Correlation of Graft Position, Knee Laxity and Clinical Outcome: Comparison with Native Anterior Cruciate Ligament Using Magnetic Resonance Imaging Study

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Objective: *To compare the sagittal obliquity of anterior cruciate ligament graft with normal native anterior cruciate ligament in contralateral knee, to determine the effect of sagittal obliquity and axial femoral tunnel graft placement on stability and functional knee score (Lysholm), and to measure size of graft after complete ligamentization.*

Material and Method: *Seventy single tunnel quadruple hamstring anterior cruciate reconstructed knee in unilateral ACL injury patients were evaluated at 18 months after surgery. At follow up, patients were evaluated including measurement of knee laxity by using side to side different on KT 1000 arthromeres and clinical outcome by completed Lysholm functional knee questionnaires. Sagittal T1 weighted magnetic resonance image with complete dimension of graft from origin to insertion on each side of knee were depicted to compare the obliquity by measuring the intersection angle of the graft line with the tibial plateau plane. The axial femoral tunnel was determined by angle between anteroposterior axis of distal femur and long axis of femoral tunnel. The diameter of graft was also measured.*

Results: *Graft obliquity was average 58° with range between 41° and 69°. In contralateral native ACL obliquity was average 50° with range between 33° and 63°. The difference between the two groups was statistically significant (p < 0.0001). Average axial femoral tunnel was 36° with range between 10° and 56°. Knee laxity (KT-1000 arthrometer; average pre-op = 6, post-op = 3) and Lysholm knee scores (average score; pre-op55, post-op score 89) were significantly improved after surgery (p < 0.01). There was no correlation between degree of sagittal obliquity and axial femoral tunnel with knee laxity and functional score in this series. Graft size was increased in average 8% after 18 months post-operatively.*

Conclusion: *ACL grafts in patients with appropriate tibial tunnel placement were more vertical than native ACL. There was no significant effect of degree of sagittal obliquity and axial femoral tunnel to antero-postero stability and knee score. ACL graft size was increased in diameter during post-operative period. Graft-notch distance should be considered during operation.*

Keywords: *Anterior cruciate ligament, Joint instability, Knee joint, Magnetic resonance imaging, Range of motion, Articular*

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Recently, arthroscopic anterior cruciate ligament reconstruction (ACLR) is the gold standard treatment for ACL injury. Techniques vary. Notch impingement must be avoided to decrease rate of graft failure and loss of range of motion (extension). Notchplasty may be required in some cases. Posteriorized tibial tunnel may decrease the incidence of notch impingement but may increase sagittal obliquity of ACL graft. Biomechanical study revealed that the increase sagittal obliquity of ACL graft can cause anteroposterior and rotatory instability but no study has reported the amount of clinical obliquity that cause such instability.

Graft hypertrophy can be the cause of postoperative impingement. An animal study demonstrated postoperative graft hypertrophy. In

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the present study, the authors wanted to measure the graft size postoperatively in time when ligamentization fully occurs.

Arthroscopic ACLR with quadruple hamstring autograft were performed in all the patients enrolled in the present study and measured by MRI.

Objectives

1. Compare sagittal obliquity of ACL graft with native contralateral ACL
2. Find correlation between axial femoral tunnel and sagittal obliquity with clinical outcome and functional knee score
3. Demonstrate enlargement of ACL graft postoperatively when ligamentization completed

Material and Method

Between 2002 and 2005, patients with ACL injury were enrolled in Lerdsin Hospital. Arthroscopic ACLR with quadruple hamstring autograft and direct interference screw fixation under 1-incision technique were used in 70 patients. Three medical staffs were assigned for each operation randomly. Functional outcome and MRI study were performed and assessed by orthopedic residents and radiologists. All patients were informed and consents were signed.

Inclusion criteria

1. Unilateral isolated primary ACL injury
2. ACLR performed at least 18 months

Exclusion criteria

1. Bilateral ACL injury
2. Contraindicated to MRI study

Clinical evaluation

1. Knee laxity: Lachman's test, Pivot shift test, KT-1000 arthrometer (MED Metric, San Diego, California) compared with normal contralateral knee (more than 3 mm difference indicate graft laxity)
2. Lysholm knee score (Appendix)

Clinical examination was performed, MRI were assigned within 4 weeks after last examination. MRI result and measurement were performed by a single radiologist. Postoperative interval before MRI performed must be more than 18 months. MRI data was analysed by E-film workstation program [DICOM]. Examinator measured all parameter three times and found its mean. Parameters examined were sagittal obliquity, axial femoral tunnel, and graft diameter.

Angle measurement

1. Sagittal obliquity measured from sagittal T_1 weighted image. This can demonstrate the entire ACL graft. Tibial plateau plane were drawn at the level of anterior edge of ACL graft insertion. Long axis of graft were drawn from the midpoint of graft insertion to the midpoint of its midportion, then measured the angle between tibial plateau plane and long axis of ACL graft both native and reconstructed side (Fig. 1).

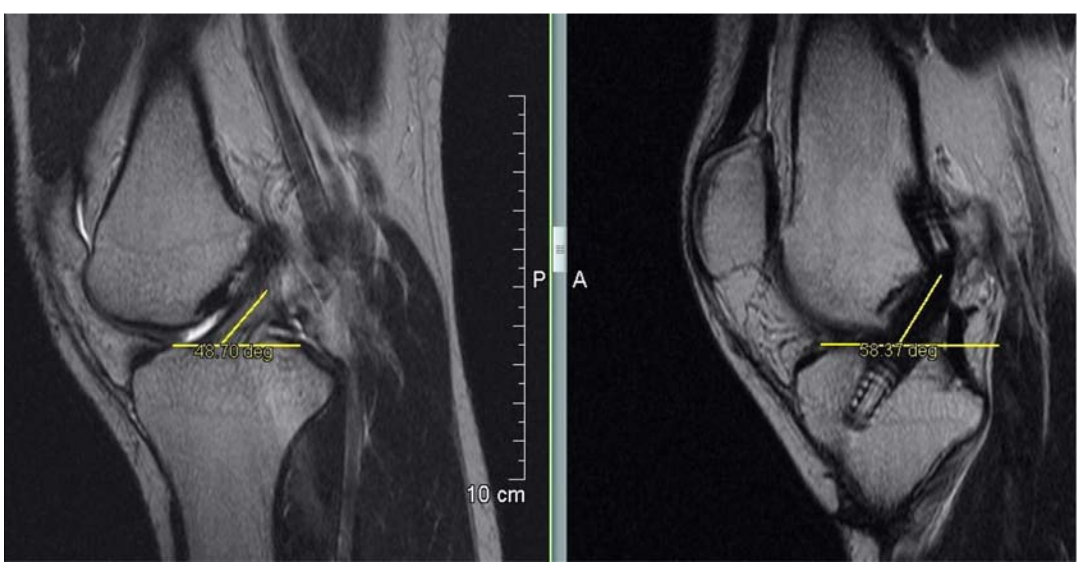

Fig. 1 Sagittal obliquity measurement compare between contralateral native ACL and ACL graft

2. Axial femoral tunnel measure from axial T_1 weight image. A circle was drawn centered on femoral intercondyle. Vertical line was drawn along AP axis of distal femur. Another line was drawn from the center of this circle to the long axis of femoral tunnel then measured angle between this two lines (Fig. 2).

3. Graft diameter measured from anterior to posterior border along the longitudinal axis of the graft (Fig. 3).

Statistical analysis

SPSS program was used to analyze all data as follows:

1. Paired t-test determined difference between

1.1 Sagittal obliquity of native ACL and ACL graft

1.2 graft diameter preoperative and postoperative

1.3 KT 1000 preoperative and postoperative

1.4 Lysholm knee score preoperative and postoperative

2. Logistic regression analysis determined correlation between sagittal obliquity, axial femoral tunnel, sex, associate meniscus injury with knee laxity (KT-1000) $p < 0.05$

3. Binary logistic regression analysis determined correlation between sagittal obliquity, axial femoral tunnel, sex, associate meniscus injury with Lysholm knee score. The authors stratified knee score into two groups, 1. Excellent and good result (score > 80) and 2. Fair and poor result (score < 84)

Results

Seventy patients were enrolled in the present study (61 male and 9 female). Average age was 30.75 years (19-58), right knee 48 patients, left knee in 22 patients. Associated meniscal injuries were noted in 34 patients (49%). In this group, 16 patients (23%) meniscus repair were performed, nine patients (13%) meniscus repair and partial menisectomy were performed, and nine patients (13%) partial menisectomy were performed. Average time between operation and MRI was 30 months.

Clinical results

1. Knee laxity (KT-1000 arthrometer) preoperative 5.7 mm (SD = 2.44), postoperative 3.1 mm (SD = 2.08) with statistical significant ($p < 0.0001$)

2. Lysholm knee score preoperative 55.86 (SD = 13.7), postoperative 88.5 (SD = 6.7) with statistical significant ($p < 0.0001$)

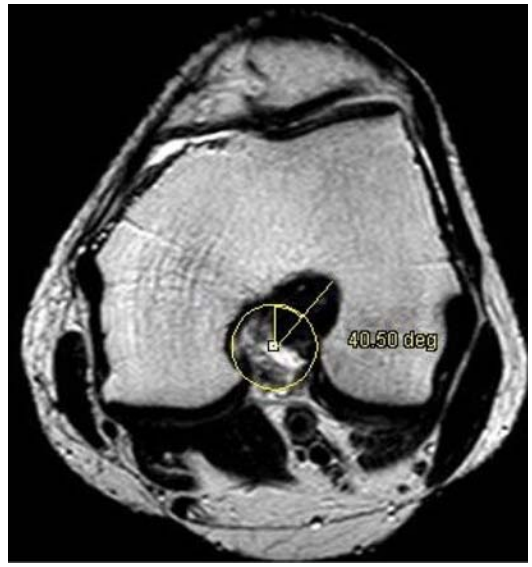

Fig. 2 Axial femoral tunnel measurement

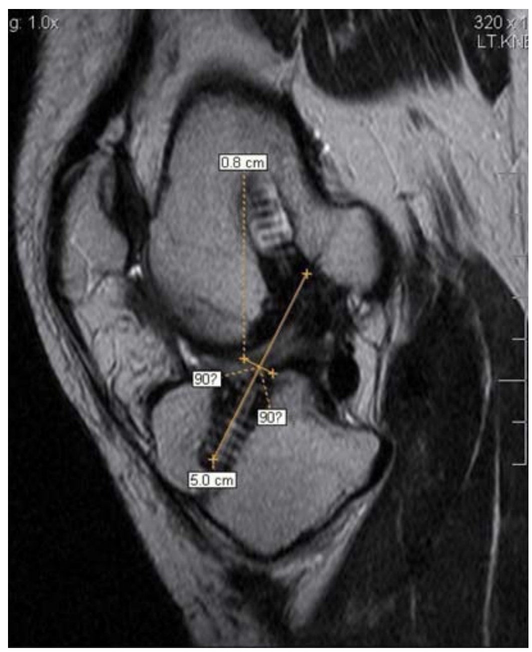

Fig. 3 Graft diameter measurement

MRI results

1. Sagittal obliquity in native ACL 49.5° (33°-63°) with SD = 5.63. In ACL graft 57.6° (41°-69°) with SD = 5.89 with statistical significance ($p < 0.0001$)

2. Axial femoral tunnel 36.3° (10°-57°)

3. Graft diameter preoperative 8.25 mm (7-10),

postoperative 8.91 mm with statistical significance ($p < 0.0001$). From the present study, the authors found that graft increased its size 8% when full ligamentization occurred.

Correlation between factors affecting clinical outcome

1. No statistical correlation was found between degree of sagittal obliquity, axial femoral tunnel, associated meniscus injury, and age with KT-1000 using logistic regression analysis ($p > 0.05$)

2. The authors found no correlation between knee score and sagittal obliquity, axial femoral tunnel, associated meniscus injury, and age using binary regression analysis ($p > 0.05$)

Discussion

Today, arthroscopic ACLR provides a good to excellent result in more than 90%. Hamstring and patella tendon are the first two commonly used. In the present study, the authors used hamstring tendon in all patients because of less kneeling pain and less harvest site problems. Long-term study by Pinczewski[5] reported that incidence of graft rupture and stability was comparable between hamstring and patella tendon graft. Although single tunnel reconstruction technique gives pleasant result, instability and graft failure still occurs. The most important factors owing to graft failure are graft impingement and tunnel malposition. Anatomical study demonstrated that diameters of native ACL we varied from its origin to insertion. At tibial insertion, the diameters are two times greater than its origin. Hamstring tendon grafts are parallel, so when reconstruct ACL using tibial anatomical footprint impingement may occur. In order to avoid impingement, notchplasty can be performed but bone regrowth can occur. Postero-medialized tibial tunnel footprint can be another option but it can also cause the graft to be steeper. Biomechanical study demonstrated that the more vertical the graft the more anteroposterior and rotatory instability it will cause. The present study intended to find the correlation between sagittal obliquity of the graft and clinical outcome.

The result of the present study demonstrated that sagittal obliquity of ACL graft was greater than native ACL and correlated with the study of Ayerza et al[10]. The present study was designed to compare sagittal obliquity between knees in the same patient, which is different from the study of Ayerza (compared with normal subjects).

The present study also demonstrated that although non-anatomic, placement of the graft anteroposterior stability and knee score still gave good results in 88% of the patients. Limitation of the present study was that the authors could not evaluate the correlation between sagittal obliquity and rotational instability.

Cadaveric biomechanical study by John C Loh[11] demonstrated that femoral tunnel placement at 10 o'clock can improve rotational stability than 11 o'clock. Another study by Lee MC et al[12] demonstrated that femoral tunnel placement more vertical can lessen knee score and increased rotational instability but can improve anteroposterior stability. In the present study, it demonstrated that femoral tunnel placement from 10°-57° did not show any statistical difference in anteroposterior laxity and knee score.

Sagittal obliquity and axial femoral tunnel placement parameters in the present study are spread widely yet still have good result. Imply that single tunnel ACLR may have wide range of acceptance in tunnel placement. Double tunnel reconstruction gains more popularity nowadays. Biomechanical study also demonstrates greater anteroposterior and rotational stability but no long-term clinical series show this benefit. Double tunnel technique has its major disadvantages because it needs very precise tunnel placement and complications are harder to solve. The work by Pinczewski[16] encourages that appropriate tunnel placement in single tunnel technique can give great anteroposterior and rotational stability. In patient with lower demand group, single tunnel technique may be a better choice. The present study cannot determine the best angle for placement of the ACL graft.

Associated meniscal injury was found in 49% of the present study group. Treatment varies from repair to menisectomy. There was no statistical correlation between meniscal injury and lower knee score. The reasons that can explain this situation are that not enough time to follow-up these patients is given and arthritis did not really develop.

According to the study of Hamada et al[18] the graft diameter increases 9%, 13%, and 7% from 3, 12, and 24 months postoperative respectively. In the present study, the authors found that graft diameter increased 8% at 30 months. From this knowledge, the authors should increase graft-notch distance when performing ACLR to prevent graft impingement postoperatively. Hamada et al[14] advocated that graft-notch distance should be 1.1, 1.3 and 1.4 mm for graft size 7, 8 and 9 mm respectively.

From the present study, the authors conclude that arthroscopic single tunnel quadruple hamstring

ACLR graft placement nonanatomically would cause an increase in sagittal obliquity but still have good clinical outcome and anteroposterior stability. Graft increased its diameter during postoperative period. Associated meniscal injury that was treated did not affect clinical outcome and knee score at mean follow-up of 30 months. Long-term follow-up should be conducted.

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Appendix Lysholm knee rating system

Lysholm Knee Rating System

Name______________________________ Date________ Therapist____________

By completing this questionnaire, your therapist will gain information as to how your knee functions during normal activities. Mark the box which best describes your knee function today.

1. LIMP (5 points)

☐	None	5
☐	Slight or periodic	3
☐	Severe and constant	0

2. SUPPORT (5 points)

☐	None	5
☐	Cane or crutch needed	2
☐	Weight bearing impossible	0

3. LOCKING (15 points)

☐	None	15
☐	Catching sensation, but no locking	10
☐	Locking occasionally	6
☐	Locking frequently	2
☐	Locked joint at examination	0

4. INSTABILITY (25 points)

☐	Never gives way	25
☐	Rarely during athletic activities/physical exertion	20
☐	Frequently during athletic activities/physical exertion	15
☐	Occasionally during daily activities	10
☐	Often during daily activities	5
☐	Every step	0

5. PAIN (25 points)

☐	None	25
☐	Intermittent and light during strenuous activities	20
☐	Marked during strenuous activity	15
☐	Marked during or after walking more than 2 km. (1.2 mi.)	10
☐	Marked during or after walking less than 2 km. (1.2 mi.)	5
☐	Constant	0

6. SWELLING (10 points)

☐	None	10
☐	After strenuous activities	6
☐	After ordinary activities	2
☐	Constant	0

7. STAIRS (10 points)

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

8. SQUATTING (5 points)

☐	No problem	5
☐	Slight problem	4
☐	Not beyond 90° of flexion of the knee (halfway)	2
☐	Impossible	0

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การศึกษาความสัมพันธ์ความชันของกราฟเอ็นไขว้หน้าหัวเข่าต่ออาการทางคลินิกของผู้ป่วย

สุริยพงษ์ เสาวพฤทธิ์, ธนะเทพ ตั้นเผ่าพงศ์, ชัยวัฒน์ ปิยะสกุลแก้ว

ภูมิหลัง*: การศึกษานี้เป็นการศึกษาในผู้ป่วยที่มีเอ็นไขว้หน้าของหัวเข่า (ACL injury) ที่ได้รับการผ่าตัดรักษาด้วยการผ่าตัด arthroscopic single tunnel ACL reconstruction ด้วย quadruple hamstring graft*

วัตถุประสงค์*:*

1. เพื่อต้องการทราบขนาดความชันของกราฟว่ามีขนาดเท่าใดโดยทำการเปรียบเทียบกับข้างปกติ

2. เพื่อศึกษาขนาดของความชัน(sagittal obliquity) และ ตำแหน่งของ femoral tunnel ว่ามีผลต่ออาการทางคลินิก (antero-posterior stability และ Lysholm knee score) อย่างไร

3. ต้องการทราบขนาดของกราฟว่าเปลี่ยนแปลงอย่างไรภายหลังการผ่าตัด

วัสดุและวิธีการ*: ผู้ป่วยที่มีเอ็นไขว้หน้าขาดเพียงข้างเดียว(unilateral injury) 70 คนที่ได้รับการผ่าตัดมาแล้วไม่น้อยกว่า 18 เดือน เข้าร่วมโครงการศึกษาจะได้รับการส่งตรวจคลื่นแม่เหล็กไฟฟ้า และตรวจวัดอาการทางคลินิกโดยประเมินจาก Lysholm knee score และ AP stability จาก KT-1000 arthrometer ส่วนข้อมูลภาพคลื่นแม่เหล็กไฟฟ้าจะนำมาวัด sagittal obliquity, ตำแหน่งของ femoral tunnel และขนาดความกว้างของกราฟด้วยโปรแกรม E-film workstation [DICOM] หลังจากนั้นก็นำข้อมูลที่ได้มาหาความสัมพันธ์กับอาการทางคลินิก*

ผลการศึกษา*: ค่าความชัน (sagittal obliquity) ในข้างที่ผ่าตัดมีค่าเฉลี่ย 58° โดยมีพิสัยระหว่าง 41°-69° ขณะที่ในข้างปกติมีค่าเฉลี่ยที่ 50° โดยมีพิสัยระหว่าง 33°-63° จากการวิเคราะห์พบว่าข้างที่ผ่าตัดมีความชันมากกว่าข้างปกติอย่างมีนัยสำคัญทางสถิติ ($p < 0.0001$) ส่วนค่าเฉลี่ยของตำแหน่ง femoral tunnel อยู่ที่ 36° มีพิสัยระหว่าง 10°-56° อาการทางคลินิกพบว่าเมื่อเปรียบเทียบก่อนผ่าตัดและหลังผ่าตัดแล้วค่า KT-1000 (ค่าเฉลี่ย KT 1000 ก่อนผ่าตัดและหลังผ่าตัด เท่ากับ 6 และ 3ตามลำดับ) และ knee score (ก่อนผ่าตัดและหลังผ่าตัด เท่ากับ 55 และ 89 ตามลำดับ) ดีขึ้นอย่างมีนัยสำคัญทางสถิติ โดยมีผู้ป่วยที่ได้ผลดีและดีมาก อยู่ที่ 88% ส่วนขนาดความกว้างของกราฟพบว่ามีขนาดใหญ่กว่าตอนผ่าตัดโดยเฉลี่ยประมาณ 8% จากการวิเคราะห์ทางสถิติพบว่าขนาดของความชันของกราฟ (sagittal obliquity) และตำแหน่ง femoral tunnel ไม่ได้ส่งผลอย่างมีนัยสำคัญทางสถิติต่ออาการทางคลินิก (antero-posterior stability และ Lysholm knee score)*

สรุป*: ACL reconstruction graft มีความชันมากกว่าข้างปกติ แต่ยังสามารถให้ AP stability และ knee score ที่ดีได้ขนาดของกราฟภายหลังผ่าตัดจะมีขนาดใหญ่ขึ้น ดังนั้นการผ่าตัดควรคำนึงถึงระยะห่าง graft-notch distance*