Technical Note

Double-Row Root Repair with Bridging Centralization Using Double Nonsliding Anchors for Medial Meniscus Posterior Root Tear

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Abstract: Medial meniscal posterior root tears disrupt the "hoop" function of the meniscus and may lead to knee osteoarthritis. Although root repair could be a key to osteoarthritis prevention, this surgery does not necessarily guarantee an optimal result even when combined with meniscal centralization and high tibial osteotomy. To address this issue, we made five modifications to the original combined approach, namely two anchors to fix the root, instead of one; bridging centralization instead of single centralization; release of the meniscotibial capsule vs no release; release of valgus stress before knot tying vs no release; and prohibiting postoperative cross-legged sitting and sitting on heels. The advantages of this approach over the original approach are numerous and comprise ease of performing concurrent open wedge high tibial osteotomy, shorter fixation distance, better anatomical reattachment of the meniscal root, increased bone-meniscus contact and contact pressure, and larger contact area between the capsule and tibial rim. The disadvantages of the approach are that knot-tying is cumbersome, pie-crusting of the medial collateral ligament is necessary in patients not undergoing open wedge high tibial osteotomy, and tears >3 mm from the attachment are a contraindication. We describe the steps in this modified approach in detail.

Meniscal hoop function has received considerable attention recently because hoop disruption can result in progressive knee osteoarthritis.[1] As medial meniscus (MM) posterior root tear (PRT) is common among various hoop disruptions,[2-4] MMPRT repair could be key to osteoarthritis prevention. However, MMPRT repair alone does not guarantee an optimal result[4,5] owing to meniscal extrusion,[6] varus alignment,[2] and medial/posterior tibial slope.[7,8] To address this issue, we began performing MMPRT repair combined with meniscal centralization and high tibial osteotomy (HTO)[8,9] to reduce meniscal extrusion and to eliminate malalignments, respectively. However, contrary to our expectations, some second-look arthroscopies showed a stretched root with scar healing. Therefore, we made 5 modifications to the original version of the combined surgery (Table 1). The two major modifications were double-row instead of single-row root repair in some types of tear, as described later in this article (Fig 1), to improve the meniscus-bone contact area,[10] and bridging centralization,[11] using nonsliding soft anchors instead of single centralization, to achieve solid contact between the meniscotibial capsule and the tibial rim (Fig 2). The modifications, pearls, and pitfalls of the modified procedure are shown in Table 1.

Indication

This technique is indicated when a patient satisfies the following criteria: 1) within 6 months of the acute onset of MMPRT; 2) meniscal extrusion width[12] < 5 mm; and 3) type 2A MMPRT; i.e., complete radial meniscal tear

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Table 1. Modifications, Pearls, and Pitfalls of the Double-Row Bridging Centralization Technique Compared with Single-Row Centralization

Five modifications to the double-row bridging centralization technique were made to the original single-row single centralization technique[8]
1. The torn meniscal root is fixed with 2 anchors, a vertical mattress suture for the medial row and 2 simple sutures for the lateral row.
2. Bridging suture is performed between the medial and posteromedial anchors for meniscal centralization.
3. The meniscotibial capsule is released using a rasp to mobilize the meniscus and enhance bone-capsule healing.
4. Before knot tying, valgus stress is released to prevent "meniscal floating" from the tibia.
5. Sitting cross-legged and sitting on heels after meniscal repair are generally prohibited.
Pearls
[A] Advantages of the suture anchor technique over the pull-out technique
1. Simultaneous OWHTO can be performed easily with suture anchor technique, without interference from anchors, unlike with pull-out repair.
2. The fixation distance is much shorter with the suture anchor technique compared with pull-out repair.
3. Better anatomical root attachment can be reconstructed with the suture anchor technique because of the lack of the need for pull-out.
[B] Advantages of the modifications in the double-row bridging centralization technique
1. Double-row repair increases the bone-meniscus contact area and the contact pressure compared with single-row repair.
2. Bridging centralization with double anchors facilitates the creation of a large contact area between the meniscotibial capsule and the tibial rim.
3. The bone-capsule junction created by double centralization may prevent further meniscal extrusion.
4. Knot tying for centralization without valgus stress can minimize time 0 meniscal extrusion.
5. Avoiding deep-knee flexion during weightbearing may prevent recurrent meniscal root tears.
Pitfalls
1. Knot tying of the 4 anchors is technically cumbersome.
2. In cases without simultaneous OWHTO, pie-crusting of the MCL is required to create sufficient room for knot tying.
3. When the distance from the attachment to the tear is >3 mm, double-row repair is not indicated.

MCL, medial collateral ligament; OWHTO, open wedge high tibial osteotomy.

0 to <3 mm from the center of the root attachment;[13] 4) Kellgren–Lawrence osteoarthritis grade <2; 5) age < 75 years; and 6) no severe osteoporosis. Different strategies for complete radial root tear (LaPrade type 2) by subtype are demonstrated in Fig 1. Single-row repair with single centralization, using Q-FIX anchors (Smith & Nephew, Andover, MA), which have minimal displacement during cyclic load testing,[14] is used for severely osteoporotic tibias. In cases with weightbearing line ratio[15] <50% and/or mechanical medial proximal tibial angle[16] < 90°, open wedge HTO (OWHTO) is performed simultaneously.

Surgical Technique

Setup (Video 1)

The operation is performed in the supine position under general anesthesia. After sterilization, the operative foot is attached to the AssistArm positioner (CONMED, Largo, FL) to maintain the desired leg position. When using a posteromedial portal (PMP), the hip-abducted, knee-flexed, and leg-elevated position is convenient to create a large posteromedial working space (Video 1). When performing simultaneous OWHTO, the superficial medial collateral ligament is completely released before arthroscopy.[8]

Arthroscopic Preparation (Video 1, Fig 3)

The MMPRT type[13] is confirmed through the anterolateral portal (ALP) and anteromedial portal (AMP). In cases without OWHTO, outside-in pie-crusting of the medial collateral ligament[17] is added to ensure adequate space for MMPRT repair. PMP and a high mid-medial portal (HMMP) are created to insert root anchors and centralization anchors, respectively. A far ALP (FALP) and a far AMP (FAMP) are added for suture retrieving and suture relay, respectively. The articular cartilage around the root attachment is removed[18] and refreshed with a radio frequency device, curette, and abrader burr through the PMP and/or AMP. The meniscotibial capsule is released using a rasp through the AMP/MMP to mobilize the meniscus and to enhance bone-capsule healing.[11]

Anchor Insertion and Suture Passing for Root Repair (Video 1, Fig 3)

An anchor for the lateral row (FiberTak; Arthrex, Naples, FL) with two sutures and a Q-FIX anchor for the medial row are inserted at the lateral and medial edges of the refreshed attachment from the PMP, respectively. All sutures are subsequently retrieved from the FALP to avoid interference with suture relay. A passing suture (2-0 Ethibond; Ethicon Inc., Somerville, NJ) for the outer rim of the meniscus is inserted using the Knee Scorpion (Arthrex) from the AMP 8 mm from the stump and 2 mm from the meniscocapsular junction. One of the lateral-row sutures and one of the medial-row sutures are relayed using a passing suture through the FAMP. The passing suture for the inner rim is then inserted 8 mm from the stump and

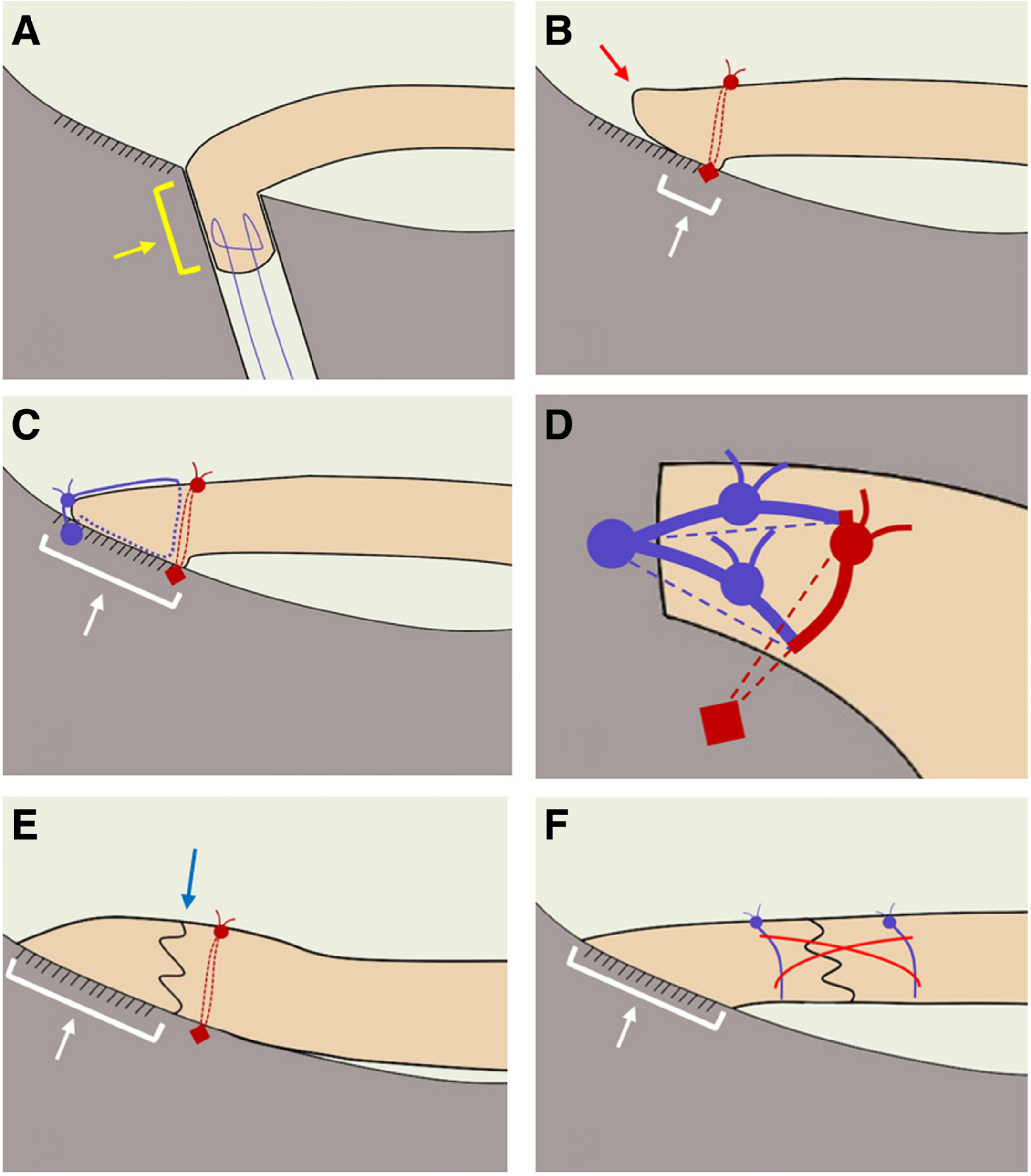

Fig 1. Strategy for type-2 medial meniscus posterior root tear (MMPRT) by subtype of tear[13] (anteroposterior view of the right knee). (A) Pull-out repair for type 2A (tear located 0 to <3 mm from the attachment). Owing to the need for the insertion of the meniscal stump into the bone tunnel (yellow arrow), and the reconstructed attachment tends to be medialized. (B) Single-row repair for type 2A. Despite anatomical reattachment, the end of the root may be flipped (red arrow) because of the lack of lateral fixation. The contact area between the root attachment and the meniscus is limited (white arrow). (C) Double-row repair for type 2A. Larger contact area (white arrow) and increased contact pressure between the root attachment and the meniscus can be obtained. (D) Three-dimensional schema for double-row repair for type 2A. (E) Strategy for type 2B MMPRT (tear located 3 to <6 mm from the attachment). Meniscus-meniscus healing (blue arrow) can be expected following single-row suture anchor repair by preserving the remnant of the meniscal root (white arrow). (F) Strategy for type 2C MMPRT (tear located 6 to <9 mm from the attachment). The tie-grip suture technique is used to achieve meniscus-meniscus healing. The attachment of the meniscal root can be completely preserved (white arrow).

2 mm from the meniscal free edge. One of the lateral-row sutures that does not correspond to the outer rim and the remaining medial-row suture are relayed in the same manner. All sutures are subsequently retrieved from the FALP.

Meniscal Centralization (Video 1; Fig 3)

A posteromedial, nonsliding, soft anchor (JuggerKnot Soft Anchor; Zimmer Biomet Japan, Tokyo, Japan) with a 1.4-mm diameter is inserted at the edge of the medial plateau through the HMMP. Both sutures from the

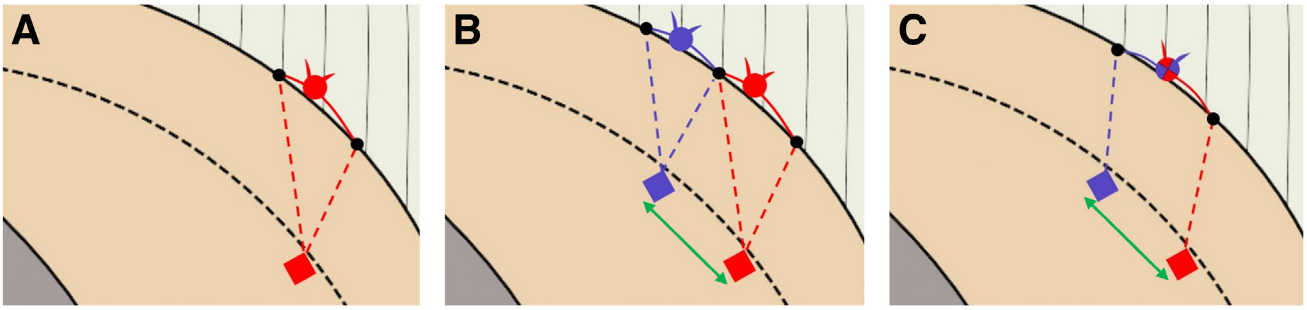

Fig 2. Various methods of meniscal centralization (right knee). (A) Single centralization at the medial edge of the tibial plateau can be performed simply, with 1 anchor insertion, 2 passing procedures, and 1 knot tying procedure. However, the contact area between the meniscotibial capsule and the tibial rim is limited (red square). (B) Despite the expanded contact area with double centralization (green double-headed arrow), the surgical steps in this approach are complicated; two anchor insertions, three passing procedures, and two knot tying procedures are required. (C) Bridging centralization facilitates achieving an improved contact area (green double-headed arrow), with 2 anchor insertions, 2 passing procedures, and 1 knot tying procedure.

posteromedial anchor are passed to the meniscocapsular junction using an ACCU-PASS (Smith & Nephew) suture passer. A medial anchor is inserted 1 cm anterior to the posteromedial anchor, and both the sutures are passed in the same manner. After relaxing the valgus stress to prevent "meniscal floating" from the tibia, 1 of 2 sutures from the posteromedial anchor and 1 of 2 sutures from the medial anchor are tied together.

Knot Tying for the Root Repair (Video 1, Fig 3)

The torn site can be automatically reduced by centralization. The medial row sutures are retrieved from the AMP and tied. The lateral row sutures are then tied, proceeding from the outer to inner rims. Once all arthroscopic procedures are completed, if necessary, HTO can be performed without interference from the anchors.

Postoperative Rehabilitation

Range-of-motion exercises are started 2 weeks after surgery, and flexion $>120°$ is restricted until 6 weeks postoperatively. Wearing a brace is encouraged until 6 weeks postoperatively as well. Full weight bearing is allowed on the first postoperative day because OWHTO is performed simultaneously with root repair in cases with varus alignment.

Discussion

Meniscal root repair procedures can be divided into two approaches: pull-out repair (POR)[5,19,20] and suture anchor repair (SAR).[4,8] The advantages and pitfalls of each approach are listed in Table 1. POR may be easier to perform compared with SAR because of the lack of need for a posteromedial portal and skilled knot tying. In comparison, SAR facilitates the combination of root repair with HTO because there is no concern over an inadvertent cut to the pulling suture during POR by a drill or screw.[8] Furthermore, better anatomical attachment can be reconstructed with SAR versus POR because there is no need to draw the meniscal stump into a bone tunnel. Although the stump in the tunnel seemingly reinforces the fixation strength, there is doubt about the superiority of this approach. First, distinct from anterior cruciate ligament reconstruction using a hamstring tendon, the meniscal length in the tunnel is much shorter with POR. Yamakado et al. reported that the bone-tendon junction within the tunnel regressed after maturation at the entrance of the tunnel due to stress shielding.[21] This might mean that even though sufficient tendinous length is inserted into a tunnel, only the bone-meniscus junction at the entrance survives. Additionally, in POR, the knee flexion angle and initial tension[6,19,22] may affect the healing process owing to the long fixation length. Therefore, stronger fixation can be expected in double-row SAR versus POR because of the shorter fixation distance and larger contact area. Regarding complications, as anchor backout is most likely with SAR,[23] resistance to osteoporosis may be higher with POR. Although the frequency of anchor hole enlargement may be lower than that of bone tunnel expansion,[24] knot impingement[25] with the medial femoral condyle can be an anchor-specific complication to avoid.

Our modifications may maximize the advantages and minimize the disadvantages of SAR, as follows: double-row repair to improve the bone-meniscus contact area;[10] compared with POR, better anatomical attachment in the intercondylar space eliminates knot impingement; and bridging centralization using double nonsliding anchors may prevent anchor backout. However, the lack of long-term results and the lack of histological examinations of the bone-meniscus/bone-capsule junctions are limitations of this technique.

In conclusion, double-row suture anchor repair with bridging centralization may improve the healing rate of MMPRT repair.

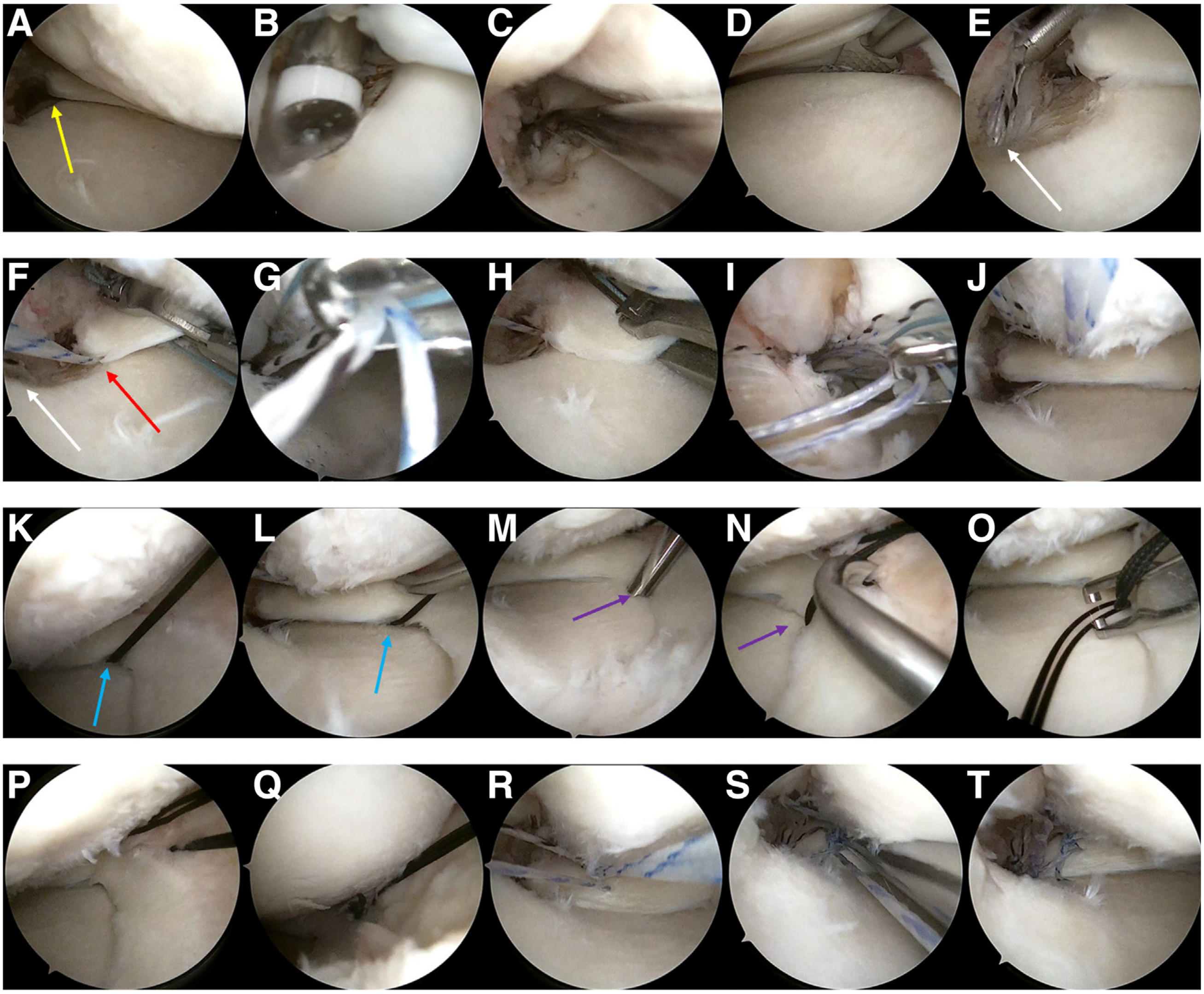

Fig 3. Surgical procedure (right knee). (A) Type 2A medial meniscus posterior root tear (MMPRT) can be confirmed (yellow arrow) through the anterolateral portal (ALP) and anteromedial portal (AMP). The remnant of the meniscal root is just visible at the attachment. (B) The articular cartilage around the root attachment is removed with a radio frequency device through the posteromedial portal (PMP). (C) The bone bed is refreshed with a curette through the AMP to enhance bone-meniscus healing. (D) The meniscotibial capsule is released through the AMP to mobilize the meniscus and enhance bone-capsule healing. (E) An anchor for the lateral row (FiberTak; Arthrex, Naples, FL) with two sutures is inserted at the lateral edge of the refreshed portion (white arrow) from the PMP. (F) After inserting an anchor for the medial row (Q-FIX; Smith & Nephew, Andover, MA) at the medial edge of the refreshed portion (red arrow), all sutures are retrieved from a far anterolateral portal (FALP). A passing suture (2-0 Ethibond; Ethicon Inc., Somerville, NJ) for the outer rim of the meniscus is inserted using a Knee Scorpion (Arthrex) from the AMP 8 mm from the stump and 2 mm from the meniscocapsular junction. (G) One of the lateral row sutures and one of the medial row sutures are relayed using the passing suture through the far anteromedial portal (FAMP). (H) The passing suture for the inner rim is inserted 8 mm from the stump and 2 mm from the meniscal free edge. (I) One of the lateral row sutures that does not correspond to the outer rim and the remaining medial row suture are relayed in the same manner. (J) All sutures are subsequently retrieved from the FALP after the relaying procedures. (K) A posteromedial, nonsliding, soft anchor (JuggerKnot Soft Anchor; Zimmer-Biomet, Tokyo, Japan) with a 1.4-mm diameter is inserted at the edge of the medial plateau (blue arrow) through the high mid-medial portal (HMMP). (L) Both sutures from the posteromedial anchor are passed to the meniscocapsular junction using an ACU-PASS (Smith & Nephew) suture passer. (M) A medial anchor for the centralization is inserted 1 cm anterior to the posteromedial anchor (purple arrow) from the HMMP. (N) The corresponding meniscocapsular junction is penetrated by an ACCU-PASS suture passer through the AMP. (O) Both sutures from the medial anchor for the centralization are relayed using the FAMP. (P) When all of the sutures for the centralization are tensioned, the meniscus can be easily centralized. (Q) After relaxing the valgus stress to prevent "meniscal floating" from the tibia, one of two sutures from the posteromedial anchor and one of two sutures from the medial anchor are tied together. (R) The medial row sutures are retrieved from the AMP and tied. (S) The lateral row sutures are then tied, proceeding from the outer rim to the inner rim. (T) Final view of the double-row repair demonstrating the anatomically reconstructed root attachment.

Acknowledgments

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