40 Years with the ACL: Influence on My 2013 ACL Reconstruction Recommendation

John Bergfeld, MD

I have nothing To disclose

• Twisting – pivot
• Come down from a jump
• Sudden pain
• Disabling
• Felt a snap or pop
• Significant effusion within 24 hrs. (3-4+)
Surgery of little help for cruciate ligament injury

The Medical Post

September 5, 1972

With the athlete and the orthopaedic consultant, although the follow-up was by no means...

If the knee components are dislocated less than 5 mm in measured on the x-ray, the surgeon...
ISOLATED TEAR OF ACL
A FIVE YEAR FOLLOW UP

2 YEARS 85% DOING WELL
5 YEARS 15% DOING WELL

John A. Feagin, Jr, MD,
Walton W. Curl, MD,

DEADLY ORTHOPAEDIC TRIAD

DEADLY ORTHOPAEDIC TRIAD
- COMMON PROBLEM (UNSTABLE KNEE)
Rotatory Instability of the Knee: Its Pathogenesis and a Clinical Test to Demonstrate Its Presence

Donald Slocum, MD and Robert Larson, MD
Eugene, Oregon

Journal of Bone and Joint Surgery – American Volume
Vol 50A(2), March 1968

DEADLY TRIAD
- COMMON PROBLEM (UNSTABLE KNEE)
- PHYSICAL SIGN ATTRIBUTED TO THE COMMON PROBLEM DESCRIBED BY PROMINENT ORTHO SURGEON
Pes Anserine Transplantation: A Surgical Procedure for Control of Rotary Instability of the Knee

By Donald Slocum, MD and Robert Larson, MD
Eugene, Oregon

Journal of Bone and Joint Surgery
Vol 50A, March 1968
BE CAREFUL OF THE DEADLY ORTHOPAEDIC TRIAD

- COMMON PROBLEM (UNSTABLE KNEE)

- PHYSICAL SIGN ATTRIBUTED TO THE COMMON PROBLEM DESCRIBED BY PROMINENT ORTHO SURGEON

- SURGICAL PROCEDURE (WITH NO BASIS IN SCIENCE) DESCRIBED BY A PROMINENT ORTHO SURGEON

AMRI

Anteromedial complex instability

1972

“Pivot Shift” – described

Galway, et al

JBJS - 1972
Hughston attributed the pivot shift to lateral capsular insufficiency
Reconstruction of the Anterior Cruciate Ligament Using the Central One-Third of the Patellar Ligament

60% POOR RESULTS

Kenneth Jones, MD

Journal of Bone and Joint Surgery
Vol 52A, October, 1970

EJNAR ERIKSSON
AMERICAN COLLEGE OF SPORTS MEDICINE
WOLFE LECTURE
1976

IVAR PALMER 1936
LESSON

UNDERSTAND THE IMPORTANCE OF REPRODUCING NORMAL ANATOMY

Clinical Experience in 130 Cruciate Ligament Reconstructions
Kurt Franke, MD
Orthopedic Clinics of North America, Vol 7 (1), 1976

Reconstruction of the Anterior Cruciate Ligament
Ejnar Eriksson, MD
Orthopedic Clinics of North America, Vol 7, 1976
Nothing in literature to help orthopedic surgeon to rationally choose an E-A procedure

No evidence exists that clinical results for primary bone-patellar tendon-bone I-A ACL substitution are improved by adding an E-A procedure

SURGICAL TREATMENT
OPERATIONCHOICE (28 SURGEONS)

Acute ACL (no significant capsular laxity)

**ACUTE**
- E-A alone: 1
- E-A and I-A: 3 (3 I-A alone occasionally)
- I-A alone: 24 (7 add E-A occasionally)
SCAFFOLDS

- Carbon fiber
- Dacron
- Polyglycolic acid
- Polypropylene
STENTS
• Proplast
• Polypropylene (LAD)
• Dacron

XENOGRAFT
• Bovine tendon

ALLOGRAFT
FREEZE DRIED ETHYLENE OXIDE STERILIZATION
“APPLE SAUCE SYNOVITIS”
LESSON

“Artificial ACL Substitutes are like shoe strings – they eventually all break”

Ejnar Eriksson
1976
We have been unable to develop a successful artificial ACL to date
Reproducing Anatomy

“When you are having your anatomy sessions, pay particular attention, because orthopaedics is all anatomy, plus a little bit of common sense.”

J. Hughston

JBJS, 2006 Dec 88A, Suppl 4, 2-10

ANATOMY OF THE ACL

LIGAMENT ITSELF

ORIGIN INSERTION

Freddie Fu
Pittsburgh, PA USA

Andrew Amis
London, England
We study the anatomy of the ACL insertion site in 0° but we do ACL surgery in 90°.

Double Bundle ACL Reconstruction Initiative
DOUBLE BUNDLE INITATIVE

Pay more attention to the ACL anatomy

Consider changing the location of the femoral drill hole for single bundle ACL

QUESTIONS:

IS SINGLE BUNDLE BETTER THAN DOUBLE BUNDLE?
CONSENSUS OF MULTIPLE STUDIES

“Little or no difference in clinical outcome”

• Both control anterior stability

• D-B may have slight advantage in control of internal tibia torsion “evidence soft”
CONSENSUS OF MULTIPLE STUDIES
“Little or no difference in clinical outcome”
• Both control anterior stability
• D-B may have slight advantage in control of internal tibia torsion “evidence soft”
• D-B technically more demanding

My Recommendation – 2013
Elite athlete
• Well done single bundle autograft Bone-Patella Tendon-Bone (B-PT-B) reconstruction placed in the anatomic tibia and femur position
My Recommendation – 2013

Recreational Athlete

- Well done single bundle autograft Bone-Patella Tendon-Bone (B-PT-B) reconstruction placed in the anatomic tibia and femur position
- Hamstring OK but slight risk of re-injury in female

Avoid allograft except for:

- Revision
- Multi-ligament procedure

Do the procedure you do best
CONSENSUS OF MULTIPLE STUDIES

“Little or no difference in clinical outcome”

- Both control anterior stability
- D-B may have slight advantage in control of internal tibia torsion “evidence soft”

CONCLUSIONS – 2012

- Elite athlete consider B-PT-B
- Recreational
  - Female athlete increased risk of reinjury
  - Athlete hamstring ok
- Avoid allograft except for revision and multi-ligament surgery
- Use of quad tendon bone
Do the procedure you do best

CONSENSUS OF MULTIPLE STUDIES

“Little or no difference in clinical outcome”

• Both control anterior stability

• D-B may have slight advantage in control of internal tibia torsion “evidence soft”

• D-B technically more demanding

• Can not be done in every case

CONCLUSIONS – 2012

• S-B vs D-B
  - No clinical difference
  - Inconclusive but tendency of D-B to better control rotation
DOUBLE BUNDLE INITATIVE

Pay more attention to the ACL anatomy

Most surgeons have changed the location of the femoral drill hole for single bundle ACL

CONSENSUS OF MULTIPLE STUDIES

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DOUBLE BUNDLE INITIATIVE

Pay more attention to the ACL anatomy

Most surgeons have changed the location of the femoral drill hole for single bundle ACL
Anatomic ACL Reconstruction

Dr. Freddie H. Fu
Distinguished Service Professor
Chairman and David Silver Professor
Department of Orthopaedic Surgery
Head Team Physician
Athletic Department
University of Pittsburgh

Disclosures

Freddie H. Fu, MD, DSc (Hon), DPs (Hon)

Royalties: Arthrocare

University of Pittsburgh Department of Orthopaedic Surgery

Royalties and Stock Options: None

Consulting Income: None

Research and Educational Support: Smith & Nephew

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Anatomic ACL Reconstruction

- Anatomy
- Individualized Surgery
- Promoting Long-Term Knee Health
- Improving Outcome Measures
Anterior cruciate ligament anatomy and function relating to anatomical reconstruction

How Do We Get There?

A 30-Year Journey

Non-Anatomical

Early 2000's

Anatomical

Today
Anatomical Variation

Kopf, Fu et al. AJSM, 2011

Accountable for 100% of the Patient

Illingworth, Fu et al. AJSM, 2011

Low

High

43°

55°

24 mm

16 mm

24 mm

20 mm

14 mm

22 mm

11 mm

22 mm

14 mm

20 mm

11 mm

Metha et al. Arthroscopy, 2011

Avoid 2D Concept to Evaluate 3D Structures

O’Clock

Lateral portal

Central Portal

Metha et al. Arthroscopy, 2011
Tunnels Should Be Drilled Independently

Objective Outcome Measurements

Non-Anatomical ACL Reconstruction

Fails To Restore Normal Knee Kinematics
The Effects of Graft Placement on Cartilage Thickness after ACL Reconstruction

Garrett et al. ORS 2012

Non-Anatomical ACL Reconstruction Decreases Cartilage Thickness

Anatomical Principle

Double-Bundle Concept

Double-Bundle Concept

Matched Anatomic Single Bundle ACL-R

Non-anatomic
Individualized Anatomic ACL Reconstruction

MRI Measurements

Intra-Operative Measurements
How Much ACL Do We Need?

Single-Bundle

60-80%

Anatomic Single-Bundle

MRI

3D-CT

68%

63%

Middleton, Paiv et al. AOSSM, 2012
Anatomic Double-Bundle MRI 3D-CT

Anatomic Grafts See More Force

Increased inclination angle decreases *in situ* force on the ACL

Araujo, Fu, et al. AAOS 2013, ISAKOS 2013 Paper #11

Increased Risk of Revision After Anteromedial Compared with Transtibial Drilling:

Danish Knee Ligament Reconstruction Register

Rahr-Wagner et al. Arthroscopy 2013

**Four-year revision rate**

- AM drilling (5.16%) vs. TT drilling (3.20%)
- Anatomical?
- Higher failure with HS graft in AM group
- No differences in BPTB group
Anatomic ACL Reconstruction
Rehabilitation Should Be Modified Accordingly

Return to Sports
Functional Testing Healing?

Time zero 3 months 6 months 1 year

We Must Allow Healing to Occur

In vivo kinematics of a hamstring graft 6 weeks after surgery during walking

Tashman S, Harner CD, et al, ongoing study
Level I

- 85% follow-up at 3-5 years
- Anatomic DB > Anatomic SB > Conventional SB

Level II

- Individualized surgery
  - < 16 mm = SB
  - ≥ 16 mm = DB
  - No clinical differences

Take Home Messages

- Anatomical
- Individualize
- Outcome
- Patient Comes First
Thank You!

University of Pittsburgh
Cathedral of Learning
Normal Anatomy

Amiss et al  Colombe et al

Anatomy of the ACL


Measuring 3D knee kinematics under torsional loading.

Hemmerich A, van der Merwe W, Vaughan CL.
Department of Human Biology, University of Cape Town, South Africa
Results: single bundle

Recon

Results – "Stiff"
Summary

- Have to know Anatomy and Biomechanics
- Know that there are variations
- Compare to the other side
- Not one operation for all
History and Rationale of Double-Bundle ACL Reconstruction

M. Kurosaka, MD, PhD.

Professor and Chairman.
Dept. of Orthopaedic Surgery,
Graduate School of Medicine,
Kobe University.

Traditional ACL reconstruction

✓ Non-anatomic tunnel placements


✓ Good stability in anterior/posterior laxity

✓ Insufficient restoration of the dynamic instability

Kato Y et al. KSSTA. 2010

Many surgeons started to notice that single AM bundle reconstruction was vertically oriented.

If we look at stability in different knee flexion and rotational stability, more anatomical 2 bundle ACL reconstruction may be advantageous.
Two bundle ACL recon advocates in 90’s

M. Ochi et al, 2004

Mae, Shino et al, Arthroscopy 2001

Rosenberg, 1995

ACL (Anterior Cruciate Ligament)

Mainly consists of two distinct bundles

Anteromedial bundle (AMB)

Posterolateral bundle (PLB)

KOBE UNIVERSITY

T. Muneta, Arthroscopy 1999

K. Yasuda; PL bundle foot print. Arthroscopy; 2005
Anatomic double bundle Reconstruction

- 2 Femoral tunnels
- 1 Tibial tunnel
- 6mm Semi-T: AM
- 5mm Gracilis: PL

Single Bundle Reconstruction

- 1 Femoral tunnel
- 1 Tibial tunnel
- 8mm Semi-T & Gracilis: AM
Fujie, 1993 & 1995

Anterior tibial translation during rotatory torque (pivot shift test)

Anatomic ACL reconstruction can control rotatory torque

ACL reconstruction; Insertion sites
Knee specialists’ decision (June 11, 2006)

Paolo Aglietti
Florence, Italy

Freddie H. Fu
Pittsburgh, USA

Kosai Shindo
Osaka, Japan

Konsei Uno
Sapporo, Japan

Chris D. Harner
Pittsburgh, USA

Toru Fukubayashi
Tokyo, Japan

Double-bundle ACL insertion sites

Plotting Site
AM insertion site
PL insertion site

Intact site
AM insertion site
PL insertion site
Double-bundle ACL anatomy

How can we measure the patients’ outcome objectively?

Configuration of Our Electromagnetic Measurement System (EMS)
Objective measurement of the Lachman test

41 subjects (82 knees) were tested under general anesthesia.

→ ACL injured knee: 30 knees
  ACL reconstructed knee: 11 knees
  ACL intact knee: 41 knees

Anterior tibial translations during the manual Lachman test

EMS
Fluoroscopy
KT-1000

The A/P value were compared

Objective measurement of the Lachman test

The Use of an Electromagnetic Measurement System for Anterior Tibial Displacement During the Lachman Test


Very strong correlation.

Objective amount of the tibial translation during the Lachman test can be detected by the EMS.

Objective measurement of the pivot shift test

Acceleration of posterior translation (mm/sec²)
Objective measurement of the pivot shift test

Acceleration of posterior translation

\[ \frac{d L}{d t^2} \text{ (mm/sec}^2) \]

Acceleration values correlate with clinical grades.


Objective outcomes of double-bundle ACL reconstruction

Prospective randomized study

Double-bundle
20 patients
-13 male
-7 female
AV. Age: 22.3

AM single
20 patients
-14 male
-6 female
22.9

PL single
20 patients
-15 male
-5 female
22.9
Results of the acceleration of posterior translation

Comparison of the Clinical Outcome of Double-Bundle, Anteromedium Single-Bundle, and Postlateral Single-Bundle Anterior Cruciate Ligament Reconstruction Using Hamstring Tendon Graft With Minimum 2-Year Follow-up


Superiority in Double-bundle at 2-years’ Follow-up

- Anterior/posterior laxity > PL single
- Negative pivot shift rate > PL single
- Knee extensor muscle strength > AM single
- Knee flexor muscle strength > PL single
- No re-injury

Anatomic single- vs double-bundle reconstruction

Original Insertion

Original Insertion
Superiority in Double-Bundle Reconstruction

The pivot shift test (Post-operative evaluation)

<table>
<thead>
<tr>
<th>Acceleration (mm/s²)</th>
<th>Anatomic SB group</th>
<th>Anatomic DB group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reconstructed</td>
<td>Intact knee</td>
</tr>
<tr>
<td>0</td>
<td>-980 ± 524</td>
<td>-640 ± 138</td>
</tr>
<tr>
<td>-200</td>
<td></td>
<td></td>
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<tr>
<td>-400</td>
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<td></td>
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<td>-1400</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-1600</td>
<td></td>
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</tr>
</tbody>
</table>

*P<0.05 (mean ± S.D.)

Summary

Double-bundle ACL Reconstruction
- Restore the ACL anatomy (AMB and PLB)
- Better clinical scores.
- Better negative pivot shift rates.
- Better stability by the EMS.

Future perspective
- Individualized ACL reconstruction could achieve the good clinical scores. *Dargel J, Surg Radiol Anat. 2006*

The road to restore the ACL individually
Is Double-bundle technique the goal for ACL reconstruction?
Navigation System for Anatomic Double Bundle ACL Reconstruction

Navigation for femoral site insertion

Prospective randomized study


Surgical Technique

Anatomic ACL Concept

In 90 degrees insertion site is horizontal

Girgis, Marshall, et al. CORR 1975

F. Fu Original
Anatomic Double-bundle ACL reconstruction
Indications for extra articular reconstruction.

Ph Neyret
E Servien S Lustig
V Villa C Debette
P Verdonk
V Duthon
Lyon University

Isolated Extra articular tenodesis

In rare circumstances, a medial and/or lateral extra-articular procedure may be indicated for severe laxity of the medial/lateral and other secondary restraints associated with a chronic ACL deficient knee treated with an intra-articular reconstruction.

Unanimously approved.

Bad prognostic factors was medial meniscectomy

Old patient (> 60y) with instable ACL deficient knee in daily life with a normal MM ?

Combined ACL Graft + extraarticular tenodesis « KJT »

Combined intra-articular and extra-articular reconstruction.

• it may protect the intra-articular graft during the graft-healing phase.
• once the patient returned to activity it provided a secondary restraint to the pivot shift.
• decreased the forces going through an intra-articular reconstruction by 43% in-vitro (Engebretsen)

Background

1. Different types of lesions occur on lateral compartment when the ACL ruptures

2. We have to deal with various types of ACL injuries that may lead to various ACL insufficiencies

3. Is a single bundle ACL R. enough to treat these various types of ACL insufficiencies
3. Is a single bundle ACL R. enough to treat these various types of ACL insufficiencies

- Yagi AJSM 2002: biomechanical advantages to the double bundle

  Japan: Kurosaka, Muneta, Takenchi, Yasuda, Ochi
  Italy: Perderzini, Maracci, Aglietti
  US: Fu AAOS 2006

3. Is a single bundle ACL R. enough to treat these various types of ACL insufficiencies

  H. Dejour since 1978 KIL
  P. Neyret since 1994 KJT
Our experience

60 Isolated Graft « KJ »

60 Combined ACL Graft « KJT »

Our experience

Post-op

4.6 ± 4.3

2.0 ± 4.2

Lateral compartment

Mobility

A
94.1 %
85.7 %

B
5.9 %
14.3 %
Ultra long-term results after ACL reconstruction combined with extra-articular tenodesis


Revision ACL reconstruction: influence of a lateral tenodesis

Dejour H. BTP+ extra-articular tenodesis

Our experience

Conclusions: This study shows a significant improvement in the IKDC score after revision ACL reconstruction. The association of a lateral extra-articular tenodesis with the intra-articular graft increases knee stability after revision ACL reconstruction; however, this additional procedure does not significantly alter the IKDC score at follow-up.

Level of evidence: Retrospective case series, Level IV.

Third time's a charm?: improving re-revision ACL reconstruction by addressing reasons for prior failures

Robert A. Magnusson, Sebastian Lastog, Guillaume Denoy, Ahmed Eygabdi, Didier Sueren, Philippe Neyret
Indications KJ + T

Sports @ risk
Antero-lateral Laxity
Revision surgery

Antero-lateral Laxity
Contra-indications KJ + T

Postero-lateral Laxity

High flexion expectation

Postero-lateral Laxity
Thank You
Return to sport following ACL reconstruction: Are we as good as we think we are?

Julian A Feller FRACS
Clinical Professor, School of Medicine, Deakin University
Adjunct Professor, Faculty of Health Sciences, La Trobe University

Disclosures

• Consultant: Tornier, Stryker
• Fellowship Funding: Smith & Nephew

Acknowledgements

• Clare Ardern
• Kate Webster PhD
• Nicholas Taylor PhD
Kvist J, 2004


- Only 56% patients who underwent ACL reconstruction returned to their preinjury level of sports activity


- 503 subjects
- Preinjury participation in competitive-level Australian football, netball, basketball, or soccer
- RTS rates at 12 months postoperatively

Ardern CL, 2011

- IKDC
  - A/B: 93%
  - C/D: 7%

- Hop-test limb symmetry index
  - >85%: 84%
  - Mean: 93.5%
Return to sport

• At 12 months
  – 1/3 had returned to full competition
  – 1/3 had returned to training and/or modified competition
  – 1/3 had not attempted sport

• Of those who had not returned to full competition
  – At least ½ planned to return to full competition

Conclusion

• 12 months may be too early to assess return to sport


Return-to-Sport Outcomes at 2 to 7 Years After Anterior Cruciate Ligament Reconstruction Surgery

Claire L. Arden,1,11 (Physiotherapist), Nicholas F. Taylor,1,12 PhD, BA(Physio), BSc, Julian A. Feilen,1 FRACS, and Kate E. Webster,1 PhD, BSc(Hons)

Investigation performed at La Trobe University, Bendigo, Victoria, Australia

• 314 participants, 40 ± 14 mths post ACLR
• Participated in regular sports activity prior to injury
Sports participation

• At any time since surgery
  – 93% RTS at some time
  – 61% pre-injury
  – 41% competitive

• At follow-up
  – 66% were playing sport
  – 45% at pre-injury level
  – 29% competitive sport

Considerations

• Patient aspirations may change following surgery

• Age an important factor
  – Played at preinjury level at some time since surgery
    • <18 72%
    • 18-25 70%
    • 26-32 65%
    • >32 47% (p=0.01)
Ardern CL, 2011

- 48 studies
- 5770 participants
- Mean follow up: 41.5 months
- 90% normal or nearly normal on impairment-based outcomes (laxity and strength)
- 85% normal or nearly normal on activity-based outcomes (IKDC)

Return to sport

- 82% returned to some kind of sports participation (93%)
- 63% returned to their pre-injury level of participation (61%)
- 44% returned to competitive sport (41%)
- Fear of re-injury most commonly cited reason for a reduction in or cessation of sports participation

Level of pre-injury sport

- Elite sportspeople may have a greater motivation and greater support to achieve a successful return to sport
  - Ardern CL (unpublished): systematic review, 7 studies, 78% returned to preinjury play (58-100%)
  - c.f. 63%

• McCullough KA et al Return to high school- and college level football after anterior cruciate ligament reconstruction: A Multicenter Orthopaedic Outcomes Network (MOON) cohort study
• 65% returned to preinjury level
• 50% cited fear of re-injury as part of the reason they did not RTS

“Fear of re-injury”

• Injury itself
• Surgery
• Rehabilitation
• Time off work
• Loss of income

Psychological factors

Psychological Responses Matter in Returning to Preinjury Level of Sport After Anterior Cruciate Ligament Reconstruction Surgery

• 187 athletes
  – 133 competitive
  – 54 recreational
Results

- Psychological factors measured before surgery and at 4 months after surgery
  - Psychological readiness to return to sport
  - Recovery expectations
  - Emotions
  - Mood
  - Sport locus of control
  - Fear of re-injury
- Positive psychological factors predicted returning to the pre-injury level sport at 12 months with 70-90% accuracy

Take home messages

- Return to sport rates are lower than anticipated from standard outcome measures
- Multifactorial
- Age is important
- Psychological factors may need to be considered in future research