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# Contemporary Graft Options in Anterior Cruciate Ligament Reconstruction

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**The optimal graft choice for anterior cruciate ligament (ACL) reconstruction remains controversial. Many factors must be considered to select the appropriate graft for each patient. Commonly used autografts include both hamstring tendon and bone-patellar tendon-bone, with long-term studies supporting either graft choice. There is also increasing support for quadriceps tendon autograft. The use of allograft is also increasing, with the benefit of less donor-site morbidity, although there is concern about slower graft incorporation time and disease transmission. Synthetic grafts are yet another option; however, further studies for an ideal synthetic ACL alternative are still underway. The goal of this article is to present the benefits and drawbacks of various ACL graft reconstruction choices so the surgeon can select the best graft for each patient.**


**KEYWORDS** ACL, allografts, anterior cruciate ligament, autografts, grafts, knee, reconstruction

The anterior cruciate ligament (ACL) plays an important role in knee stability. The native ACL serves as the primary restraint to prevent anterior translation of the tibia relative to the femur and acts as a secondary restraint to tibial rotation and varus/valgus stress.[1,2] ACL reconstruction is indicated to prevent knee laxity and functional instability during activities of daily living and athletic activity. Reconstruction also serves to decrease the risk of meniscal injury and the eventual development of degenerative joint disease.[3]

Nevertheless, the optimal graft choice for ACL reconstruction remains controversial. Ideal properties of an ACL graft include structural and biomechanical properties that are similar to those of the native ACL, rapid biological remodeling and incorporation into host tissues, and minimal donor-site morbidity.[4] Appropriate graft selection for an ACL reconstruction requires a consideration of many factors, including a patient's age, activity level, and postoperative physical goals, as well as the availability of allograft and autograft tissue, any previous surgeries, medical comorbidities, and the experience and preference of the surgeon. Generally, graft choices can be divided into 3 categories: autografts, allografts, and synthetic grafts. Currently, the most common choices for autograft include ipsilateral or contralateral patellar tendon, hamstring tendon (HT, semitendinosus and gracilis tendons), and the quadriceps tendon (QT). Allograft choices include the previously mentioned autograft options in addition to the tibialis anterior (TA), tibialis posterior, and Achilles tendon (AT). Synthetic options include scaffolds, stents, and prostheses.

Comparisons between grafts can be performed on the basis of many criteria, including biomechanical properties, biology of healing, ease of graft harvest, fixation strength, graft-site morbidity, average graft size, and return-to-sport guidelines. The goal of this article is to review the graft options for ACL reconstruction and to present the risks and benefits of each graft choice to help the surgeon determine the best graft for each patient.

## Autografts

Historically, most surgeons have preferred autografts to allografts; the 2 most common choices of autografts have been bone-patellar tendon-bone (BPTB) and HTs.[5] Autografts decrease the risk of disease transmission and offer the most biologically favorable option for incorporation, although often at the expense of donor-site morbidity. Nonetheless, ow-

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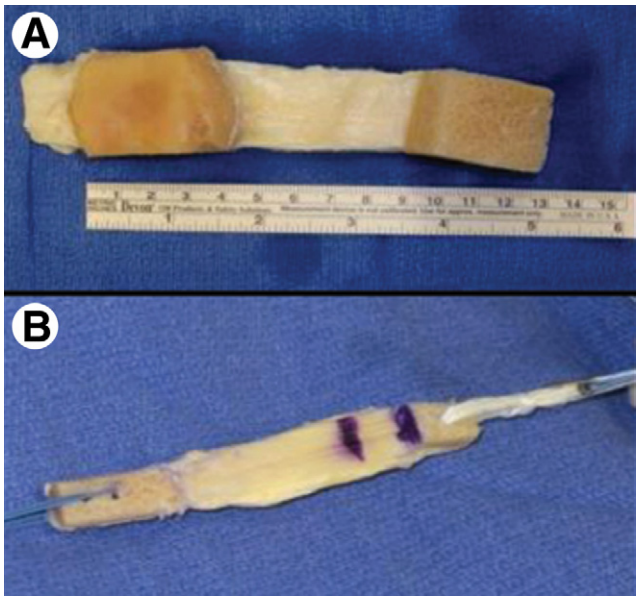


**Figure 1** An example of bone-patellar tendon-bone allograft (A) after harvest from the patient and (B) after preparation for reconstruction. Reprinted with permission of Vyas et al.[10]

ing to their superior mechanical properties, autograft tendons are generally preferred to allograft tendons for ACL reconstruction, especially in younger more active patients.[6] Autografts also have the most evidence of success at long-term follow-up.[7-9]

## Bone-Patellar Tendon-Bone

BPTB autograft is the most commonly used autograft in young and active patients. The graft is generally taken from the middle third of the patellar tendon, with bone plugs from the patella and tibial tubercle (Fig. 1). There are data verifying the long-term success of BPTB in ACL reconstruction, including faster incorporation and healing into bone tunnels when compared with soft-tissue grafts, making it a common choice for ACL reconstruction.[11] Furthermore, the biomechanical properties of BPTB are similar to those of native ACL (Table 1). While the native ACL has an ultimate tensile load of 2160 N with a stiffness of 242 N/mm and a cross-sectional area of 44 $mm^2$, BPTB autograft has an ultimate tensile load of 2977 N, a stiffness of 620 N/mm, and a cross-sectional area of 35 $mm^2$.[12]

One of the advantages of BPTB autograft is bone-to-bone healing and a more rapid incorporation and healing at the graft attachment site. The bone plugs are placed into the femoral and tibial tunnels and allow for healing by creeping substitution that is stronger and faster than soft-tissue-to-bone healing.[4] With bone-to-bone healing, the graft integrates into the host bone within 6 weeks, whereas soft-tissue grafts can take 8-12 weeks or longer to achieve healing at the tendon–bone interface.[4] Incorporation is a 4-stage process, including graft necrosis, cellular repopulation, revascularization, and collagen remodeling. Animal models have shown slower incorporation rates into bone tunnels with soft-tissue grafts compared with bone-plug grafts such as BPTB.[13] A recent rabbit model study showed that bone-to-bone healing was mature at 8 weeks, whereas tendon-to-bone healing was mature at 12 weeks.[14]

Historically, clinical results after ACL reconstruction have been most consistent with use of BPTB autograft. Reinhardt et al[15] performed a systematic review of level-I randomized control trials comparing BPTB with HT (semitendinosus and gracilis) autografts. Only 6 of 28 studies fit the inclusion criteria, which included a minimum of 80% follow-up at a minimum of 2 years. The studies comparing BPTB with 4-strand HT demonstrated an overall graft failure rate of 4.2% in the BPTB group and 10.9% in the HT groups. The authors also showed that in 5 of the 6 studies reviewed, there was an increased side-to-side difference in anterior laxity in the HT groups compared with the BPTB groups.[15] With re-

**Table 1** Common ACL Grafts, Including Data from West and Harner[4]

| Tissue | Ultimate Tensile Load (N) | Stiffness (N/mm) | Cross-Sectional Area ($mm^2$) | Advantages | Disadvantages |
|---|---|---|---|---|---|
| Intact ACL | 2160 | 242 | 44 | | |
| Bone-patellar-tendon bone (10 mm) | 2977 | 620 | 35 | Bone-to-bone healing | Anterior knee pain, larger incision |
| Quadrupled hamstring | 4090 | 776 | 53 | Small incision, less anterior knee pain | Hamstring weakness, soft-tissue healing, bone tunnel widening |
| Quadriceps tendon (10 mm) | 2352 | 463 | 62 | Bone-to-bone healing, thick, can be made into 2 bundles | Anterior knee pain, larger incision, patella fracture if take bone plug, soft-tissue healing |
| Patellar tendon allograft | 1403 | 224 | | Bone-to-bone healing | Longer incorporation |
| Achilles allograft | 1189 | 741[3] | 105 | | Longer incorporation, soft-tissue healing |
| Tibialis anterior allograft | 3012 | 343 | | | Longer incorporation, soft-tissue healing |