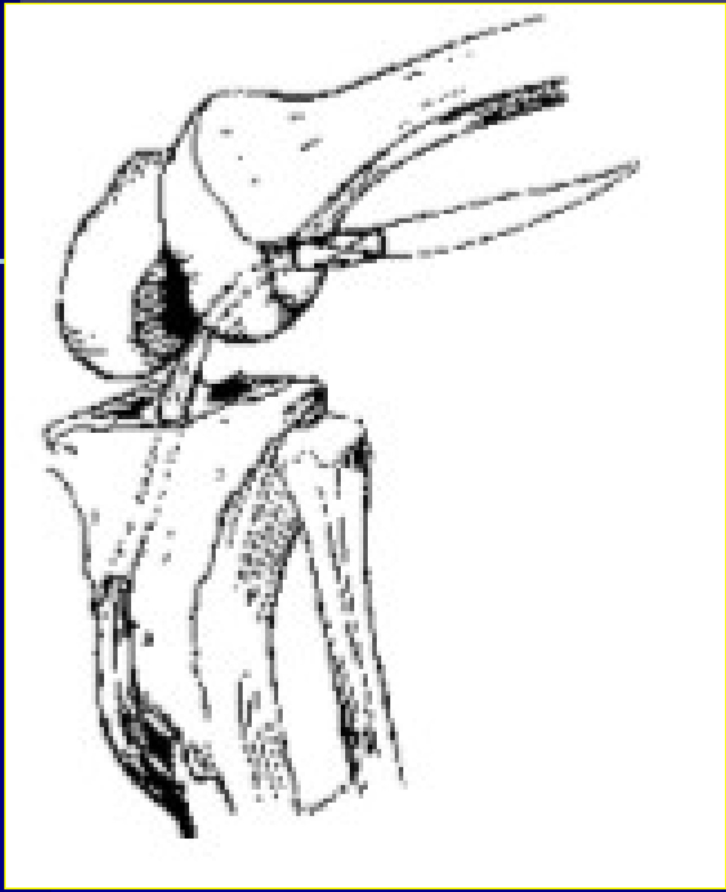
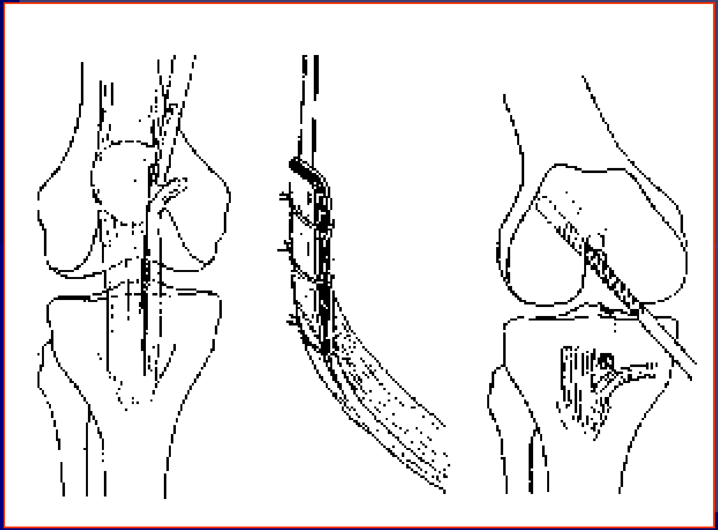
Graft Fixation in ACL Reconstruction

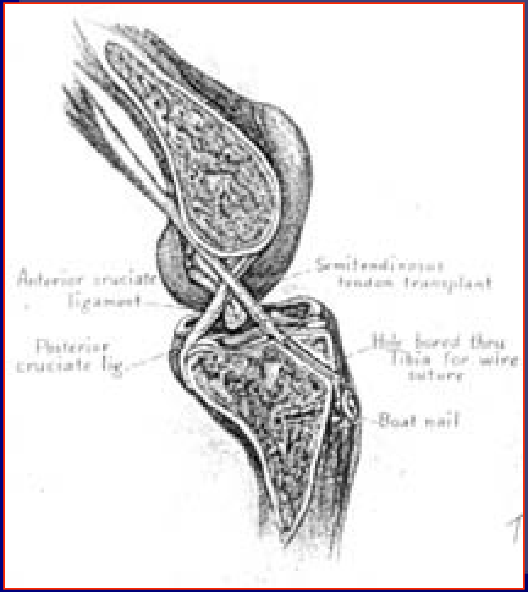
Christos K. Yiannakopoulos, MD

The Silent Epidemic

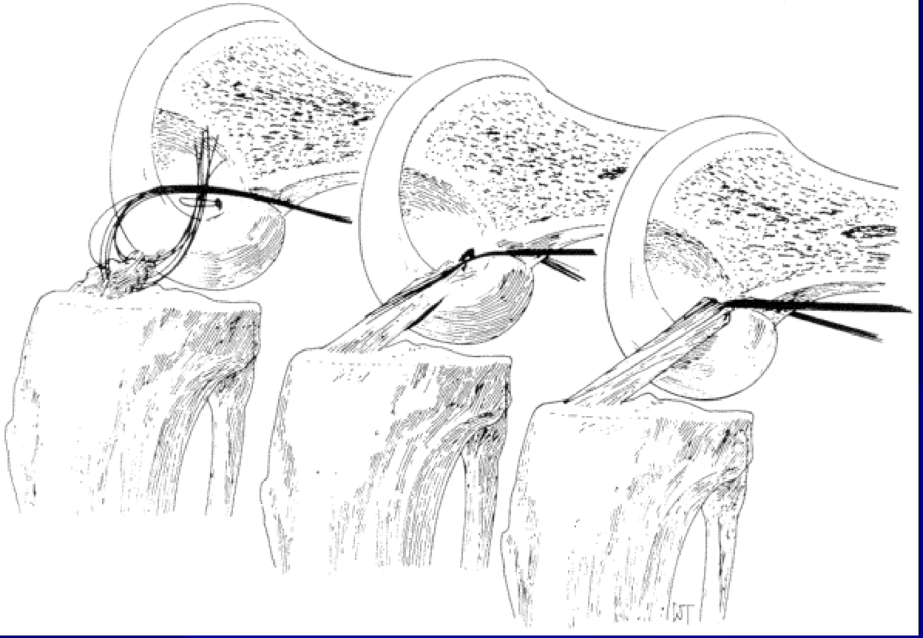
- ✓ 100.000 new ACL injuries occur in the US per annum
- ✓ > 75.000 ACL reconstructions per annum
- ✓ $ 1.000.000.000



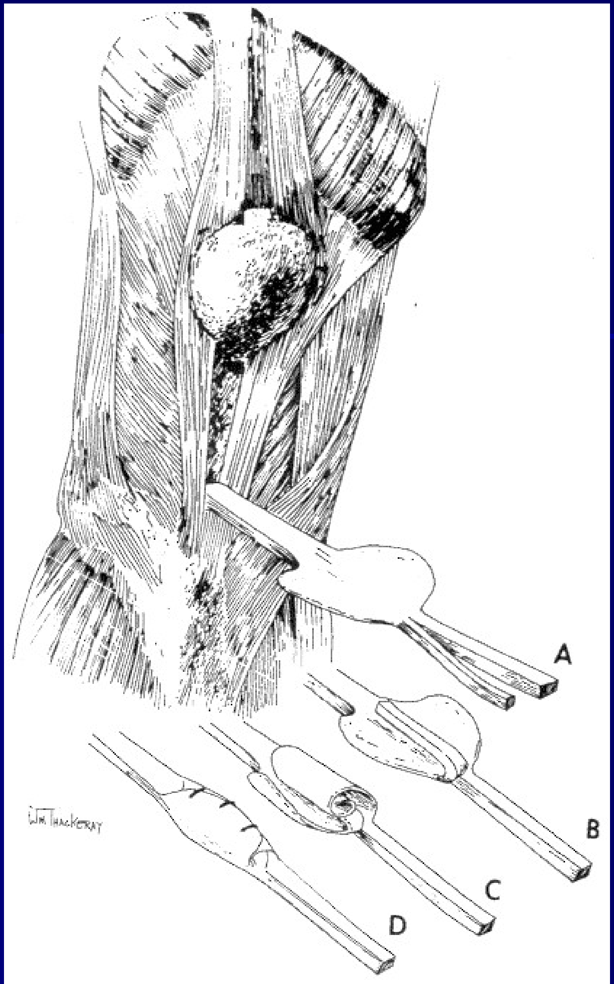




The Jones Procedure as the “Gold Standard” ?



Direct Repair



Marshall's modification

ACL Functions

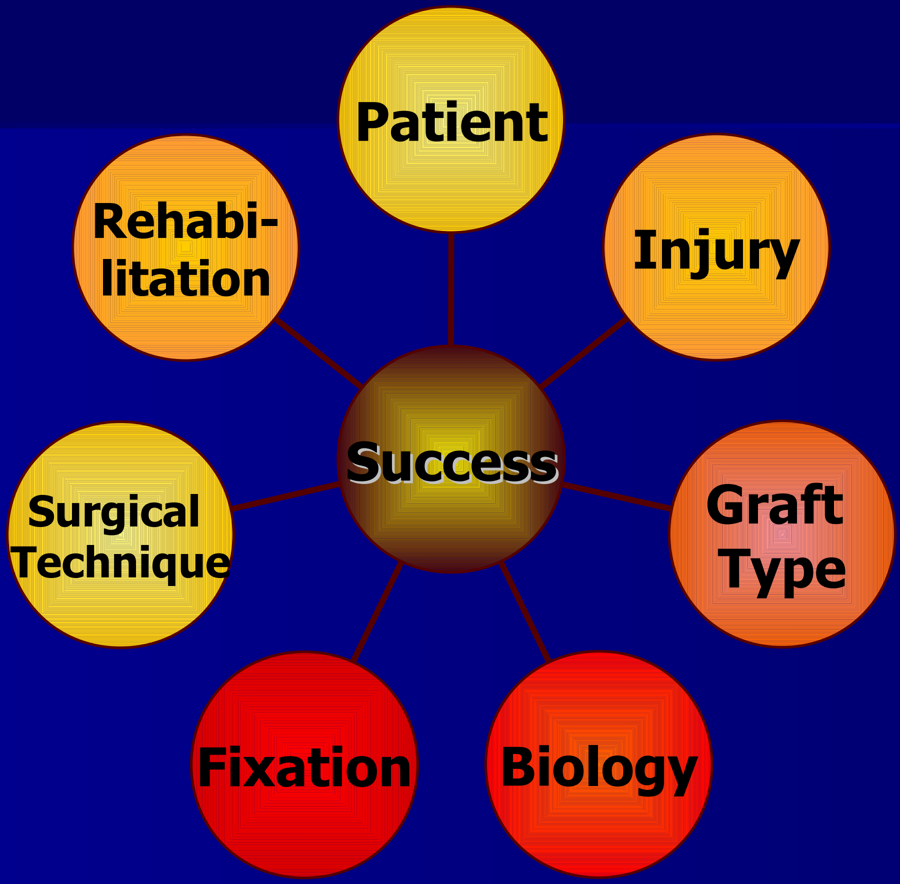
- ✓ It fines tunes the screw home mechanism during terminal knee extension
- ✓ It provides a check to internal tibial rotation, thereby affording rotatory control to the knee
- ✓ Resists anterior tibial translation on the femur
- ✓ It is a secondary restraint to both varus and valgus forces in all ranges of flexion
- ✓ Prevents hyperextension of the knee

Goals of ACL reconstruction

1) Abolition of pivot shift
2) A supple knee
3) Restoration to pre-injury activity levels
4) Long term preservation of integrity of a healthy knee joint

Current problems with ACL Reconstruction

1. Donor site morbidity
2. Impingement
3. Incorrect femoral tunnel placement
4. Graft Fixation



Patient
Rehabi-
litation
Injury
Success
Surgical
Technique
Graft
Type
Fixation
Biology

Currently ACL reconstruction does not:

1) Restore normal proprioception of the ACL
2) Reproduce the multi-stranded structure of the ACL
3) Restore normal knee joint kinematics
4) Preserve the articular integrity of the knee joint

Graft Fixation

Biological

- BPTB 6-8 wks
- Hams 12 wks

Mechanical

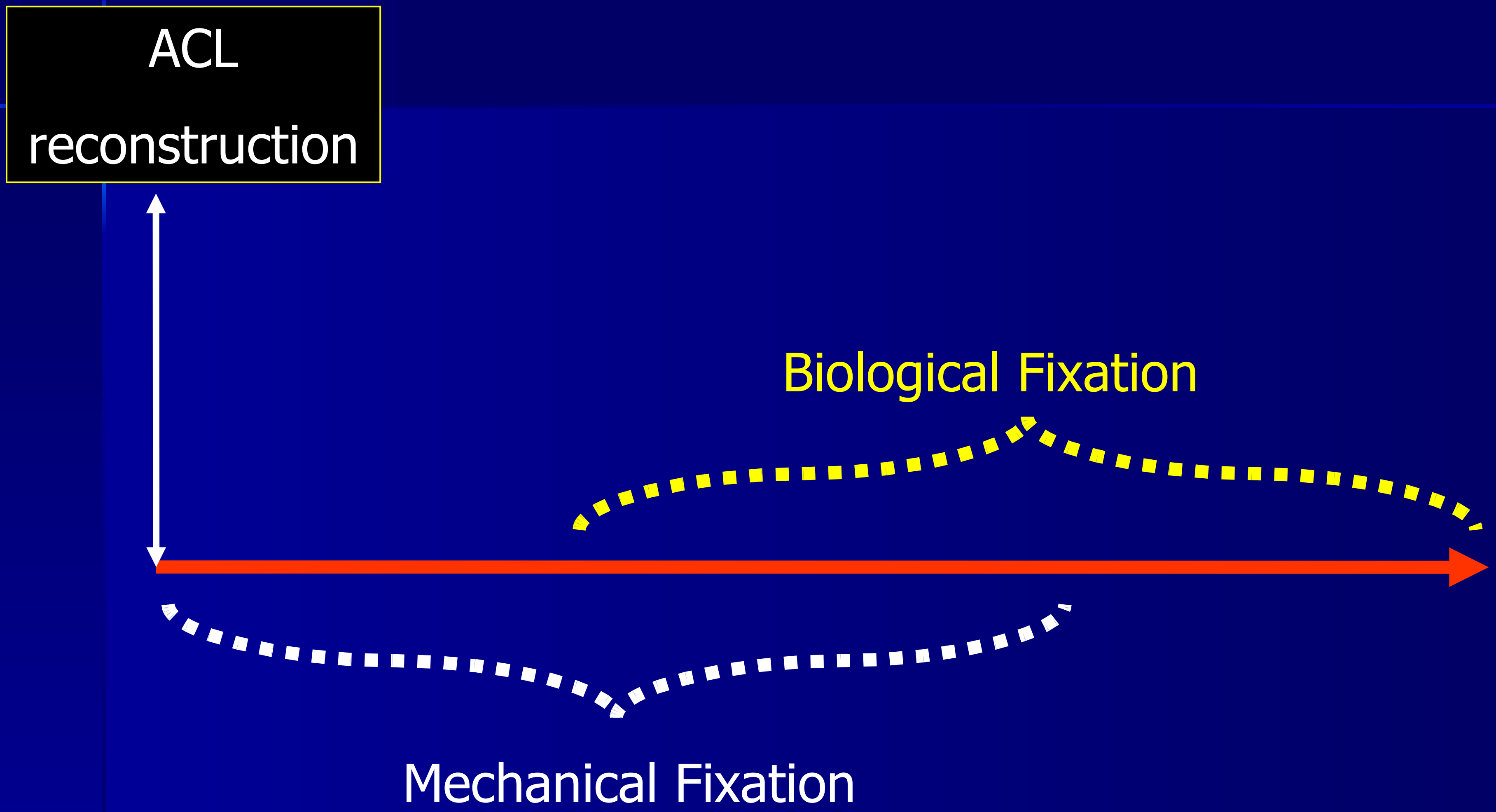
Direct

- Staples
- IFS

Indirect

- Endobutton
- Cross Pin
- Sutures-post

Graft Fixation



Fixation

- Current methods of anchorage rely upon biological fixation occurring in bony tunnels before the ligament fails at a point of high stress concentration

A time interval of unknown duration exists between

time zero (when graft fixation is the weakest link)

and adequate biologic incorporation of the graft into the tunnel

(when the graft substitute tissue becomes the weakest link of the construct).

The duration of this period is unknown, but is longer for soft-tissue grafts than for grafts with bone plugs.

Graft fixation must resist slippage during cyclic loading during the first 2 months after surgery prior to conversion from mechanical to biologic fixation

No graft can reproduce the normal insertion site

Graft fixation is (not always) the weak link

during this period

This is therefore a race against time

Forces Present in the Cruciate Ligaments During Activities of Daily Living

	ACL	PCL
Descending Stairs	445	262
Level Walking	169	352
Ascending Stairs	67	641
Descending Ramp	93	449
Ascending	27	1215

Forces Present in the Cruciate Ligaments During Activities of Daily Living

The ACL graft is loaded to approximately 150 to 500 N during normal daily activities

Conclusion

Zero time fixation strength should be at least 500 N

to permit safe post-operative mobilisation

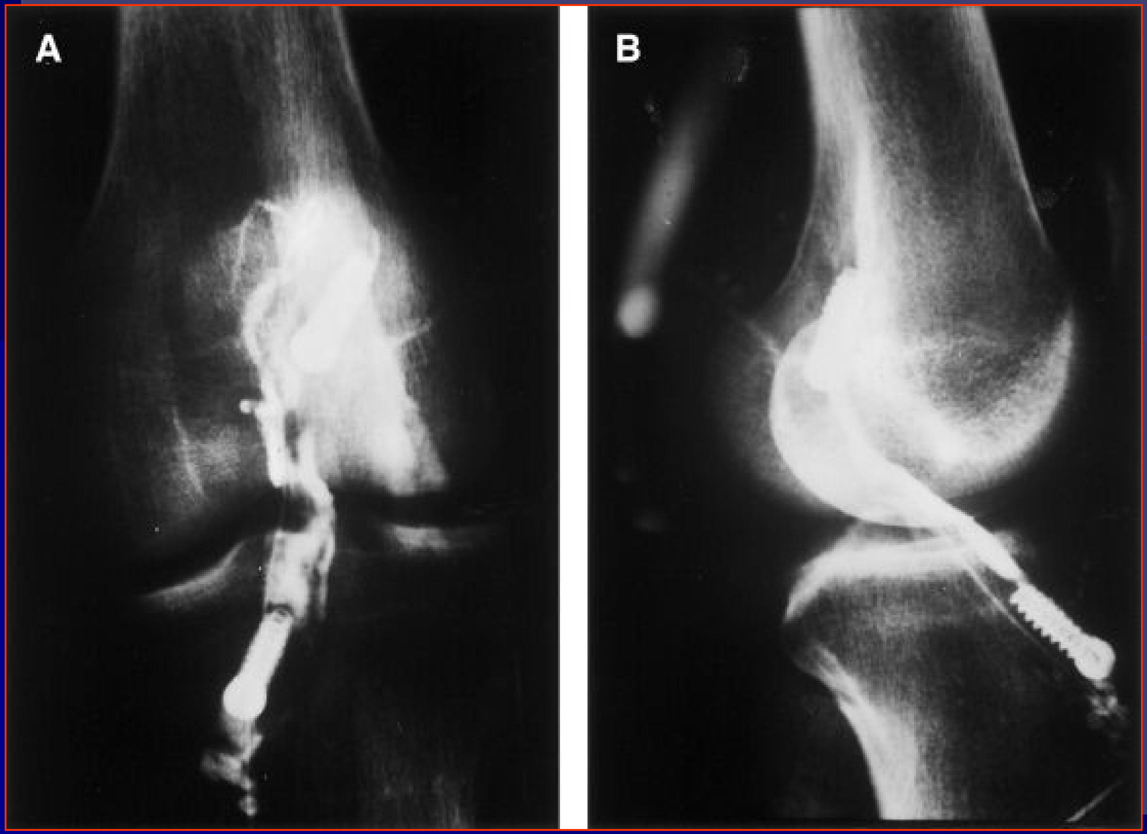
Tendon to Bone Healing
Vs
Bone to Bone Healing

During the postoperative period, the maximum loads to the graft substitute construct are provided by rehabilitation.

These loads should be less than or equal to the graft fixation strength achieved in the operating room, at time zero.

In cases where the surgeon is concerned about poor fixation, the rehabilitation program should be customized to the fixation. (low BMD, Tunnel lysis)

These patients must undergo a less aggressive rehabilitation protocol due to inferior fixation.



QHT graft + IFS

Removal of tibial screw 4 weeks pop

No residual laxity

Arthroscopy 2003

Graft Fixation Devices

- Screws (blunted threads)
- Sutures over Post
- Staples ("belt buckle" technique)
- Cross pin designs
- Devices for cortical fixation
- Button
- Washer
- Other

Graft Fixation Devices

Site

- Femoral
- Tibial
- Cortical - Cancellous

Method

- Direct
- Indirect

Material

- Absorbable
- Non-absorbable

Graft Fixation Device Choice

- ✓ Familiarity
- ✓ Price
- ✓ Ease of use
- ✓ Efficacy
- ✓ Availability
- ✓ Other

Direct vs Indirect Fixation

Direct

staples-washer-IFS-cross pins

Indirect

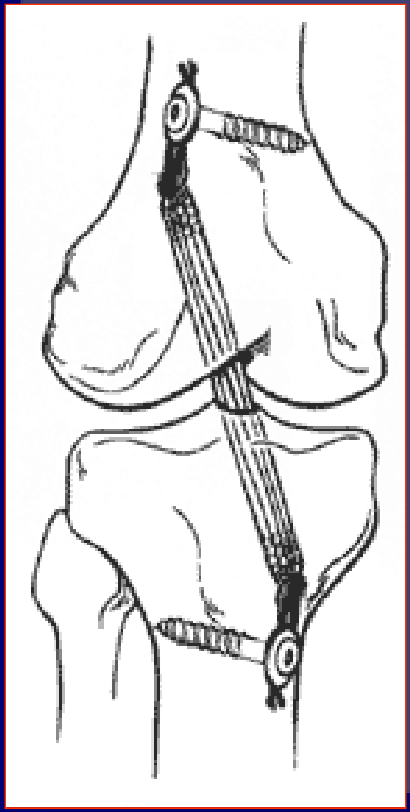
tapes+buttons- suture posts

Direct vs Indirect Fixation

- Direct fixation reduces graft motion.
- Significant in animals.
- Significance in clinical studies not shown

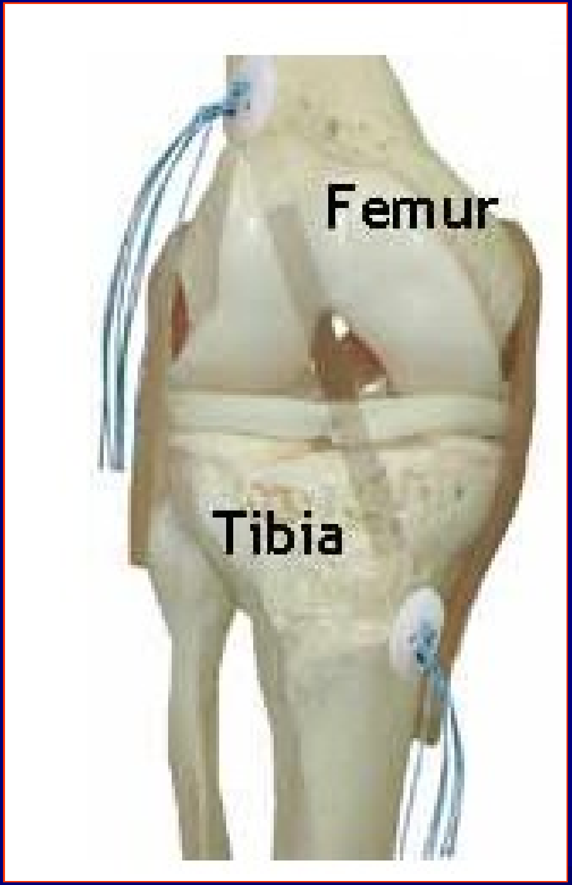
Sutures and post technique

- ✓ Postop immobilization
- ✓ Slower initial rehabilitation
- ✓ Bungee cord effect
- ✓ Higher failure rates



Pull out strength is not the only decisive factor in ACL reconstruction

Shelbourne achieved excellent results using button fixation (UTL 248 N)



Shelbourne KD, Gray T. Anterior cruciate ligament reconstruction with autogenous patellar tendon graft followed by accelerated rehabilitation. Am J Sports Med 1997;25:786-795.

Functions of Graft Fixation Devices

1. Provide apposition of the graft with surrounding tissue
2. Resist slippage or migration under repeated loading
3. Resist sudden traumatic loading
4. Restore normal anatomy (close to the joint, Double bundle)
5. Restore the load-displacement response to normal

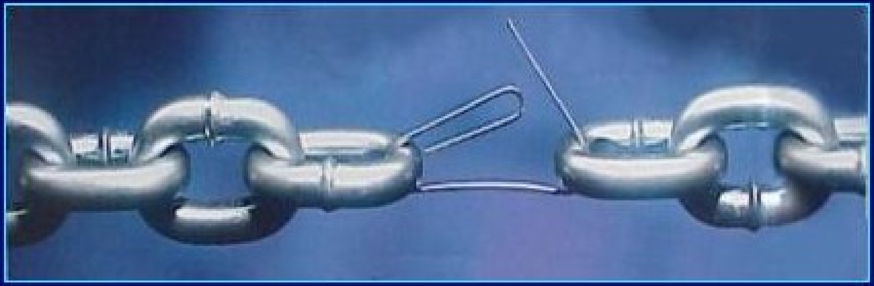
The Ideal Graft Fixation Technique

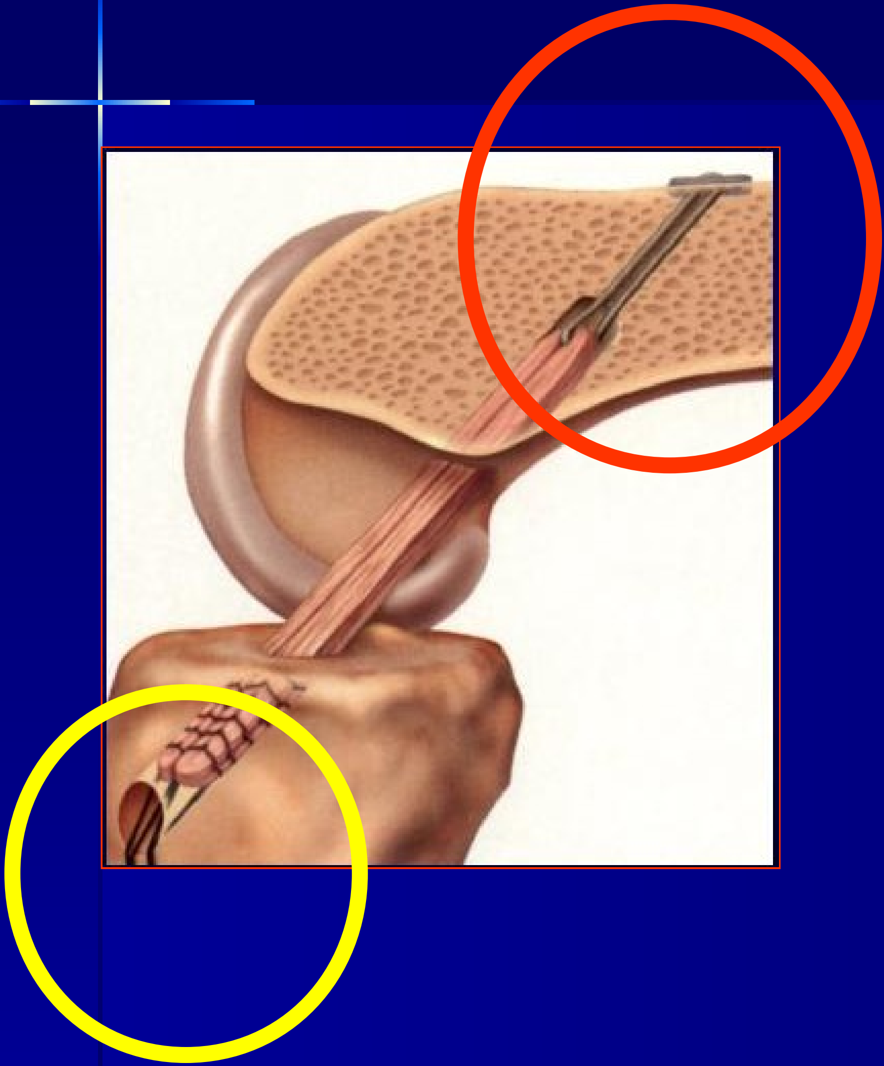
- strong, rigid fixation
- anatomic fixation at the articular surface
- no inflammatory response
- ultimate reliance on good biological fixation
- Avoidance of damage or crushing of the graft at the point of fixation
- does not hinder future procedures or investigative techniques

The Ideal Graft Fixation Technique

does not exist yet !

The ultimate strength of the graft – fixation method complex equals the strength of its weakest part





Endobutton

1000 N

Sutures over Post

150 N

Graft Fixation Methods

- ✓ Aperture fixation
- ✓ Semiaperture
- ✓ Suspended fixation (outside fixation)

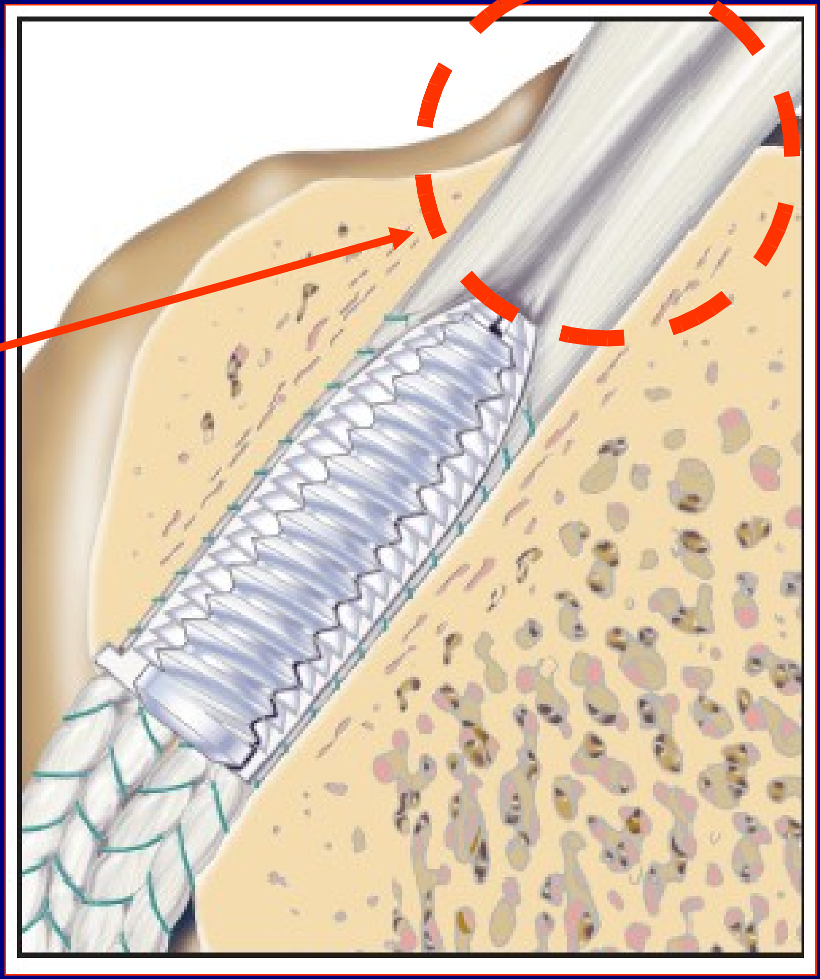
Aperture fixation

- Near anatomic origin adjacent to the articular surface
- Interference Screw
- Anchoring the graft at the entrance into the joint, reduces graft length and elasticity

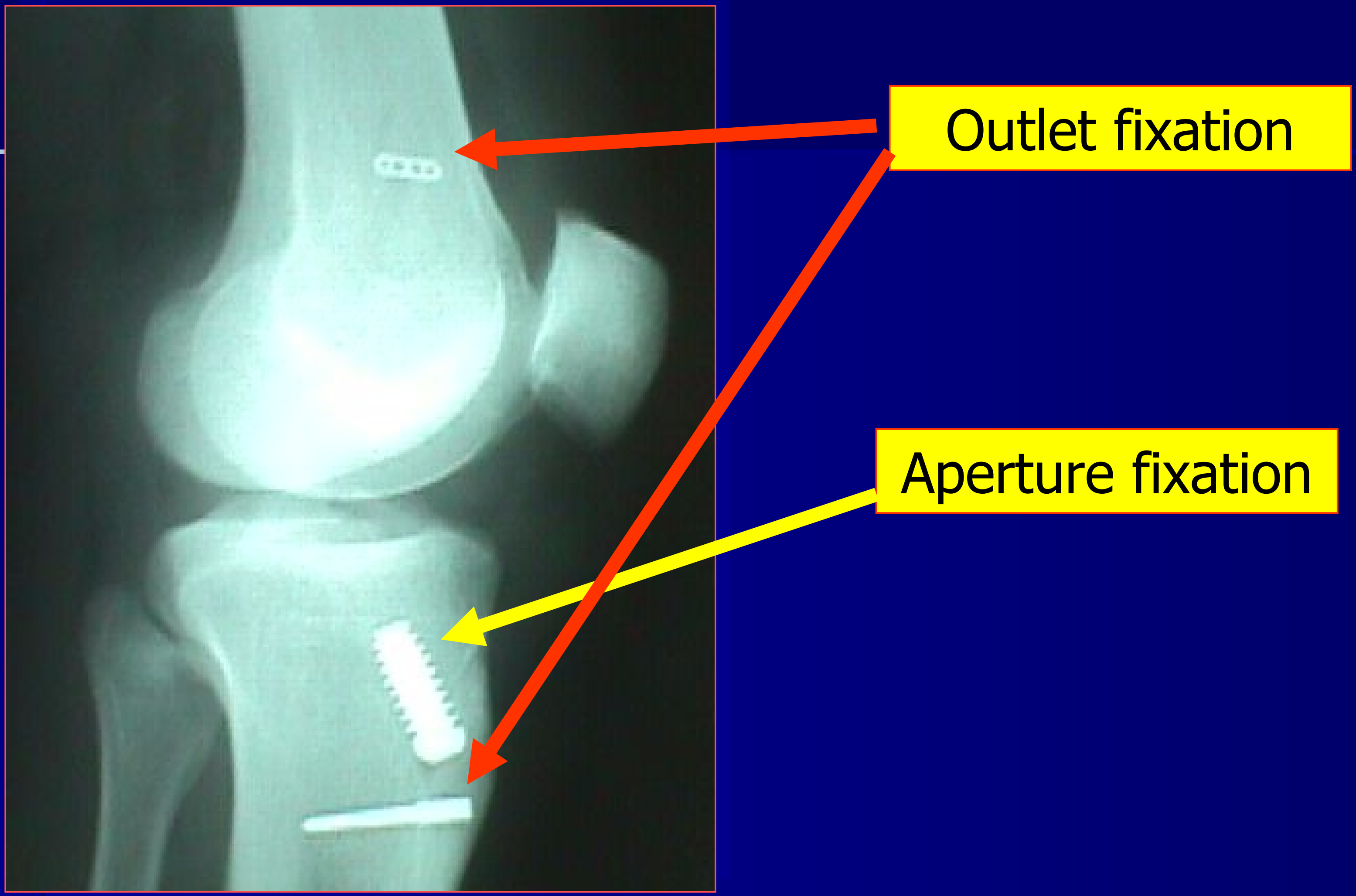
Semi- Aperture

- Intrafix
- leaves 15 mm

tendon free



Suspended Fixation
(outside fixation)


Outlet fixation
Aperture fixation

Aperture fixation vs distal fixation

Avoidance of:

- suture stretch
- graft-tunnel pistoning
- windshield-wipering

- delayed incorporation of the graft in the tunnel
- tunnel enlargement
- clinical failure

Disproving the current theory on the effect of location of the fixation within the drill hole, the shorter working length of the apertural methods did not improve the stiffness of the constructs

Biomechanics Of ACL Graft Fixation

Models of Biomechanical Testing of ACL Graft Fixation

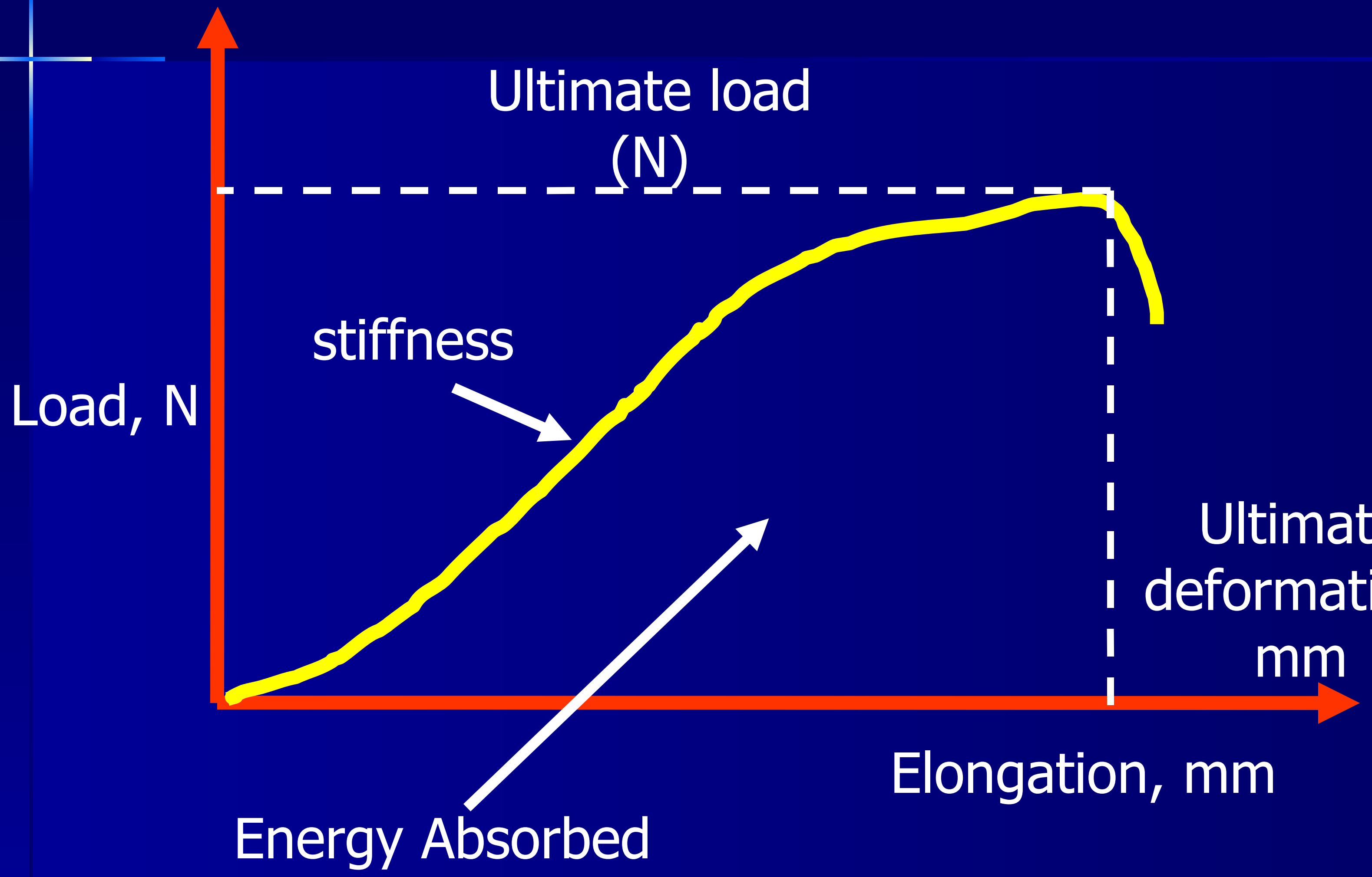
- Test specimen has strong influence on biomechanical data
- Bovine, porcine,young human, and elderly human cadaveric knees

Biomechanics

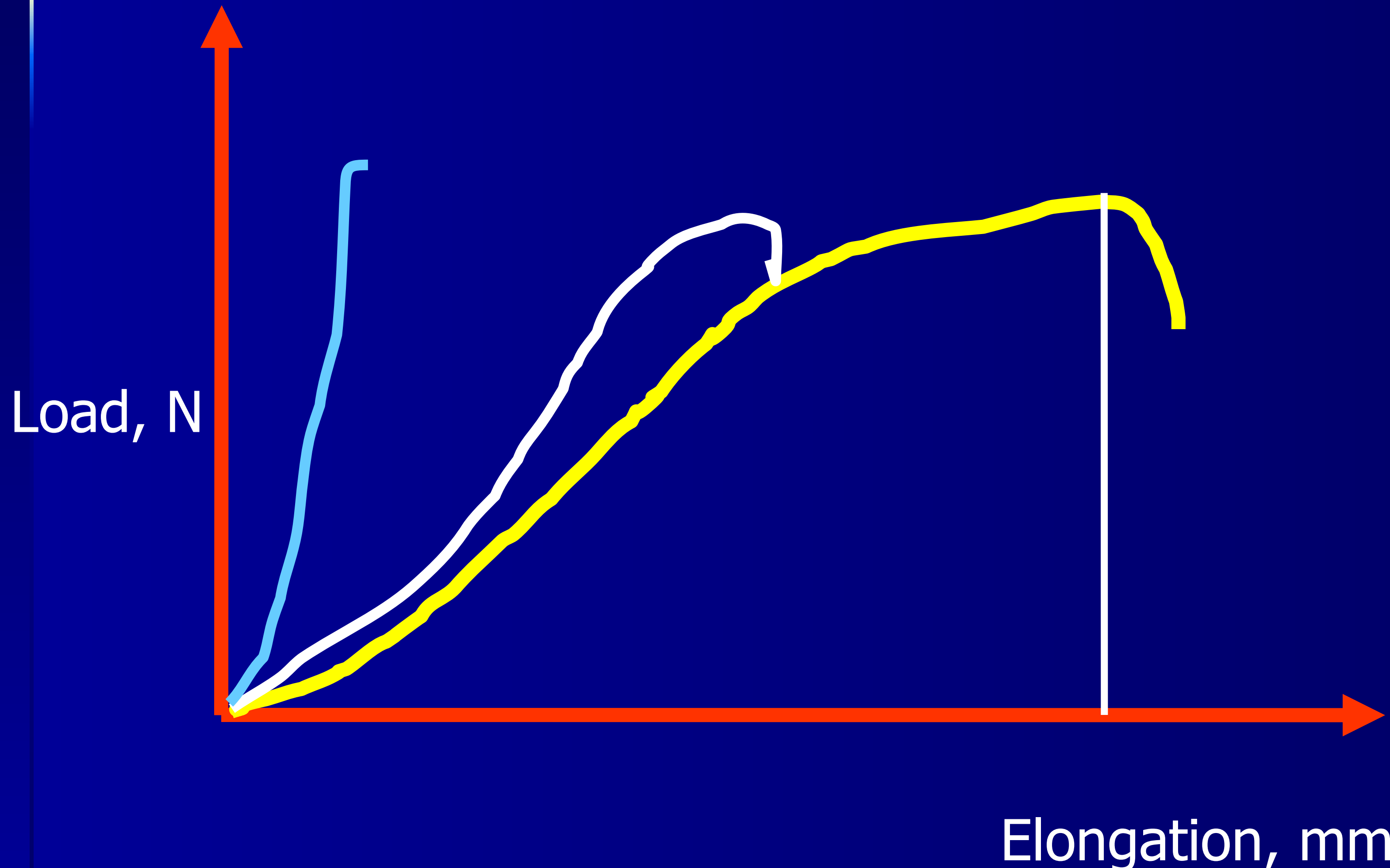
- Single Cycle Loading (sudden overload)
- Cyclic Loading (Repetitive loading)
- Fatigue Loading
- Stress-Relaxation

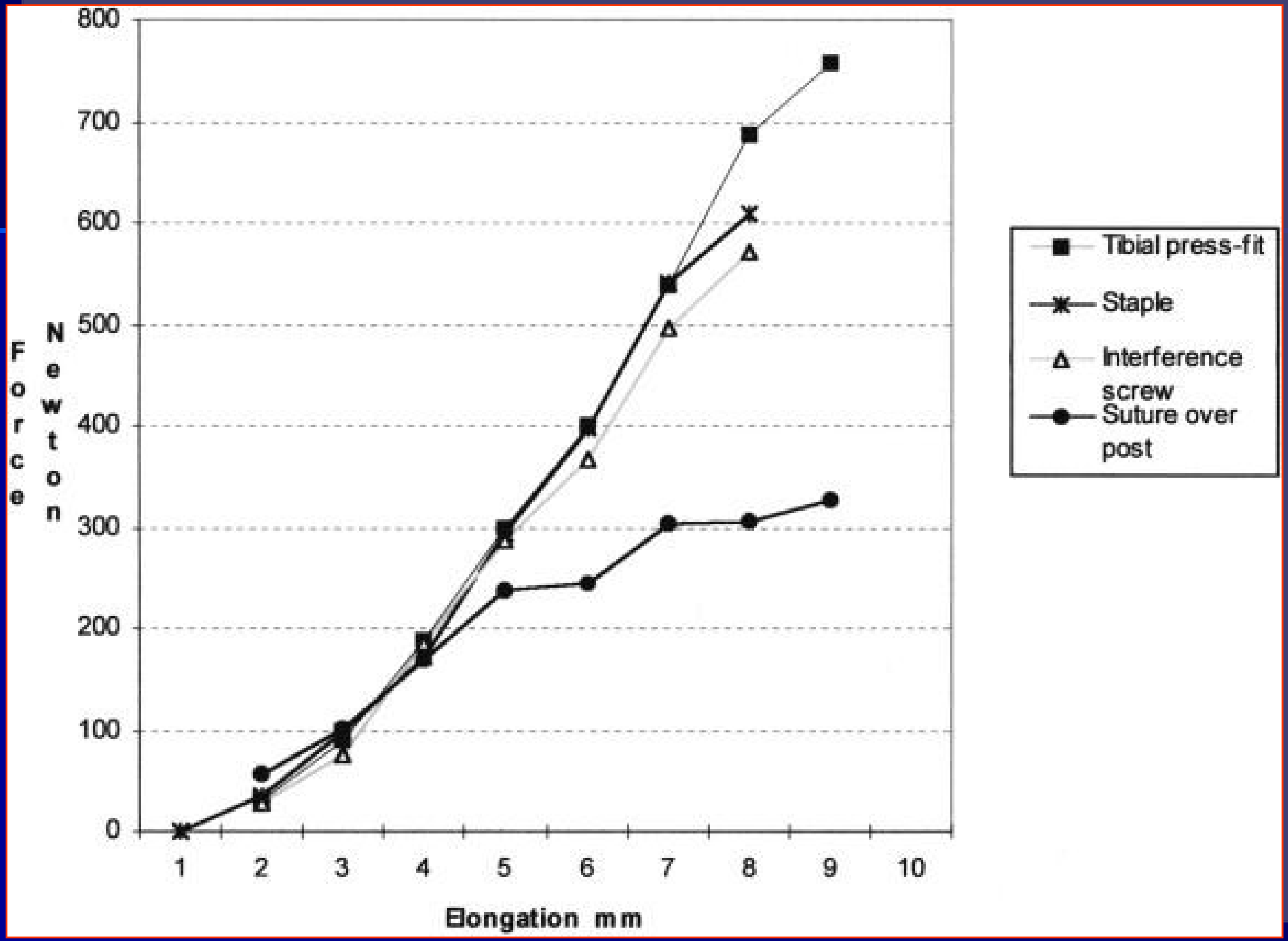
All techniques describe graft properties at time zero

Biomechanics



Initial Failure Load is not always the most important factor in fixation method selection

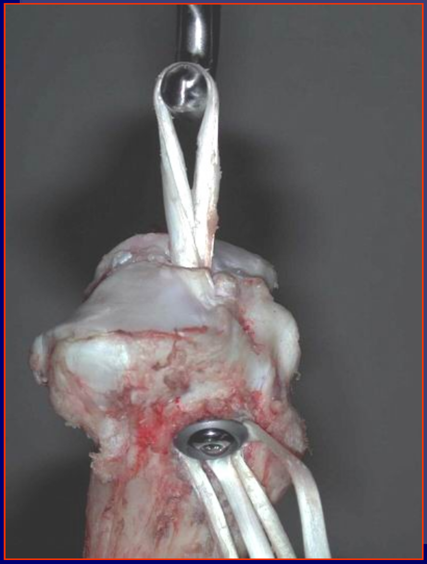




Boszotta & Anderl 2001

Caution should be used in extrapolating the results of any study to clinical estimates as we cannot assume that the structural properties of fixation devices determined in animal tissue predict its performance in human knees.

Porcine tissues used for surrogates for human tissues underestimate graft slippage past the fixation and overestimate fixation strength



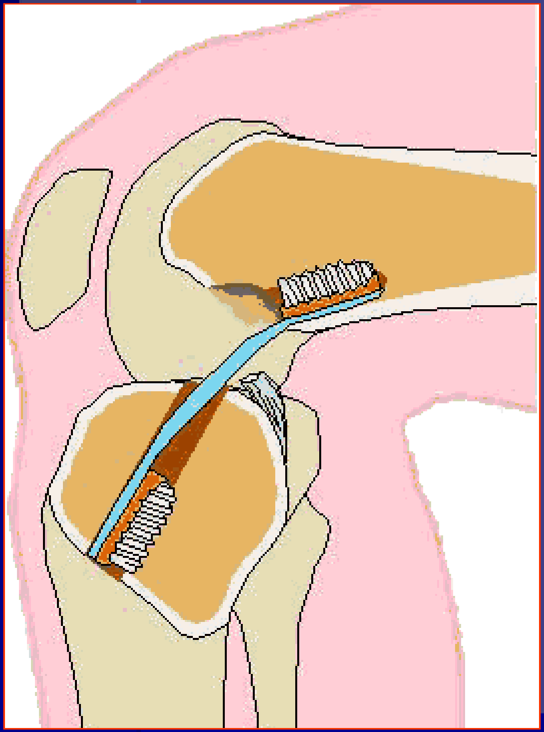
General Remarks

All forms of graft fixation are weaker and less stiff than ACL replacement grafts

The tibial fixation site is weaker and fails predominantly

Bone - Patellar Tendon - Bone Graft

Bone - Patellar Tendon - Bone Graft



- ✓ Interference Screw Fixation
- ✓ Cross Pin Fixation
- ✓ Press Fit Fixation
- ✓ Other forms of fixation

Bone-Patellar Tendon-Bone Graft

- ✓ Gold standard
- ✓ Equal results with metallic, titanium, absorbable screws

Interference Screw Fixation of the BPTB graft is the gold standard for ACL reconstruction !!!!

- ✓ Fixation Strength 416 N
- ✓ Stiffness 51 N/mm
- ✓ Slippage 3.8 mm at 500 N

Kurosaka, 1988

Interference Screw Fixation

Porcine tibia

	BPTB	Hamstrings	
UTL	658	490	N
Stiffness	400	3500	N/mm
Slippage	2.5	6.3	mm

Tendon Damage – IF Screw

Femoral fixation of the graft is stronger than the tibial tunnel fixation.

- ✓ Greater bone mineral density of the distal femur
- ✓ Angle of stress relative to fixation
- ✓ The tibial fixation is subjected to more loads

The weak link in the system at time zero, immediately after surgery, is the tibial fixation point.

Femoral Fixation of a BPTB Graft

Construct	Failure (N)	Stiffness (N/mm)
EndoButton[b]	554 (276)	27.0 (13.5)
Mitek device[b]	511 (350)	18.3 (8.3)
Press-fit[b]	350 (48)	36.8 (16.3)
Interference screw from outside-in[87]	423 (175)	46 (24)
Endoscopic interference screw[87]	588 (282)	33 (14)
Interference screw outside-in[14]	235 (124)	82.8 (30.1)
Endoscopic interference screw[14]	256 (130)	70.2 (28.9)
Metal endoscopic interference screw[19]	558.3 (67.9)	No stiffness reported
BioScrew endoscopic interference screw[19]	552.5 (56.4)	No stiffness reported
Metal interference screw[70]	640 N (201)	No stiffness reported
BioScrew interference screw[70]	418 N (118)	No stiffness reported
Metal interference screw[44]	436 (111–903)	No stiffness reported
Biodegradable interference screw[44]	565 (248–987)	No stiffness reported

Brand et al., 2000

Fixation strength and stiffness are increased

BPTB

- ✓ Larger diameter screws

(9.0 vs 6.5 mm and 9 vs 7 mm in 10 mm drill holes)

- ✓ Compaction Drilling

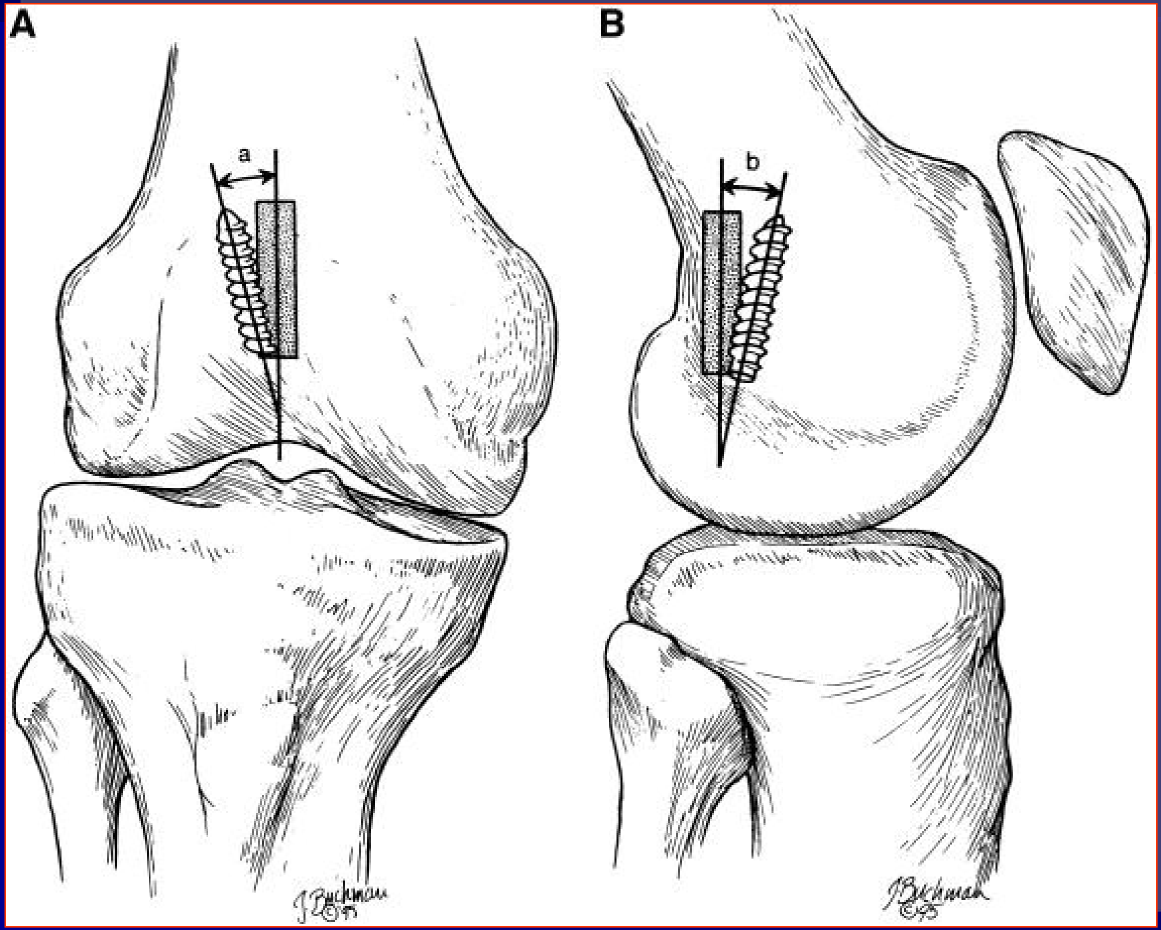
- ✓ Circular bone plugs > cylindrical

Fixation strength and stiffness are increased

Soft-tissue Grafts

- screw diameter should >1 mm that of the osseous tunnel
- use of a longer screw (28 mm vs 23 mm)

Screw Divergence



Screw Divergence

Optimal interference fixation occurs when screws are placed parallel to the bone plug or soft-tissue graft,

thus allowing

maximal surface area contact between screw and graft.

screw divergence of >15° dramatically decreases the fixation strength of the construct.

Divergence Prevention

- ✓ Notching the anterior edge of the femoral tunnel prior to screw insertion
- ✓ Flexing the knee 100°-120°
- ✓ Placing the screwdriver through the tibial tunnel

Divergence Prevention

The in-line direction of pull in the tibial tunnel

compared to the wedge effect in the femoral tunnel

makes avoidance of screw divergence more critical

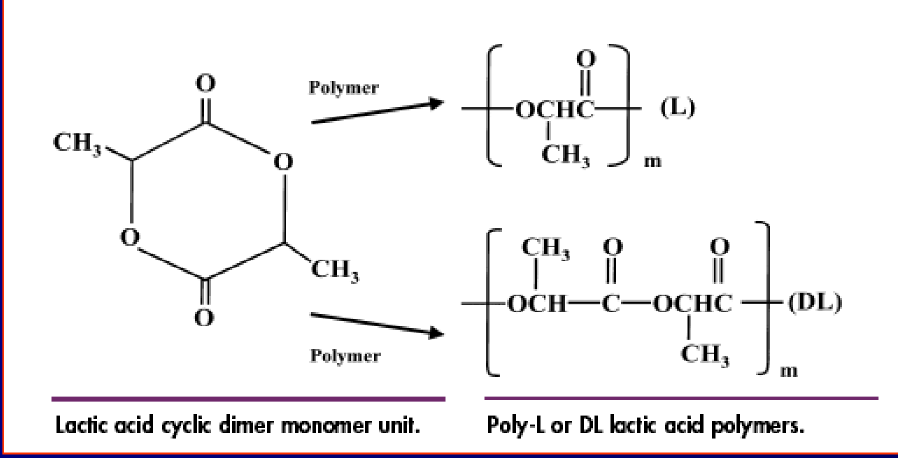
on the tibial side than the femoral side

Divergence Prevention

Although laboratory significance has been demonstrated, screw divergence has not been correlated with laxity clinically

Bioabsorbable Screws

- ✓ Biocompatible, non-immunogenic, non-toxic
- ✓ Polyglycolic acid (PGA)
- ✓ Poly-L-lactic acid (PLLA)
- ✓ Co-Polymers (PGA/PLLA, PGA/TMC,PGA/ PDS)



Interference Screw: Ideal Material?

- Retain sufficient strength over time
- Versatile processing
- Reproducible synthesis for consistency
- No inflammatory response
- Completely resorb without residual
- After resorption, body should “forget” that the implant was there
- The sharp threads of metallic interference screws used for bone plug fixation are blunted

Hydrolysis

- Elimination via the Krebs cycle and excreted in the urine
- Little difference in the rate of degradation from the different locations in the body
- Depends on MW, area, crystallinity, porous vs non-porous
- PLLA takes from 2-5 years to be completely absorbed

Bioabsorbable Screws

- High initial tensile strength@ crystallinity
- High crystallinity increases EtoF (less brittle)
- High modulus
- Low elongation to failure
- PLA maintains up to 75% of its initial mechanical strength 20 weeks in vivo

Clinically, bioabsorbable screws have provided good results

The literature is mixed regarding complete dissolution of the bioabsorbable implant

Potential disadvantages are:

- screw breakage during insertion
- inflammatory response
- inadequate fixation after partial degradation prior to biologic incorporation.

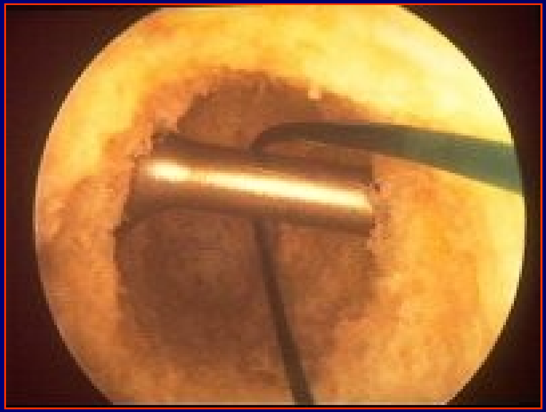
However,

- more bone plug fractures have been seen with metal interference screws
- similar cysts have been seen with metallic fixation as those reported with bioabsorbable screws

Hamstring Tendon Graft

Hamstring Graft Fixation

Fixation has evolved from staples to endobutton to interference screws and ultimately to cross pins



Hamstring Reconstruction Techniques

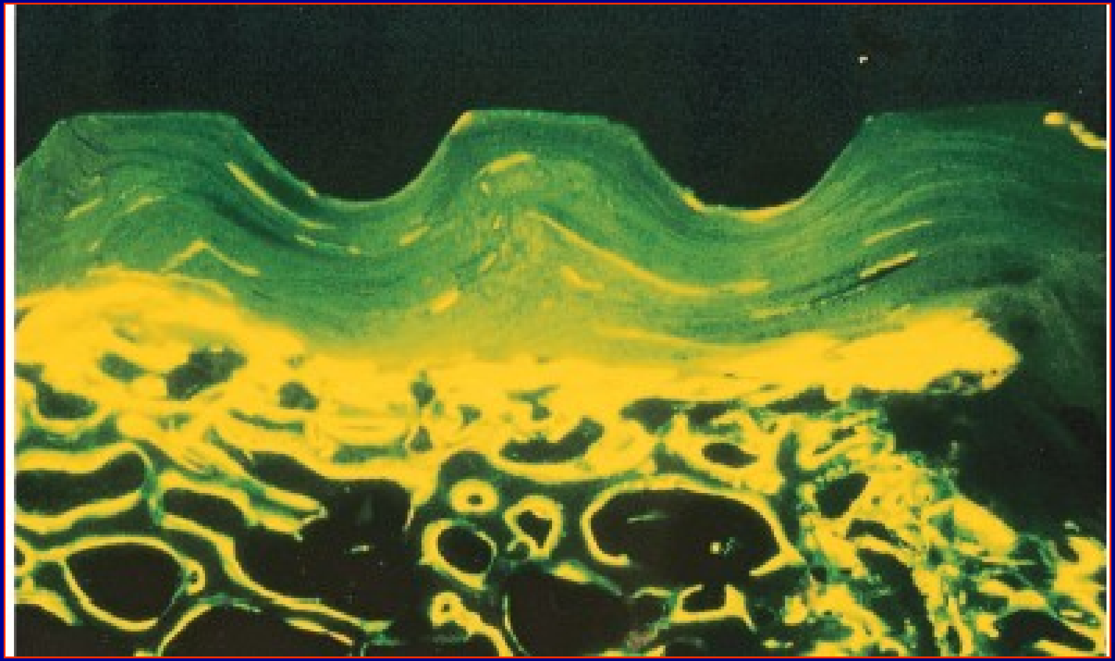
- fixation devices
- fixation level
- fixation method (direct *vs* indirect)
- graft configuration

Quadrupled Hamstring Graft Fixation Prerequisites

Free tendon grafts rely on establishing bone to tendon incorporation over time, thus requiring direct apposition of tendon to bone without detrimental reduction of initial fixation

Quadrupled Hamstring Graft Fixation Prerequisites

- Tight fit
- Sufficient Tendon Length
- Preservation of tendon integrity
- Postoperative Protection
- Outlet fixation



Brand et al., 2000

Early fixation techniques for soft-tissue grafts were limited to distal, indirect fixation techniques (suspensory fixation) which are hindered by

- inferior stiffness
- windshield-wipering (anterior/posterior)
- bungee cord effects (superior/inferior)

which may lead to delayed biological incorporation and tunnel enlargement.

Disadvantages of Hamstring Graft Fixation ???

- ✓ Less secure initial and long term fixation
- ✓ Increased knee laxity after reconstruction
- ✓ Lack of regrowth or regeneration

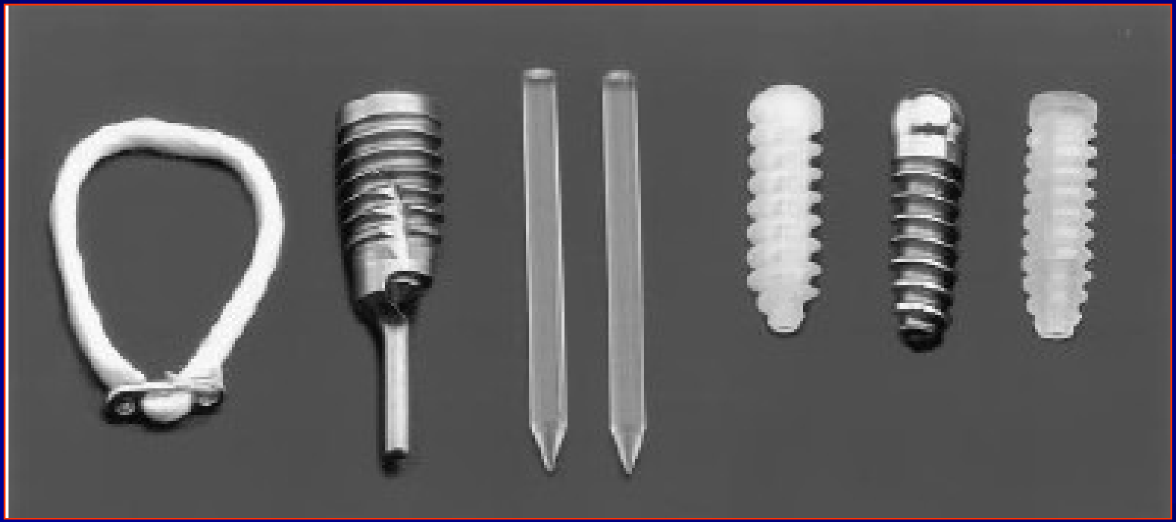
Recently there has been a surge of interest in the use of hamstring tendon grafts due in part to improvements in graft fixation techniques.

Femoral Fixation of a QHT Graft

Construct	Failure (N)	Stiffness (N/mm)
QHT with Trans-Fix[c]	523 (263)	34.2 (14.3)
QHT with Bone Mulch[c]	583 (108)	24.4 (4.17)
QHT with an EndoButton, mersilene tape[c]	520 (50)	34.8 (22.3)
QHT with EndoButton and Endotape[c]	618 (242) 663 (211) 678 (179)	22.4 (6.9) 18.1 (6.9) 20.6 (7.8)
QHT with EndoButton and three #5 suture[c]	699 (210)	30.2 (8.5)
QHT with EndoButton and 2 loops of Endotape[c]	628 (359)	21.2 (5.5)
Semitendinosus fixed with the EndoButton and tibial post[74]	612 (73)	47 (19)
QHT with Mitek[c]	412 (189)	20.3 (5.6)
QHT with the RCI titanium screw[18]	242 (90.7)	No stiffness reported
QHT with BioScrew[18]	341 (162.9)	No stiffness reported
QHT BioScrew, 0.5 mm graft sleeves[86]	530 (186)	No stiffness reported

Brand et al., 2000

Femoral Fixation



Endobutton, Bone Mulch Screw, Rigid Fix, Bio-Screw, Rigid Fix Bioscrew, RCI screw, Smartscrew ACL

Fresh Hamstring Tendons

Kousa et al. Am J Sports Med 2003

Results of Single-Cycle Loading Test for Each Fixation Device

Fixation	N	Yield load (N) (mean ± SD)	Stiffness (N/mm) (mean ± SD)
EndoButton CL	10	1086 ± 185	79 ± 7.2[a]
Bone Mulch Screw	10	1112 ± 295	115 ± 28
RigidFix	10	868 ± 171	77 ± 17[a]
BioScrew	10	589 ± 204[a,c,e]	66 ± 28[a,f]
RCI screw	10	546 ± 174[a,c,e]	68 ± 15[a,f]
SmartScrew ACL	10	794 ± 152[b,d]	96 ± 20

1500 Loading Cycles 50-150 N

Results of Single-Cycle Loading after Cyclic Loading for Each Fixation Device

Fixation	N	Yield load (N) (mean ± SD)	Stiffness (N/mm) (mean ± SD)
EndoButton CL	10	781 ± 252	105 ± 13[a,b,c]
Bone Mulch Screw	10	925 ± 280	189 ± 38
RigidFix	10	768 ± 253	136 ± 13[a]
BioScrew	9	565 ± 137[d]	113 ± 15[a,e]
RCI screw	9	534 ± 129[d,f]	134 ± 23[a]
SmartScrew ACL	10	842 ± 201	162 ± 28

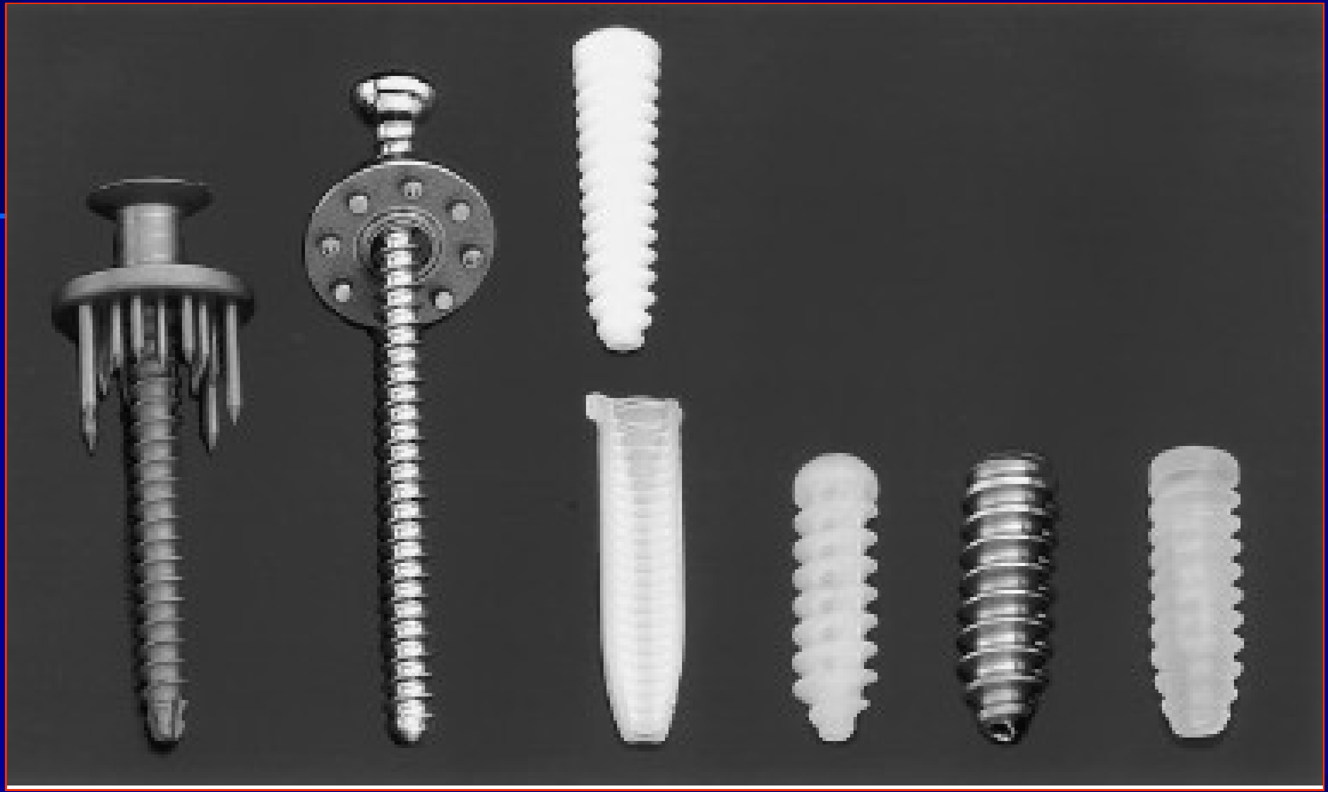
Only Screws failed during the cyclic loading

Considerable differences are shown between static and cyclic loading

The structural properties of a fixation method may not be the same in animal and human tissue

Interference screws perform better in animal tissue

Tibial Fixation

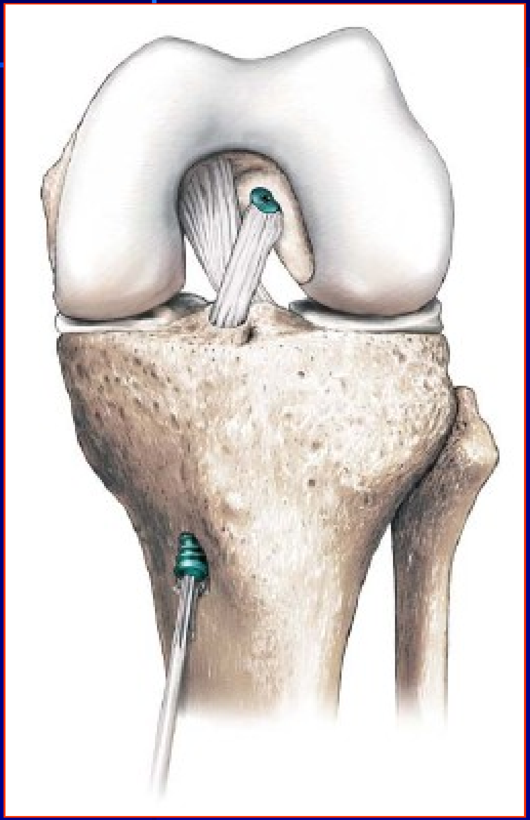


WasherLoc, Tandem spiked washer, Intrafix, Bioscrew, Softsilk IFS, Smartscrew ACL

Kousa et al. Am J Sports Med 2003

Results of Single-Cycle Loading Test for Each Fixation Device

Fixation	N	Yield load (N) (mean ± SD)	Stiffness (N/mm) (mean ± SD)
WasherLoc	10	975 ± 232[a]	87 ± 23[a]
Tandem spiked washers	10	769 ± 141[b]	69 ± 14[b]
Intrafix	10	1332 ± 304	223 ± 62
BioScrew	10	612 ± 176[b,c]	91 ± 34[b]
SoftSilk	10	471 ± 107[b,d,e]	61 ± 12[a,f]
SmartScrew ACL	10	665 ± 201[b,g]	115 ± 34[b]



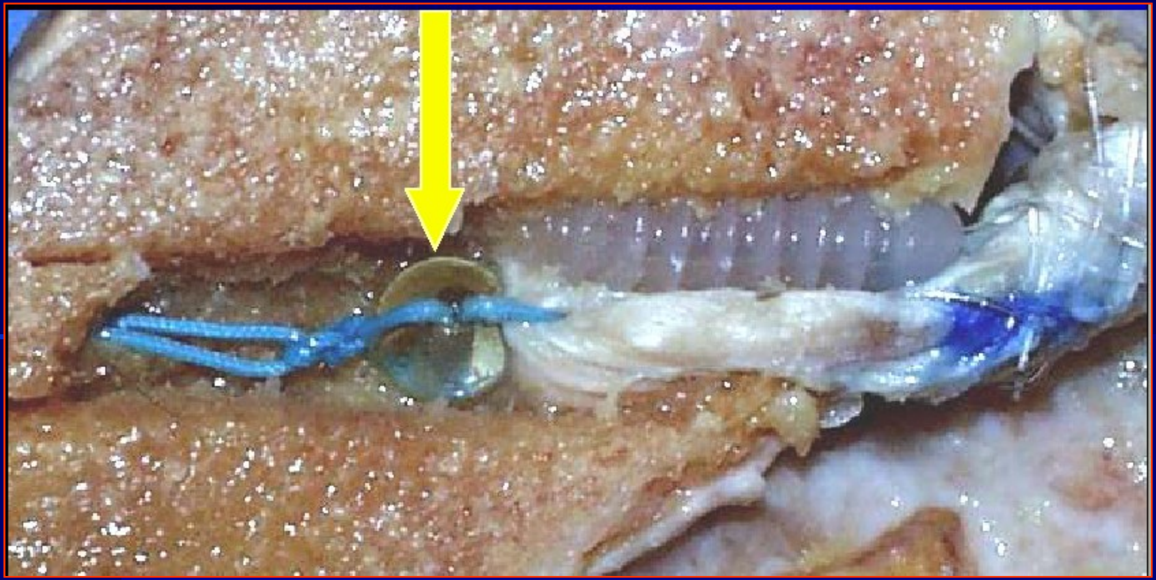
Direct soft-tissue fixation with interference screws still allows considerable graft slippage, which can be limited by using a bone block or application of a backup or hybrid fixation, especially on the tibial fixation site.

IFS demonstrate the tendency

for the tendon to slip past the screw.

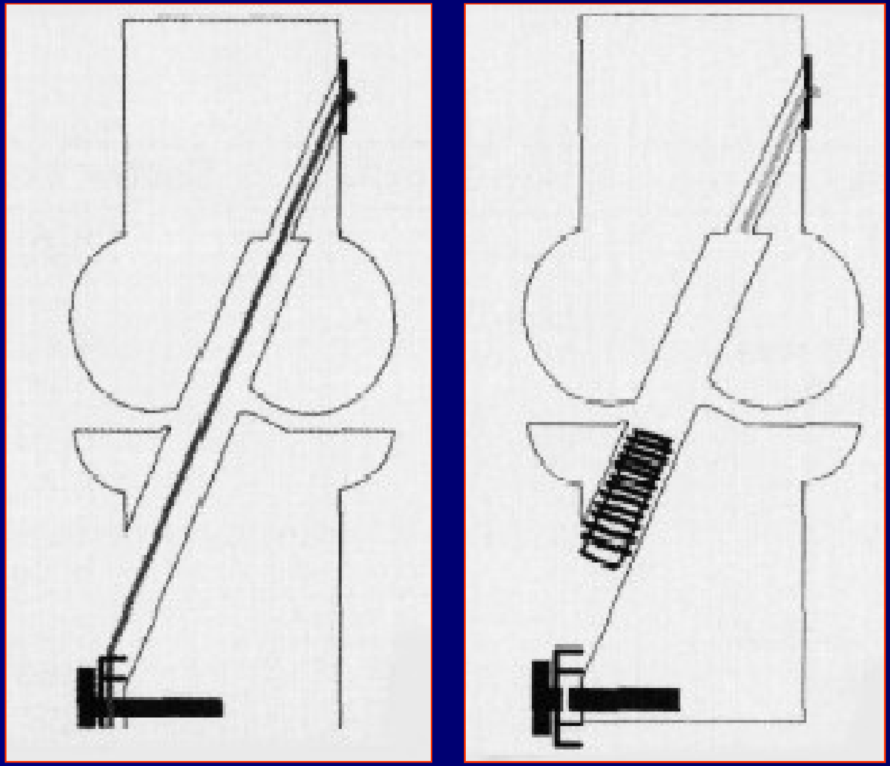
Augmentation with sutures tied to an intraarticular anchor (ball-disc) or external post, staple or button improves initial fixation strength

Endopearl



Combined Fixation

- ✓ Screw + Outlet fixation
- ✓ Cross pin + Screw



- ✓ Graft Pretensioning
- ✓ Preconditioning
- ✓ Initial Tensioning

Have been recommended for elimination of viscoelastic tendon creep and prevention of postoperative knee laxity

Initial Graft Tension for ACL Reconstruction

10N ?

20N?

30N ?

80N?

100N?

120N?

???

Enough load should be applied:

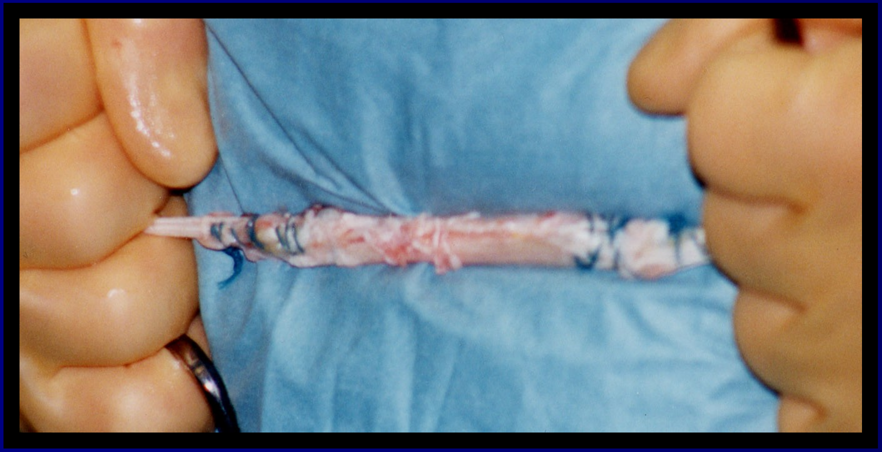
- ✓ To prevent slippage
- ✓ To eliminate pathological anterior laxity
- ✓ To maintain physiologic laxity and kinematics

Preconditioning of the Graft

- Static
- Cyclic

→

- Pre-implantation
- Intraoperative



Graft Preconditioning

Clinically applicable preconditioning protocols

do not fully eliminate the intrinsic tendon

creep.

The initially set tension decreases considerably postoperatively due to the remaining tendon creep

Initial Graft Tension for ACL Reconstruction

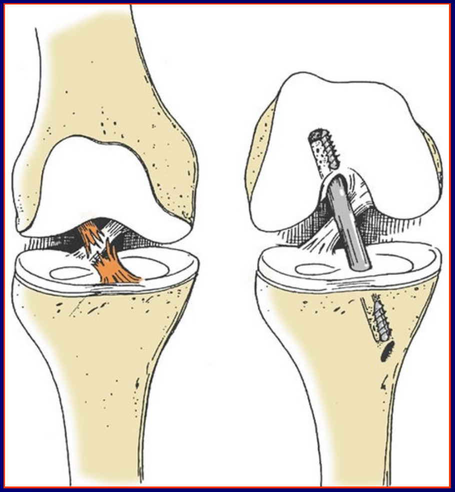
Graft tension affects remodeling of the autograft in ACL reconstruction.

Not only stress-deprivation but also stress-enhancement significantly affect the mechanical properties of tendon autografts.

High initial tension reduces the postoperative anterior laxity of the knee joint after ACL reconstruction using the doubled hamstring tendons

Initial Graft Tension for ACL Reconstruction

Increase of initial tension from 20 to 80 N significantly increases the initial stiffness of the fixation

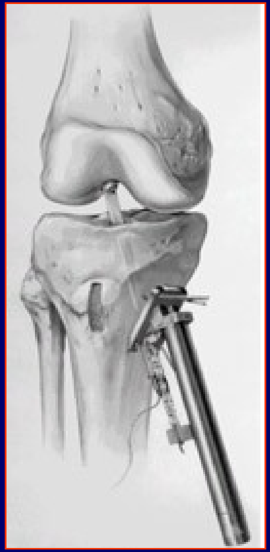


Initial Graft Tension for ACL Reconstruction

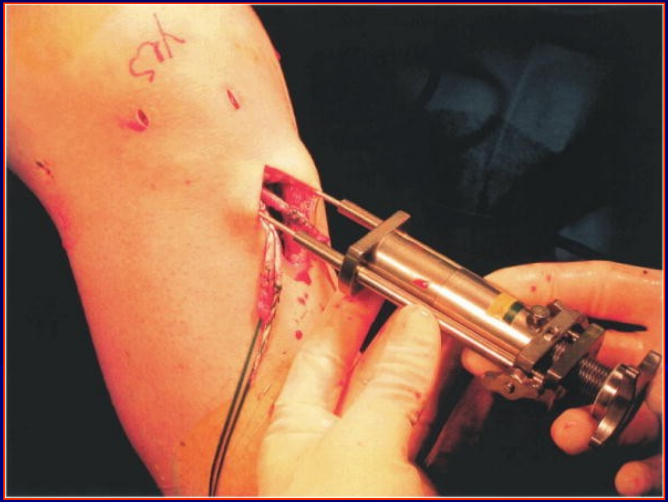
Additional increase of initial graft tension above 80 N does not increase the stiffness of the FT graft using an interference-screw-fixation for ACL reconstruction after cyclic loading.

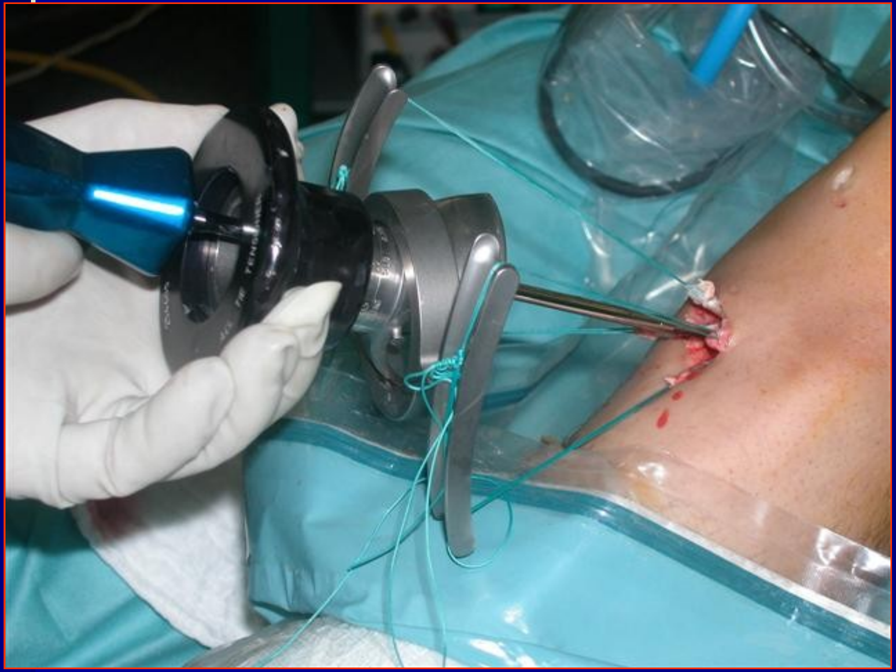
Initial Graft Tension for ACL Reconstruction

Pathological changes in the graft such as increased central necrosis rate or cartilage damage due to 'overconstraining' of the knee may occur



Graft Tensioning





There is a range of tensions
at which ACL grafts can be fixed

Most surgeons do not tension
the graft maximally

Cunningham, 2002

Inadequate Tension results in

- continued instability

Excessive graft tension

- restriction of ROM
- arthrosis acceleration

Alternative Fixation Methods

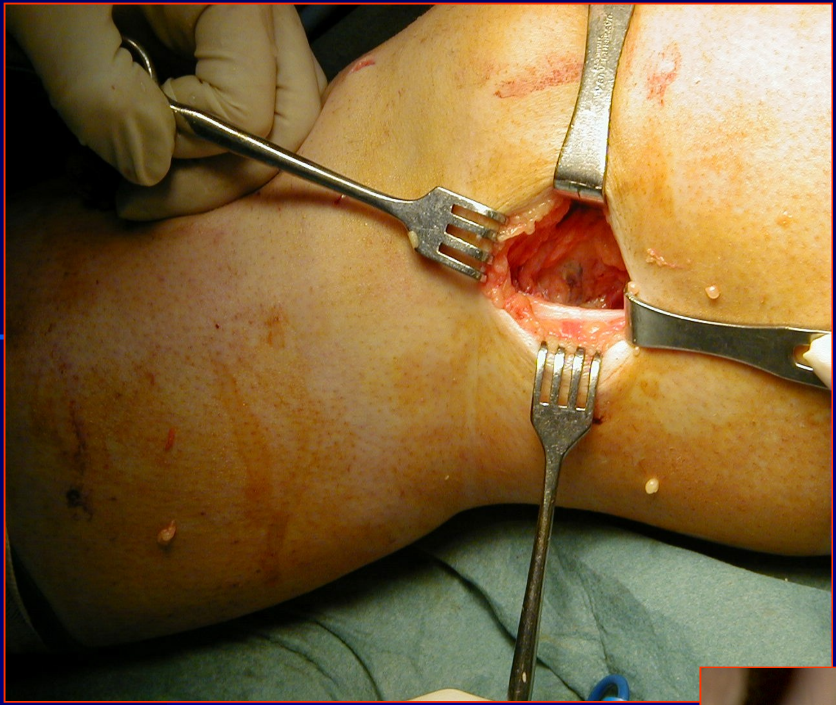
Over The Top Femoral Fixation

- Primary and Revision Surgery
- Avoids problems associated with drilling a femoral tunnel
- Clinically successful
- Biomechanically sound
- Reproducible

Over The Top Femoral Fixation

Indications

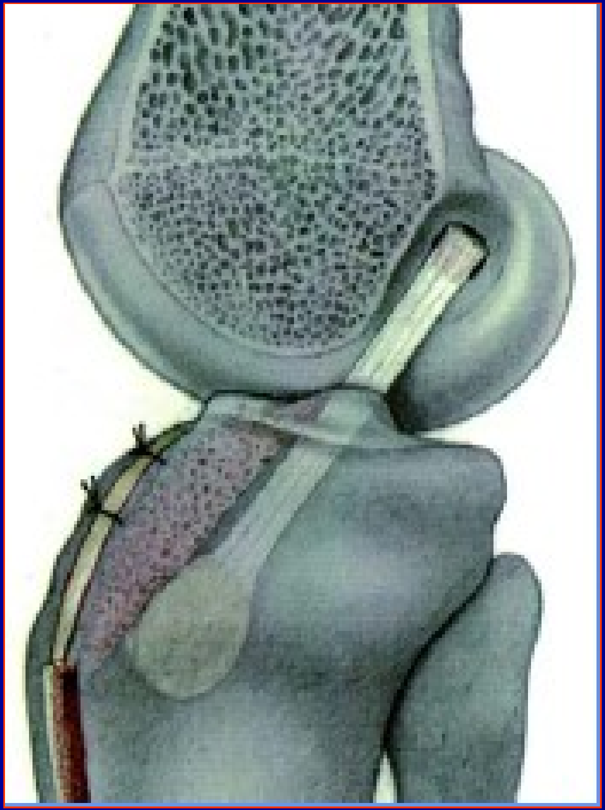
- ✓ Posterior wall perforation
- ✓ Adolescent ACL reconstruction
- ✓ Revision surgery
- ✓ Surgeon’s Preference

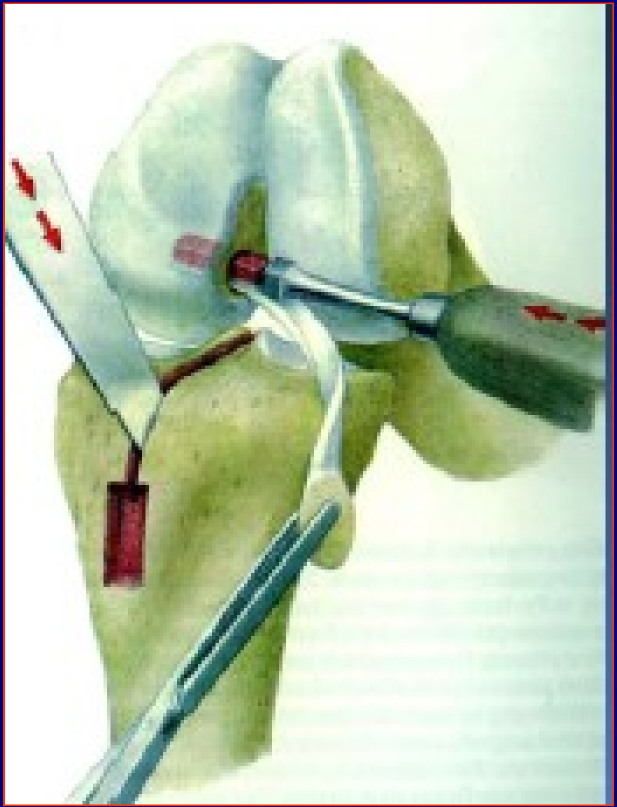


BH Soffix + Bollard OTT Fixation

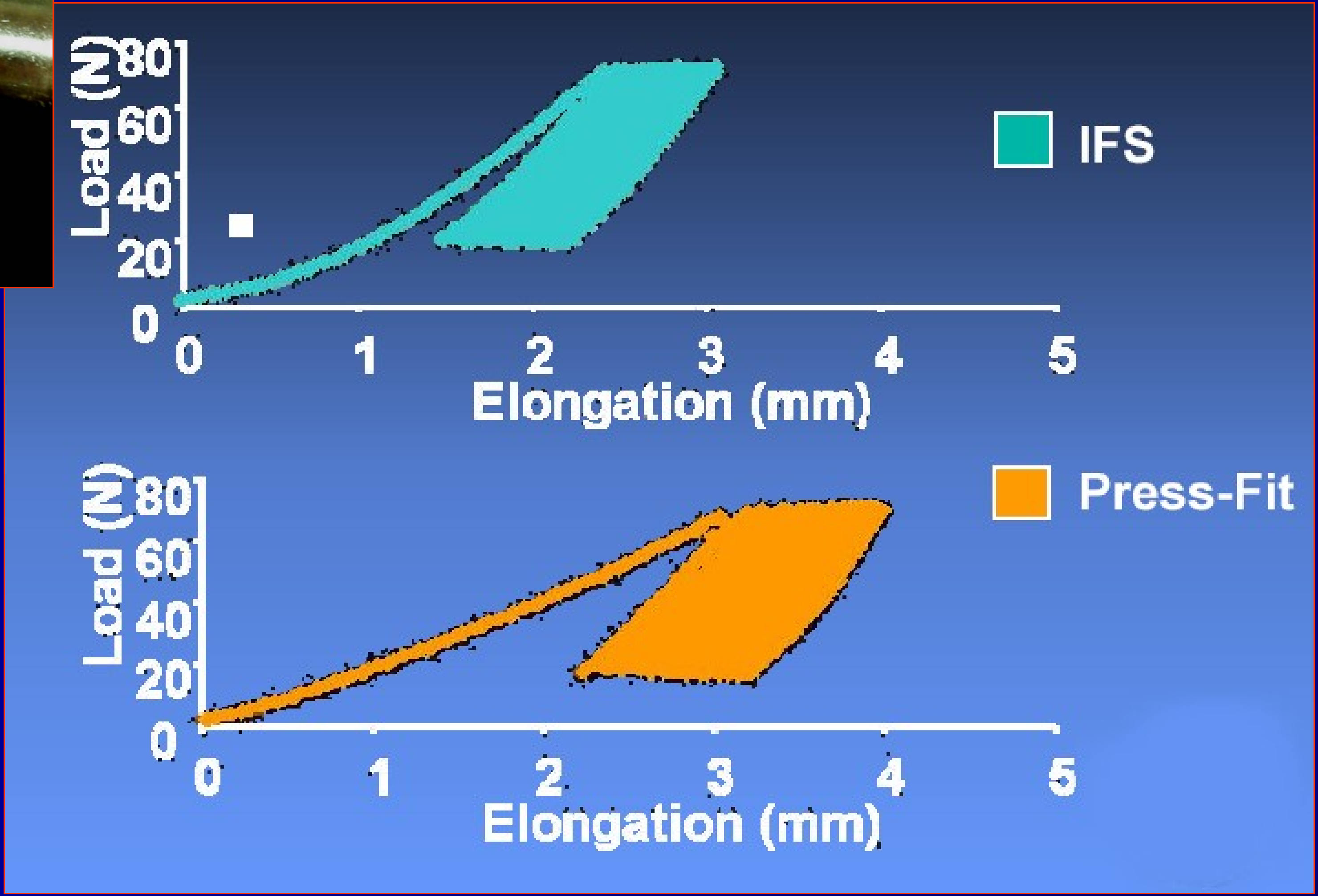
Press Fit Femoral and Tibial Fixation

Press Fit Femoral and Tibial Fixation





Cyclic Elongation - Creep



Press fit fixation, Musahl 2000

Advantages - Disadvantages

- ✓ No hardware
- ✓ Bone to bone healing
- ✓ No intraarticular defects
- ✓ Easier revision surgery
- ✓ Mini-Arthrotomy

ACL PROSTHESES

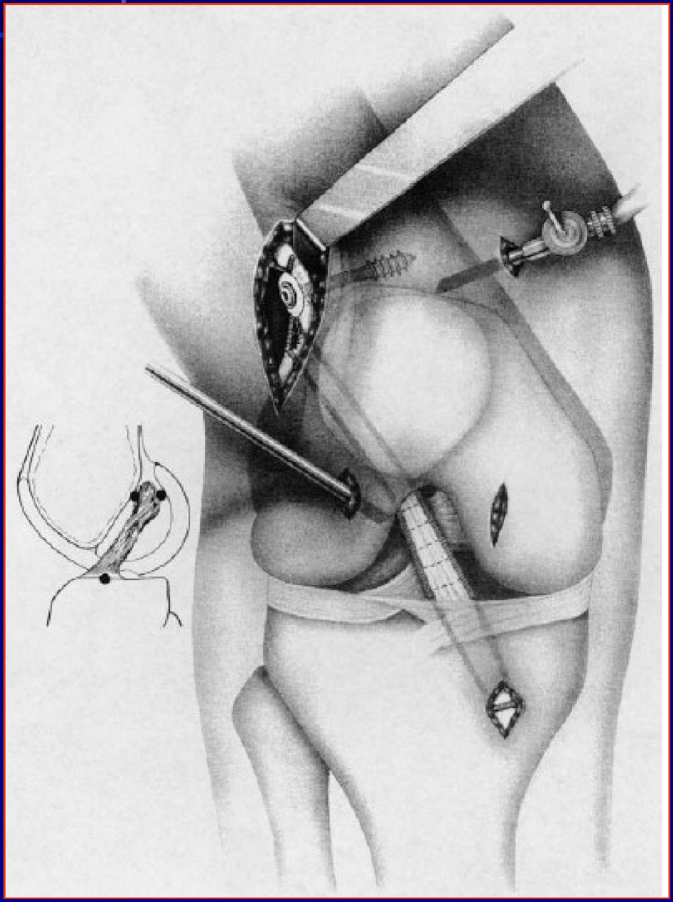
ACL PROSTHESES

- ✓ Permanent Prostheses
- ✓ Non Degradable Scaffolds designed for tissue ingrowth
- ✓ Graft Augmentation Devices
- ✓ Resorbable Synthetics and Tissue-Derived Biomaterials
- ✓ Fibroblast Seeded Scaffolds

Synthetic Ligaments

- ✓ Scarcity of literature
- ✓ Not relying on permanent bone-polyester fixation
- ✓ The strength of the fixation is static and declines with time
- ✓ The ligament material fails progressively with time
- ✓ Ultimate rupture and failure is inevitable
- ✓ Foreign Body Reaction - Synovitis
- ✓ Not recommended for ACL reconstruction

Augmentation

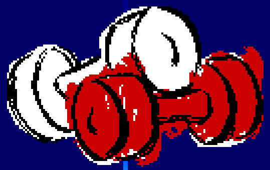


- ✓ Stress shielding (28-45%)
- ✓ Unknown biological impact
- ✓ Clinically not necessary
- ✓ Probably useful in insufficient graft material

Conclusion

- ✓ Intraoperatively achieved fixation strength guides the postoperative regimen.
- ✓ Rehabilitation and reintroduction of activities should correlate with fixation strength achieved in the operating room.
- ✓ Clinical results are good with most fixation techniques

Conclusion



Improvement of biological incorporation of replacement grafts will lead to better insertion site healing and faster ingrowth of the graft.

The Future

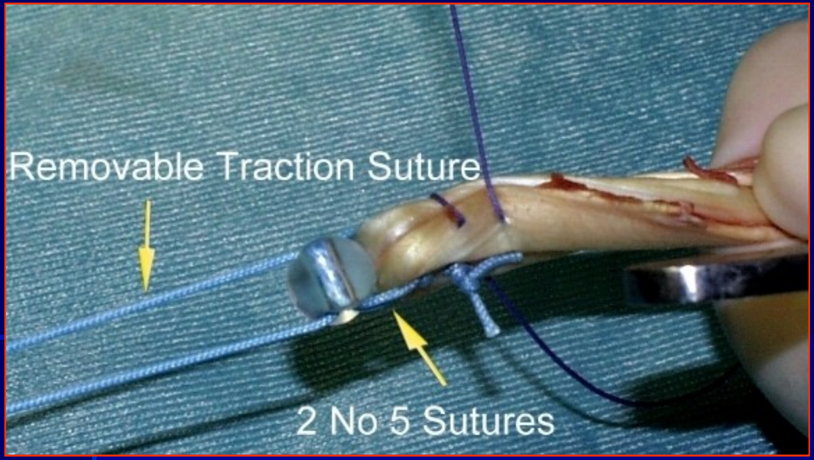
- Gene therapy
- Cell therapy
- Tissue Engineering
- Growth Factors

Ευχαριστώ

Conclusion

If the surgeon performs < 30 ACL reconstructions/year he should use 1 technique

If he performs > 50 ACL reconstructions/year he should be familiar with more techniques


Removable Traction Suture
2 No 5 Sutures

Over-tensioning of the graft increases the forces in the graft at all angles of flexion causing:

- Posterior tibial subluxation
- Tensioning of the PCL
- Decreased range of AP laxity

It is not possible to find levels of graft tension that restored AP laxities at all flexion positions and restored forces in both grafts to those of their native cruciate counterparts during passive motion.

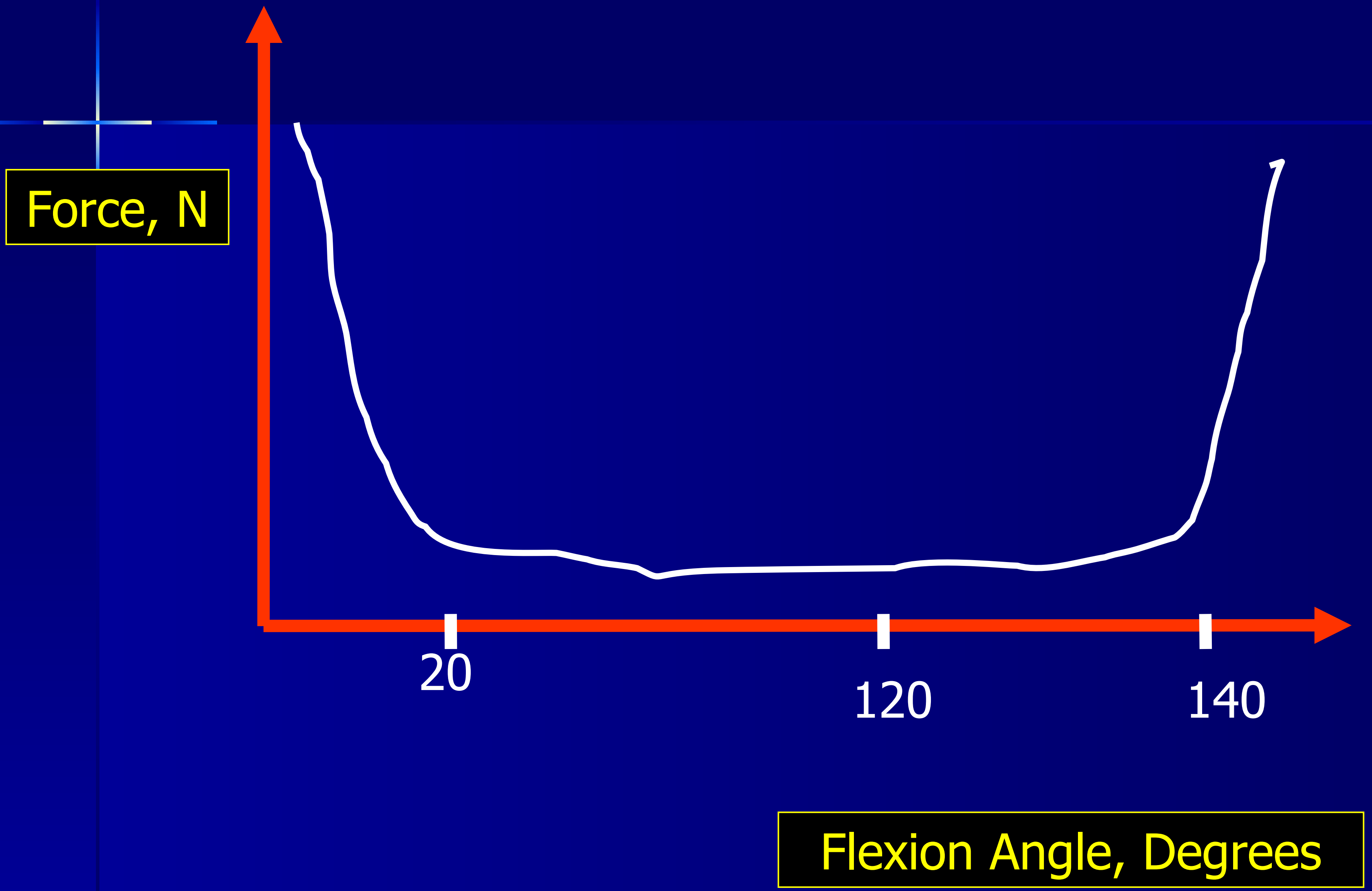
Goals of ACL reconstruction

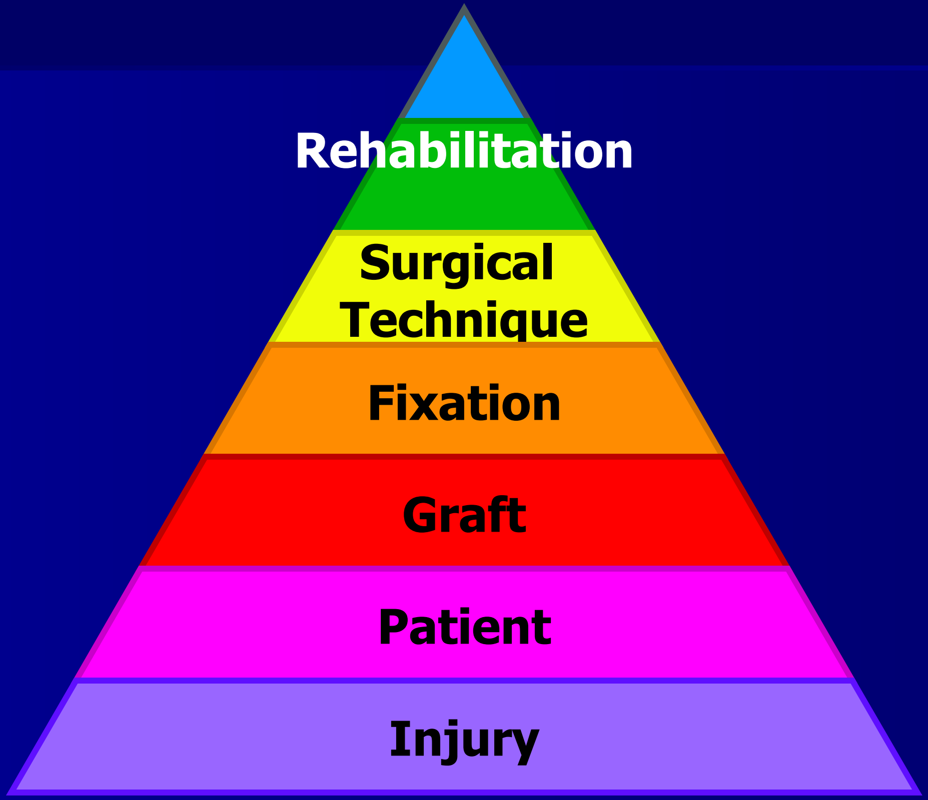
- Sufficient initial strength to avoid fixation failure
- Sufficient stiffness to restore stability of the knee
- Anatomic fixation to minimize graft movement within the tunnel
- Sufficient resistance against slippage under cyclic loading

454 N is the critical graft substitute strength required to endure daily activities, which are recreated during rehabilitation

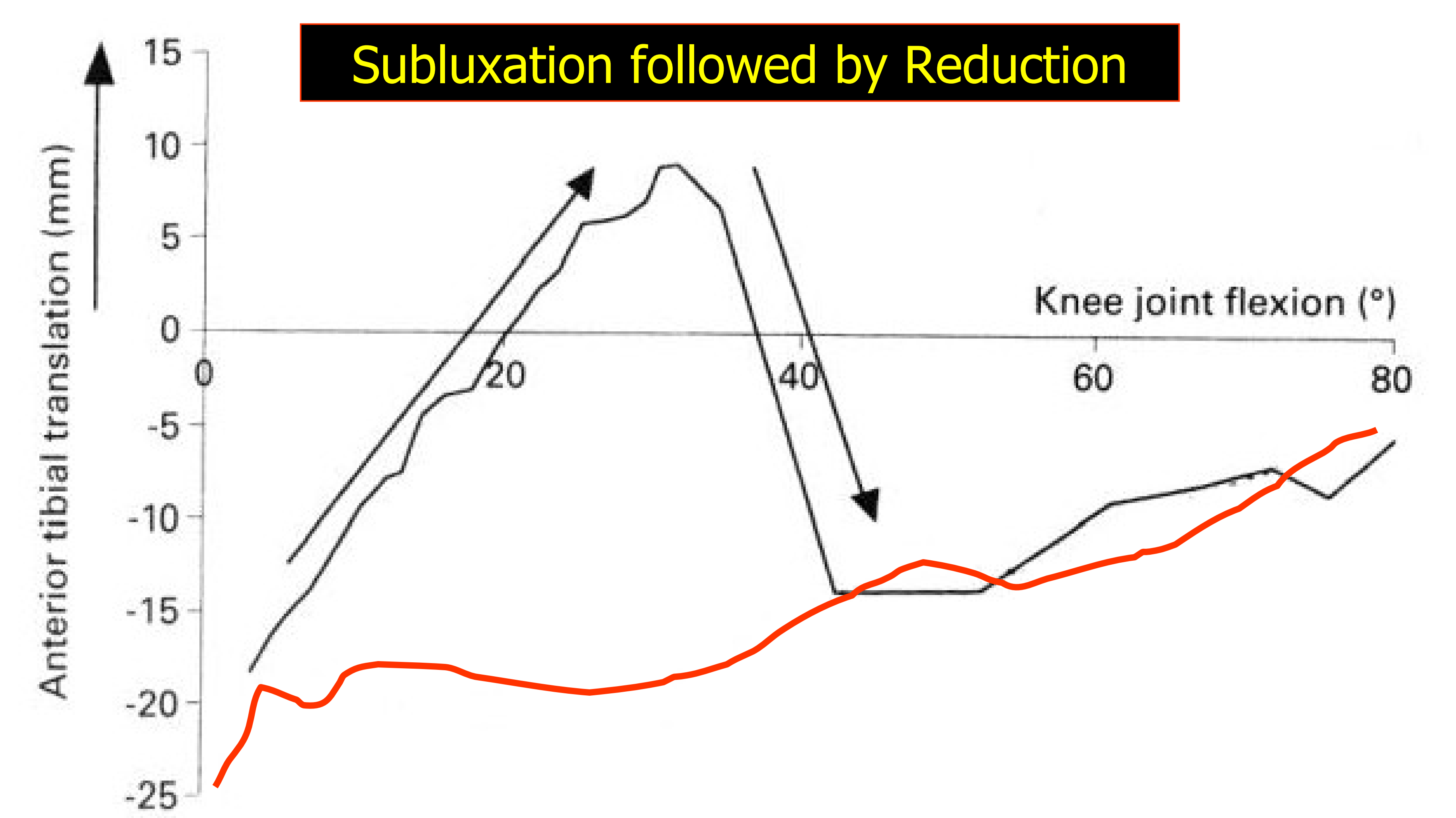
Noyes FR, Butler DL, Grood ES, Zernicke RF, Hefzy MS. Biomechanical analysis of human ligament grafts used in knee-ligament repairs and reconstructions. J Bone Joint Surg (Am) 1984;66:344-352

Tension Pattern of the Intact ACL




Rehabilitation
Surgical Technique
Fixation
Graft
Patient
Injury

Intraoperative Knee Kinematics



the effect of reconstruction on the anterior translation characteristics of the centre of the tibia during the pivot-shift test

Graft Options

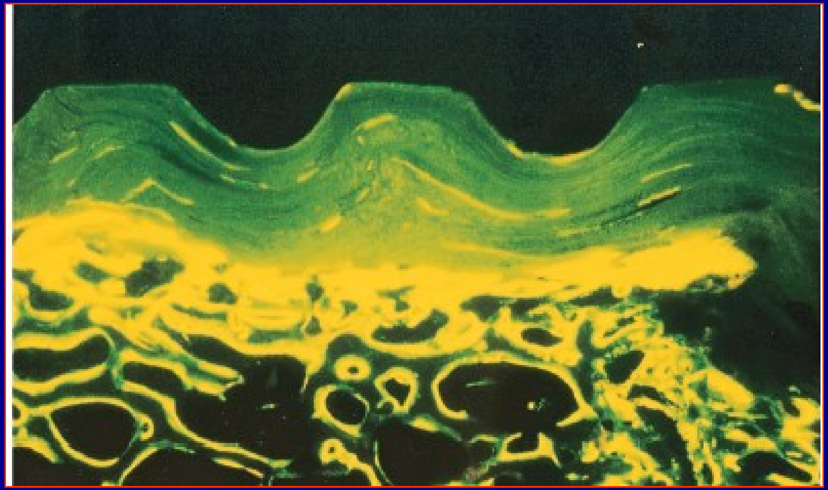
- Autograft – BPTB, QHT, Quadriceps
- Allograft – BPTB, Achilles Tendon
- Xenograft – Bovine
- Synthetic Grafts – Prosthetic Ligament, Ligament Augmentation Device, Scaffold
- Tissue Engineering– Future of ACL reconstruction

Hamstrings vs BPTB

- ✓ 7 prospective studies BPTB and QHT grafts
- ✓ 4 have found similar laxity values and functional results between the two types of graft tissues
- ✓ 3 found statistically tighter instrument measured values with the BPTB graft that did not correlate with functional outcome

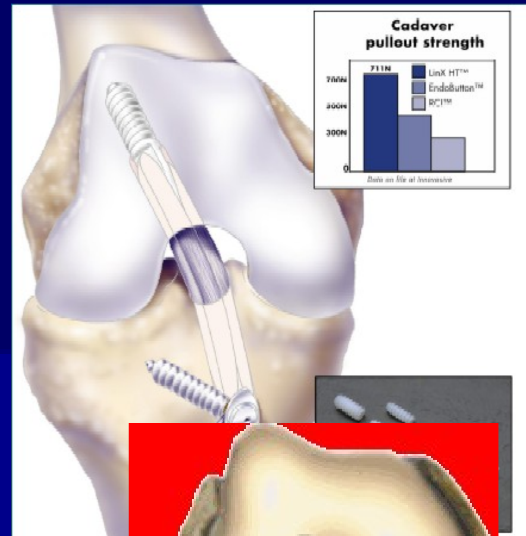
The ideal fixation for hamstring graft should have the following features

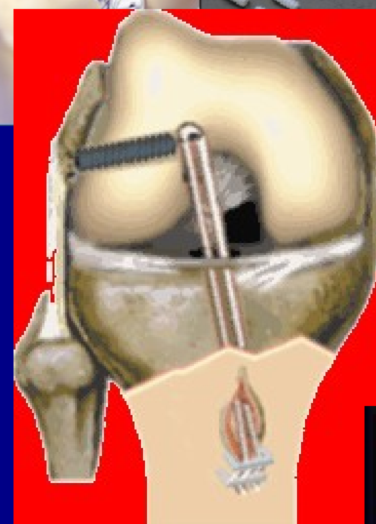
- Minimum length of free graft to reduce the bungee cord effect
- Ultimate reliance on good biological fixation
- Zero time fixation strength should be at least 500N

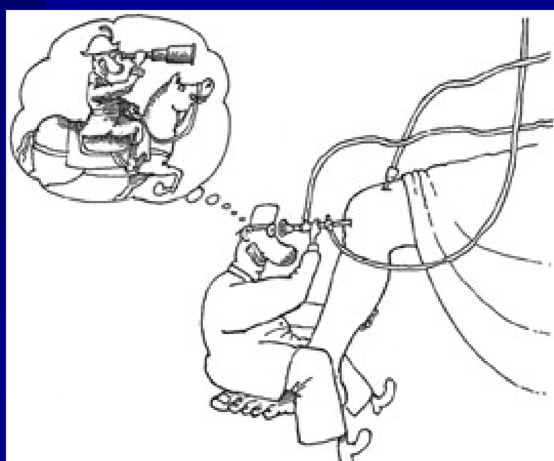


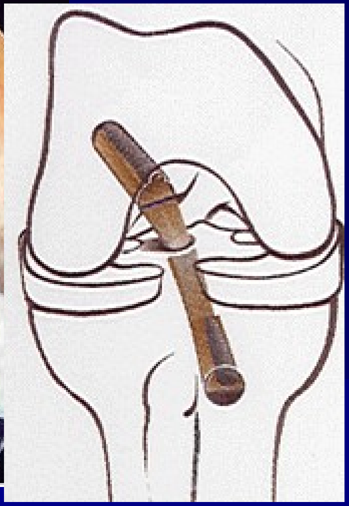
Brand et al., 2000

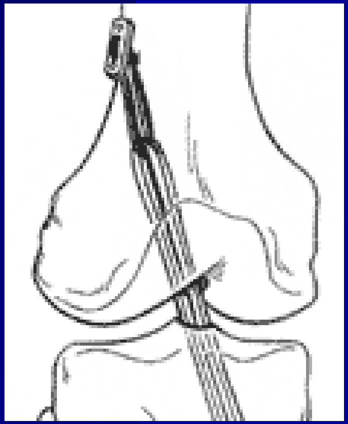
Screw & Washer System

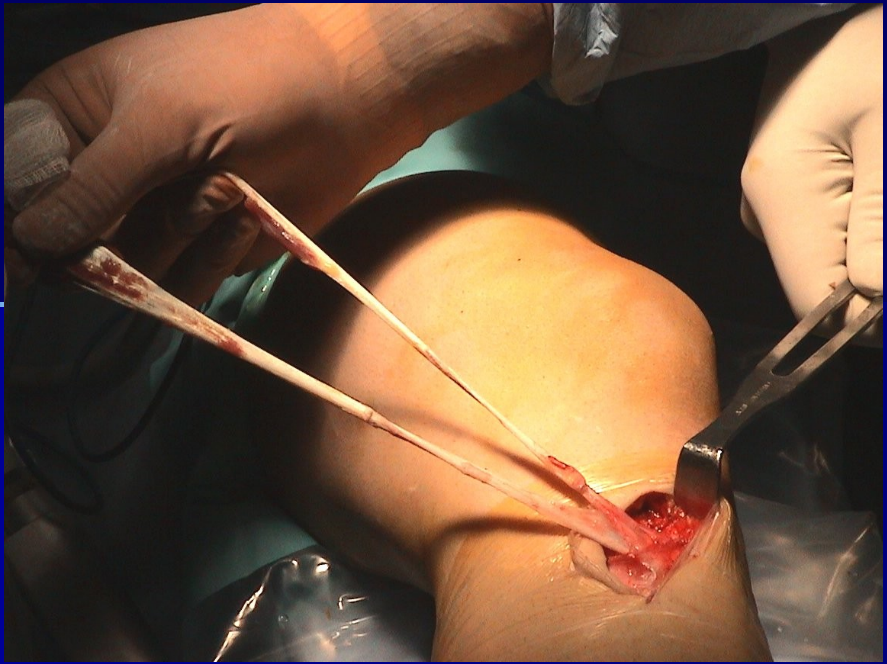

Cadaver
pullout strength
711N
LinX HT™
EndoButton™
300N
0

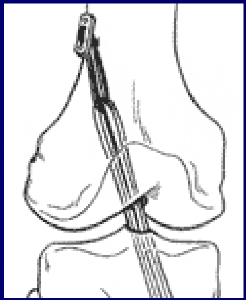


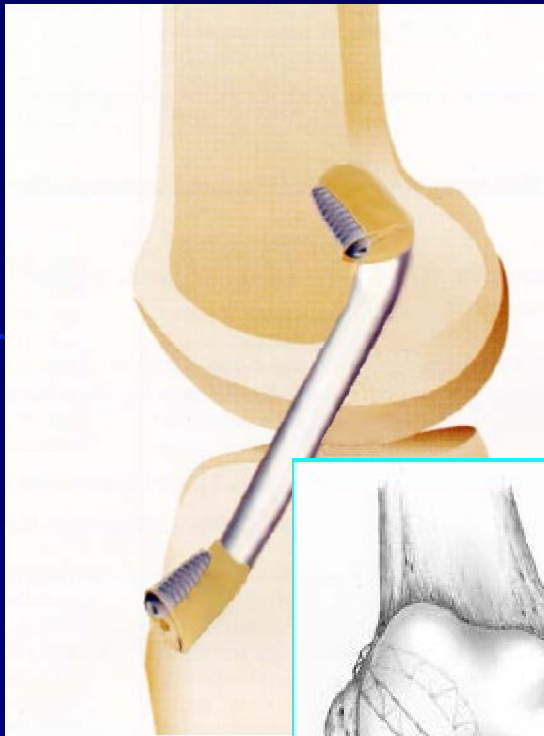


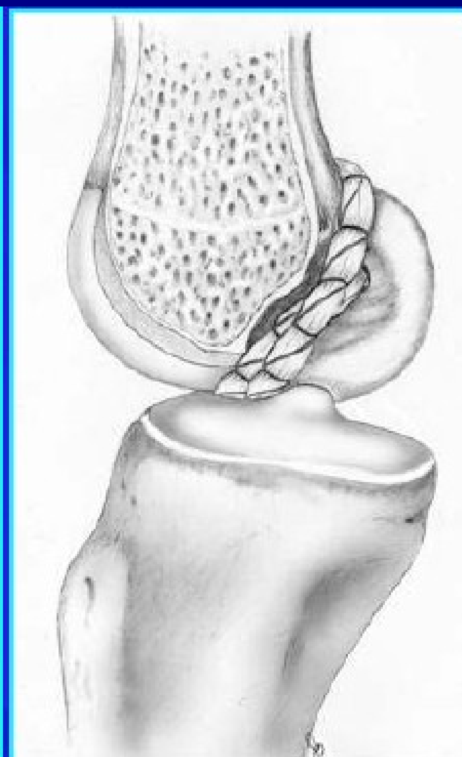



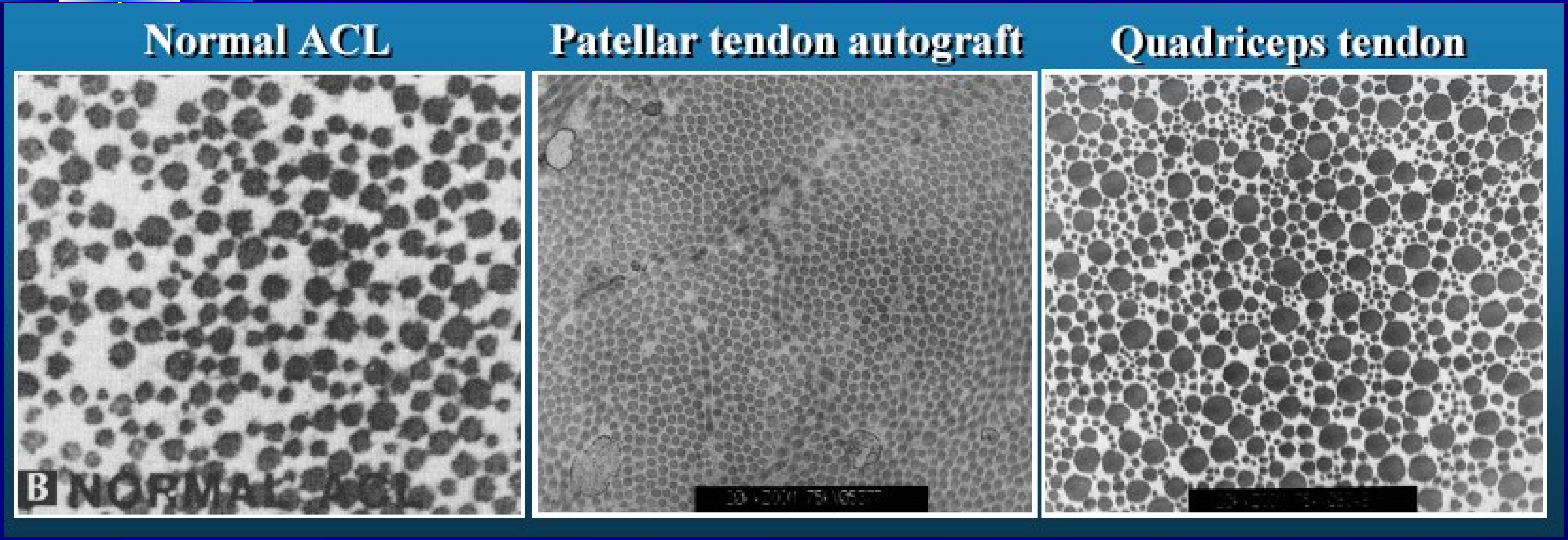


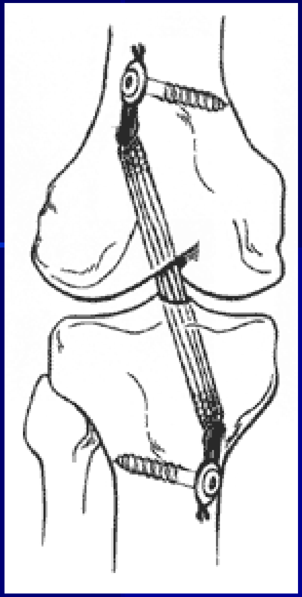



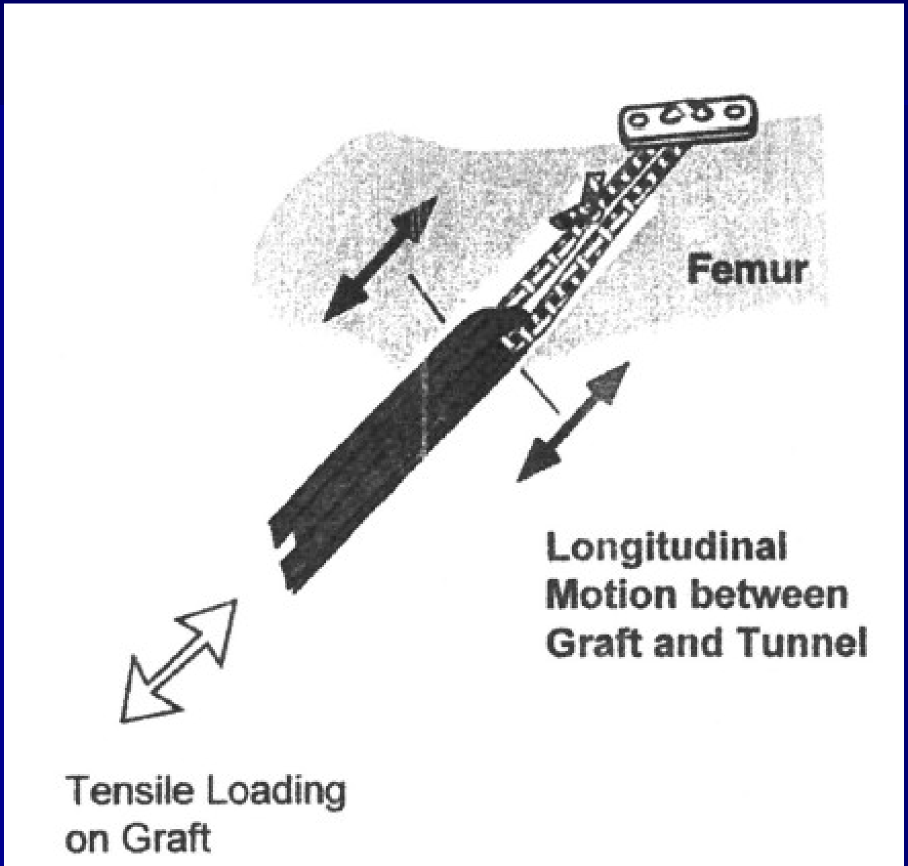





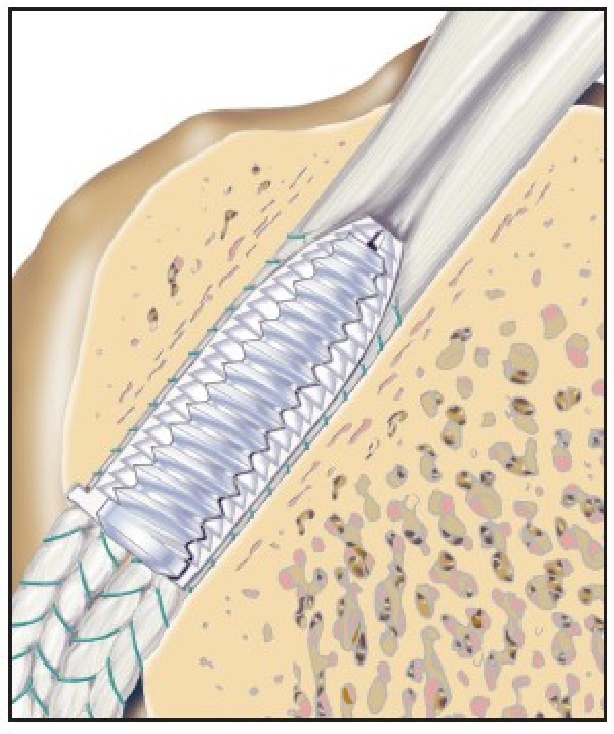


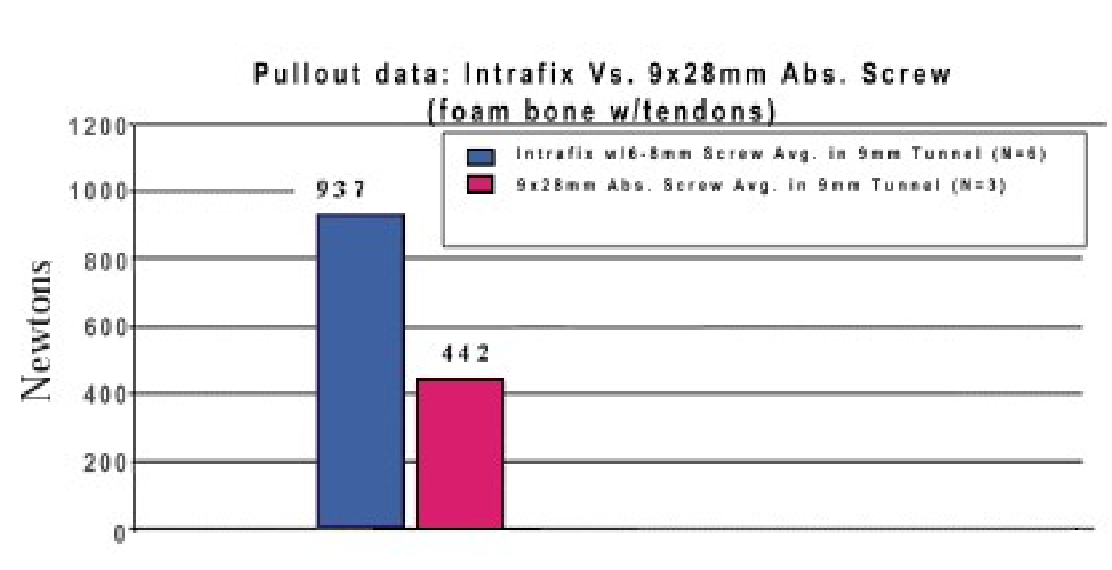

Normal ACL
Patellar tendon autograft
Quadriceps tendon
B NORMAL ACL




Femur
Longitudinal
Motion between
Graft and Tunnel
Tensile Loading
on Graft

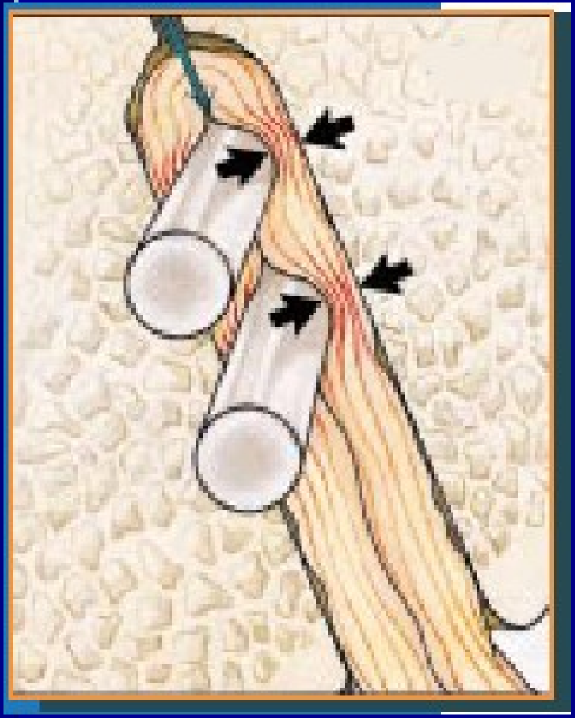
Intrafix

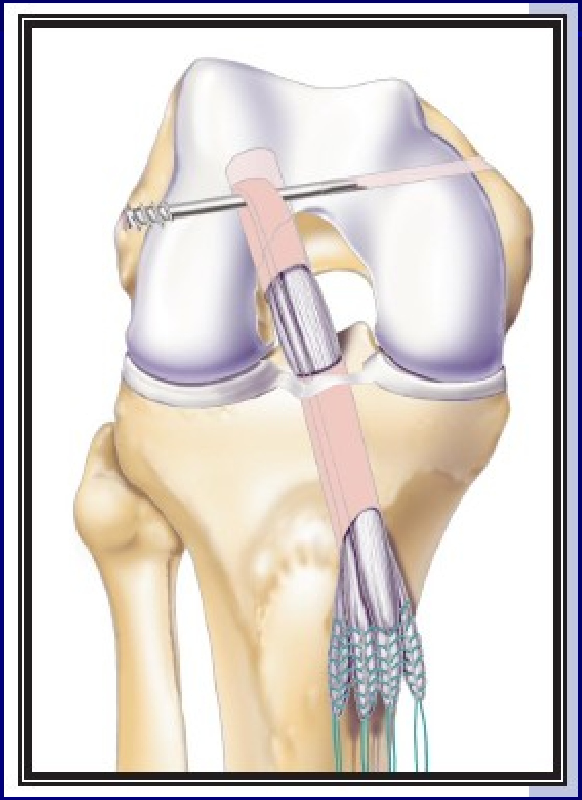




Pullout data: Intrafix Vs. 9x28mm Abs. Screw
(foam bone w/tendons)
Intrafix w/6-8mm Screw Avg. in 9mm Tunnel (N=6)
9x28mm Abs. Screw Avg. in 9mm Tunnel (N=3)
Newtons
1200
1000
800
600
400
200
0
937
442

Cross pin fixation





slingshot

In tension most ligament reconstructions fail at or near the fixation to bone

Modes of Failure

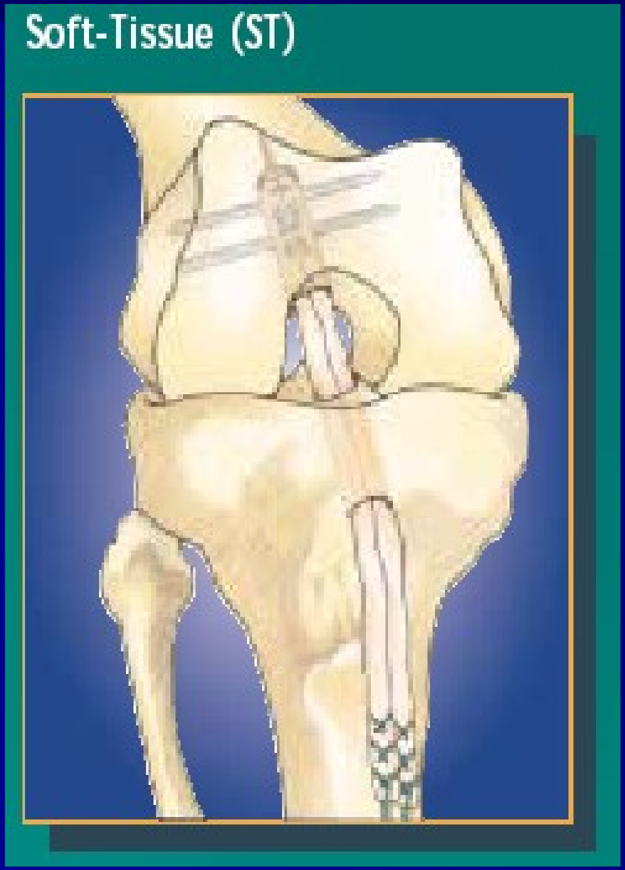
Suture knot

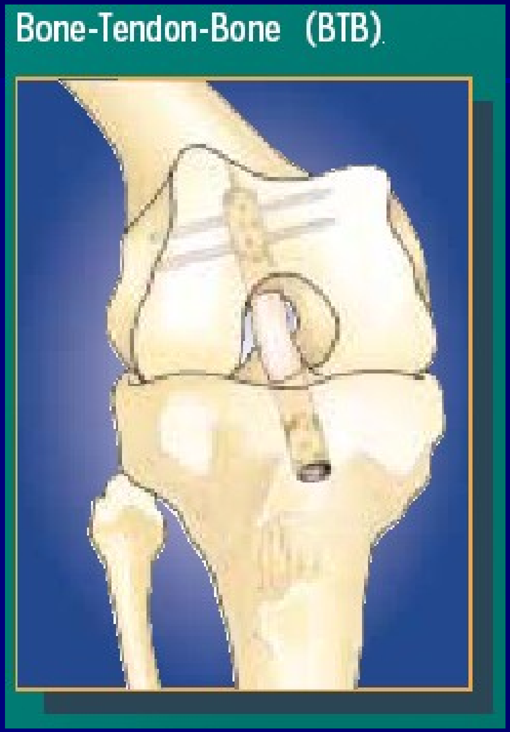
Cracking of bone block

Slipping of sutures through soft tissue

Slipping of graft past an IFS

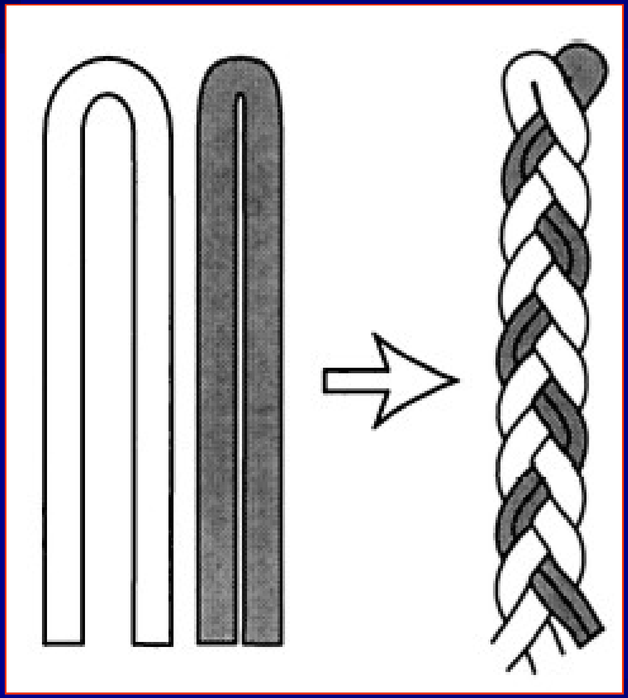
Rigid Fix





Gobbi et al., 2002

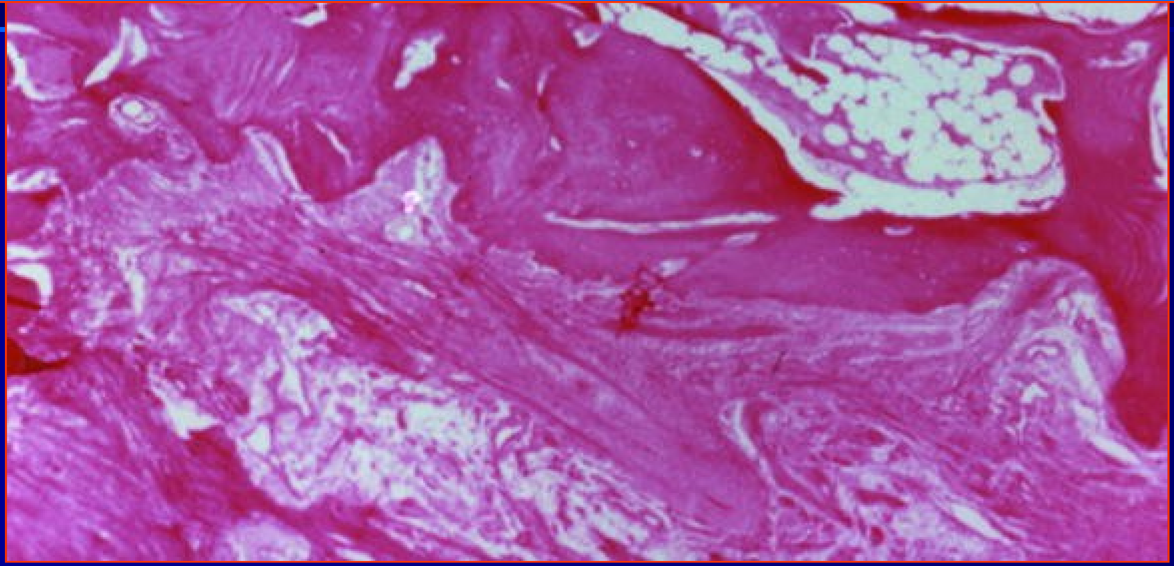
Braiding of the Hamstring Tendons



- ✓ Reduction in Strength and Stiffness
- ✓ Failure at the midsubstance
- ✓ Braiding is not advisable

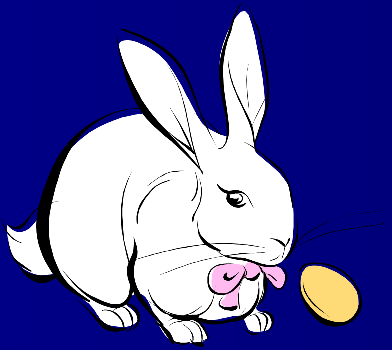
Postmortem examination of poly-L lactic acid interference screws 4 months after implantation during anterior cruciate ligament reconstruction

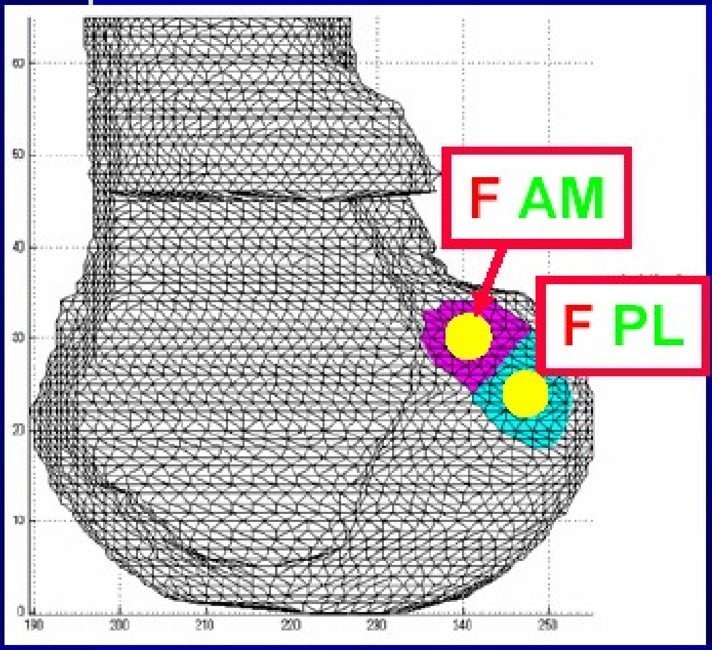
McGuire et al. Arthroscopy, 2001

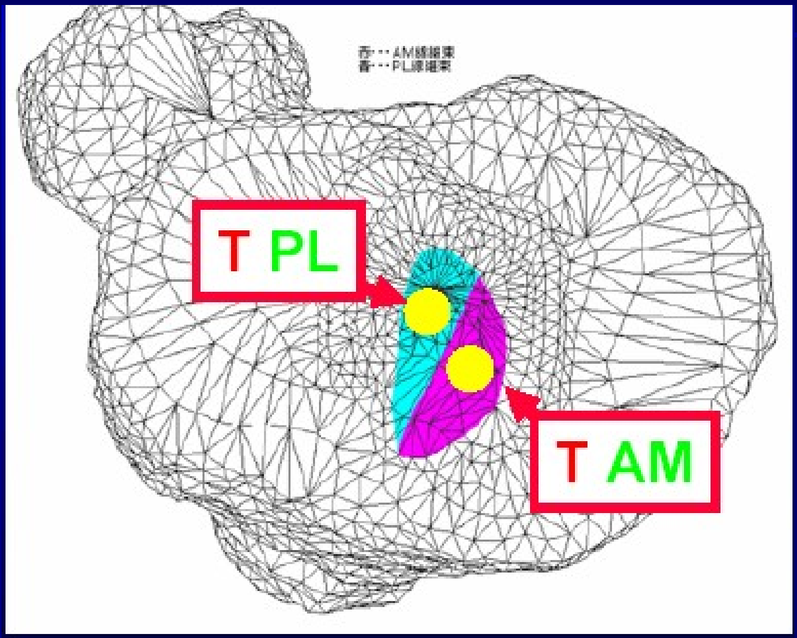


No histologic evidence of foreign-body reaction or inflammatory response was seen in the area surrounding the femoral screw.


WRONG
WAY




F AM
F PL
60
50
40
30
20
10
0
190
200
210
220
230
240
250


T PL
T AM


The challenge by Gareth Gorman which has almost certainly ended Pascal Vandeipuin's season.
(Photo: Paddy Gallagher)

Conclusion

"There are many choices of device to use for femoral fixation of a hamstring tendon graft, but none of the currently used soft tissue fixation devices has been proven to be biomechanically superior to the others."

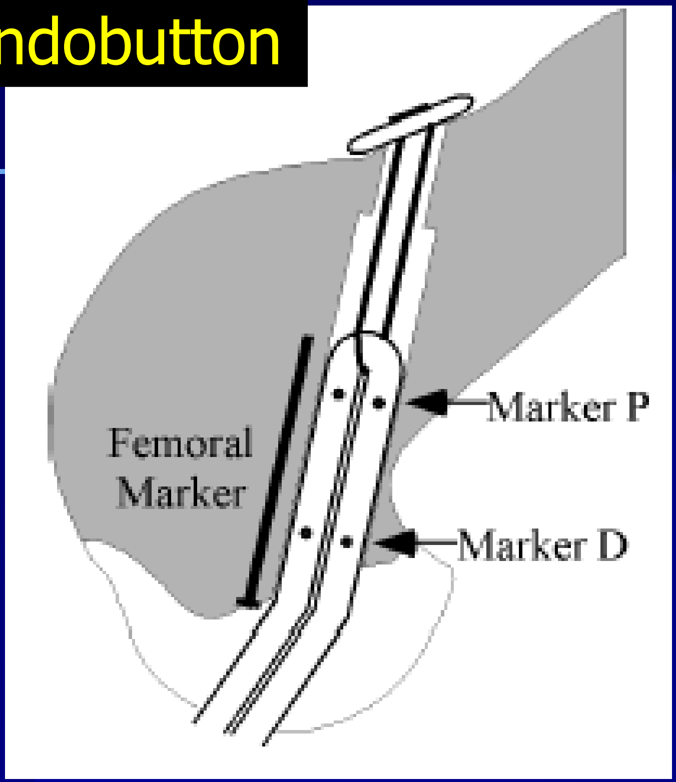
Graft load can be a high as 560 N with a 1500 N quadriceps contraction

Extension exercises can induce loads in ACL greater than the strength of most fixation methods

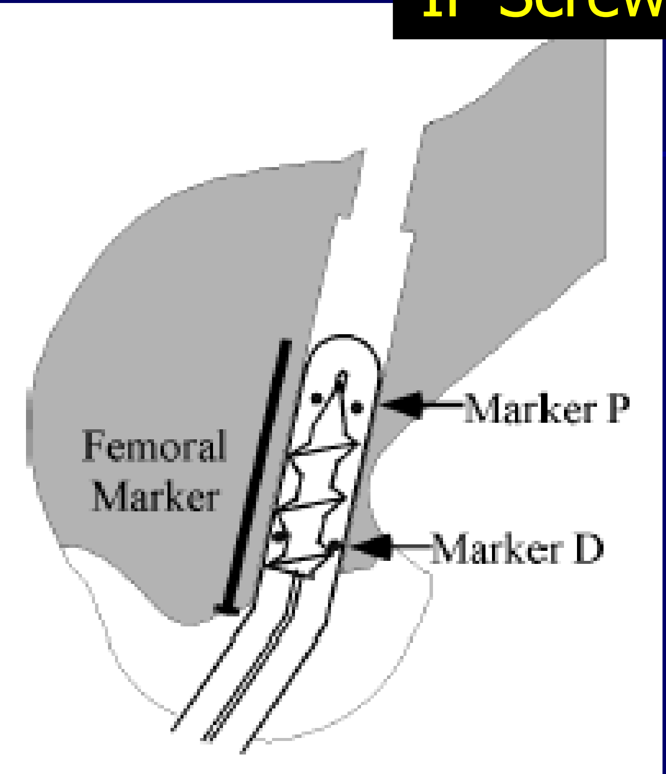
Most devices appear to achieve this

Graft Tunnel Motion

Endobutton



IF Screw



Graft-tunnel motion 2.4 vs 0.5 mm

Elongation of tendon 0.4 mm vs 0.1 mm

The elongation of the tendon accounts for only a small amount of graft-tunnel motion

Graft Fixation in the ACL

- BPTB graft has slightly higher initial strength than intact ACL
- In multiple studies conducted to characterize strength of different screws, failure always occurred at fixation site
- Fixation rigidly depends on screw design