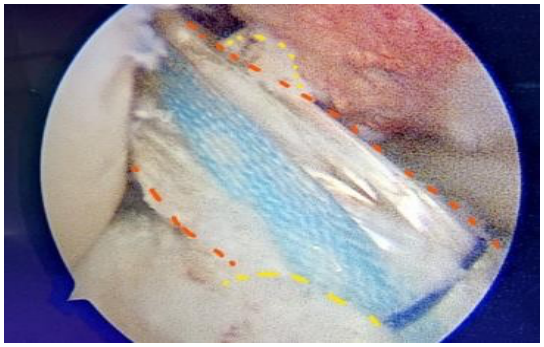

Figure 2: Arthroscopic view of Knee showing Left to right tibial remnant in yellow, middle red newly reconstructed taut graft through remnant and remnant in yellow dotted line to the right.

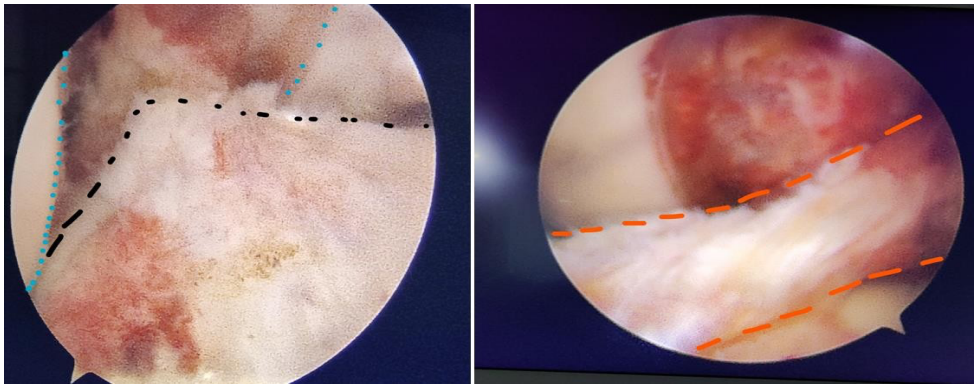

Figure 3: (Left) Arthroscopic view of ACL reconstruction by NRR method – black dotted line is medial tibial spine with petechial spots after shaving remnant completely.
Figure 4: (Right) Arthroscopic view of Reconstructed ACL without visible remnant in red dotted line.

Figure 5, 6 (Up and Down): NWB test, first passive movement by examiner in preset angle and followed by active movement by patient to match preset angle respectively.

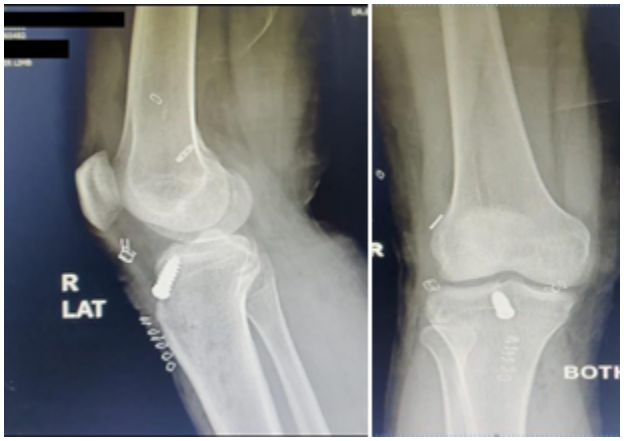

Figure 7, 8: X-ray Right Knee AP and Lateral view showing Anterior placement of tibial tunnel leading to loss of terminal extensionin patient.

Table 1: Post ACL reconstruction rehabilitation protocol

Headings	Exercises	Milestones
0-3 days (In-patient)	1) Closed knee Kinetic chain exercises (CKC) 2) Knee ROM 0-90 degree 3) Ankle ROM 4) isometric quadriceps, glutei, hamstring stetching exercises, Staight leg raising.	1) Independent mobilizing when discharging the patient. 2) knee ROM till 90 degrees. 3) swelling reduction management
0-2 weeks	Additional to 0-3 days 1) CKC 2) Knee ROM 0-120 degree 3) Static cycling with least resistance.	1) Knee ROM 0-120 degree 2) Full weight bearing. 3) minimal effusion. 4) full isometric quadriceps contraction without any extensor lag
2-6 weeks	Addition to early exercises 1) Progressive increase in resistance training with therabands 2) weights etc for muscle strengthening. 3) Proprioceptive training with balancing platform with eye open 4) Core stability exercises	achieving full range of knee movement 1) Minimal joint effusion. 2) Unilateral CKC squat with knee valgus control. 3) Step up with knee valgus control. 4) Single leg stance eyes open
6-12 weeks	Addition to early exercises 1) Rowing machine 2) Road cycling 3) Proprioception training	1) Bilateral equal muscle strength. 2) Bilateral equal Single leg stance
12 weeks – 2 year	1) Jogging with progessing to change of direction and rotation. 2) Agility training. 3) Introduction of sports specific and occupation specific rehabilitation	1) Good proprioception. 2) Miltestones based on type of sports activity. 3) Single leg hop test till 3-4 steps

Table 2: Demographic data comparison between RR and NRR group

Demographic data	RR Group	NRR Group	Total
Age(yrs)	34.1±7.6	32.2±4.8	
Sex (N, %)	M-10(59) F-7(41)	M-8(57) F-6(43)	M-18 F-13
Side (N, %)	L-10(59) R-7(41)	L-7(50) R-7(50)	L-17 R-14
Time interval between injury and surgery(weeks)	11±6	10±5	

Table 3: Means of Lysholm Score comparison between RR and NRR group at before surgery, 6weeks, 3 and 6 months, 1 year and 2 years.

Lysholm Score (Mean±SD)	Before surgery	6 weeks	3months	6 months	1 year	2 years
RR	53±4.4	63±3.4	74±6.1	85±7	93±5	94±3.5
NRR	52±5.7	66±2.8	69±3.8	73±4	86±7	90±6
P value	0.74	0.035	0.031	0.01	0.01	0.01

Table 4: Means of NWB test comparison between RR and NRR group at before surgery, 6weeks, 3 and 6 months, 1 year and 2 years.

NWB test (Mean±SD)	Before surgery	6weeks	3 months	6 months	1 year	2 years
RR	42±2.7	40.4±2.8	35.6±2.8	33±3	33.5±1	32 ±3
NRR	40.7±3	42.5±2.4	40±2.6	39±3	35±2	34±2
P value	0.27	0.04	0.031	0.01	0.02	0.03

Table 5: Means of WB test comparison between RR and NRR group at before surgery, 6weeks, 3 and 6 months, 1 year and 2 years.

WB test (Mean±SD)	Before surgery	6weeks	3 months	6 months	1 year	2 years
RR	44.3±3.3	42.3±3	38±3	35±3.7	34.3±5	33±3
NRR	44±3.3	46.3±2.6	42.4±3.3	41±3.4	35±1	34.3±4
P value	0.78	0.01	0.01	0.01	0.02	0.02

Table 6: Pearson's Correlation comparison between different variable with significance of test in all patients

Time period	Lysholm Score × NWB test	Lysholm Score × WB test	Lysholm score × Single leg hop test	Single leg hop test with NWB and WB test
At 3 months Pearson's correlation (P value)	-0.662(0.001)	-0.718(0.001)	-0.740(0.004)	NWB -0.664(0.004) WB –(0.714(0.004)
At 6 months Pearson's correlation (P value)	-0.668(0.001)	-0.890(0.001)	0.640(0.001)	NWB – 0.890(0.004) WB –0.682(0.001)
At 2 years Pearson's correlation (P value)	-0.677(0.001)	-0.750(0.004)	0.667(0.001)	NWB-0.668(0.001) WB-0.788(0.001)

Table 7: Three types of ACL retention method described in literature and their indications.

Tibia Remnant tensioning	Selective bundle augmentation	Tibia Remnant sparing
Indication – when tear is near femoral end and good length and thickness of remnant is intact Procedure – sutures passed through proximal end and fixation done on femoral side.	Indication – partial ACL tear Procedure –In Anteroinferior tear with Posterolateral bundle intact, anteromedial bundle reconstructed. In high noon tear with intact anteromedial bundle tear, PL bundle reconstruction done.	Indication – Complete ACL tear with tibia footprint remnant Procedure – tibia tunnel drilled through tibia remnant without damaging remnant and ACL graft passed through remnant.

Discussion

Proprioception is an ability to sense joint position orientation, perceive passive movement with velocity, direction and to estimate force required to make a movement [7,8]. Anterior cruciate ligament tibial end has high number of mechanoreceptors like Ruffini's nerve endings, Pacini's receptors, and Golgi tendon organ-like endings [8,9]. ACL injury disrupts neuromuscular reflex arc as loss of mechanoreceptors which leads to loss of feedback to brain and feed forward mechanism to muscle around joint for adaption according to task [1,8]. This leads to re-injury chances and early osteoarthritis of joint. Animal studies revealed ACL remnant consist of synovial covering which improve graft healing, early neovascularisation, early return of propriocetion and ligamentization [8-10]. Time between injury to surgery and amount of tibial footprint retaining is an important component of this study. Most of mechanoreceptors disappear within a year from injury [1,11]. It is important to retain > 1/3 of tibia footprint graft to avoid remnant compromise [5]. Proprioception recovery depend on lot of variable factors like patient pre-injury activities, Amount of injury to ACL, other associated injury, time interval between injury and surgery, intra-operative factors like remnant amount, graft tensioning, rehabilitation methods etc. Strong factors of our study is inclusion of isolated ACL injury, time interval <6months, remnant retention >1/3, supervised physiotherapy with similar protocol for all patient. We have tried to reduce many variable factors in our study. There are three type of remnant retention procedures mentioned in literature (Table: 7) [1]. Proprioception testing can be done by various methods like 1) joint position sense 2) tendency to detect passive motion [5,7,10-12]. Joint position sense is most adopted method in literature to assess proprioception [5,7,10-12]. There are clinical methods and machines available for assessment. Yong Woo En *et al* evaluated change of brain activities in fully recovered ACL reconstructed patient with normal healthy individual by EEG. They used theta and alpha 2 waves from prefrontal cortex, pre-motor cortex while single leg stand and postural control tests. There was similar postural control but change of brain activities on unstable platform due to change of neural feedback. This tells us proprioception is not just sensory component. It includes afferent, CNS processing and motor activity in closed loop. Central processing is main component as proprioception can be improved with exercises. It is complex neuromuscular arc which works constantly [8]. A Meta analysis study revealed ACLR with remnant preservation show significant better outcome on lysholm score, proprioception testing but similar outcome with IKDC

score, Lachman's test and pivot shift test. This study shows that Proprioception testing with reproduction of passive movement test is not isolating ACL ligament proprioception, as there are receptors in ligament, tendons, joint capsule and menisci. Still more sophisticated tools needed to better understanding of proprioception of ACL [1,2]. Yufeng Liu *et al* did study which includes 46 patient which divided in two groups on basis of amount of graft preservation during surgery revealed more than 1/3 graft has better outcome. In their study, early angles 15 and 30 degree were showing better proprioception recovery than higher flexion. Tibial stump sparing method used as tibial stump has proven to have higher number of receptors. Most of ACL reconstructed patient had recovered proprioception at end of 6 months. Recovery was equivalent between groups at end of 12 months which is showing retaining remnant only accelerates the process but long term results were same. This can prevent re-tears in postoperative patients [5]. Jong Min Lim *et al* did study of postoperative rehabilitation by comparing two groups of home based and supervised physiotherapy with dynamometer for isokinetic exercises. He revealed similar strength in both group but better proprioception and functional outcome in supervised in department physiotherapy by trained health professionals [12]. Few authors believe that Joint position sense test and detection of passive movement test are not enough for proprioception testing. Instead checking postural sway on moving platform better quantify postural control [11]. Retaining remnant can lead to loss of terminal extension and Cyclops lesion [1,2]. But in our study, there was only one patient with loss of extension in RR group [Fig: 1].X ray knee revealed anterior placement of tibial tunnel. We feel that Cyclops lesion is because of wrong placement of tibial tunnel, collection of debris of tunnel drilling in joint and graft impingement at ends of tunnel and notch in joint.

In our study, Proprioception recovery was significantly accelerated by remnant retention at end of six months. Both WB and NWB test were significantly correlating with lysholm score and single leg hop test but WB test was more significant at end of six months. The reason may be WB test is dynamic test and require balancing the weight of the whole body. In Our study, we encountered two complications during following. One 43 year old female patient presented with right knee ACL tear operated with RR method at 7 weeks from injury. She was unable to perform terminal extension till 2 years of follow-up. Her Knee score was 64. NWB, WB test was 32 and 45 at end of 2 years respectively. Single leg hop test was non-balancing. Follow-up x ray was showing anterior placement of tibial tunnel [Fig: 5, 6]. Another one was graft site skin wound infection. Thorough debridement and suturing was done. Proprioception assessment was done at 30 degree of angle and it was significant correlating with recovery in RR group as compare to NRR group. It may be because graft is most taut at this angle. In our study, graft tibial side fixation was done at 30 degree with manual reduction of anterior subluxation of knee. Extra stability at 30 degree can be considered one reason of good proprioception recovery along with remnant retention. Considering patients with isolated complete ACL tear within 6 month from injury, sparing >1/3 tibia remnant during surgery, supervised physiotherapy protocol for each patient are the strengths of the study. Repeat Diagnostic arthroscopy and repeat MRI could have given us more information. Including other sophisticated methods like postural sway, threshold to detect passive motion with dynamometer, KT machine can provide valuable information. Large number of cases and

longer follow up time can give further weightage to the study. There is need of better understanding of proprioception. Performing EEG while proprioception assessment can provide valuable information. There is requirement of developing methods of masking other structure's proprioception sense while assessing ACL.

Conclusion

Proprioception recovery is significant in Remnant Retention anterior cruciate ligament reconstruction as compare to Non Remnant Retaining surgery both clinically and functionally at end of 2 years. Minimum one third of remnant retention can accelerates the healing process.

Joint position sense is easily reproducible test to evaluate proprioception in outpatient setup without sophisticated equipments. Non weight bearing test is good in early follow up as patient will have pain in weight bearing test. Weight bearing test is good for intermediate and long term follow-up for assessment. Time interval between injury and surgery less than 6 months will give better proprioception recovery.

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