

Functional Outcome after Arthroscopic Anterior Cruciate Ligament Reconstruction Using Quadrupled Hamstring Graft- A Prospective Analysis

Anil Karampudi¹, M A Sameer Imrose², Desai Chinmay Harish³,
Samiullah Md⁴

¹(Department of Orthopaedics, Osmania medical college, Hyderabad, India)

²(Department of Orthopaedics, Osmania medical college, Hyderabad, India)

³(Department of Orthopaedics, GMERS medical college, Gujarat, India)

⁴(Department of Orthopaedics, Osmania medical college, Hyderabad, India)

*correspondence: Dr.Anil Karampudi

Abstract:

Background: Knee joint is one of the largest and most complex joints in the body. It is supported by several extrinsic and intrinsic ligaments. Among which anterior cruciate ligament (ACL) is responsible for large part of knee stability. It not only prevents anterior translation of knee joint but also gives rotational strength. This mandates the importance of ACL reconstruction in case of tears with proven excellent functional outcomes. Arthroscopic reconstruction of knee ligaments has advantages of small surgical scars, less hemorrhage, less postoperative pain, low rate of infection, minimal hospital stay, early mobilization, rapid recovery and good compliance to rehabilitation. Semitendinosus autograft is more commonly used because of easy harvesting, no donor site morbidity as seen with bone patellar tendon bone grafts, no loss of extensor mechanism and tensile strength of quadrupled graft is more than normal ACL strength. Endobutton is a cortical fixation device for femoral tunnel which can withstand strong forces. Interference screws are aperture fixation device helps in tight bone-tendon interface.

Aim: To study the functional outcome of arthroscopic single bundle ACL reconstruction using quadrupled hamstring autograft and titanium interference screw.

Materials and methods: This is an evaluation of 50 patients of clinical and radiological ACL tear admitted in tertiary teaching hospital, Hyderabad from June 2018 to December 2020 who underwent arthroscopic single bundle ACL reconstruction with quadrupled hamstring autograft using endobutton and titanium interference screws. In all the patients surgery was planned after 3 weeks from the time of injury. Functional outcome is measured using Lysholm knee scoring system.

Results: Most of the patients were males and left knee being more commonly involved, though gender and limb sidedness has no role in overall functional outcome. Younger population being commonly involved with mean age of 29.5 years. Most common mode of injury was Road Traffic Accident. Average Lysholm score preoperatively was 65.4 and after 1 year follow up was 91.25. Full range of motion attained in 40% of patients after 1 year, 56% of patients had 10° decrease in ROM, 4% of patients had 20° loss of ROM. Quadriceps power was 4/5 MRC grade in 2% of patients and 5/5 in 98% of patients. 3 patients had complications like superficial infection, 5 had knee effusion and 4 had Knee Pain. No deep infections, graft failure or graft tenderness were reported.

Conclusion: Arthroscopic assisted single bundle ACL reconstruction with quadrupled hamstring autograft using titanium interference screws and endobutton provided a stable knee with good functional outcome, minimal postoperative morbidity, better compliance for rehabilitation and early return to their occupation.

Key words: ACL tear, Arthroscopic reconstruction, Functional outcome.

Date of Submission: 30-05-2021

Date of Acceptance: 13-06-2021

I. Introduction

Anterior cruciate ligament (ACL) is a primary knee stabilizer which not only prevents anterior translation of knee but also counteracts rotational and valgus stress. ACL injury is the commonest ligamentous injury in the body and has been extensively studied all over the world from the past 20 years. ACL has poor capacity for intrinsic repair. This explains the importance of ligament reconstruction as a means of stabilizing and restoring the functional status of the knee. Numerous authors have described successful ACL reconstruction using several autografts like patellar tendon, quadriceps tendon, hamstring tendon and allografts like Achilles

tendon, tibialis anterior and hamstring tendon¹. Previously bone patellar tendon bone graft is most commonly used for reconstruction but has concerns regarding loss of extensor mechanism, patellar fracture, anterior knee pain and patella infra which prompted the surgeons to use other graft materials. Hamstring graft using semitendinosus and gracilis represents an alternative option without disturbance of extensor mechanism or donor site morbidity, greater cross-sectional area and superior mechanical resistance. The cells of quadrupled hamstring tendon graft survive intra-articular implantation but the cells of bone patellar tendon bone graft do not, because hamstring graft is nourished by synovial fluid and doesn't depend on revascularization for viability.

In 1954, after the development of arthroscope, many new possibilities to the field of knee surgery has emerged. Arthroscopic assisted ACL reconstruction has advantages of being minimally invasive, accurate graft placement, less tissue damage which leads to less infection rate, minimal hospital stay, early recovery and rehabilitation.

Various fixation devices have been described for holding the graft in the tibial and femoral tunnel such as suspensory devices, posts, screws and suture buttons. We used endobutton on the femoral side and titanium interference screw in the tibial tunnel.

Though the surgery has become common over the past 20 years, there is yet some consensus needed on timing of surgery, type of implant, outcome predictors like age, associated injuries. Although the patient age, height, weight and gender are associated with graft thickness, it is difficult to predict the diameter of a quadruple tendon preoperatively².

The objective of this study is to use Lysholm scoring system to evaluate functional outcome of series of patients.

AIM OF THE STUDY

AIM AND OBJECTIVES: To study and evaluate the functional outcome of arthroscopic reconstruction of anterior cruciate ligament.

INCLUSION CRITERIA: All cases with isolated anterior cruciate ligament injury are included in the study irrespective of the mode of injury/duration/mechanism of injury.

- clinically Lachman test positive
- Anterior drawers test positive,
- Pivot shift test positive ,
- MRI diagnosed ACL tear.

EXCLUSION CRITERIA:

- Cases with multiligament injury
- Patients with bony ACL avulsion
- other associated fractures
- Cases with revision ACL reconstructions

II. Materials And Methods

A prospective longitudinal study conducted on 50 patients admitted with clinical and radiological deficiency of ACL in the department of orthopaedics, tertiary teaching hospital, Hyderabad, Telangana state, India from June 2018 to December 2020.

In acute presentation after hemodynamic stabilization patients were subjected to detailed clinical evaluation including history and physical examination. Radiographs, CT scan and MRI of the knees taken.

All the patients were treated with arthroscopic single bundle ACL reconstruction with hamstring autograft using titanium interference screw and endobutton.

Implants & Instrumentation:

- 1) Non- absorbable sutures Ethibond No.2
- 2) Standard 4mm 30°arthroscope with camera and light settings.
- 3) Pneumatic tourniquet
- 4) Interference screws
- 5) Spiked ligament staples
- 6) Endobutton

**STANDARD OPERATIVE MANAGEMENT:
ARTHROSCOPIC ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION WITH
QUADRAPLED HAMSTRING AUTOGRAFT METHOD:**

A 2-3cms oblique incision is made directly over the pes anserinus in line with hamstring tendons with knee in 90 deg flexion. Semitendinosus and Gracilis tendons are identified, separated, adhesions removed and are harvested using a tendon harvester (stripper). The harvested and prepared tendons are double folded to form a 4 stranded (quadrupled) hamstring graft.

Graft diameter is determined with a graft sizer. Using arthroscopy guidance using femoral offset (standard 7mm) through trans portal approach using a Beth pin drill is passed into the medial surface of lateral femoral condyle posterior to 'residents ridge' in 2 O' Clock position. The pin is exited through lateral femoral cortex. A graduated tunnel reamer of appropriate size chosen according to graft size is used to create femoral tunnel over the Beth pin of appropriate length chosen according to the graft length (usually 20-30mm long). The pin is used to pass a No.5 Ethibond sutureloop through the tunnel.

The Tibial tunnel is created using a Universal tibial guide (STORZ) based on the length of graft available. Usually it is set to 55 deg angle. For a short length graft the angle needs to be decreased and vice versa. Tibial tunnel is also created with the help of reamer over Beth pin which was directed into the lateral slope of medial tibial spine using the Tibial guide. Using grasper the Ethibond loop in femoral tunnel is pulled out of the tibial tunnel. With the help of this loop the graft is passed into the femoral tunnel through the tibial tunnel.

With the help of flexible guide wire the graft is fixed in tunnels with interference screw of appropriate size after keeping the graft taut by pulling both ends of graft. Lachmann test is done to check for any laxity of graft.

Wound is closed in layers. Aseptic dressing is done. Compression bandage is then applied over it, and the knee is immobilized in full extension in a brace.



Identification of hamstring tendons and harvesting using Harvester



Graft preparation and measurement

POSTOPERATIVE PROTOCOL: Current standard rehabilitation protocol was followed.
FOLLOW-UP:

Patients were followed up upto 1 year. Each time during the visit patients were subjected to the following:

Clinical evaluation: Look for any tenderness around the knee. Any abnormal swelling and surgical wound site discharge must be noted. Evaluate functional ability of the patient [from history and scoring system].

Radiographic assessment: Look for any screw loosening, step-off of the fragments from the fracture bed and loosening of interference screw in patients who underwent ligament reconstruction.

LYSHOLM KNEE SCORING SCALE

1. LIMP

- No limp=5
- Slight or periodical=3
- Severe and constant=0

2. SUPPORT USING CANE /CRUTCHES

- No support=5
- With some weight bearing=2
- Impossible=0

3. RESTRAINING

- No restraining or restraining feeling=15
- Has the feeling but no restraining=10
- Occasional restraining=6
- Frequent=2
- Joint restraining at examination=0

4. INSTABILITY

- Never miss a step=25
- Seldom, during athletics or other vigorous activities=20
- Frequently during athletics or other vigorous activities (unable to participate)=15
- Occasionally in daily activities=10
- Frequently in daily activities=5
- At every step=0

5. PAIN

- No pain=25
- Intermittent or slight during vigorous activities=20
- Marked during vigorous activities=15
- Marked during or after walking more than 2 km=10
- Marked during or after walking less than 2 km=5
- Continuous=0

6. SWELLING

- No swelling=10
- After vigorous activities=6
- After ordinary activities=2
- Continuous=0

7. CLIMBING STAIRS

- No problem=10
- Slight problem=6
- One step at a time=2
- Impossible=0

8.SQUATTING

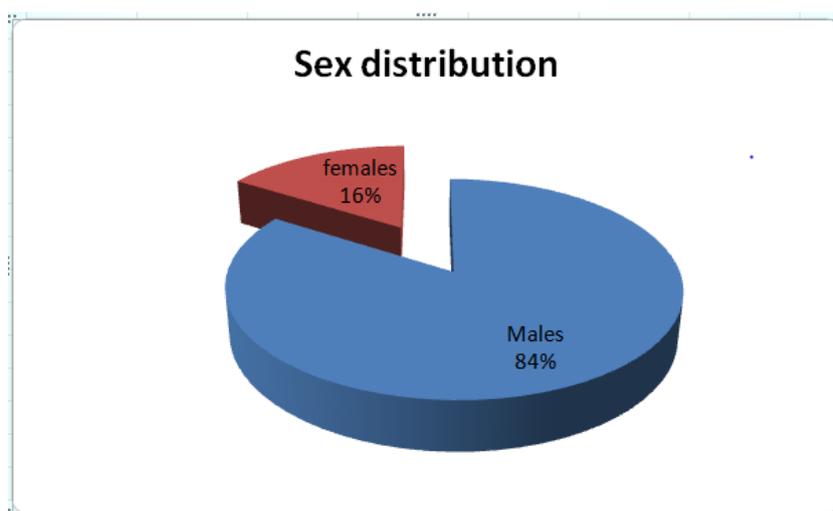
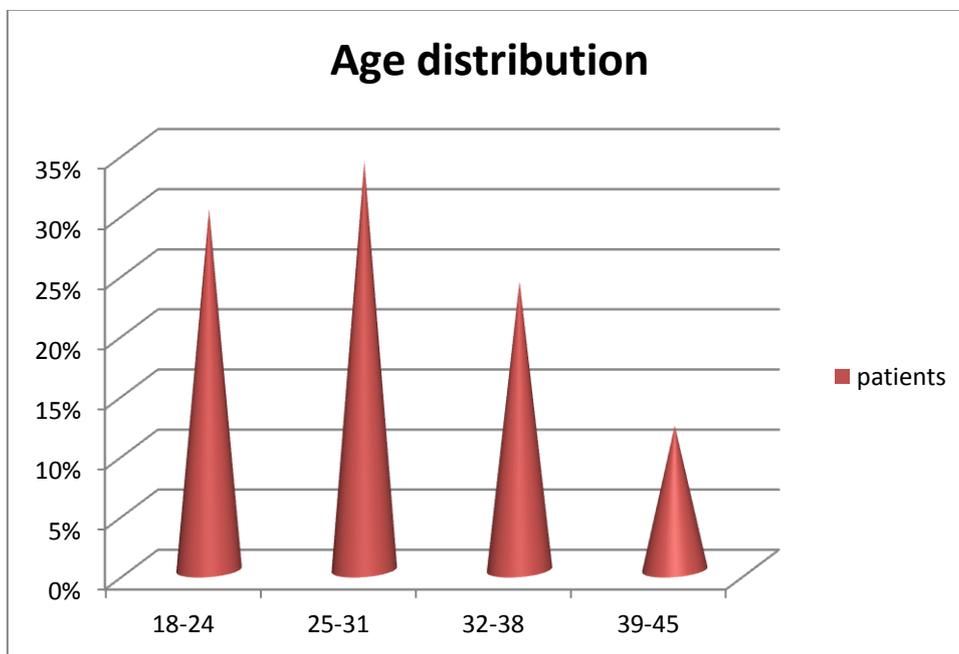
- No problem=5
- Slight problem=4
- Cannot squat beyond a 90°=2
- Impossible=0

III. Results

AGE/SEX DISTRIBUTION:

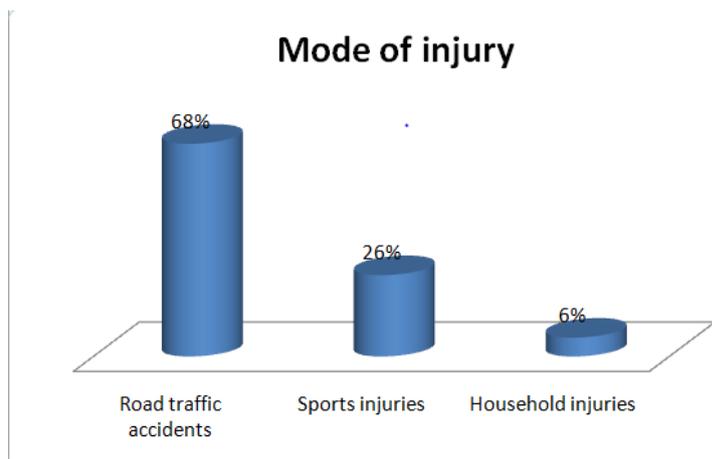
Most of the patients in our study were aged between 25-31years (34%). 15% patients were aged between 18-24. 24% were aged between 32-38 and 12% patients were aged between 39-45. 42 patients were males and 8 were females.

Age	Number	Percentage
18-24	15	30%
25-31	17	34%
32-38	12	24%
39-45	6	12%
Total	50	100%



MODE OF INJURY:

34 patients were due to road traffic accidents [collision followed by accidental fall from two-wheeler], 13 patients were due to sports injuries and 3 patients were due to household injuries.

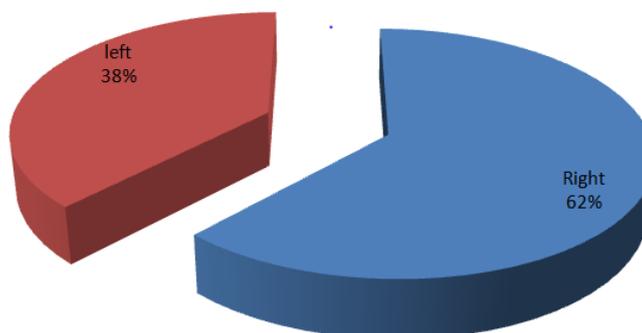


Mode of injury	Number	Percentage
Road traffic accidents	34	68%
Sports injuries	13	26%
Household injuries	3	6%

SIDE PREDOMINANCE:

In this study, 31 patients had injury to left knee and 19 had injury to right knee.

Side predominance



Side of injury	Number	Percentage
Right	19	38%
Left	31	62%

ASSOCIATED INJURIES:

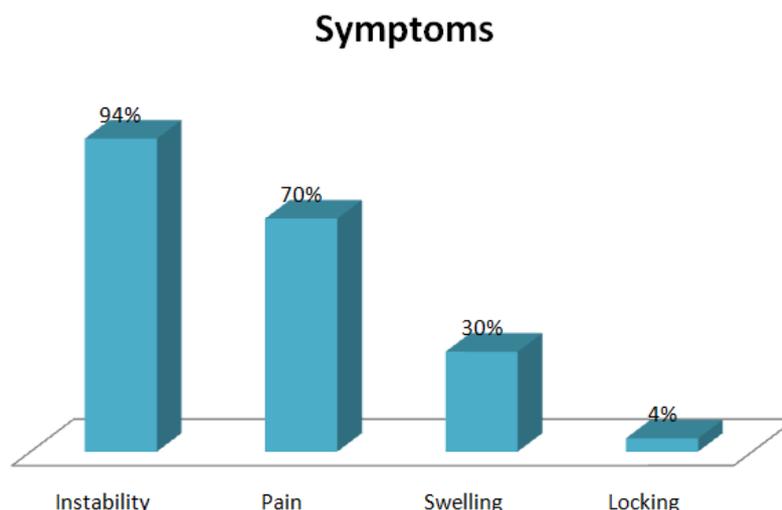
Out of the 50 patients in our study 4 had associated meniscal injuries of them 1 patient had isolated grade 1 lateral meniscal tear, 3 had isolated medial meniscal tear of which 2 patients required repair using “inside out” technique.

Meniscal injuries	Number
Present	4
Absent	46

Meniscal injuries	Number
Lateral meniscus	1
Medial meniscus	3
Both	0

PRESENTING SYMPTOMS: In this study, 47 patients had instability, 35 patients had pain, 15 had swelling and 2 had locking of knee joint.

Symptoms	Number	Percentage
Instability	47	94%
Pain	35	70%
Swelling	15	30%
Locking	2	4%

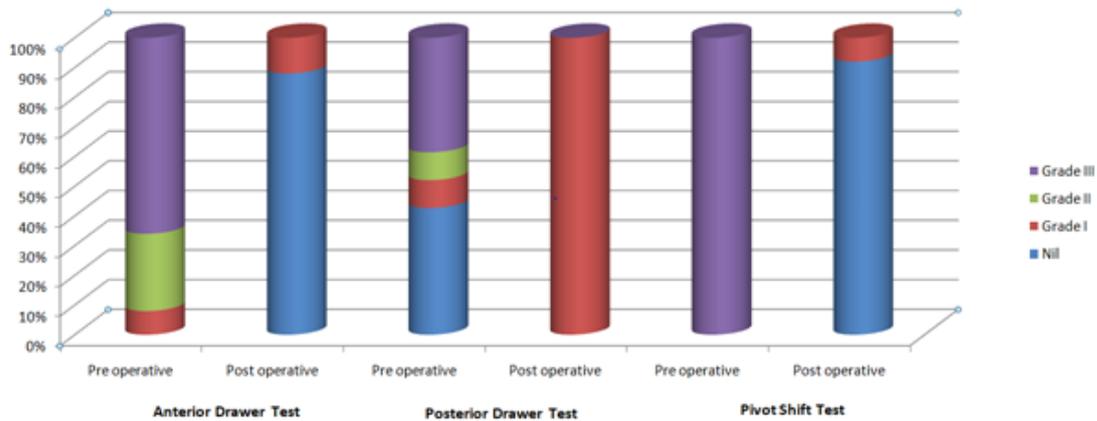


LAXITY TESTS: In all the patients anterior drawer, Lachman and pivot shift tests were done preoperatively and postoperatively at 1 year follow up. Preoperatively 13 patients had grade 3 anterior drawer test and 4 patients had grade 2. Postoperatively 44 patients had negative anterior drawer test. 37 patients had grade 3 lachman test, 9 had grade 2 and 4 had grade 1 preoperatively. Postoperatively 9 patients had grade 1 lachman test while rest of them are negative for lachman.

Anterior drawer test	Anterior drawer test grade			
	Nil	Grade I	Grade II	Grade III
Pre operative	0	4	13	33
Post operative(1 year)	44	6	0	0

Lachman test	Lachman test grade			
	Nil	Grade I	Grade II	Grade III
Pre operative	0	4	9	37
Post operative(1 year)	41	9	0	0

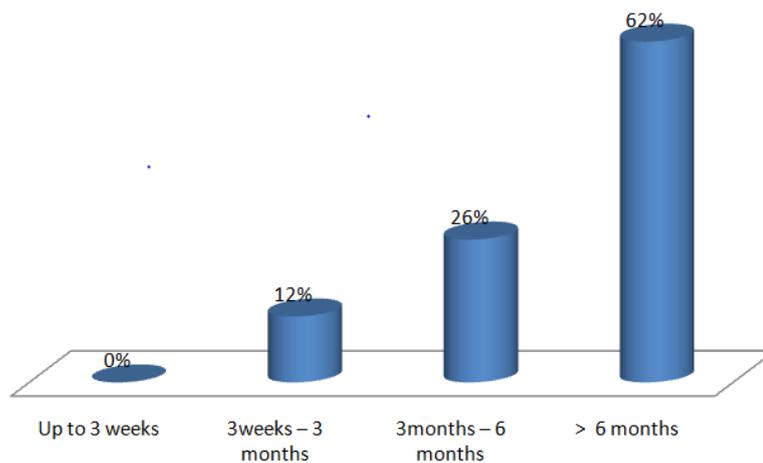
Pivot shift test	Pivot shift test grade			
	Nil	Grade I	Grade II	Grade III
Pre operative	0	0	0	50
Post operative(1 year)	46	4	0	0



DURATION FROM TIME OF INJURY TO SURGERY: In this study most of the patients (31) were operated after 6 months from the time of injury. None of the patients were operated before 3 weeks. 6 patients were operated between 3weeks -3 months, and 13 were operated between 3 months-6 months.

Duration	Number	Percentage
Up to 3 weeks	0	0%
3weeks – 3 months	6	12%
3months – 6 months	13	26%
> 6 months	31	62%
Total	50	100%

Duration from injury to surgery

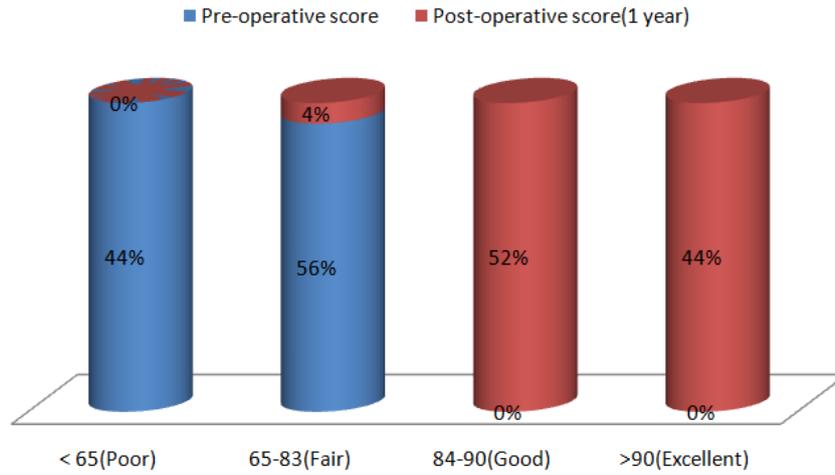


GRAFT SIZE: All the patients have graft thickness of more than 7mm. Average graft thickness and graft length was 7.85mm and 101.3 mm respectively.

LYSHOLM’S SCORE: In our study Lysholm score was done preoperatively and postoperatively at 1 year follow up. Average Lysholm score preoperatively and 1 year postoperatively was 65.4 and 91.25 respectively.

Lysholm score	Pre-operative score		Post-operative score(1 year)	
	Number	Percentage	Number	Percentage
< 65(Poor)	22	44%	0	0%
65-83(Fair)	56	56%	2	4%
84-90(Good)	0	0%	26	52%
>90(Excellent)	0	0%	22	44%

Lysholm's Knee Score

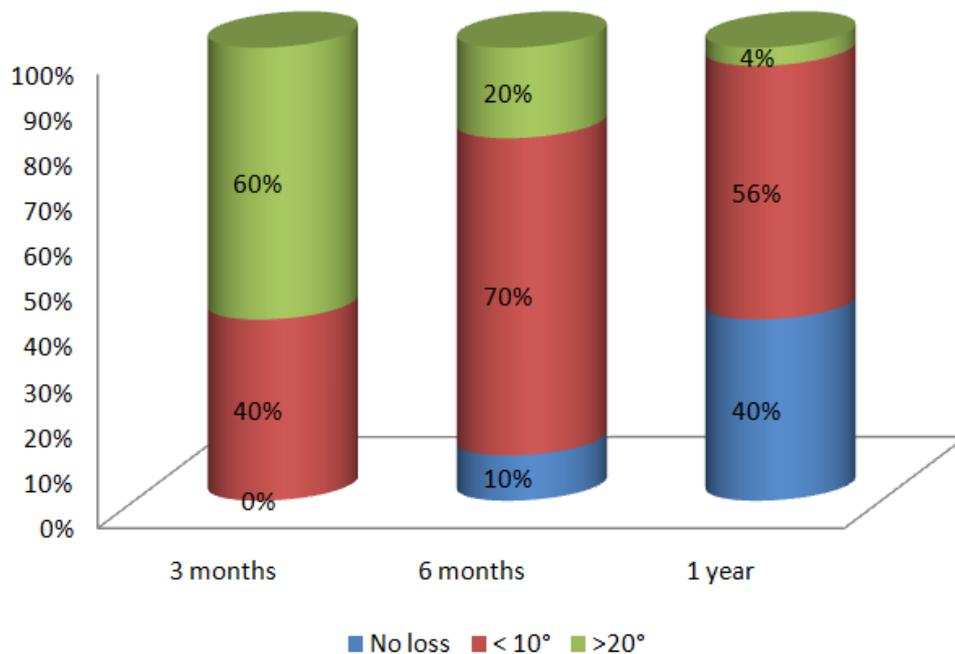


RANGE OF MOTION (ROM):

In this study of 50 patients, at 3 months follow up, 30 patients had $>20^\circ$ loss of ROM and 20 patients had 10° of loss. At 6 months follow up, 5 patients had normal ROM, 35 patients had upto 10° of loss, 10 patients had 20° decrease in ROM. At 1 year follow up 20 patients had normal ROM, 28 patients had $<10^\circ$ loss of ROM and 2 patients had $>20^\circ$ loss of ROM. It was noted that these 2 patients had associated meniscal injury and was repaired.

Loss of ROM	3 months		6 months		1 year	
	Number	Percentage	Number	Percentage	Number	Percentage
No loss	0	0%	5	10%	20	40%
$< 10^\circ$	20	40%	35	70%	28	56%
$>20^\circ$	30	60%	10	20%	2	4%

Loss of ROM



QUADRICEPS POWER (MEDICAL RESEARCH COUNCIL GRADE):

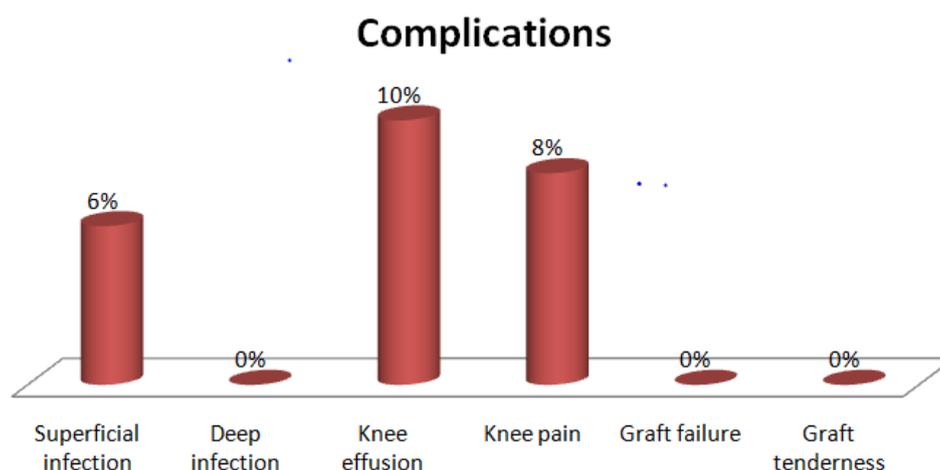
At three months follow up 15 patients had 4/5 (MRC GRADE) quadriceps power rest had 5/5. At six months of follow up 5 patients had grade of 4/5(MRC) power and 45 patients had 5/5 power. At 1 year follow up, only 1 patient had 4/5 power and rest are normal.

Quadriceps power(MRCgrade)	3 months		6 months		1 year	
	Number	Percentage	Number	Percentage	Number	Percentage
4/5	15	30%	5	10%	1	2%
5/5	35	70%	45	90%	49	98%

COMPLICATIONS:

In our study, there were no case of deep infection, graft failure or graft side tenderness. 3 patients developed superficial infection, 5 patients developed knee effusion, 4 patients developed knee pain.

Complications	Number	Percentage
Superficial infection	3	6%
Deep infection	0	0%
Knee effusion	5	10%
Knee pain	4	8%
Graft failure	0	0%
Graft tenderness	0	0%



IV. Discussion

Knee ligament injuries following Road traffic accidents, sports injuries are frequently being reported and addressed these days. Main goal in the management of these injuries is to regain the pre-injury functional status, strength and restore the stability of the knee.

In the study we took 50 patients with ACL injuries. Main aim of the present study is to find out the functional outcome after Arthroscopic single bundle ACL reconstruction using quadrupled hamstring autograft and were followed up to 1 year.

Studies conducted by various authors suggest knee ligament injuries are more common in young active individuals. Siebold et al.³ reported a mean age of 29 years. Specchiulli et al.⁴ reported mean age of 27 which is comparable to D Chaudhary et al.⁵(26.8 years) , N.M. Jomha et al.⁶(26 years) and D.J. Deehan et al.⁷(25years) . In the present study we got a mean age of 29.5 which is comparable to the above studies.

Authors	Mean age(years)
D.J. Deehan et al. ⁷	25
D Chaudhary et al. ⁵	26.8
N.M. Jomha et al. ⁶	26
Siebold et al. ³	29
Specchiulli et al. ⁴	27
Present study	29.5

In our study left side is more predominant than right and most of the patients were males (84%). Sidedness in various studies is as follows:

Authors	Right	Left
N.M. Jomha et al. ⁶	45.76%	54.24%
D Chaudhary et al. ⁵	56.41%	43.59%
D.J. Deehan et al. ⁷	61%	39%
Present study	38%	62%

Brown et al.⁸ study suggest that females are more at risk of ACL ligament injuries but contrary to this males are more predominantly involved due to risk of work exposure to strenuous environments. They also hypothesized that limb sidedness has no influence on either the injury or overall functional outcome. Our study didn't find any significance of limb sidedness or gender to functional outcome.

Common causes of knee ligament injuries are sporting activity, road traffic accidents and household injuries. Most of the studies suggest sports injury to be the predominant cause. Patond et al.⁹ suggests sports activities are the main reason for ACL injuries. D Chaudhary et al.⁵ reported 66.7% of patients had injuries while sporting activity while 30.8% are due to road accidents and 2.5% are due to household injuries. Contrary to this our study shows 68% of injuries are due to road accidents, 26% are due to sport injuries and 6% are due to household injuries.

Authors	Mode of injury
Patond et al. ⁹	Sports injuries > Road accidents
D Chaudhary et al. ⁵	Sports injuries > Road accidents> household injuries
Present study	Road accidents > sports

Though some authors suggest to wait for 3 weeks from the time of injury to surgery¹⁰, there's no clear consensus on this. All the patients in our study were treated at acute presentation with ROM knee bracing and restricted activity till knee effusion subside and functional range of motion attained, then reconstruction was planned at a later stage. Preoperative edema, range of motion and hyperemia has an influence on overall functional outcome post surgery. Though 62% of the patients in our study are treated after 6 months, delay in surgery didn't much affect the functional outcome.

Marscalo MW et al.¹¹ in his multicentric retrospective study of cohort data of 263 patient of ACL reconstruction with hamstring autograft, found that smaller graft size of <8mm is a predictor of poor functional scores. Conte EJ et al.¹² in his systematic review found that graft diameter of >8mm decreases failure rates. Treme et al.¹³ proposed that graft length is related to the height and BMI of the patient, while the diameter is related to the thigh thickness. He further opined that graft diameter of <7mm will have higher failure rates. In our study all the patients have graft thickness of more than 7mm. Average graft thickness and graft length was 7.85mm and 101.3 mm respectively.

Clinical assessment of all the patients was done by anterior drawer test, lachman test and pivot shift test. Anterior drawer and lachman test was positive in all the patients, majority have complete tear. Pivot shift test is correlated to complete ACL tear in all the cases. Postoperatively majority of the patients had negative laxity tests.

Kocher et al.¹⁴ evaluated the relation between an objective assessment of knee laxity and the subjective assessment of symptoms and function. He opined that the pivot shift test was a better correlator of "functional stability" than the Lachman test or instrumented knee laxity. After 1 year only 4 out of 50 patients in our study show grade 1 pivot shift test rest are all negative.

In a study conducted by H. E. Bourke *et al.*¹⁵ functional outcome of 152 patients after 15 years of follow up was 93 according to Lysholm knee scoring system. This cannot be compared with the present study because of very long duration of follow up i.e.15 years which could be one of the reasons for good functional score.

Daniel B. O'Neill et al.¹⁶ conducted a study on 125 patients who are divided into 3 groups. Group 1(40 patients) treated with 2 incision reconstruction using semitendinosus autograft has a score of >90 in 88% patients. Group 2(40 patients) treated with 2 incision reconstruction using bone patellar tendon bone autograft has a score of >90 in 90% of patients. Group 3(45 patients) treated with arthroscopic ACL reconstruction using bone patellar tendon bone autograft has score of >90 in 93% of the patients.

Gulick et al.¹⁷ studied 57 patients treated with ACL reconstruction, functional outcome was same as pre-injury level in about 84%. A retrospective study conducted by Fareed et al.¹⁸ on arthroscopic ACL reconstruction, a satisfactory functional outcome is seen in 96% after a mean follow up of 25.4 months. Cooley et al.¹⁹ reported normal to near normal outcome in about 85% of the patients treated with quadrupled semitendinosus autograft.

In the present study, Lysholm's score was measured preoperatively and 1 year postoperatively. We made sure all the patients strictly followed postoperative rehabilitation protocol. Preoperatively 44% of patients had poor score and 56% of patients had fair score. At 12 months follow up 26 patients (52%) had a good Lysholm's score and 22 patients(44%) had excellent score. Average Lysholm score preoperatively was 65.4 which has improved to 91.25 after 1 year. Most of the patients returned to their occupation after 9-12 months depending on the level of activity at workplace. Lesser scores in our study as compared to others were probably because of short follow up period of 1 year. Although lesser scores, early return to occupation is seen in many patients probably because of lesser functional demand knees in our study as none of the patients were professional athletes and some of the patients though involved in the sporting activity but as an occasional recreational purposes.

Post operative range of movements of knee joint is also a good indicator of functional outcome. Corry IS et al.²⁰ and Aglietti et al.²¹ in their respective studies concluded that in ACL reconstruction using hamstring graft, the postoperative ROM following rehabilitation protocol was almost equal to the pre injury status at the end of follow up. In our study, after 1 year, only 2 patients had 20° loss of range. These 2 patients had associated meniscal injury and were repaired simultaneously.

Loss of quadriceps power postoperatively will affect overall functional outcome of the patient. Main purpose of postoperative rehabilitation is to improve range of motion and quadriceps power and bring back to the pre-injury level. In our study, after 1 year only 1 patient had 4/5 grade and rest are all normal.

Kim HJ et al.²² studied 98 cases of ACL reconstruction who were followed up for 17 months reported 7 cases (7.1%) of infection (5 deep and 2 superficial). Judd et al.²³ suggested probable causes of wound complication which include soft tissue injuries involved in harvesting the tendons and creating a tibial tunnel and the use of an additional metallic post, washer, and braided sutures in subcutaneous position. He also reported that hamstring grafts were associated with a higher incidence of infection. Chen L et al.²⁴ used endobutton for femoral fixation for 10 years with no fixation failure while treating ACL reconstruction using quadrupled semitendinosus tendon autograft. Thigh muscle wasting and atrophy are complications due to improper rehabilitation or poor compliance by the patient. D. J. Deehan et al.⁷ in their study noted that 87% had wasting of less than 1 cm, 9% had a wasting of 1-2 cms and 4% had wasting of 3 cms. N.M. Jomha et al.⁶ in their study noted that 66.1% patients had no thigh atrophy, 27.12% patients had thigh atrophy of less than 1 cm and 6.78% patients had thigh atrophy of 1-2 cms.

In our study, there were no cases of deep infection, graft failure or graft side tenderness. 3 patients developed superficial infection that was treated with antibiotics, 5 patients developed knee effusion which was relieved with medication and physiotherapy, 4 patients developed knee pain.

V. Conclusion

Arthroscopic assisted single bundle ACL reconstruction with quadrupled hamstring autograft using titanium interference screws and endobutton provided a stable knee with good functional outcome, minimal postoperative morbidity, better compliance for rehabilitation and early return to their occupation. Adequate graft thickness, timing of surgery, precision in technique and strict postoperative rehabilitation protocol strongly influence the overall functional outcome of surgery.

LIMITATIONS TO OUR STUDY

We have found several limitations within our study such as small sample size, lack of control group, short period of follow up and none of the patients in our study are high functional demand patients or professional athletes. All these will influence the functional outcome of the patients.

CONFLICT OF INTEREST: Nil

References

- [1]. Meighan AA, Keating JF, Will E. Outcome after reconstruction of the anterior cruciate ligament in athletic patients. A comparison of early versus delayed surgery. *J Bone Joint Surg Br.* 2003;85:521-4.
- [2]. Tuman JM, Diduch DR, Rubino LJ, Baumfeld JA, Nguyen HS, Hart JM. Predictors for hamstring graft diameter in anterior cruciate ligament re-construction. *Am J Sports Med.* 1949;35(11):1945-9.
- [3]. Siebold R, Dehler C, Ellert T. Prospective randomized comparison of double-bundle versus single bundle anterior cruciate ligament reconstruction. *J Arth Related Surg.* 2008; 24:137-45.
- [4]. Specchiuli F, Laforgia Mocchi, Miotta Scialpi, Solaring. Anterior cruciate ligament reconstruction: A comparison of 2 techniques. *Clin Orthop.* 1995; 311:142-7.
- [5]. Chaudhary D, Monga P, Joshi D, Easwaran R, Bhatia N, Singh AK. Arthroscopic reconstruction of the anterior cruciate ligament using bone-patellar tendonbone autograft: Experience of the first 100 cases. *Journal of Orthopaedic Surgery.* 2005; 13(2):147-152.
- [6]. Jomha NM, Pinczewski LA, Clingeleffer A, Otto DD. Arthroscopic reconstruction of the anterior cruciate ligament with patellar-tendon autograft and interference screw fixation; *J Bone Joint Surg.(Br).* 1999; 81-B:775-9.
- [7]. Deehan DJ, Salmon LJ, Webb VJ, Davies ALA. Pinczewski-Endoscopic reconstruction of the anterior cruciate ligament with an ipsilateral patellar tendon autograft, *J Bone Joint Surg. (Br).* 2000; 82-B; 984-91.

- [8]. Brown TN, Palmeri-Smith RM, Mc Lean SG. Sex and limb differences in hip and knee kinematics and kinetics during anticipated and unanticipated jump landings: implications for anterior cruciate ligament injury. *British J Sports Med.* 2009; 43:1049-56.
- [9]. Patond KR, Chauhan VD, Kumar N. Semitendinosus transfer for anterior cruciate ligament insufficiency. *Ind J of orthopaedics.* 1992; 26:1.
- [10]. Shelbourne KD, Patel DV. Timing of surgery in anterior cruciate ligament- injured knees. *Knee Surg Sports Traumatol Arthrosc.* 1995; 3(3):148- 56.
- [11]. Marscalo MW, Flanigan DC, Mitchell J, Pedroza AD, Jones MH, Andrish JT *et al.* The Influence of Hamstring Autograft Size on Patient Reported Outcomes and Risk of Revision After Anterior Cruciate Ligament Reconstruction: A Multicenter Orthopaedic Outcomes Network (MOON) Cohort Study. *Arthroscopy: The Journal of Arthroscopic and Related Surgery.* 2013; 29(12):1948-53. DOI: <http://dx.doi.org/10.1016/j.arthro.2013.08.025>
- [12]. Conte EJ, Hyatt AE, Gatt CJ, Dhawan A. Hamstring Autograft Size Can Be Predicted and Is a Potential Risk Factor for Anterior Cruciate Ligament Reconstruction Failure. *Arthroscopy.* 2014; 3(7):882-90. DOI: <http://dx.doi.org/10.1016/j.arthro.2014.03.028>
- [13]. Treme G, Diduch DR, Billante MJ, Miller MD, Hart JM. Hamstring graft size prediction: a prospective clinical evaluation. *Am J Sports Med.* 2008; 36(11):2004-9.
- [14]. Kocher MS, Richard Steadman J, Briggs KK, Sterett WI, Hawkins RJ. Relationships Between Objective Assessment of Ligament Stability and Subjective Assessment of Symptoms and Function After Anterior Cruciate Ligament Reconstruction. *Am J Sports Med.* 2004;32(3):629-34.
- [15]. Bourke HE, Gordon DJ, Salmon LJ, Waller A, Linklater J, Pinczewski LA. The outcome at 15 years of endoscopic acl reconstruction using hamstring tendon autograft. *J Bone Joint Surg Br.* 2012; 94-B:630-7.
- [16]. Daniel B, O'Neill MD. Nassau Bay-Arthroscopic Assisted Reconstruction of the Anterior Cruciate Ligament. *The journal of Bone and Joint Surgery.* 1996; 78A(6):803-813.
- [17]. Gulick TD, Yoder HN. Anterior cruciate ligament reconstruction: Clinical outcomes of patella tendon and hamstring tendon grafts. *J Sports Sci Med.* 2002; 1:63-71.
- [18]. Fareed H, Dionellis P, Paterson FW. Arthroscopic ACL Reconstruction using 4 strand hamstring tendon graft. *J Bone Joint Surg.* 2003; 85:231-6.
- [19]. Cooley V, Deffner K, Rosenberg T. Quadrupled semitendinosus anterior cruciate ligament reconstruction: 5-year results in patients without meniscus loss. *Arthroscopy.* 2001; 17:795-800.
- [20]. Corry IS, Webb JM, Clingeleffer AJ, Pinczewski LA. Arthroscopic Reconstruction of the Anterior Cruciate Ligament A Comparison of Patellar Tendon Autograft and Four-Strand Hamstring Tendon Autograft. *Am J Sports Med.* 1999; 27(4):444-54.
- [21]. Aglietti P, Buzzi R, Zaccherotti G, De Biase P. Patellar tendon versus doubled semitendinosus and gracilis tendons for anterior cruciate ligament reconstruction. *Am J Sports Med.* 1994; 22:211-8.
- [22]. Kim HJ, Lee HJ, Lee JC, Min SG, Kyung HS. Evaluation of Infection after Anterior Cruciate Ligament Reconstruction during a Short Period. *Knee Surg Relat Res.* 2017; 29(1):45-51.
- [23]. Judd D, Bottoni C, Kim D, Burke M, Hooker S. Infections following arthroscopic anterior cruciate ligament reconstruction. *Arthroscopy.* 2006; 22:375-84.
- [24]. Chen L, Cooley V, Rosenberg T. ACL reconstruction with hamstring tendon. *Orthop Clin North Am.* 2003; 34(1):9-18.

Dr. Anil Karampudi, et. al. "Functional Outcome after Arthroscopic Anterior Cruciate Ligament Reconstruction Using Quadrupled Hamstring Graft- A Prospective Analysis." *IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)*, 20(06), 2021, pp. 27-39.