Study of anatomical single bundle ACL reconstruction effect on control of internal tibial rotation compared to contralateral non injured side

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Abstract

Background
The anterior cruciate ligament (ACL) is one of the most commonly injured ligaments of the knee in contact sports players. It accounts for about 200,000 injuries per year in the United States alone.
Patients & Methods
During the period From 1/1/2013 till 31/12/2015 a prospective case series study was conducted to evaluate the outcome of patients undergoing arthroscopic anatomic single bundle (ASB) ACL reconstruction in forty patients with ACL deficient knees.
Results
Follow up of the patients was ranging from 62 to 49 months with a mean of 55 (SD 3.9m) months with no loss of follow up of any of the study patients.There was significant improvement in limping, locking, stability, post-operative pain, swelling, climbing stairs, squatting and need of support pre and post-operative.There was a significant improvement in total lysholm score post-operative with p value < 0.001, show pre and post-operative lysholm score.
Conclusion
Anatomical Single bundle ACL reconstruction is a reliable method with good results and near normal functional outcome.

Key words
Single bundle ACLR, gait analysis assessment.

Introduction

Anterior cruciate ligament reconstruction with standard single bundle techniques provide satisfactory subjective results and restores antero-posterior stability in the vast majority of patients in the short term. Moreover, many authors have clinically detected residual minimal rotatory instability in almost a fifth of cases independent of the graft, surgical technique and choice of fixation device. So, it's evident that single bundle ACL reconstruction does not perfectly restore normal knee kinematics, especially rotatory instability [4].

The fact that so many different methods have been described for reconstruction of ACL in patients with functional instability indicates the ideal solution to this problem has not yet been found, Several solutions have been proposed to increase rotational control of reconstructed graft including a more horizontal graft orientation as through a lower femoral tunnel entry point (such as 10 o'clock position) [5].

Conventional single bundle techniques of ACL reconstruction have focused usually on the restoration of the anteromedial bundle while paying limited attention to the posterolateral bundle. An anatomical SB procedure is performed by placing one single bone tunnel in the center of the tibial and femoral ACL footprints. This results in a randomized percentage of surgically restored ACL footprint.

The aim of the study is to detect the difference in functional outcome and gait analysis regarding internal tibial rotation of both the operated limb and the contralateral non injured limb.

Patients and methods

During the period from 1/1/2013 till 31/12/2015 a prospective case series study was conducted to evaluate the outcome of patients undergoing arthroscopic anatomic single bundle (ASB) ACL reconstruction in forty patients with ACL deficient knees.

Inclusion criteria:

Age from 20 to 40 years, normal contralateral knee with no previous ipsilateralnor contralateral knee surgery and no other associated ligamentous injuries (PCL or collaterals) or chondral lesions.

Associated meniscal injuries had been managed either by repair or menisectomy

Patient demographics:

The mean age of the patients was 29.3 years (from 20-40), 34 male patients and 6 female patients, sports injury was in 30 patients and 10 non-sports injury. 16 patients had associated medial meniscus injury, 10 patients lateral meniscus injury, 6 patients with both meniscal injury and 8 had isolated ACL injury.

Pre-operative evaluation:

Complete pre-operative history and clinical assessment was done according to the following protocol:

A. Complete complain analysis using lysholm score questioning: limp, support, locking, instability, pain, swelling, stair climbing, squatting.

B. Clinical examination: (according to IKDC score assessment)

C. Radiological evaluation:

1. Plain X-ray: radiographic evaluation was done according to the IKDC recommendations.Bilateral complete knee series: Standing anteropostrior, lateral with knee in extension, 45° posteroanterior flexion weight bearing, notch, and Merchant views.
2. MRI evaluation: MR imaging was utilized to assess for additional injuries that may be associated with ACL tears.

Operative details:

There was no pre-operative time limitations for surgery.All patients were operated under general anesthesia, with a pneumatic tourniquet applied while patients lying in supine position with the affected knee flexed and hanging down freely or lying on the operator knee according to the steps done.

- Examination under general anesthesia: Patients were re-examined under anesthesia; findings were compared with the contralateral side and the previous preoperative examination.

- Graft Harvesting The hamstring tendons harvested and prepared in a doubled or tripled fashion to achieve at least 9mm diameter.In all cases graft fixation was done using toggle-loc endobutton on femoral side and interference bioscrew on tibial side.

- Arthroscopic Reconstruction:the 3-portal technique was used, where the main anterolateral (AL) and anteromedial (AM) portals were created along the patellar tendon edges, with an accessory anteromedial portal (AAM), located approximately 1 cm below and medial to the main AM portal, was finally created under direct visualization of the arthroscope with the help of a spinal needle Fig.(1).

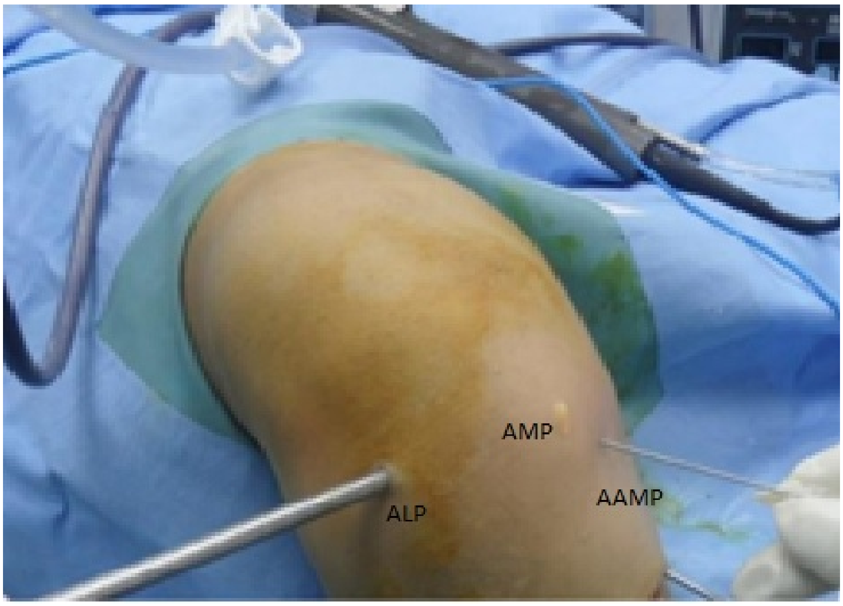

Figure 1: Creating AAM portal under direct visualisation.

- Initially, using the standard AL and AM portals, scopic assessment and notch debridement was done, followed by tibial guide pin insertion using tibial C-guide without tunneling to avoid knee evacuation Figure (2).

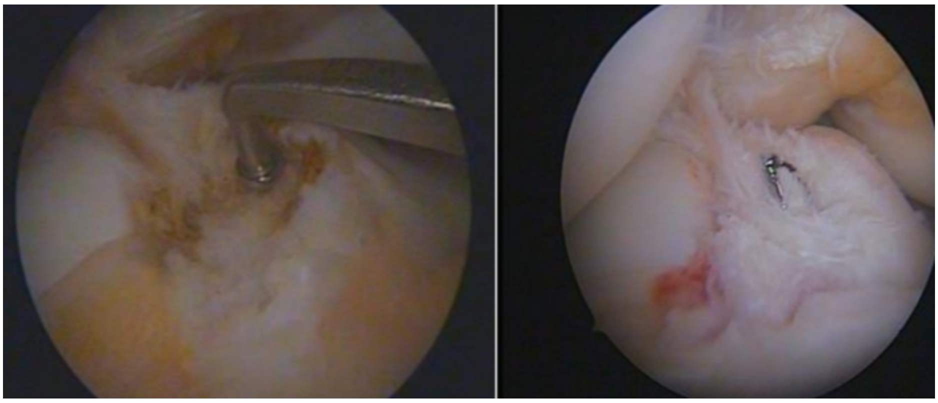

Figure 2: Tibial tunnel preparation

- Then AAM portal was used for instrumentation and femoral tunnel drilling while visualizing the femoral footprint through the AM portal. The posterior edge of the lateral femoral condyle must be clearly identified. The medial aspect of the lateral femoral condyle contains the lateral inter condylar ridge (resident's ridge) representing the superior most boundary of the femoral ACL origin.

- With the knee flexed 120º so as to make the resident's ridge horizontal in line with femoral shaft; trying to feel the bifurcate ridge by probing, which is the landmark separating the native ACL bundles. If not felt, a point in the center of the femoral footprint was marked taking in consideration the tunnel should be totally behind the resident's ridge, typically in the lower one third of the lateral notch. Figure (3).

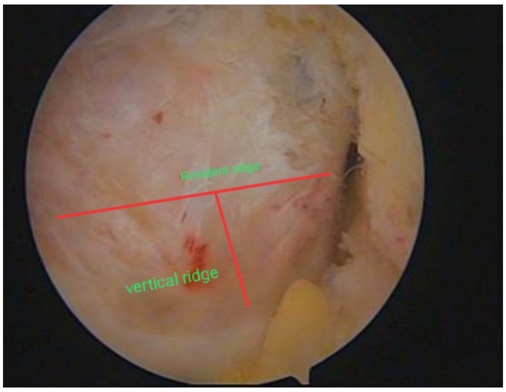

Figure 3: Landmarks for femoral tunneling

- This was followed by reaming the tibial tunnel over the pre-placed tibial guide pin.

- Graft passage through tunnels and after settling of toggle loc button over lateral femoral cortex, tibial side fixation using interference screw while knee in 30° flexion figure (4).

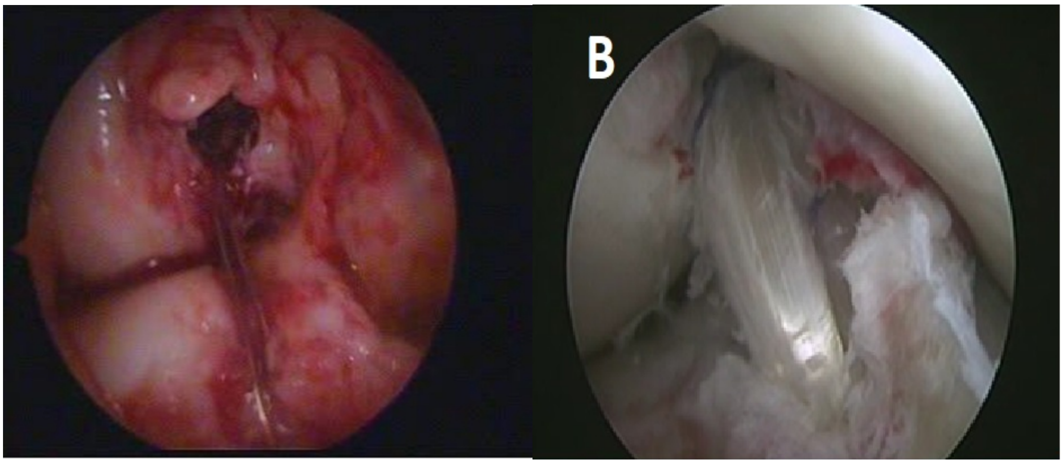

Figure 4: Femoral tunneling and graft passage

Postoperative care: Radiographs of the knee to ensure proper fixation and correct positioning of the tunnels; Dressings were changed and the wound was inspected after 24 hours; Discharging the patient was within 24 hours; Physiotherapy program started from the 2nd post-operative day. **Rehabilitation Protocol:** Adopting a postoperative rehabilitation program which was similar to that described by **Miller, 2003** [6] and the progression through the various stages as tolerated guided by the presence and degree of pain and swelling.

Follow-up evaluation and assessment: All patients were evaluated after surgery every two weeks up to the second postoperative month, monthly up to 6-8 months.

- After assessment of the patients clinically and radiographically, the postoperative rating scales were recorded and all data were documented.

1- Clinical evaluation: Postoperative clinical evaluation the both subjectively using Lysholm knee score and the IKDC scoring system (knee examination form) was used for objective evaluation.

2- Assessment of laxity by KT-1000 arthrometer: Anterior laxity was qualified with KT-1000 (MEDmetric, San Diego, CA). The patient's knees were placed in 20 degrees to 30 degrees flexion with symmetrical tibial rotation maintained. Anterior displacement of the tibia was measured with maximum manual pull. Data were reported as difference between involved and noninvolved knees.

Tibial translation was recorded as: **Normal** (1 to 3mm side to side difference), **nearly normal** (>3 to 5mm side to side difference), **Abnormal** (>5 to 10mm side to side difference or soft), **Severely abnormal** (>10 mm side to side difference). (IKDC) guidelines, 1991).

3- Radiological evaluation: AP and lateral plain radiology were taken for all cases, and the positions of the tunnels were evaluated; The joint cartilage space was measured in patellofemoral, medial and lateral compartments. It was recorded according to guidelines of IKDC figure (5).

Figure 5: Post-operative Radiographs

4-Kinematic analysis: Instruments: Motion Analysis System (Qualisys, Inc, Gothenburg, Sweden) fig.(6) : Qualisys, a 3D motion analysis system was used to measure the concerned kinetic parameters. These parameters involve sagittal plane hip, knee and ankle extension moments, in addition to the Summated Extension Moment. The "Qualisys" Motion Analysis System consists of: a motion capture unit (camera system), a force platform unit, reflective markers, calibration unit, and a personal computer with its accompanying softwares; **Motion capture unit (MCU):**The unit consists of six infrared high speed optical cameras. Each camera is held in its place on a tripod stand. The cameras' position can be adjusted easily on the tripod stand to track the marker position while capturing. The basic principle is to expose the reflective markers to infrared light emitted from the cameras and to detect the light reflected by the markers. The camera system is composed of six cameras to carry out multi camera measurements. **The force plate unit:** An AMTI (Advanced Mechanical Technology Inc., USA) force plate is impeded in the center of a walk way. Its dimensions are 40 cm in width and 60 cm in length. The signals from the plate are first amplified by an internal amplifier and fed to the computer through an analogue to digital (A/D) converter. Thus the final output of the system is the digitized voltage values.**Reflective markers:**Twenty passive reflective markers comprised of plastic balls of 1.5cm diameter, coated with reflective material were used as body surface markers. The markers were attached to the skin with double-sided adhesive tape. The markers were attached to the following bony landmarks; acromion processes, 12th thoracic vertebral spinous process, second sacral vertebrae, anterior superior iliac spines, greater trochanters, superior border of patellae, inferior to the lateral aspect of the lateral femoral condyles (knee joint line), tibial tuberosities, lateral malleoli, posterior aspect of the calcaneus bilaterally, and on the dorsum of the feet between the second and third metatarsal bones. **Calibration unit:** It can provide the camera system with measurement points to be used for analysis. **A personal computer and accompanying software:** A personal computer with its accompanying software was used for data recording and analysis.

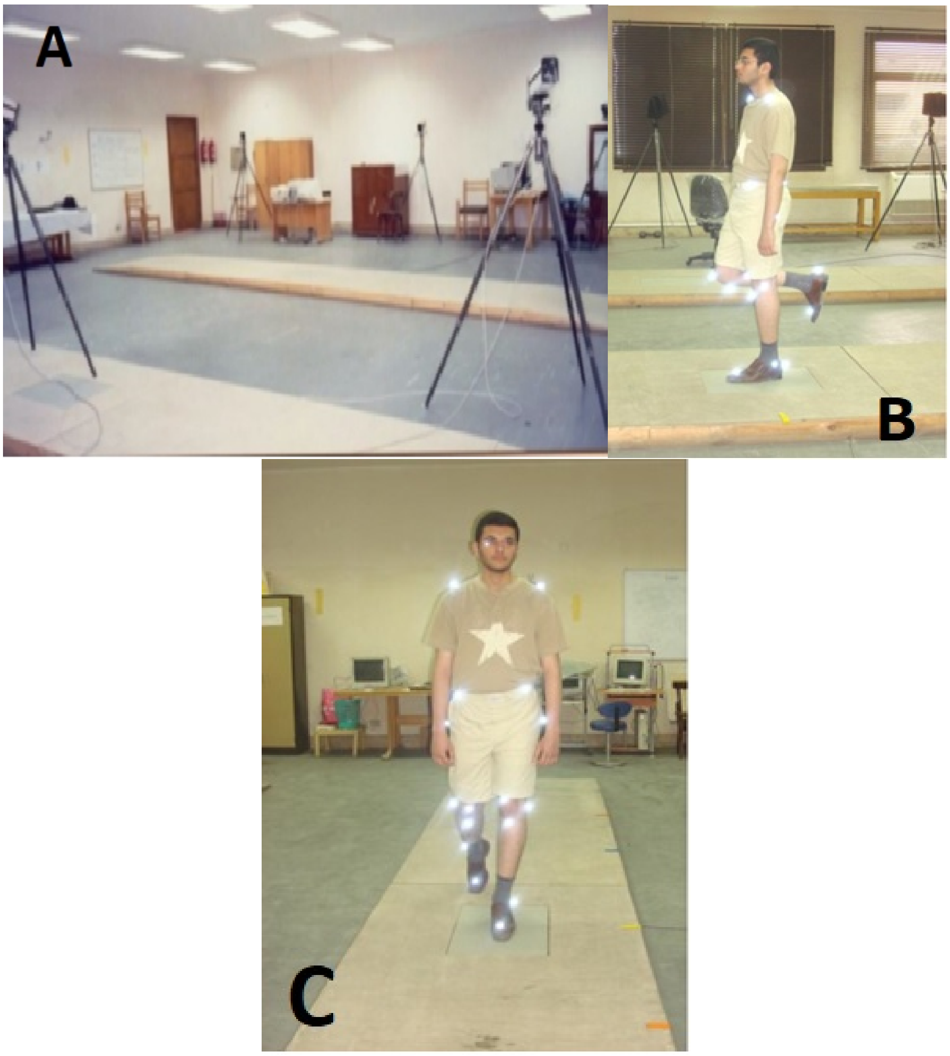

Fig.6: a-Motion capture unit. B &C- Force plate unit and reflective markers

Statistical analysis: Data were coded and entered using the statistical package SPSS (Statistical Package for the Social Sciences) version 25. For comparison of serial measurements within each patient (pre and post) the non-parametric Wilcoxon signed rank test was used ***(Chan, 2003a)*** [7]. Correlations between quantitative variables were done using Spearman correlation coefficient ***(Chan, 2003b)*** [8]. P-values less than 0.05 were considered as statistically significant.

Results

During the period from 1/1/2013 till 31/12/2015 a prospective case series study was conducted to evaluate the outcome of patients undergoing arthroscopic anatomic single bundle (ASB) ACL reconstruction in Forty (40) patients with ACL deficient knees compared to contralateral non injured normal side.

Follow up of the patients was ranging from 62 to 49 months with a mean of 55 (SD 3.9m) months with no loss of follow up of any of the study patients.

Table 1: Showing the data of the patients' pre and post-operative

	Pre					Post					P value
	Mean	SD	Median	Minimum	Maximum	Mean	SD	Median	Minimum	Maximum	
limp	3.10	1.81	3.00	.00	5.00	4.70	.72	5.00	3.00	5.00	<0.001
support	3.95	1.45	5.00	2.00	5.00	4.70	.91	5.00	2.00	5.00	0.002
locking	11.15	4.75	15.00	2.00	15.00	13.55	2.67	15.00	6.00	15.00	0.002
stairs	6.45	2.82	6.00	.00	10.00	9.40	1.45	10.00	6.00	10.00	<0.001
instability	16.50	5.80	15.00	10.00	25.00	24.00	2.03	25.00	20.00	25.00	<0.001
pain	13.75	7.14	12.50	.00	25.00	21.25	5.03	25.00	10.00	25.00	<0.001
swelling	6.50	3.03	6.00	.00	10.00	9.05	2.01	10.00	3.00	10.00	<0.001
squatting	2.90	1.81	4.00	.00	5.00	4.50	.93	5.00	2.00	5.00	<0.001
total score	64.55	18.66	65.00	30.00	95.00	92.15	9.72	95.00	64.00	100.00	<0.001

There was significant improvement in limping, locking, stability, post-operative pain, swelling, climbing stairs, squatting and need of support pre and post-operative.

Significant improvement in total lysholm score post-operative with p value < 0.001, figure (6) show pre and post-operative lysholm score.

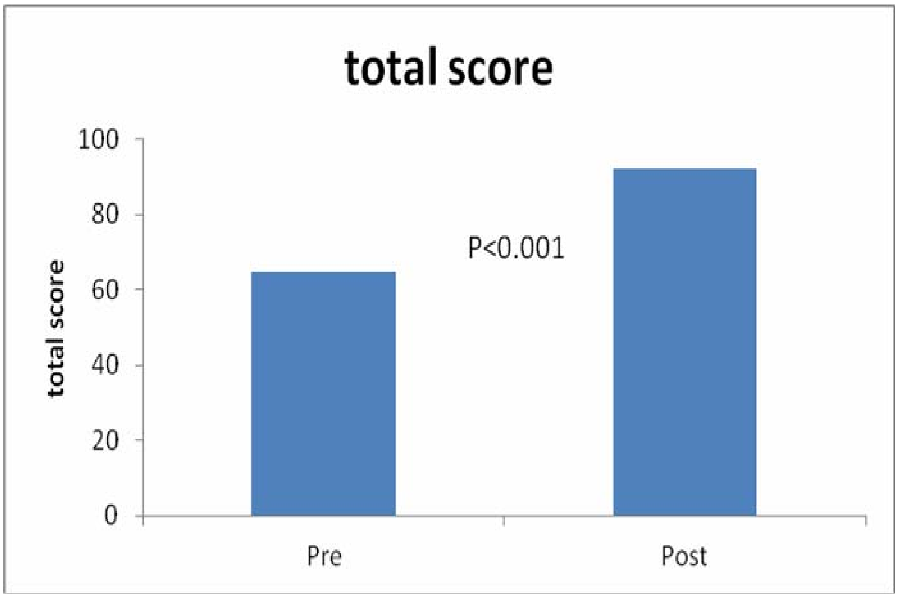

Figure 7: Show pre and post-operative lysholm score

There a significant correlation between KT 1000 test and improvement in stability, squatting, limbing and post-operative pain.

Gait analysis assessment:

Regarding results of gait analysis there was a significant difference between operated and normal sides in knee internal rotation angle but there was no significant difference in knee extension moment.

Table 2: Showing results of gait analysis

	Operated					Non operated					
	Mean	SD	Median	Minimum	Maximum	Mean	SD	Median	Minimum	Maximum	P value
Knee int. rot. Angle	-6.88	5.59	-5.04	-20.50-	-1.36	-8.72	2.77	-8.96	-12.40	-2.55	0.002
knee extension moment	1.54	.70	1.59	.36	3.25	1.67	1.07	1.85	-.34	3.52	0.133

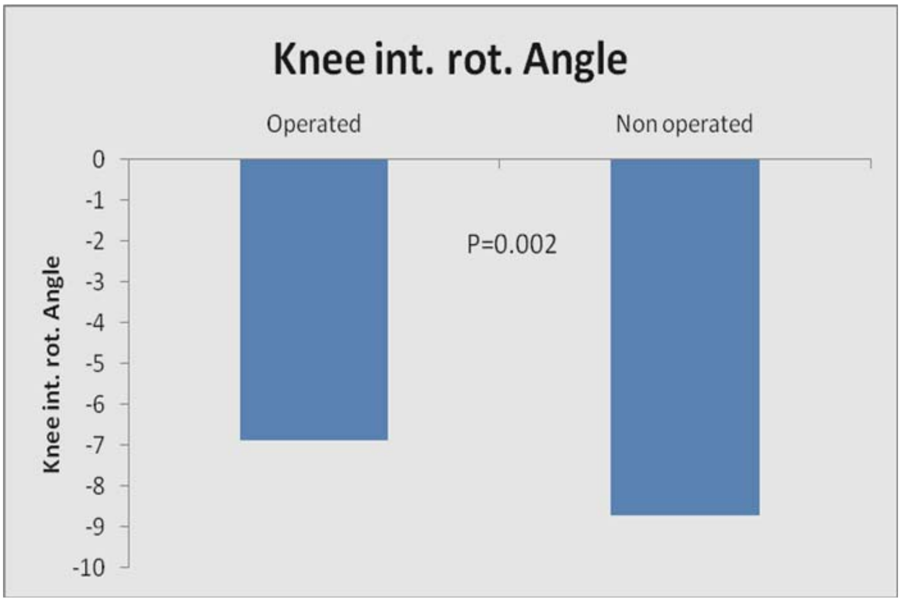

Figure 8: Showing internal rotation angle in operated and normal limbs

Complications:

Table 3: showing complications occurred.

		Count	%
EFFUSION	yes	3	7.5%
	no	37	92.5%
EXT. LAG	yes	5	12.5%
	no	35	87.5%
LIMTED FLEXION	yes	4	10.0%
	no	36	90.0%
LAXITY	yes	3	7.5%
	no	37	92.5%

Discussion

The fact that so many different methods have been described for reconstruction of ACL in patients with functional instability indicates the ideal solution to this problem has not yet been found [11].

As a result of better understanding of ACL anatomy and biomechanical function, reconstruction of the anterior cruciate ligament (ACL) has been increasingly successful during the past 15 years. Nevertheless, a review of the literature shows that simple ACL reconstruction results in insufficient long-term outcomes. This raised the question of a recurrence of instability and the efficacy of the ACL reconstruction in the prevention of osteoarthritis [12].

Current grafts control the anteroposterior stability of a knee near extension but are less effective in providing rotatory stability. To improve the stability of the knee and to approximate the complex biomechanical role of the ACL, several authors have recently proposed the reconstruction of the posterolateral bundle (PLB) in addition to the AM bundle [13].

Yagi et al 2002, showed better anterior and rotational stability with DB ACL reconstruction compared to SB ACL reconstruction in a robotic cadaver model. Especially rotational stability was significantly closer to that of an intact knee when an additional PL bundle reconstruction was performed compared to a SB ACL reconstruction without PL bundle. In this study non anatomical single bundle reconstruction was done. However, in our current study anatomic single bundle technique was conducted in vivo. [14].

Steven C. et al 2011, showed that both “anatomic” single and double bundle ACL reconstruction adequately restore tibial rotational excursion in a human, in vivo kinematic model. The results of this dynamic study do not support the theoretical advantage of a double-bundle ACL reconstruction over an “anatomic” single-bundle ACL reconstruction, which goes hand in hand with our results [15].

In a study by **Jason Y. et al, 2009** to compare the kinematics of a central anatomic single bundle ACL reconstruction with a double bundle ACL reconstruction by use of hamstring grafts and anatomic tunnel placement. Anterior tibial translation and rotation were measured with using a computer navigation system in 8 pairs of fresh frozen cadaveric knees. The study concluded that central anatomic single bundle ACL reconstruction with tunnels centered within the tibial and femoral insertions and double bundle ACL reconstruction can restore normal anterior translation and internal tibial rotation under anterior and rotational loads applied at 30° and 60° of flexion, which was consistent with our study in which anatomical single bundle reconstruction in vivo patients showed similar results [16].

However, the study by **Branch T. P. et al 2011** showed that while relative side-to-side differences in IR did not differ between the SB (1.3°) and DB groups (1.1°, P = 0.82), absolute IR differences were significantly less with the DB reconstruction (2.1° vs. 4.7°, P = 0.001), in this study single bundle reconstruction was non anatomical alike our study [17].

A meta-analysis of random controlled trials by ***Xu et al.*** revealed that DB ACLR resulted in significantly better anterior and rotational stability and higher IKDC objective scores compared with single-bundle reconstruction. However, this meta-analysis did not detect any significant differences in subjective outcome measures between double- bundle and single-bundle reconstruction, as evidenced by the Lysholm score, Tegner activity scale, and IKDC subjective score, this meta-analysis did not consider anatomical and non-anatomical single bundle reconstruction [18].

In our study we were comparing the operated limb and the non-operated limb regarding post-operative results and gait differences in both limbs and as the non-operated limb is having intact both bundles.

There was no significant difference between operated and non-operated limbs regarding total lysholm scores and IKDC.

There was significant difference in knee internal rotation angle between operated and non-operated limbs with no significant difference in both limbs in knee extension moment.

Our study included 40 patients and they was followed up for at least 48 months, the weakness in our study is there is no comparative groups, and the need to compare anatomical single bundle with anatomical double bundle ACL reconstruction.

Conclusion

Anatomical Single bundle ACL reconstruction is a reliable method with good results and near normal functional outcome regarding restoration of translational and rotational stability of the knee.

References

1. Hootman JM, Dick R, Agel J: Epidemiology of collegiate injuries for 15 sports: summary and recommendations for injury prevention initiatives. J Athl Train. 2007, 42:311-19.
2. VaishyaR ,Hasija R: Joint hypermobility and anterior cruciate ligament injury . J OrthopSurg (Hong Kong). 2013, 21:182–84.
3. Dragoo JL, Bruan HJ, Durham JL, Chen MR, Harris AHS. Incidence and risk factors for injuries to the anterior cruciate ligament in National Collegiate Athletic Association football: data from 2004-2005 through 2008-2009 national collegiate athletic association injury surveillance system. *Am J Sports Med.* 2012; 40 (5): 990- 995.
4. Aglietti P., Cuomo P. and Giron F. Double bundle anterior cruciate ligament reconstruction In: Surgery of the knee, 4th (ed.), ch 42, P 677-685, W. Norman Scott. Churchill Livingston, Elsevier, 2006.
5. Gabriel M., Wong E. and Woo S. Distribution of in situ forces in anterior cruciate ligament in response to rotatory loads. J Orthop Res 22: 85-89, 2004.
6. Miller R.: Injuries of the knee. In: Campbell's operative orthopedics, Canale S. (edr): 10th (ed.), p 2165-2338 Mosby, St Louis, 2003.
7. Chan YH (2003a): Biostatistics102: Quantitative Data – Parametric & Non-parametric Tests. Singapore Med J.;44(8): 391-396.
8. Chan YH (2003b): Biostatistics 104: Correlational Analysis. Singapore Med J.;44(12) : 614-619.
9. Biau D., Tournoux C., Katsahian S., Schranz P. and Nizard R.: Bone-patellar tendon-bone autografts versus hamstring autografts for reconstruction of anterior cruciate ligament: meta-analysis . BMJ 332: 995-1001, 2006.
10. Manifold G., Cushner D. and Scott N.: Arthroscopic anterior cruciate reconstruction with bone-patellar tendon bone autograft: indications, technique ,complications and managemnent In: Surgery of the knee, 4th (ed.), ch 39, p 632-646 W.Norman Scott. Churchill Livingston, Elsevier, 2006.
11. Johnson R., Beynnon B., Nicholas C. and Renstrom P.: Current concept review: The treatment of injuries of the ACL. J Bone Joint Surg 74 A: 140, 1992.
12. Nedeff D., Bach J.: Arthroscopic anterior cruciate ligament recon-

struction using patellar tendon autografts: A comprehensive review of contemporary literature. Knee Surg, 14: 243-258, 2001.

13. Bellier G., Christel P., Colombet P., et al: Double stranded hamstring graft for anterior cruciate ligament reconstruction. Arthroscopy, 20:890-894, 2004.
14. Yagi M., Wong E., Kanamori A. et al: Biomechanical analysis of an anatomic anterior cruciate ligament reconstruction. Am J Sports Med 30: 660-666, 2002.
15. Steven C. et al: Tibial rotation in Single-Bundle and Double-Bundle Anterior Cruciate Ligament Reconstructions. A kinematic 3-D in vivo analysis. Knee Surg Sports TraumatolArthrosc19, supplement 1,115-121, december2011.
16. Jason Y., Gardiner A., Shah V. and Steiner M.: Equal kinematics between central anatomic single bundle and double bundle anterior cruciate ligament reconstructions. Arthroscopy: J ArthroscRelSurg 25(5), 464-472, 2009.
17. Branch T., Seibold R., Freedberg H. and Jacobs G.: Double bundle ACL reconstruction demonstrated superior clinical stability to single bundle ACL reconstruction: a matched pairs analysis of instrumented tests of tibial anterior translation and internal rotation laxity. Knee Surg Sports TraumatolArthrosc 19(3), 432-440, 2011.
18. Xu M, Gao S, Zeng C, et al. Outcomes of anterior cruciate ligament reconstruction using single-bundle versus double-bundle technique: meta-analysis of 19 randomized controlled trials. Arthroscopy. 2013;29(February (2)):357–365.