Technical Note

Four-Strand Hamstring Diamond Braid Technique for Anterior Cruciate Ligament Reconstruction

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Abstract: Several factors affect the success of an anterior cruciate ligament reconstruction, including graft origin, type, and morphology. Hamstring and bone—patellar tendon—bone autografts are the most widely used, and there are many different techniques of graft preparation with each. In this Technical Note and accompanying video, a 4-strand hamstring autograft technique is described that uses a simple diamond-type braid to produce a more ovoid morphology with increased cross-sectional area. Increased graft diameters have been associated with higher success rates and more positive long-term outcomes. Therefore, this braiding construct may provide additional tensile strength with increased resistance to failure than grafts that are otherwise undersized using conventional techniques.

The anterior cruciate ligament (ACL) serves as an intra-articular connection between the posterolateral femur and medial tibia, providing rotational stability to the knee and preventing anterior translation.[1] ACL tears and sprains are the most common ligamentous injuries to the knee, with 1 in 3000 Americans experiencing injury every year.[2] The incidence is higher in athletes; 1 in 29 female athletes and 1 in 50 male athletes will have an ACL injury.[3] Currently, the standard treatment for active patients consists of surgical ACL reconstruction followed by rehabilitation.

Hamstring and bone—patellar tendon—bone (BPTB) autografts remain the most popular graft choice for the younger, more active patient population. BPTB has been shown to offer both faster healing and increased knee stability compared with hamstring autograft.[4] However, despite these data, the use of hamstring autografts has been increasing due to reduced donor site morbidity and decreased anterior knee pain associated with the BPTB technique.[4] Although these techniques differ in recovery time and subjective stability, both are considered equivocal in terms of long-term clinical outcomes, such as infection rate, range of motion, and rate of reoperation.[5]

There are many different preparation techniques for ACL grafts after they have been harvested. The technique used depends heavily on the graft length, width, and surgeon preference. The ideal graft should provide similar strength and range of motion to the native ACL. The most commonly used method to achieve this is by folding the hamstring tendon longitudinally on top of itself until a 3- to 6-strand construct is achieved prior to whipstitching the strands to secure the final graft dimensions.[6]

Recently, Samitier and Vinagre[7] published a graft braiding technique using a 4-strand hamstring autograft they developed to maximize the diameter of small grafts. As described by the authors, the advantages of this technique were ease of mastery, reproducibility, and partial mimicry of the shape of the native ACL in addition to increasing final graft diameter compared to folding. This construct is remarkable in that it is the first to use a woven configuration and has a flat ribbon-like profile that mimics portions of the native ACL.[7]

The purpose of this Technical Note and video is to describe an alternative, simple, 4-strand braiding technique that produces a thicker yet braided graft for ACL

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reconstruction, which may result in the salvage of autografts that would be too small under standard folded morphologies without augmentation with allograft. We believe braided constructs may not only prevent graft augmentation but also improve graft durability, provide safer return to sport, and increase tensile strength, with further testing needed to determine failure dynamics and thresholds.

Surgical Technique

Preoperative Considerations

Preoperative assessment of the patient includes patient history and physical exam to accurately diagnose an ACL tear. Patients may receive magnetic resonance imaging of the affected knee to confirm the diagnosis as well as identify concomitant injury.

Patient Positioning

The patient is positioned supine on the operating table with all bony prominences well paddled and a lateral post placed on the affected side of the patient at the hip. The extremity is then prepared with antiseptic cleaning solution and draped in a sterile fashion.

Graft Harvest

The anatomic landmarks of the inferior pole of patella, tibial tubercle, and pes anserine tendons are marked, and a 2-cm incision is made over the insertion of pes anserine tendons medial to the tibial tubercle. Metzenbaum scissors and pickups are used to dissect down to the sartorial fascia, which is then released. The gracilis and semitendinosus tendons are dissected and released from the gastrocnemius and sartorial fascial adhesions. A tendon stripper is then used to strip each tendon separately from their proximal musculotendinous attachments. The tendons are then taken to the back table for preparation while a diagnostic arthroscopy and ACL debridement are performed.

Four-Strand Diamond Braid Graft Preparation

The harvested autograft is placed on the graft preparation board, and excess muscle and frayed tendon are removed with an osteotome and scissors. The harvested tendons are whipstitched with an Ethibond Excel (Ethicon) suture at each end for control prior to each being folded in half to obtain 4 strands. After folding the graft tendons at their midpoint and loading them onto an ACL TightRope (Arthrex), a 0-Vicryl (Ethicon) suture is passed through all tendons ∼1 cm distal to the TightRope to secure the graft transversely and prevent sliding during braiding. The proximal end of each strand is held taut for the braid (Fig 1).

Measurements of the length and diameter are made before the hamstring braid configuration. The unbraided graft measures 6.5 mm in diameter and 10 cm in length. With 4 strands laid out left to right, the distal end of the leftmost graft strand is passed under the second and third strands, leaving the initial leftmost graft strand in the third position from the left (Fig 2). Then, this strand is passed over one position to the left so that the described strand is in the second position. Next, the distal end of the graft on the right is passed under the second and third strands so that the rightmost strand is in the second position. Then, this same strand is passed over one position to the right so that it is in the third position. These steps are repeated until the end of the graft and then the strands are sutured together. Care is taken to keep the braided hamstring graft tensioned. The final graft length and diameter are measured.

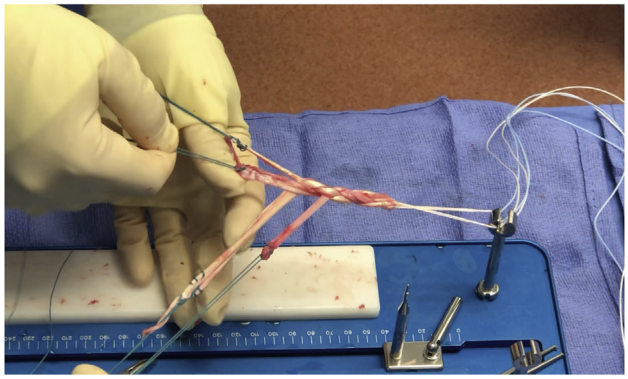

Fig 1. Diamond braid back table setup: overhead photo of the graft preparation station taken midway through the diamond braid technique. Both ends of each of our 2 harvested tendons were whipstitched using 2-0 Ethibond Excel (Ethicon) sutures prior to folding over TightRope and loading onto the graft station. Strong distal suture anchorage is critical to maintaining the high tension necessary for proper braiding without slack. Multiple users are necessary to maintain adequate tension, which is one downside of this technique.

Graft Passage and Fixation

A Beath pin is fired bicortically through the lateral femoral cortex, and a reamer is reamed over the pin to create a femoral socket of 30 mm. A 0-Vicryl suture is placed in the end of the Beath pin and shuttled through the femoral tunnel and out of the lateral thigh. A tibial guide is inserted into the anteromedial portal to confirm tunnel placement, and then a Beath pin is fired through the tibial guide. A barrel reamer is used to ream over the pin. A suture grasper is used to shuttle the suture from the femoral tunnel out of the tibial tunnel, and then the graft and TightRope are passed with the suture. Once the TightRope button has been flipped firmly against the lateral femoral cortex, the graft is slid into the femoral tunnel and through the joint space (Fig 3). Intraoperative fluoroscopy is used to confirm button placement, and the knee is cycled 20 times to remove graft creep. The tibial fixation is secured with an

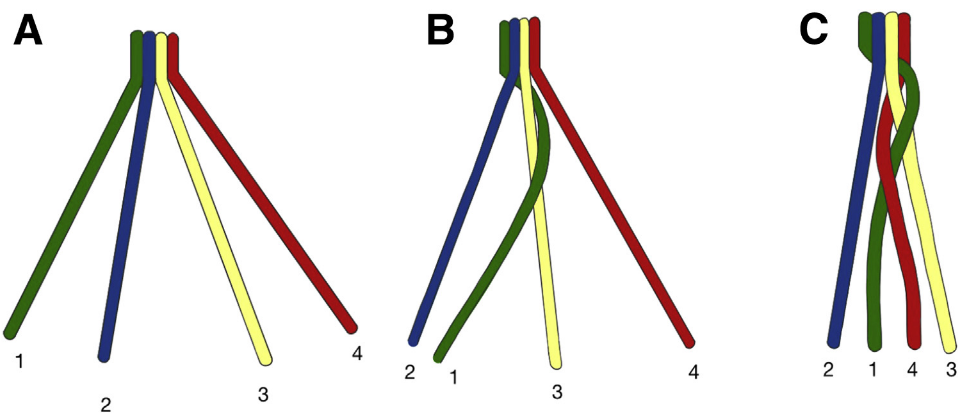

Fig 2. The braiding technique for the 4-strand diamond braid. Starting with strand 1 (A, green), the strand should be passed under strands 2 and 3 and then passed back over strand 3 (B). Then, strand 4 on the right distal end (B, red) should be passed under strands 1 and 3 and back over strand 1 (C). These steps must be continued to the end of the graft.

interference screw, and the white TightRope sutures are retensioned for final positioning.

Final Examination and Postoperative Care

Once the graft is in place, a C-arm is used to confirm the location of the TightRope and interference screw. The arthroscope is then reinserted to confirm graft placement and tension (Fig 4). Finally, the arthroscopic portals are closed using 3-0 nylon suture and the tibial incision with 0 Vicryl, 2-0 Vicryl, and 4-0 Monocryl. The extremity is bandaged and placed in a knee brace locked in full extension. The patient begins formal physical therapy after the first postoperative visit. The pearls and pitfalls of this technique are outlined in Table 1, and a video is included (Video 1).

Discussion

There have been extensive studies regarding ACL graft preparation techniques and success rates. An article published by Conte et al.[8] suggested that grafts smaller than 8 mm in diameter have high failure rates. These data are supported by Figueroa et al.,[9] who found that increasing the graft size by as little as 0.5 mm can lead to statistically significant increases in graft success and longevity, and other studies reported that a smaller graft diameter size is correlated with increased revision

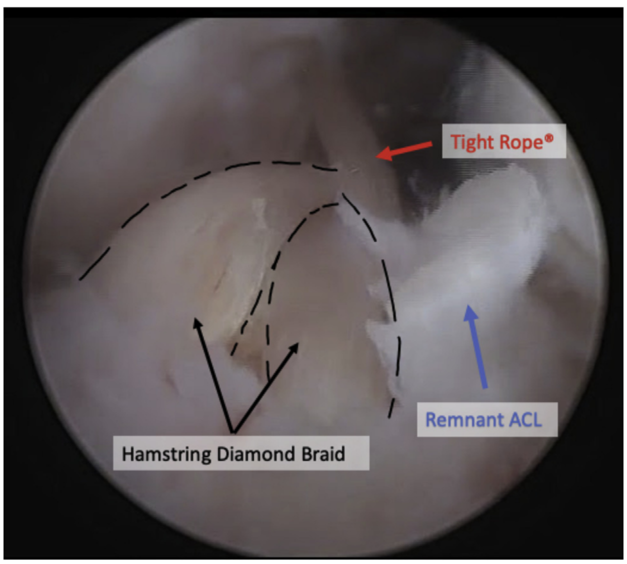

Fig 3. Arthroscopic view from the superomedial portal: our hamstring diamond braid can be seen emanating from the tibial tunnel as it is shuttled using TightRope toward the posteromedial aspect of the lateral femoral epicondyle. Once in position, care should be taken to make sure the braid is not twisted upon its own axis prior to fixation, as this is more difficult to perceive with this technique.

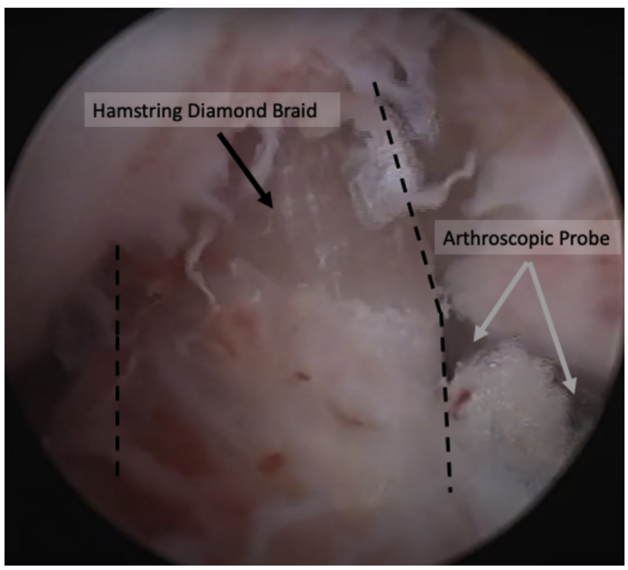

Fig 4. Final position of hamstring diamond braid anterior cruciate ligament graft: taut positioning of the graft can be appreciated from the lateral portal. An arthroscopic probe can be seen in the inferior field of view as it is passed behind the graft for testing. Once in final position, probing the diamond braid is critical to determine adequate tension and to make sure no fraying or displacement between braided arms has taken place during tensioning.

Table 1. Pearls and Pitfalls

Pearls:

- Take care to harvest the maximum graft length as possible to offset the foreshortening our diamond braid requires compared with folded or flat braid.
- Use a 2-person technique for back table braiding in order to maintain high tension throughout the construct and maintain consistent cross-sectional area.
- It is important to place high tension through the 0-Vicryl transverse stitches at the distal and proximal ends of the construct in order to resist unwinding and maintain intended tension.

Pitfalls:

- Do not perform a diamond braid if graft length is too short to overcome the 8- to 10-mm shortening required compared with similar techniques.
- Forcing the graft through undersized burr holes is particularly damaging to a braided construct, and care should be taken to avoid high resistance while passing the graft.
- Final tensioning of the graft once in position is difficult if the final braid is not tight, without slack, and secured both distally and proximally with tight transverse sutures.

rates.[10-12] Additional studies report that an increase of 1 mm in graft diameter is correlated with a significant increase in the Knee Injury and Osteoarthritis Outcome Score 1 and 2 years postoperatively.[13]

Therefore, an important goal when preparing small grafts is to thicken the graft diameter without over-shortening graft length. This Technical Note and video demonstrate a 4-strand hamstring autograft braiding technique that increases the diameter of the graft by almost 1.5 mm with approximately 10 mm of shortening. This braiding technique presents the potential to be applied in the preparation of undersized grafts in which an increase in graft diameter is desired without augmentation with allograft.

Samitier and Vinagre[7] reported a similar 4-strand braiding technique, and the resulting braid was flatter compared with the method presented in this Technical Note. By changing the type of braid, our technique accomplishes a rounder, thicker braid with increased graft diameter compared with folded techniques.

A potential disadvantage of this braiding technique is the increased shortening of the graft length, by approximately 10 mm. The gold standard is to implant a graft no less than 8 to 9 cm in length in order to provide successful fixation to both tibial and femoral tunnels.[7] Indeed, studies have shown that a final ACL graft length of 8 to 10 cm is desirable for good bone-tendon interface healing characteristics.[14] The advantages and disadvantages of this technique are outlined in Table 2.

This Technical Note and accompanying video of a 4-strand diamond braiding technique present a simple, reproducible way of increasing the ACL hamstring autograft diameter of an undersized hamstring autograft while maintaining the strength through the mechanical advantages of a woven configuration. Future research exploring the biomechanical properties of diamond-braided grafts is needed to for definitive evaluation and comparison of our technique.

Table 2. Advantages and Disadvantages

Advantages:

- Simple and easy technique that does not require extensive practice or extensive tissue folding experience
- Reproducible final graft shape and length
- Thickens graft by ∼1.5 mm
- Our thicker graft gives this construct a theoretical increase in tensile strength and larger anchor footprint.

Disadvantages:

- Final graft shortening of ∼8 to 10 mm compared with similar techniques can make a diamond braid difficult or not possible in some situations.
- Requires at least two operators for back table braid in order to maintain appropriate tension
- Larger cross-sectional area may make passage of graft more difficult with standard reamer diameters and passage tools.

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