ACL BTB Auto-Graft:
The reason it remains the GOLD STANDARD for the ‘enlightened’ sports medicine surgeon

HISTORICAL ROOTS
In 1917, Ernest W. Hey Groves of Bristol performed the first ACL reconstruction using an IT band transplant. (1). In 1936, Palmer described the use of a patellar tendon graft in his doctoral thesis (2). This same year Campbell described using a tibial based patellar tendon as an intra-articular graft (3). Despite these early surgical descriptions of ACL reconstructions, the majority of ACL injuries were treated with repair and/or extra-articular reconstructions.

In the 70’s, anatomic and biomechanical knowledge from the research teams of Arnoczky, Cabaud, Kennedy, Noyes, defined the ACL as the primary restraint to anterior subluxation of the tibia (4-8). Hence, the focus of surgical stabilization of the ACL deficient knee centered on the anatomic restoration of the ACL, with intra-articular techniques becoming more widespread (9, 10).

An intra-articular graft using a tibial based medial third of the patella tendon was described by Ericksson, (11-12) with a tibial based central third being described by Jones (13). The ‘free’ bone-patellar tendon-bone graft was soon to follow, popularized by Erickson and Clancy (14-16).

One technique appeared to establish itself as the superior procedure because of its simplicity and consistent positive results: the free bone-tendon-bone graft of the central one-third of the patellar tendon. Around the same time, metal interference screws were introduced to enhance with fixation of the (mechanical weak link) reconstructed graft (17).

In the early 90s, the Jones procedure was backed up with a lateral (extra-articular) reinforcement; towards the mid-90s, the procedure was used without this feature, with equally good results.

There were several non-surgically related reasons for the increased rate of success of the intra-articular BTB ACL reconstruction operation, including earlier diagnosis & treatment of ACL injuries, improved treatment of associated lesions, more evidence-based rehabilitation, and the technique of arthroscopic assisted graft placement.

ADVANTAGES
- early bone to bone healing at 6 weeks,
- consistent size and shape of the graft
ease of harvest
- long term results
- proven success over decades of use and in the hands of many surgeons

**DISADVANTAGES**
- harvest site morbidity (18-20).
- anterior knee pain (21).
- patellofemoral joint tightness with arthrofibrosis (22).
- assorted patella and tendon related complications including fracture, patellar tendon rupture (23-26, 18).

Most of the peri-operative patella and tendon related complications are historical only. More recent reviews of ACL BTB auto graft surgery (27), including a systematic review (28) show no early patella or patella tendon complications.

**Graft Strength**
Noyes originally reported that one strand HS is only 70% of the strength of the ACL. Howell demonstrated that 4 bundles of composite graft has 4,300 N to failure compared to 1750 N to failure for the native ACL (29-30).

**Graft Stiffness**
BTB fixed with interference screw vs. 2B HS with screw and washers
With appropriate fixation, both grafts approximated the intact ACL in strength, but only patellar tendon grafts secured with interference screws were comparable in stiffness (31).

Brown has shown that a 4 bundle semi-t and gracilis composite graft is 2X the patellar tendon stiffness and 3X normal ACL stiffness (32).

**A brief review of Comparison Studies (by year of publication)**
  Pertinent Findings: A statistically significant weakness in peak hamstrings torque at 60 deg/sec when reconstruction was performed with double-looped semitendinosus and gracilis tendons (33).
- 1991: Holmes et al. (34) performed a similar retrospective analysis and found that the BTB ACL reconstruction was a statistically significantly better method for patients with chronic ACL insufficiency.
“This paper [points out] the superiority of using the middle third of the patellar tendon over the use of the semitendinosus tendon in chronically unstable knees” (34).

- **1997**: Feagin and co-authors (35), in a long term comparison study of BTB auto and 2B HS, suggested that the stiffer BTB construct is preferred for the reconstruction of the chronic ACL deficient knee when the secondary restraints are compromised.

- **1999/2002/2012**: Pinczewski and his research team published comparison results on BTB auto and 4S HS in a consecutive series. N= 167, F/U 2yr. +

Pertinent Findings: The KT-1000 arthrometer testing showed a slight increased mean laxity in the female patients in HS group. Kneeling pain after HS reconstruction was significantly less common than with the BTB group (36).

Same cohort @ 5 years. Methods: Two groups of 90 patients each were followed for a minimum of 5 years. Pertinent Findings: 31% of the BTB group (25) had a fixed flexion deformity and 19% of the HS group (14) had fixed flexion deformity. Radiologic assessment revealed early osteoarthritic changes in 4% of the HS group (2) and in 18% of the BTB group (11) at 5 years (37).

Same cohort @ 15 years: 15 yrs. after ACL reconstruction, expected survival of the ACL graft was 89% and expected survival of the contra-lateral ACL was 86%. Graft choice did not affect ACL graft rupture, but using BTB increased the risk of contra-lateral ACL rupture compared with HT. Men had a less favorable survival rate of the ACL graft than did women, and a family history of ACL rupture increased the risk of both ACL graft and contra-lateral ACL rupture (38).

- **2001**: A prospective RCT, 3 methods of ACL reconstruction: autogenous BTB graft (group 1), 2S HS graft reconstruction combined with an extraarticular procedure (group 2), and 2S HS graft reconstruction alone (group 3). At a mean of 35.4 +/- 11.6 mo. postoperatively, 102 patients returned for evaluation.

Conclusions: ACL reconstruction with a 2S HS or a BTB autograft may yield similar subjective results; however, the BTB autograft may provide better objective stability in the long term (39).

- **2001**: prospective RCT with BTB vs. 4S HS.

Differences at 24 months included: There was a significant weakness in isokinetic knee flexion strength among the hamstring tendon group. Anterior knee pain was not significantly different between the groups, but kneeling pain was significantly less common in the hamstring tendon group (40).
• 2002: the objective results of anterior cruciate ligament replacement with a bone-patellar tendon-bone autograft were superior to those of replacement with a two-strand semitendinosus gracilis graft with regard to knee laxity, pivot-shift grade, and strength of the knee flexor muscles. However, the two groups had comparable results in terms of patient satisfaction, activity level, and knee function (41).

• 2003: Prospective RCT, N=65 patients, 4S HS vs. BTB auto, F/U up to 36 mo.
  Pertinent Findings: BTB group had increased Pain on kneeling & greater extension deficits. There were greater quadriceps peak torque deficits in the BTB group at 4 and 8 months but not thereafter. In the HS group, active flexion deficits were greater from 8 to 24 months, and KT-1000 arthrometer side-to-side differences in anterior knee laxity at 134 N were greater. Both grafts resulted in satisfactory functional outcomes but with increased morbidity in the patellar tendon group and increased knee laxity and radiographic femoral tunnel widening in the hamstring tendon group (42).

META-ANALYSIS

• 2001: Meta-analysis of controlled trials of BTB versus 4S HS tendons for ACL reconstruction.
  Methods: Included CTs that used standard evaluation techniques with a minimum 2-year F/U.
  Pertinent Findings: significant differences between BTB and 4S HS reconstructions.

  **BTB have a greater chance of attaining a statically stable knee (as measured by KT) and nearly a 20% greater chance of returning to pre-injury activity levels (43).**

• 2003: Articles from January 1966 to May 2000 describing arthroscopic ACL reconstruction with either BTB or HS autograft ; F/U minimum 24 months.
  Results: 1348 patients in the BTB (21 studies) and 628 patients in the HS group (13 studies). The rate of graft failure in the BTB group was significantly lower (1.9% versus 4.9%) and a significantly higher proportion of patients in the BTB group had a side-to-side difference of less than 3 mm on KT-1000 arthrometer testing than in the HS group (79% versus 73.8%).
  BTB: There was a higher rate of manipulation under anesthesia or lysis of adhesions (6.3% versus 3.3%) and of anterior knee pain (17.4% versus 11.5%)
  HS: there was a higher incidence of hardware removal in the hamstring tendon group (5.5% versus 3.1%).
  Conclusions: **BTB autografts had a significantly lower rate of graft failure and resulted in better static knee stability and increased patient satisfaction compared with HS autografts.** However, BTB reconstructions resulted in an increased rate of anterior knee pain.
Motion loss was not significantly different between the two groups, although a trend was seen for a higher incidence of extension loss in the BTB group (1.9%) compared with the HS group (0.7%). The data pool for flexion loss contained too much heterogeneity to allow for meaningful analysis. There was a statistically significant difference in the sex ratios between the two groups, with a greater percentage of male patients included in the BTB group (44).

**Systematic review**

2004: Systematic review of these 9 RCTs designed to compare autograft types (PT vs HG).

No study reported a significant difference in graft failure between BTB vs. HS autografts. Objective differences (range of motion, isokinetic strength, arthrometer testing) were not detected between groups in the majority of studies, suggesting that their sensitivity to detect clinical outcomes may be limited. Increased kneeling pain in the patellar tendon group was seen consistently in the studies evaluated. Subjective differences in anterior knee pain or return-to-activity level were not consistently observed in these studies. With numbers available, failure rates were not significantly different between groups.

*These findings suggest that graft type may not be the primary determinant for successful outcomes after anterior cruciate ligament surgery (28).*

**Reference List:**


