Graft harvesting techniques: Managing damaged graft, inadequate tendon diameter

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Graft harvesting techniques

- Hamstring tendon graft
- Quad tendon
- Rectus partial graft
- Peroneus tendon
- Bone–patellar tendon–bone (BPTB) graft

Hamstring tendon graft

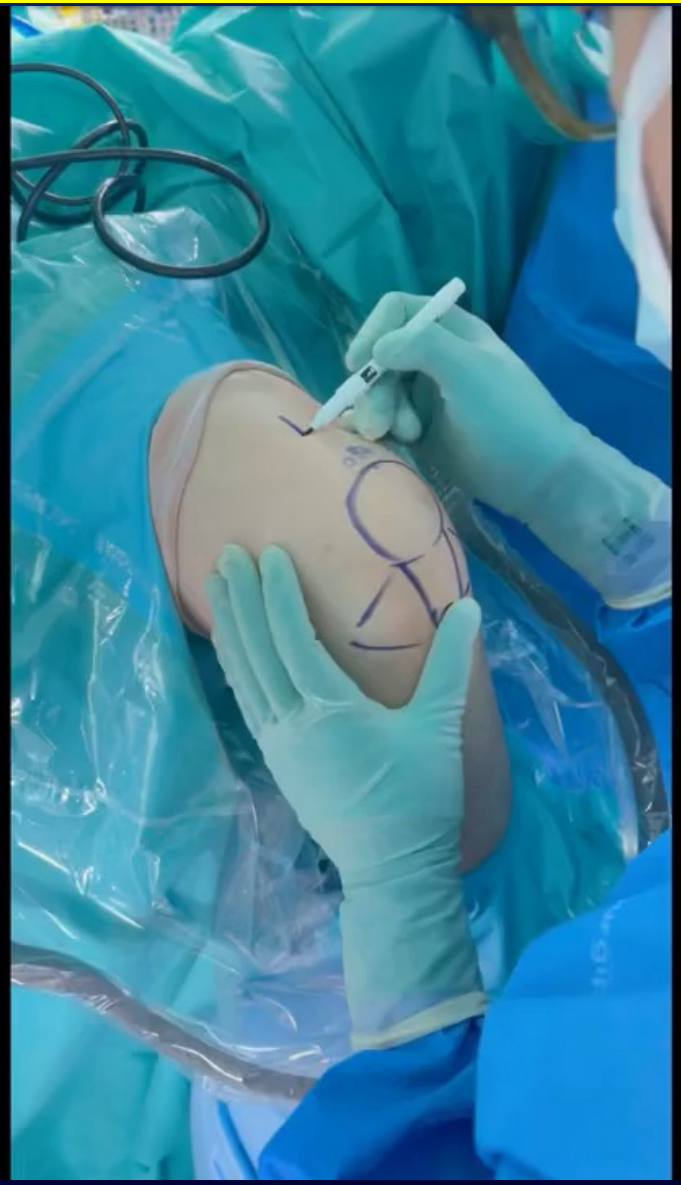


Courtesy of
Prof. Dr. Thore Zantop

Quad tendon graft



Rectus partial graft



Courtesy of
계명대 김두한 교수님

Peroneus tendon graft



Courtesy of
Prof. Dr. Wolf Petersen

Harvest-related Complications

- **Hamstring (HT) Autograft**

  Premature tendon amputation

  Prevention

  - **Release all vincula/tethers before harvest**
    - **at least 10–12 cm**
  - **Release anomalous insertions**
    - **e.g., low-lying muscle/accessory tendon**

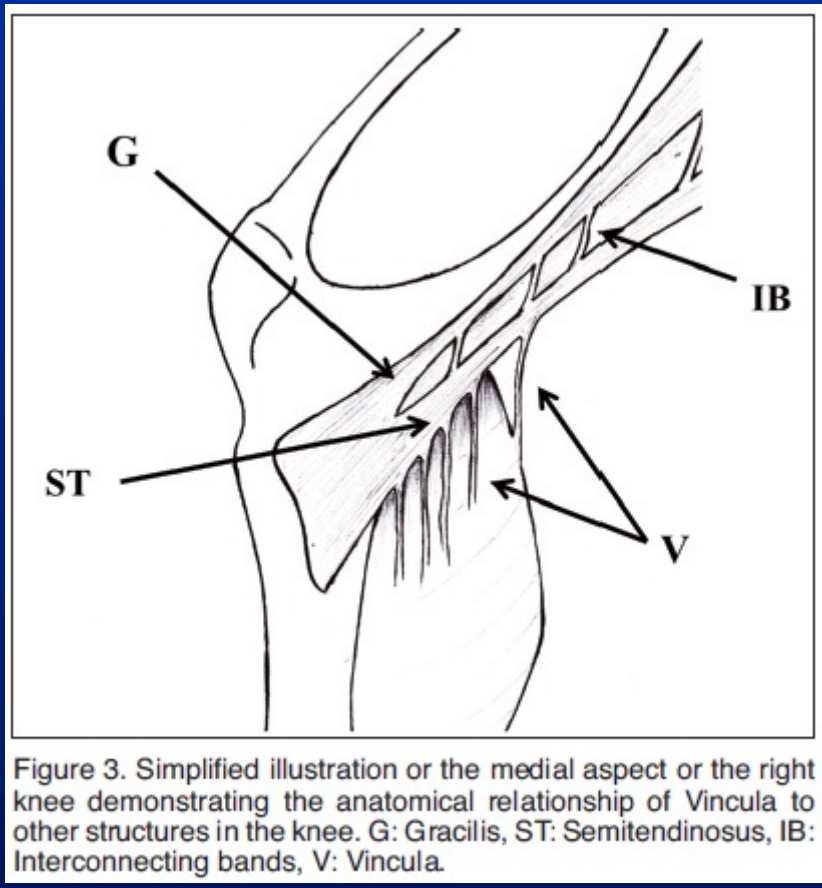


Figure 3. Simplified illustration or the medial aspect or the right knee demonstrating the anatomical relationship of Vincula to other structures in the knee. G: Gracilis, ST: Semitendinosus, IB: Interconnecting bands, V: Vincula.

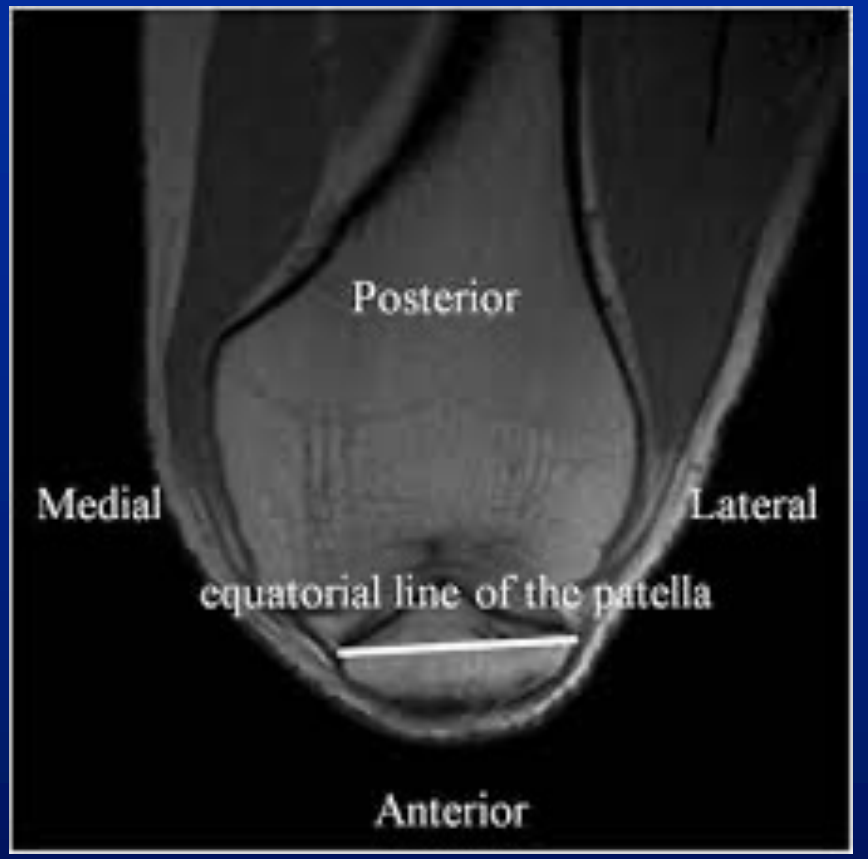
Harvest-related Complications

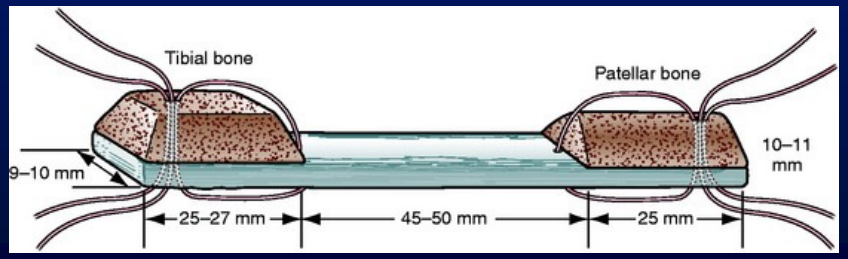
- **Bone-Patellar Tendon-Bone (BPTB)**

  Anterior knee pain and patellar fracture

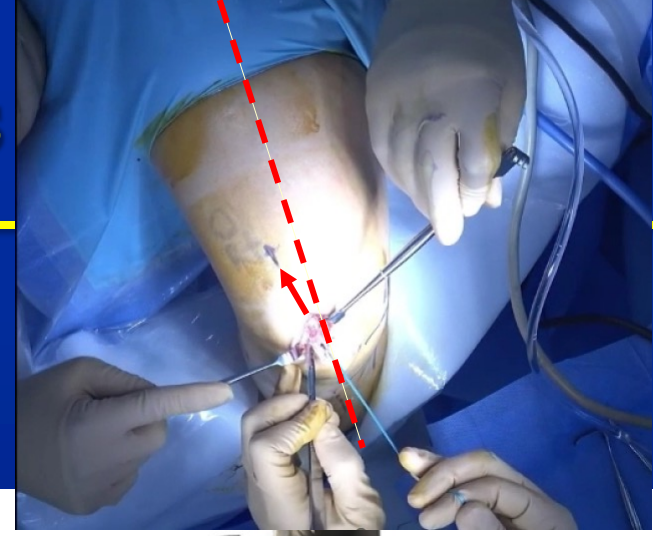
  Prevention

  - **Limit bone plug length to 20–25 mm and avoid harvesting above the patellar equator**
  - **Use a trapezoidal plug shape (no more than 1 cm deep) to reduce patellar stress**
  - **Avoid excessive levering during plug extraction**





Harvest-related Complications

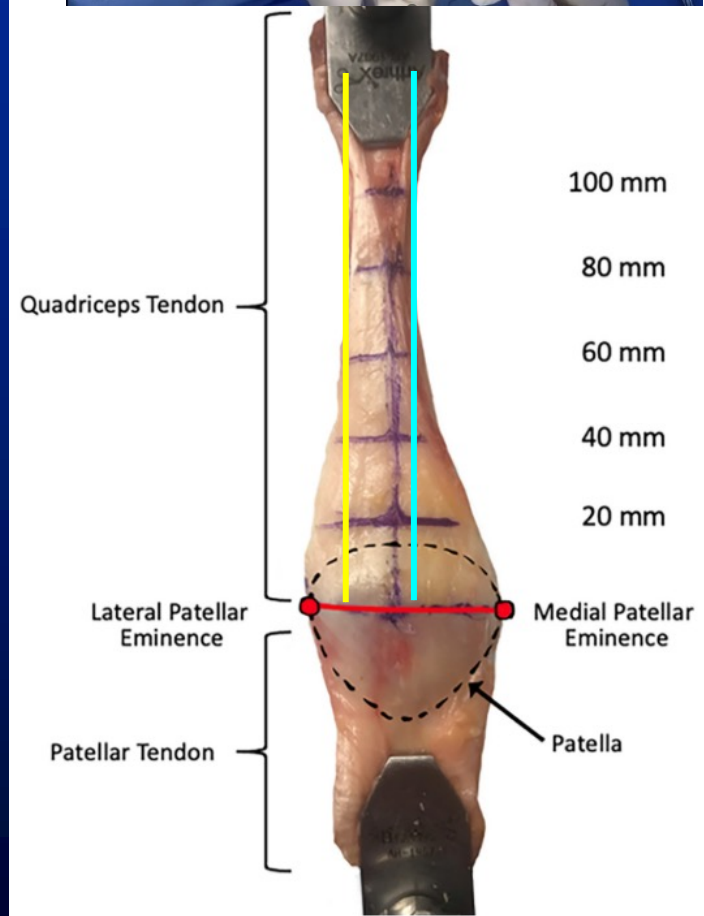


- Quadriceps tendon(QT)

  Short graft length

  Prevention

  - Harvesting without a bone plug :
    - Harvest should cheat toward the **lateral side (longer tendon)**
  - Harvesting with the bone plug :
    - Avoid putting plug too lateral (risk near lateral patella); align just medial to **medial tendon border**



Inadequate tendon diameter

- HT autograft diameter is variable; quadrupled HT often 7–8 mm
- Smaller diameter is associated with higher revision/failure risk

  Registry data

  - ~0.85× lower revision rate per 0.5 mm increase above 7 mm

  Snaebjornsson et al. (2019) JBJS

  In young patients (<20), much higher failure when graft is small

  - > 8.5mm : 4.5%
  - ≤ 8 mm : 16.5%
  - ≤ 7 mm : 24.1%

  Spragg et al. (2016) Am J Sports Med

Estimate tendon diameter

- Simple regression analysis demonstrated that **height**, **weight**, and **BMI** can be used to predict **ST and GT autograft** length and diameter

Xie et al. (2012) AJSM

TABLE 3
Correlation Coefficients for Relationships Between Graft Size and Length and Clinical Data[a]

	ST Diameter	GT Diameter	ST Length	GT Length
Age, y	−0.054	−0.167[b]	0.036	−0.14[b]
Height, cm	0.410[b]	0.256[b]	0.60[b]	0.474[b]
Weight, kg	0.459[b]	0.310[b]	0.413[b]	0.347[b]
BMI	0.341[b]	0.237[b]	0.15[b]	0.136[b]
Gender	0.467[b]	0.173[b]	0.333[b]	0.136[b]
Tegner score	0.07	0.01	0.12	0.04

[a]BMI, body mass index; GT, gracilis tendon; ST, semitendinosus tendon. The correlation between gender and other variables is calculated as a point biserial correlation (females = 1 and males = 2).
[b]$P < .05$.

ST Diameter = 0.78 + 0.038 (height in cm)
($r = 0.44$; $R^2 = 0.19$; $P < .001$;
95% confidence interval [CI], 6.53-8.18)

ST Diameter = 5.68 + 0.02 (weight in kg)
($r = 0.47$; $R^2 = 0.22$; $P < .001$; (95% CI, 6.75-8.78)

GT Diameter = 1.408 + 0.026 (height in cm)
($r = 0.37$; $R^2 = 0.13$; $P < .001$; 95% CI, 5.35-6.48)

GT Diameter = 5.035 + 0.01 (weight in kg)
($r = 0.30$; $R^2 = 0.09$; $P < .001$; 95% CI, 5.59-6.67)

Estimate tendon diameter

Indian Journal of Orthopaedics (2020) 54:444–453
https://doi.org/10.1007/s43465-019-00014-4

ORIGINAL ARTICLE

Factors that Predicts the Size of Autologous Hamstring Tendon Graft for Double-Bundle ACL Reconstruction

Du-Hyun Ro[1] · Sahnghoon Lee[1] · Yool Cho[1] · Young-Min Lee[1] · Myung-Chul Lee[1] · Seong Hwan Kim[2]

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- **4-strand ST diameter**

  0.03 Hamstring length – 0.007 Leg length + 0.76 Sex

- **3-strand ST diameter**

  0.03 Hamstring length + 0.03 Age + 0.079 BMI

- **4-stran GR diameter**

  0.02 Hamstring length – 0.001 Femur length + 0.72 Sex





Ro et al. (2020) IJO

Estimate tendon diameter

- **Estimation with MRI : specificity(92.6%), AUC: 0.856** *Liau et al. (2017) KSRR*



Fig. 2 T2-weighted MRI showing sagittal cuts of the knee of two patients, demonstrating differing axes of pes tendons which are used as reference for subsequent measures

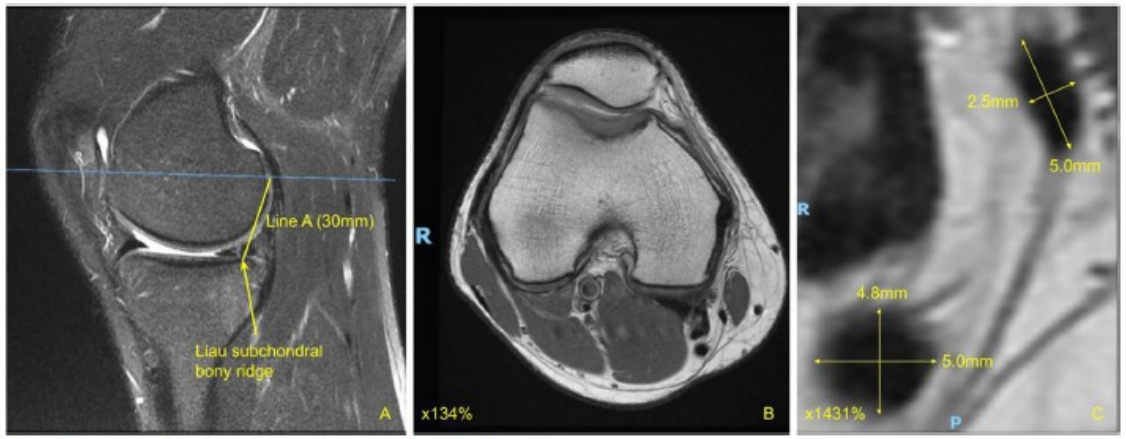
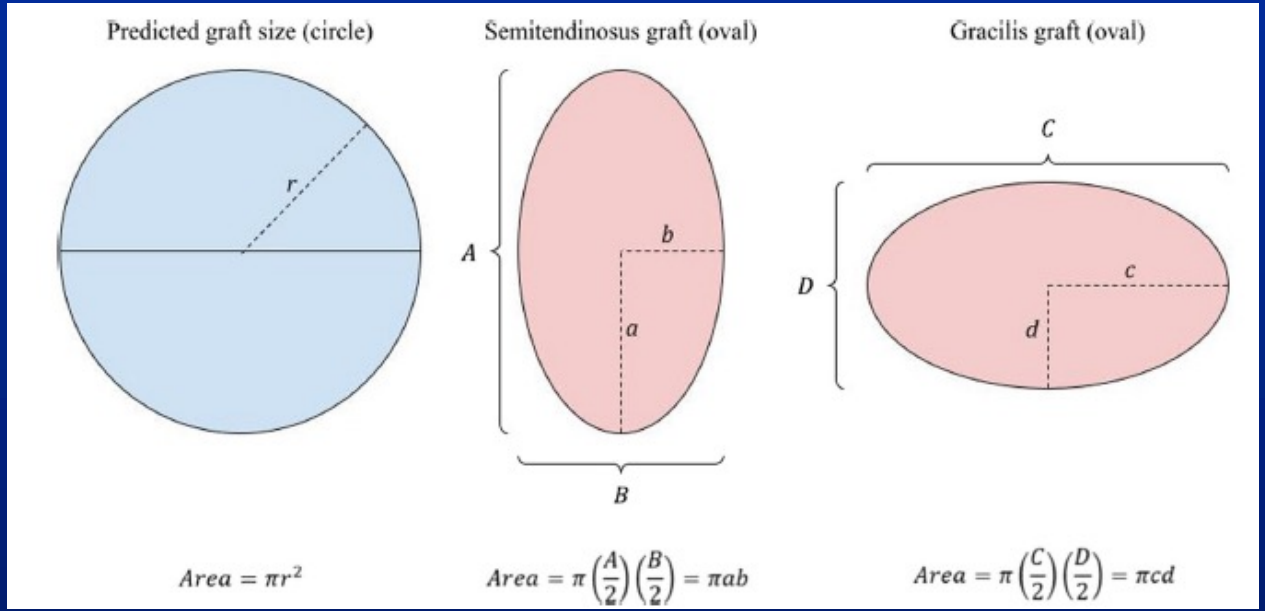


Fig. 3 T2-weighted MRI showing sagittal and axial cuts of the affected knee



πr^2 = Total area of predicted graft = 2(semitendinosus area + gracilis area) = $2\pi(ab + cd)$

$r^2 = 2(ab + cd)$

$r^2 = 2\left(\frac{A}{2}\times\frac{B}{2} + \frac{C}{2}\times\frac{D}{2}\right)$

$\therefore$ Diameter of predicted graft size $(2r) = 2\times\sqrt{2\left(\frac{A}{2}\times\frac{B}{2} + \frac{C}{2}\times\frac{D}{2}\right)}$

$= 2\times\sqrt{\frac{AB + CD}{2}}$

$= \sqrt{2(AB + CD)}$

Inadequate tendon diameter

- Options to manage insufficient hamstring autograft diameter
  - 5-strand (or 6-strand) graft creation
  - Augmentation with allograft (hybridization)
  - Augmentation with autograft
  - Synthetic augmentation
  - Graft manipulation (braiding)

5-Strand Hamstring

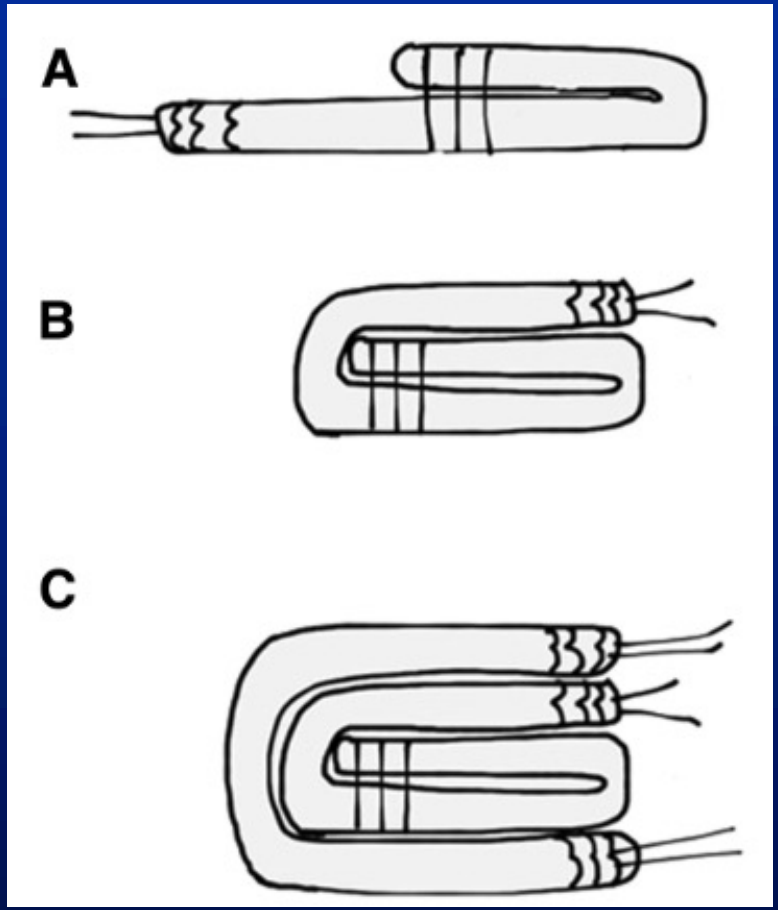
- Tripled semitendinosus + doubled gracilis
- Needs semitendinosus length ~22–23 cm

  to yield ~7 cm when tripled
- Can substantially increase diameter +1.4 mm

Krishna et al. (2018) Arthroscopy

- Studies comparing 5-strand (to reach ≥8 mm) vs naturally large 4-strand (≥8 mm) show similar rerupture/outcome scores (2.5 yr follow-up)

Calvo et al. (2017) Arthroscopy



Krishna et al. (2018) Arthroscopy

Hybridization

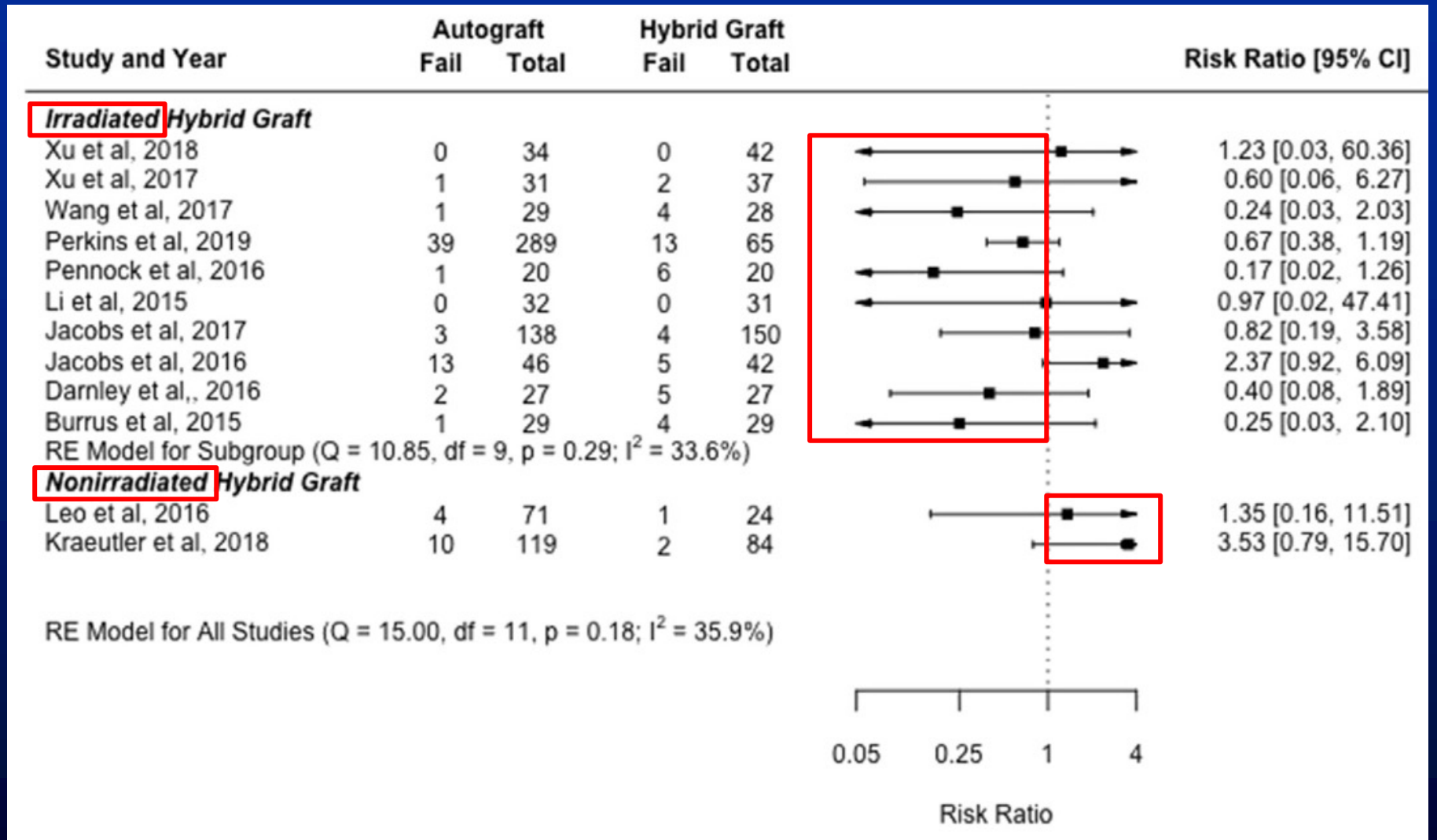
- Add **allograft** to a small **autograft** → "hybrid graft"
- Some studies show **higher failure rates** in hybrid groups *Sochacki et al. (2019) Arthroscopy*

Table 2. Individual Study Outcome Measures

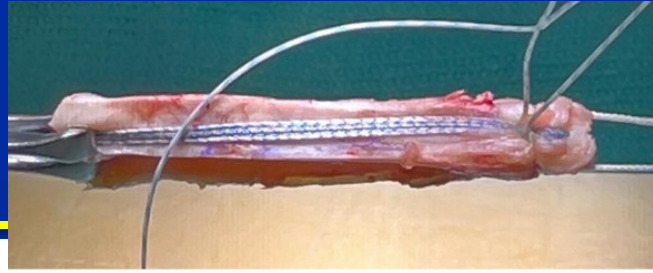
	Li et al.,[20] 2015	Wang et al.,[21] 2018	Kraeutler et al.,[22] 2018	Xu et al.,[23] 2017	Leo et al.,[24] 2016	Burrus et al.,[25] 2015
Graft failures						
Autograft	NR	1 (3.4%)	10 (8.4%)	1 (3.2%)	4 (5.6%)	1 (3.4%)
Hybrid	NR	4 (14.3%)	2 (2.4%)	2 (5.4%)	1 (4.2%)	4 (13.8%)
Reoperations						
Autograft	NR	1 (3.4%): revision ACLR	10 (8.4%): revision ACLR	1 (3.2%): revision ACLR	2 (2.8%): revision ACLR	3 (10.3%): revision ACLR in 1, ACL debridement in 1, and meniscectomy plus chondroplasty in 1
Hybrid	NR	4 (14.3%): revision ACLR	2 (2.4%): revision ACLR	2 (5.4%): revision ACLR	1 (4.2%): revision ACLR	14 (48.3%)*: revision ACLR in 3 (meniscectomy plus chondroplasty in 2), ACL debridement in 7, meniscectomy plus chondroplasty in 3, and meniscectomy in 1

Hybridization

- **Higher failure rates in Irradiated hybrid Graft** *Belk et al. (2019) Arthroscopy*



Synthetic reinforcement



- Suture tape "**internal splint**" reinforcement as **load-sharing** "seatbelt"
- In vitro data: **less elongation** and **higher failure load** (especially small diameter grafts)
- No robust long-term human outcome data yet

  → promising but still "early"

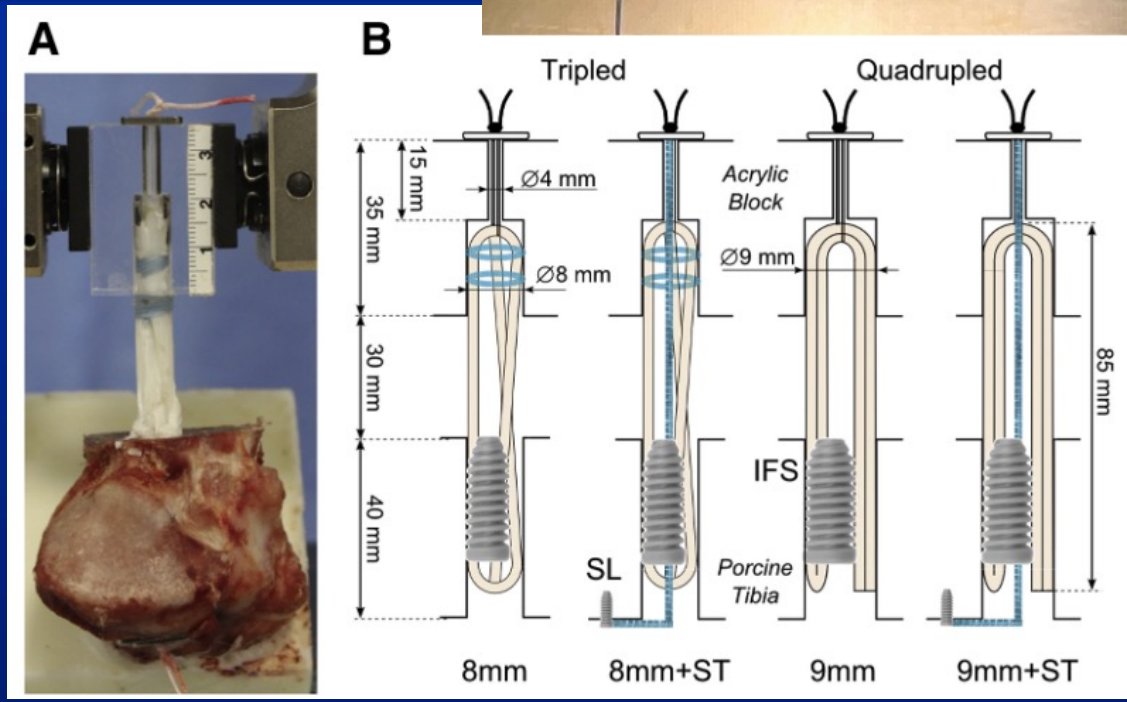


Table 1. Test Results of All Test Variables With Mode of Failure

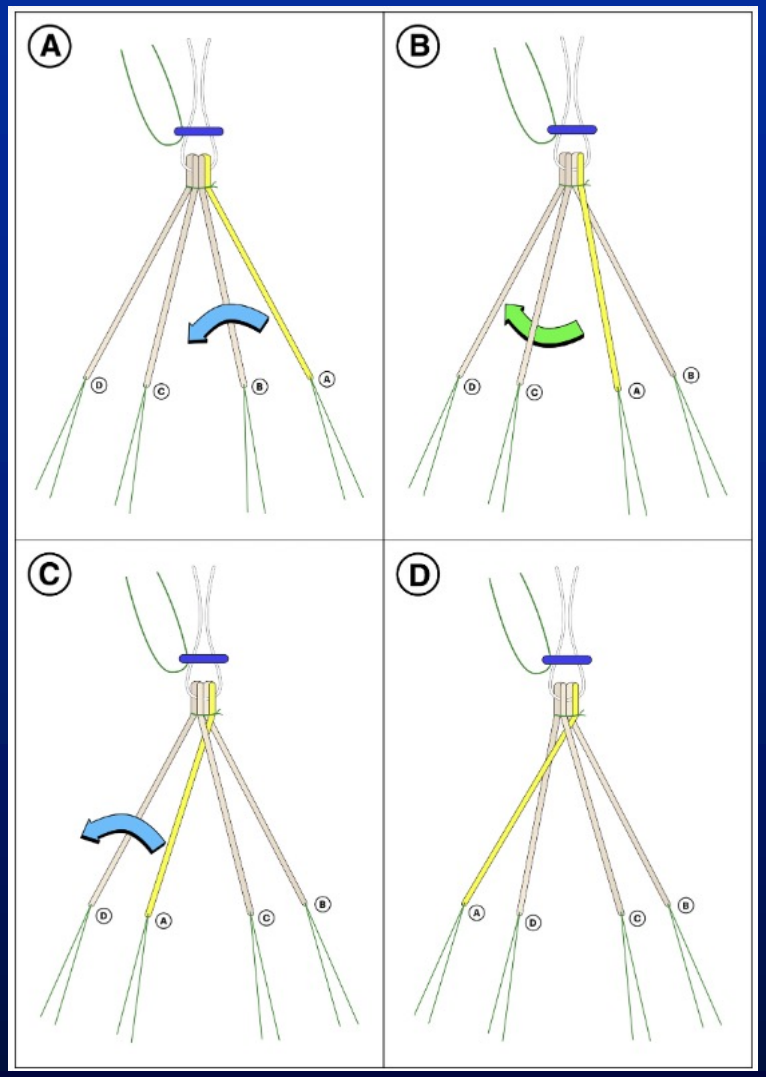
	8 mm	8 mm + ST	9 mm	9 mm + ST
Load decrease (F_D, Δbc), %	29.4 ± 7.1	22.6 ± 5.4	29.6 ± 4.7	24.4 ± 6.9
Initial elongation (s_I, Δad), mm	0.49 ± 0.48	−0.19 ± 0.37	0.35 ± 0.42	−0.12 ± 0.15
Dynamic elongation for 250-N load block ($s_{D,250}$, Δdf), mm	1.69 ± 0.39	1.16 ± 0.27	1.46 ± 0.20	1.08 ± 0.13
Dynamic elongation for 400-N load block ($s_{D,400}$, Δdh), mm	4.06 ± 0.53	2.20 ± 0.36	2.90 ± 0.34	2.09 ± 0.41
Total elongation (s_T, Δah), mm	4.54 ± 0.75	2.01 ± 0.50	3.25 ± 0.49	1.98 ± 0.51
Final hysteresis width at end of 400-N block ($HW_{F,400}$, Δhi), mm	2.21 ± 0.11	1.44 ± 0.10	1.95 ± 0.10	1.40 ± 0.16
Dynamic stiffness of initial load cycle of 250-N block ($D_{I,250}$, Δde), N/mm	134 ± 13	207 ± 21	146 ± 14	206 ± 27
Final dynamic stiffness for 250-N block ($D_{F,250}$, Δfg), N/mm	158 ± 6.1	247 ± 16	175 ± 11	245 ± 27
Final dynamic stiffness for 400-N block ($D_{F,400}$, Δhi), N/mm	176 ± 9	272 ± 19	200 ± 10	280 ± 32
Ultimate failure load (F_{UF}, Δjk), N	829 ± 100	1,074 ± 148	939 ± 76	1,125 ± 157
Ultimate stiffness (D_{UF}, Δjk), N/mm	225 ± 14	352 ± 39	259 ± 9	350 ± 45
Failure mode	ALD suture rupture in 40% and graft slippage in 60%	Graft and ST slippage in 100%	ALD suture rupture in 50% and graft slippage in 50%	Graft and ST slippage in 100%

Benjamin et al. (2019) Arthroscopy

Braiding

- Proposed to increase strength
- Earlier data show decreased strength
- Newer techniques claim improvements
- Insufficient supportive biomechanical evidence



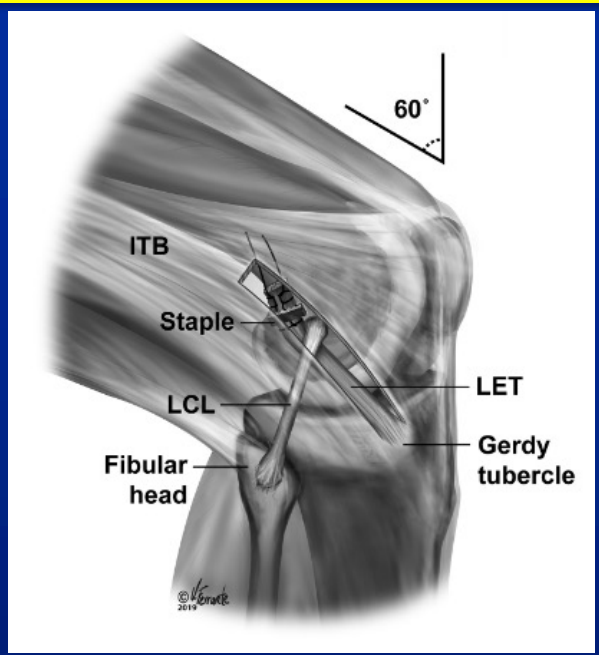


Samitier et al. (2019) Arthroscopy Techniques

LET (Lateral Extra-articular Tenodesis)

- **Decrease forces** carried by the **ACL graft** during simulated **pivoting loads**
- **Reduce anterior tibial translation** and improve control during pivot-shift–type loading

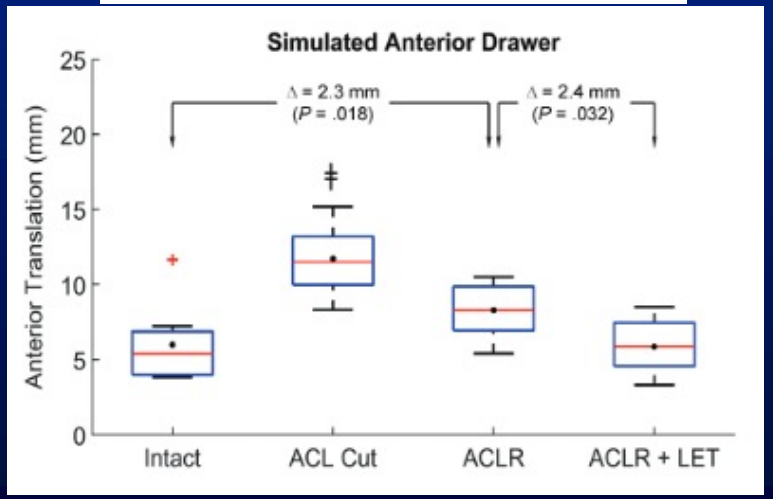
Marom et al. (2020) AJSM



- **Graft rupture rate**

ACLR : 11% vs ACLR+LET : 4.5%

Getgood et al. (2019) OJSM



Marom et al. (2020) AJSM

Graft Passage Complications

- **Bone Plug incarceration** at joint/femoral aperture

  Higher risk with **independent femoral drilling** (nonlinear tunnels)

  Prevention:

  - Avoid long plugs
  - **Femoral plug ≤ 25 mm**, ideally 18–20 mm
  - Using a shaver to gently **chamfer the tunnel aperture**
  - **Steering** the plug with **probe** as it passes through the joint

Graft Passage Complications

- **Allograft bone plug fracture**

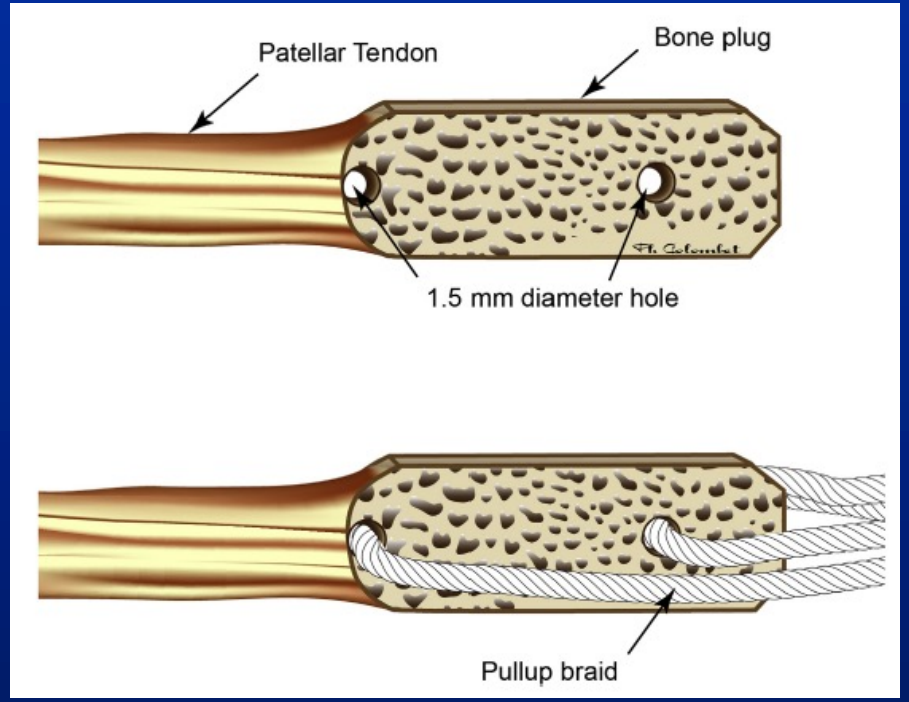
  Week bone plug (Allograft, Osteoporosis)

  → Passing suture/device may **cut through plug** if resistance occurs

- **Prevention**

  Add an **extra passing suture** that captures 1–1.5 cm of proximal

  - → Tensile load bypasses bone plug



Colombet, et al. (2019) Arthroscopy Techniques

Take Home Message

- Most harvest-related errors are preventable

  Release all tethers, secure adequate graft length, respect safe bone-plug sizing

- Graft diameter matters

  Small hamstring grafts have higher failure risk

  So estimate pre-op and target ≥8 mm when possible

- If graft is small, consider 5-strand, Synthetic reinforcement and add LET to reduce graft load

Thank you for your attention

