Technical Note

A Technique of Arthroscopic Primary Anterior Cruciate Ligament Repair With Polyester Suture Tape Augmentation

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Abstract: Restoring anterior cruciate ligament (ACL) function after a rupture is critical for reducing long-term knee damage. Primary reconstruction is well established as a golden standard for treatment of complete ACL tear. Nevertheless, carefully selected patients can substantially benefit from a primary repair in comparison to reconstruction. We present a technique of arthroscopic primary ACL repair with polyester suture tape augmentation. Our method expands the spectrum of ACL repair techniques by creating a comfortable pulley-like system of tensioning the ligament and suture tape with a cortical button-suture construct.

Anterior cruciate ligament (ACL) tear is a common orthopaedic injury with an incidence of 8 to 68.6 per 100,000 people.[1,2] Arthroscopic reconstruction is the gold standard in addressing complete ACL tears. However, after a long period of abundance, primary repair is gaining attention.[3] We believe carefully selected patients can benefit from a primary ACL repair with tape augmentation compared to reconstruction.

This technique of primary arthroscopic ACL repair with nonabsorbable polyester suture tape augmentation creates a pulley-like system with the use of a 4-hole femoral button and sutures. This construct allows for precise approximation and tensioning of the tibial stump with suture tape augmentation. It is dedicated to the tears located in a proximal quarter of the length of the ACL with more than or equal to 75% of the distal ACL intact. That corresponds to type I and II tears by Daniels et al.,[4] who modified the widely adopted Sherman classification.[5]

Most patients meeting the inclusion criteria for the procedure are low-demand elderly people who underwent a low-energy trauma that resulted in an isolated, proximal ACL tear. For those patients, a classic reconstruction with a long rehabilitation protocol may be too demanding or even seen as overtreatment.

Surgical Technique

The arthroscopic technique of primary ACL repair with suture tape internal augmentation is presented in Video 1. Advantages and limitations of the technique are presented in Table 1, along with pearls and pitfalls in Table 2 and indications and contradictions in Table 3. Steps of the technique are listed in Table 4.

Patient Positioning, Preparation, and Surgical Approaches

The surgery takes place in the operating room adapted to arthroscopic procedures. The patient is placed in a supine position with the tourniquet on the operated limb and set in a holder, allowing them to freely execute knee movements (Fig 1).

Standard anterolateral (AL) and anteromedial arthroscopic portals are used for this technique. During tibial canal preparation, the cortex is accessed approximately 1 cm proximal to the pes anserinus and about 1.5 cm medial to the tibial tuberosity, with careful surgical tissue preparation focusing on avoiding damage to a branch of the saphenous nerve.

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Table 1. Advantages and Limitations of the Technique

Advantages	Limitations
Relatively short surgery time	If the stump does not heal properly, the surgery may fail
Native anatomy and biology of the distal attachment preservation	Indications limited to a small group of ACL patients
Proprioception preservation	Lack of long-term results or strong evidence described in the literature
Minimally invasive procedure	
Relatively faster rehabilitation and return to activity/sport	
May be better suited for patients with high-risk medical conditions (compared to the allo/autograft technique)	
Almost any arthroscopic instrumentation set and cortical buttons can be used	
If failed, revision surgery is similar to primary ACL reconstruction	
Potential growth plate-sparing treatment for pediatric patients (smaller drill than reconstruction)	
Donor side morbidity is excluded	
Pulley-like cortical button-suture construct allows convenient and precise stump tensioning	

ACL, anterior cruciate ligament.

Table 2. Pearls and Pitfalls of the Technique

Step	Pearl	Pitfall
Joint inspection	Lesions undetected earlier may be visualized and treated (e.g., meniscal ramp lesion, damage to posterior root of lateral or medial meniscus).	
ACL stump suturing	Optimal suture placement is as close to the middle of the substance as possible.	Penetrating the stump too close to the loose end results in inadequate durability of the construct.
Canal drilling	Before femoral tunnel preparation, microfractures at the femoral footprint of the ACL can be performed to enhance the healing response.	Inadequate position of the joint exit point of the tibial canal causes suboptimal force distribution and may lead to ACL overstrain in nonprotected ROM.
Cortical button preparation	Care should be taken at this moment as it is the most complicated step.	Wrong preparation may cause trouble setting the button.
Tensioning the suture and the tape	We recommend mobilization of the stump first, followed by tape tensioning and ACL fixation. This step should be performed with an extended knee to avoid flexion contracture.	Suboptimal tape tensioning: Setting the tape too tight alters knee mechanics, with a high risk of flexion contracture. Placing it too loose will lead to inefficient ACL protection and therefore highly probable overstrain. Too forceful ACL suture tensioning may damage the stump.
X-ray control	To assess femoral cortical button position and rule out soft tissue impingement, a C-arm examination is conducted.	

ACL, anterior cruciate ligament; ROM, range of motion.

Table 3. Indications and Contradictions of the Technique

Indications
Full-thickness ACL proximal tear (tibial ACL stump at minimum 75% of the total ACL length; modified Sherman I or II) with no concomitant lesions
Low-demand patients or children before skeletal maturation
Contradictions
Damaged/low tissue quality of the distal stump
Sports requiring pivoting movements
Major knee extensor apparatus injury
Relative contradictions
Benign joint hypermobility syndrome
Systemic conditions influencing the musculoskeletal system (e.g., rheumatoid diseases)
Collagenopathies
Relatively old lesion

ACL, anterior cruciate ligament.

Table 4. Step-by-Step Table of the Technique

Step 1	Patient positioning and preparation
Step 2	Anteromedial portal preparation
Step 3	Anterolateral portal preparation under direct visualization
Step 4	Assessment of the ACL tear and joint for any concomitant lesions
Step 5	Arming the Scorpion (Arthrex) with the suture
Step 6	Passing the suture through the ACL and pulling the loop outside the joint
Step 7	One loose end of the suture is driven through the loop and the suture is tightened on the ACL
Step 8	Drilling the tibial tunnel with any ACL reconstruction tibial tunnel aiming device
Step 9	Pulling the ACL suture outside the joint through the tibial tunnel
Step 10	Creation of the femoral canal with any dedicated ACL reconstruction aiming device
Step 11	Insertion of suture loop inside the joint from the tibial canal
Step 12	Arming the cortical button
Step 13	Setting both directional sutures from the cortical button through the loop
Step 14	Pulling the directional sutures by the loop through the femoral canal
Step 15	Passing and placing the cortical button on the femoral cortex
Step 16	C-arm examination
Step 17	Approximation of the tibial stump of the ACL
Step 18	Tightening of the nonabsorbable tape
Step 19	Knotting the ACL suture and the tape on the tibial button
Step 20	Assessment of stability
Step 21	Skin closure

ACL, anterior cruciate ligament.

Equipment

- Standard 4-mm 30° arthroscope (Smith & Nephew)
- Arthroscopic probe (Smith & Nephew)
- A 3-mm shaver (Stryker)
- FiberTape suture (Arthrex)
- Guiding sutures: Ethibond Excel 5, Vicryl 2 (Johnson & Johnson): we recommend 2 sutures of different colors to avoid confusion.
- Knee Scorpion Suture Passer (Arthrex)
- ACL stump suture (FiberWire 2; Arthrex)
- Arthroscopic suture cutter (Smith & Nephew)
- Tibial round cortical button (10 or 14 mm; Medgal)
- Femoral 4-hole cortical button (4 × 12 mm; Medgal)
- ACL reconstruction aiming device (Arthrex)
- Drill 4.5 mm (Arthrex)
- Suture retriever (Smith & Nephew)
- Guidewire (2.4 mm diameter; Smith & Nephew)

Joint Inspection and ACL Stump Suturing

Arthroscopic portals are created: first the anteromedial portal and then the AL portal under direct visualization. The ACL stump is visualized and reviewed. General joint inspection and a search for any concomitant lesions are conducted (Fig 2). At this step, lesions undetected earlier should be treated. Potentially common coexisting damage can include meniscal ramp lesion and injury to the posterior root of the lateral or medial meniscus. After that, a Scorpion (Arthrex) is

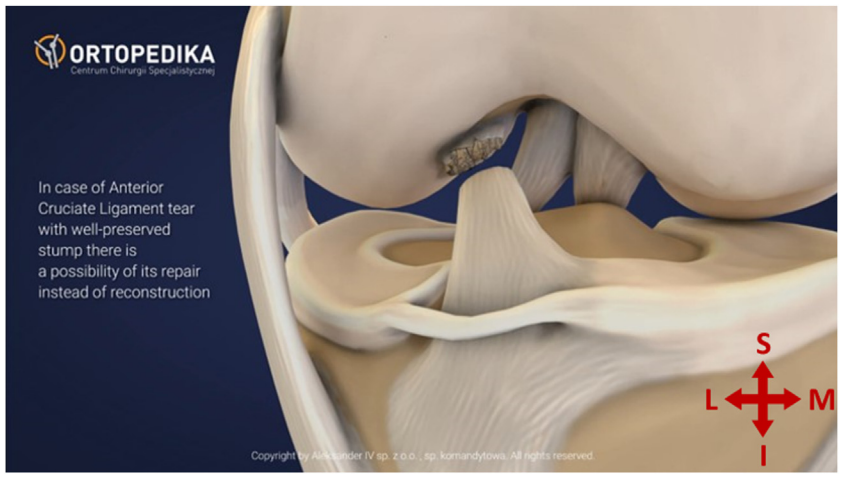

Fig 1. One of the steps of the arthroscopic primary ACL repair technique with polyester suture tape augmentation. The visualization of the operated region presents a well-preserved distal stump of the torn ACL. (ACL, anterior cruciate ligament.)

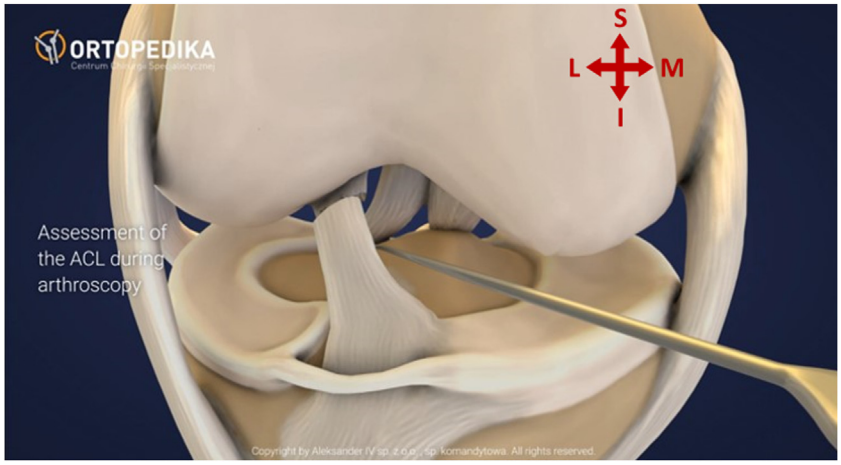

Fig 2. One of the steps of the arthroscopic primary ACL repair technique with polyester suture tape augmentation. View from the medial side of the right knee. The assessment of the ACL is carried out by its manipulation with a probe. If any pathologic hypermobility occurs or the rupture site is visualized in the femoral part of the ACL, a definite diagnosis is made, and it fulfills this technique's indications. Next, the joint is assessed for any concomitant lesions to address them as necessary. (ACL, anterior cruciate ligament.)

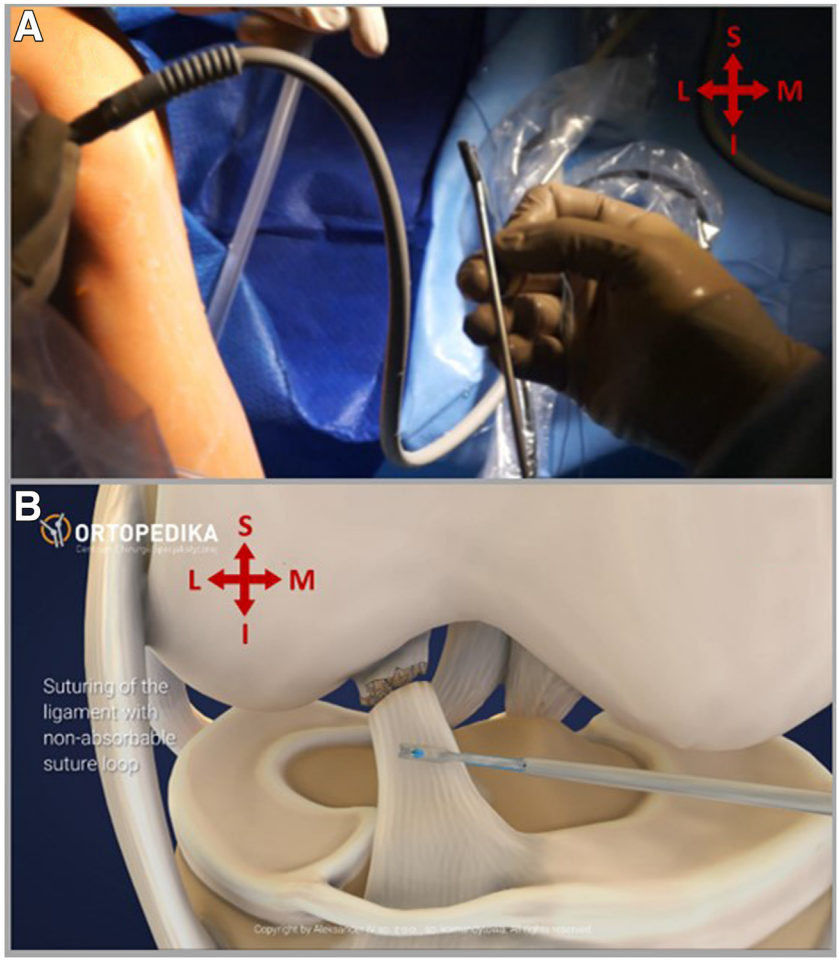

Fig 3. One of the steps of the arthroscopic primary ACL repair technique with polyester suture tape augmentation. (A, B) View of the right knee. A Scorpion (Arthrex) device is armed with a nonabsorbable suture loop and inserted through the AM portal to the knee joint. The scorpion is used to pass the loop through the tibial stump of the torn ACL. (ACL, anterior cruciate ligament; AM, anteromedial.)

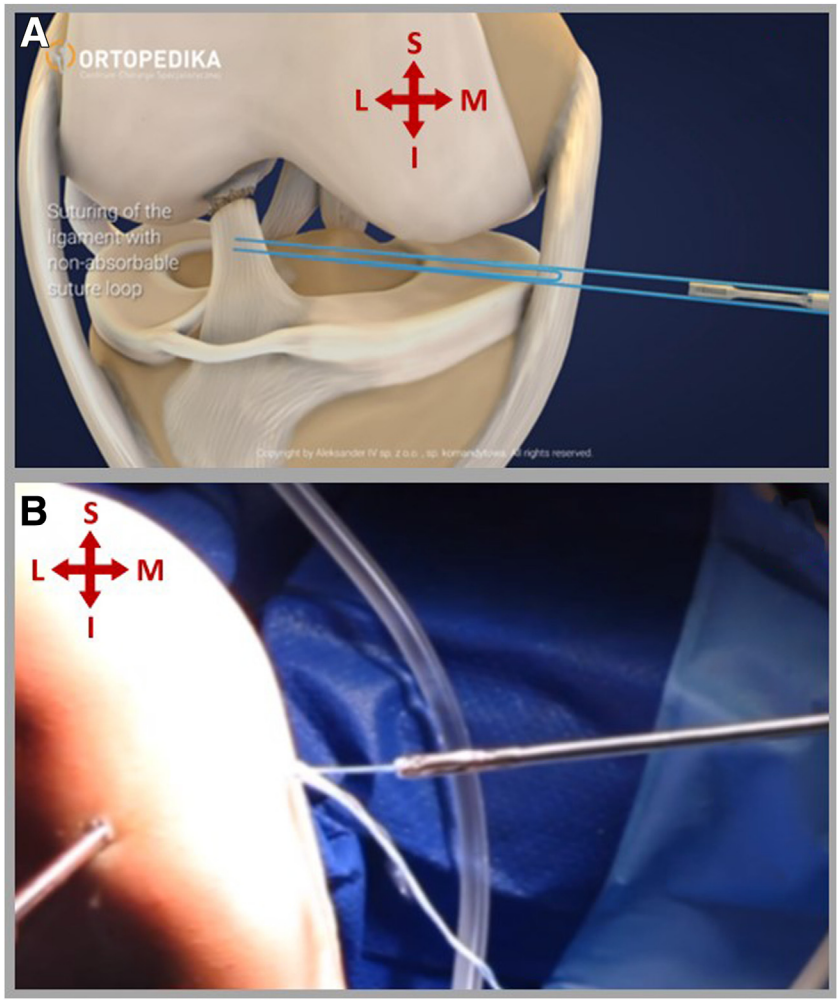

Fig 4. One of the steps of the arthroscopic primary ACL repair technique with polyester suture tape augmentation. View from (A) the medial side of the right knee and (B) the lateral side. (A) The lasso end of the looped wire is dragged outside the joint through the AM portal. It is worth leaving the lasso end of the looped wire protruding from the portal by about 2 to 3 cm, as in the next step (Fig 5). (B) One loose end of the suture will be carried out through the lasso end of the looped wire. (ACL, anterior cruciate ligament; AM, anteromedial.)

armed with a looped wire (FiberWire 2; Arthrex). Next, a looped wire is passed through the midsubstance of the tibial stump of the torn ACL by the Scorpion (Arthrex) (Fig 3). Care should be taken to penetrate the stump at full thickness and not at the level of the damaged tip.

The lasso end of the wire is dragged outside the joint from the AL portal. It is practical to leave the lasso end protruding from the portal as in the next step (Fig 4), and 1 loose end of the suture will be carried out through the lasso end of the wire. Then, by pulling both loose ends of the looped wire, we make a knot on the tibial portion of the ACL (Fig 5).

Bony Canal Drilling

With the use of an aiming device from any ACL reconstruction set, the tibial canal is drilled in knee flexion. The drill passes through the distal ACL attachment and the tibial stump (Fig 6). Through the canal, both loose ends of the stump suture are dragged outside the joint (Figs 7-8). Before femoral tunnel preparation, microfractures at the femoral footprint of the ACL can be performed to enhance the healing response. A femoral tunnel is prepared with an aiming device for ACL reconstruction with an offset of 5 to 6 mm (Fig 9). With the knee flexed, a guidewire with a suture loop is inserted into the femoral canal from the inside and carried through the skin to the outside so that the loop remains in the joint; the suture passes the femoral canal, and the loose end of the suture is secured outside. Then, the loop is carried out of the joint through the tibial canal and secured (Fig 10). The cortical button preparation is held.

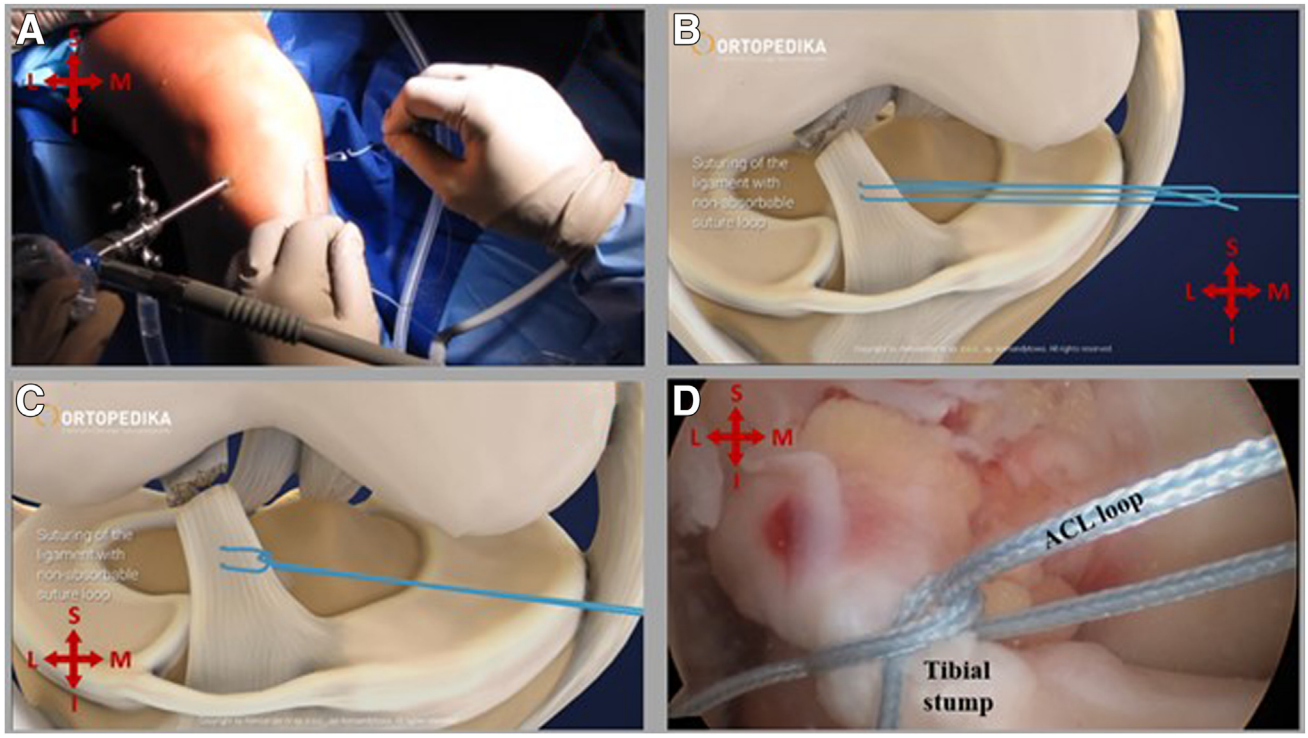

Fig 5. One of the steps of the arthroscopic primary ACL repair technique with polyester suture tape augmentation. (A, B) One of the loose ends of the nonabsorbable suture is carried through the lasso end of the looped wire. (C) Noth loose ends are tightened. (D) View from the AL portal of the right knee. With this maneuver, a firm knot is created around the tibial stump of the ACL. At the end of the procedure, tensioning of this wire will approximate the tibial stump. (ACL, anterior cruciate ligament; AL, anterolateral.)

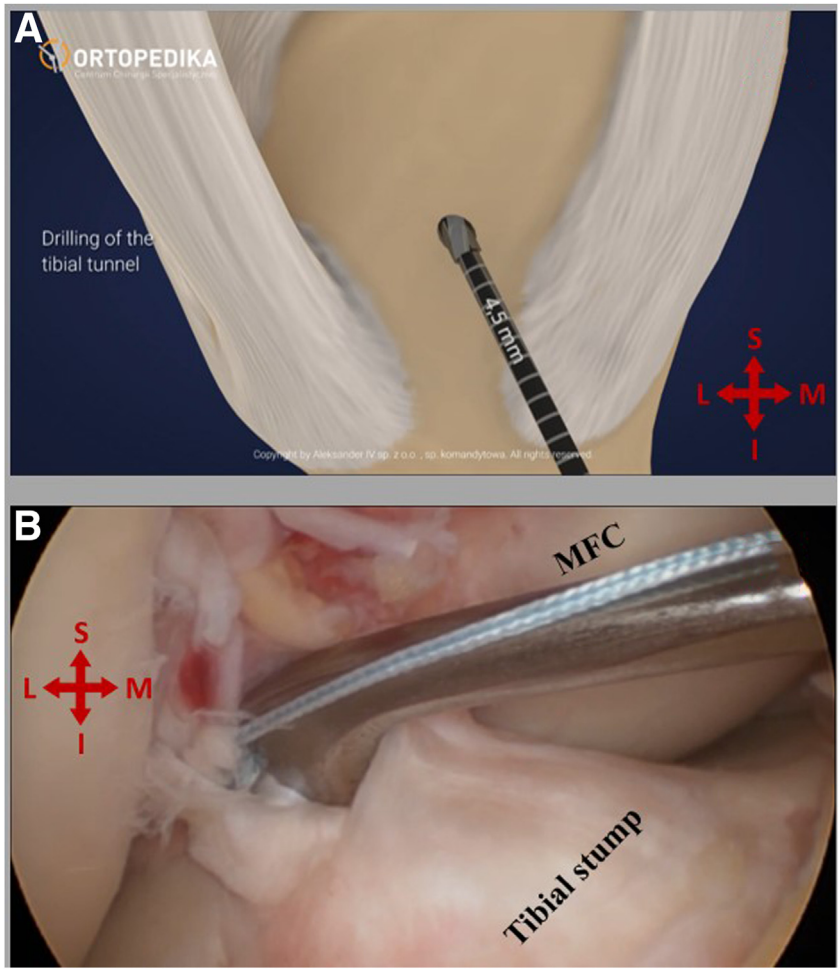

Fig 6. One of the steps of the arthroscopic primary ACL repair technique with polyester suture tape augmentation. (A) The next step is a tibial tunnel drilled with the help of any ACLR tibial tunnel aiming device. (B) View from the AL portal on the ACL in the right knee. The intra-articular part of the device should be set over the tibial stump of the ACL. (ACL, anterior cruciate ligament; ACLR, anterior cruciate ligament reconstruction AL, anterolateral; MFC, medial femoral condyle.)

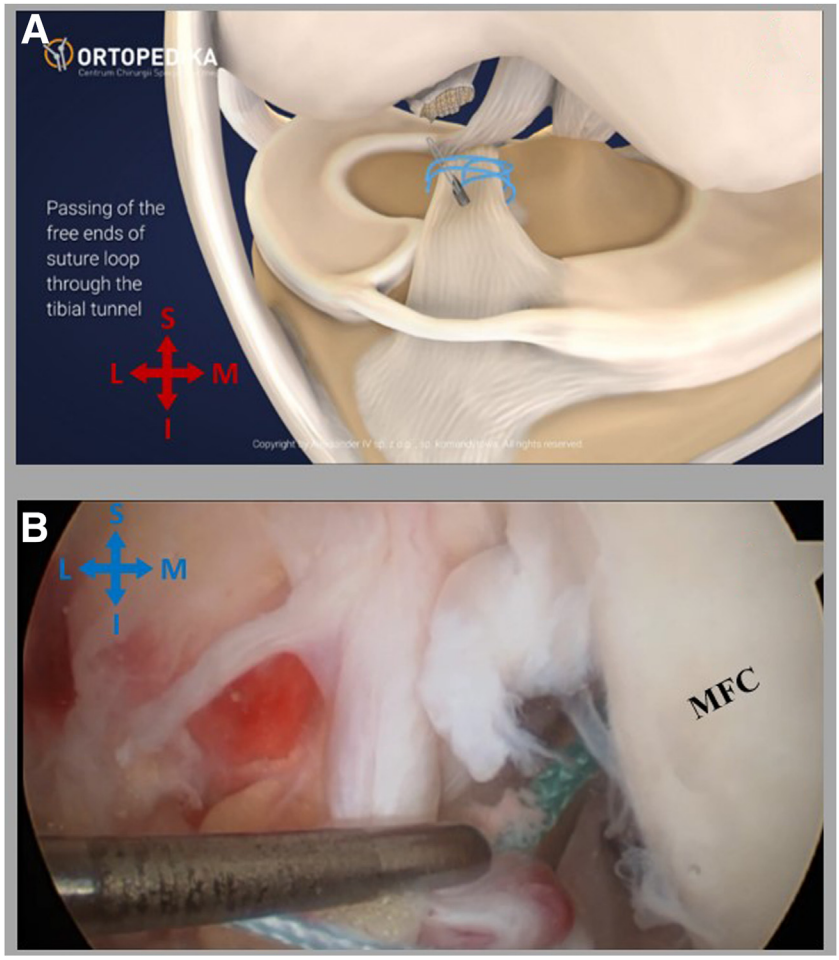

Fig 7. One of the steps of the arthroscopic primary ACL repair technique with polyester suture tape augmentation. (A) View from the medial side of the right knee in the figure. (B) View from the anteromedial portal. A suture retriever (Smith & Nephew) (A: gray in animation; B: green in arthroscopic view) (A) is passed from the tibial tunnel into the joint. (B) View from the AM portal in the right knee. (ACL, anterior cruciate ligament; AM, anteromedial.)

Four-Hole Cortical Button Preparation and Implantation

We use a 4-hole femoral cortical button. Extra attention should be paid at this moment as it is the most complicated step, and any mistake could cause trouble setting the button. We set up the button in the following order. With the button remaining in the horizontal flat position, the suture tape is carried through one of the inner holes from the downside and through another one from the upside to the downside. Next, 2 ends of the ACL sutures are passed separately through the same holes. We thread them from the downside through the hole and from upside to downside so that they lie on the border of the button. This position is crucial to create a pulley-like system to later approximate the stump of the ACL. Next, 2 directional sutures are passed separately from the downside to the upside through the outer holes (Fig 11). Then, the directional sutures are grabbed by the loop of the suture retriever protruding from the tibial tunnel (Fig 12). A suture retriever with sutures is carried through the joint onto the femoral site (Fig 13). Under adequate tension, the cortical button is set in a vertical position and carried through the bony canals and the joint (Figs 14-15). Next, it is positioned on the bony cortex of the femur (Fig 16). Directional sutures are removed. To control the proper cortical button placement, x-ray control is conducted.

Construct Tensioning and Fixation

The tibial portion of the torn ACL is mobilized by handheld maneuvers of the ACL suture and arthroscopically visualized if the approximation to the femoral footprint is achievable (Fig 17). Next, tape augmentation is tensioned and fixed with a knot to the tibial cortical button. Finally, the ACL suture is tensioned and knotted to the same button. It is strongly advised to perform tensioning with an extended knee to avoid flexion contracture. The augmented ACL is then inspected for stability, and if it is satisfying, the

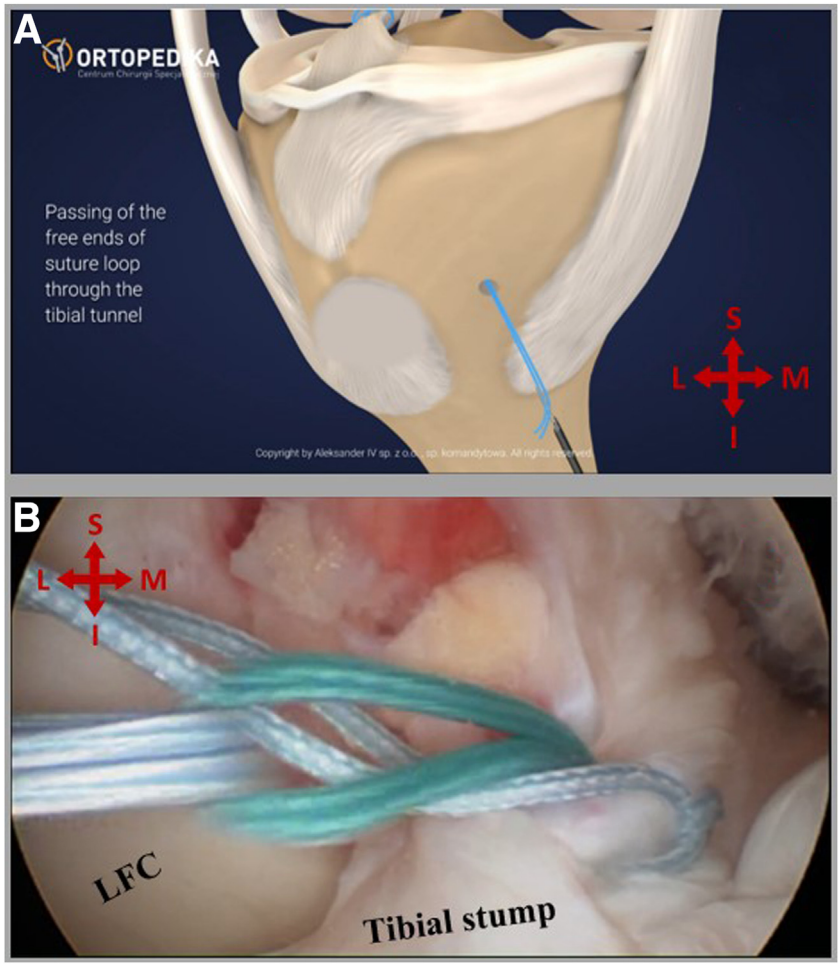

Fig 8. One of the steps of the arthroscopic primary ACL repair technique with polyester suture tape augmentation. (A) View from the medial side of the right knee in the figure. (B) View from the anteromedial portal. By pulling the suture retriever (Smith & Nephew) (green in B), the ACL suture (white-blue in B, blue in A) is driven outside the joint. (ACL, anterior cruciate ligament.)

Fig 9. One of the steps of the arthroscopic primary ACL repair technique with polyester suture tape augmentation. View from the anterolateral side of the right knee. Then through the AM portal, an aiming device and the guidewire for the creation of the femoral canal are inserted. Next, the femoral canal is drilled with a 4.5-mm drill on the guidewire. (ACL, anterior cruciate ligament; AM, anteromedial.)

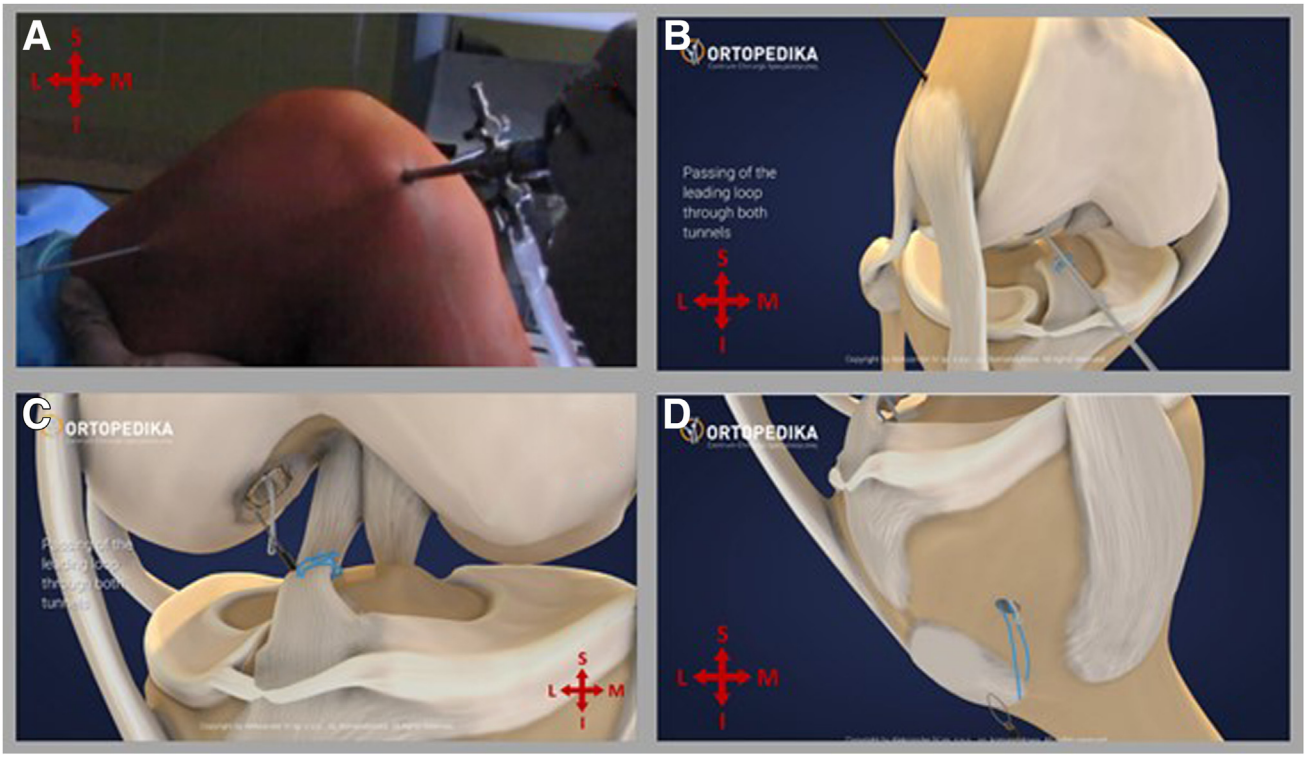

Fig 10. One of the steps of the arthroscopic primary ACL repair technique with polyester suture tape augmentation. View from the lateral side of the right knee. The knee is placed in a flexed position. (A, B) One guidewire is threaded with a suture at the lasso end of the looped wire and passed from the AM portal through the femoral tunnel to outside the joint. Next, the lasso end of the looped wire is dragged through the tibial tunnel outside the joint. As a result, 2 loose ends of the suture protrude from the portal over the femoral tunnel. (C, D) The lasso end of the looped wire overhangs from the tibial tunnel. (ACL, anterior cruciate ligament; AM, anteromedial.)

instrumentation can be pulled out from the joint and wounds closed (Fig 18).

Discussion

We choose the repair technique over the standard reconstruction in a limited number of patients because of its advantages, listed in Table 1. Available data stating outcomes of primary repair with augmentation are diverse, yet many recent articles approve it as comparable to gold-standard reconstruction. It is underlined that more prospective research with longer follow-up is needed. Complications other than failure rate are stated to be consequently low in literature. The failure rate itself greatly varies across articles.[3,6-9] To minimize the risk of failure, we strongly advise closely following the indications for this technique listed in Table 3.

Not augmenting the repair fails to keep the distal ACL stump close to its insertion or proximal stump, preventing the ligament from healing. Based on biomechanical studies by Massey et al.[10] and Bachmeier et al.,[11] augmentation with a suture tape seems to be a solution to that problem and provides sufficient mechanical support.

It seems that the construct ensures optimal biologic-synthetic load sharing. Canine model research by Bachmaier et al.[11] states no stress shield effect but rather a seatbelt concept on the augmented ligament. This environment would ensure mechanical stress that allows for an efficient healing response and at the same time prevents overstrain and elongation.

Although tape augmentation seems to add adequate protection from retearing the ligament, its kinematics may differ from native tissue. Hoogeslag et al.[7] presented a biomechanical comparison of ACL repair without an augment and repair that was augmented with a static and dynamic tape construct with ACL-intact and ACL-deficient knees. Dynamic augmentation seemed to mimic the physiologic tibial anterior translation most accurately. Further investigation is necessary to discover the clinical significance of that

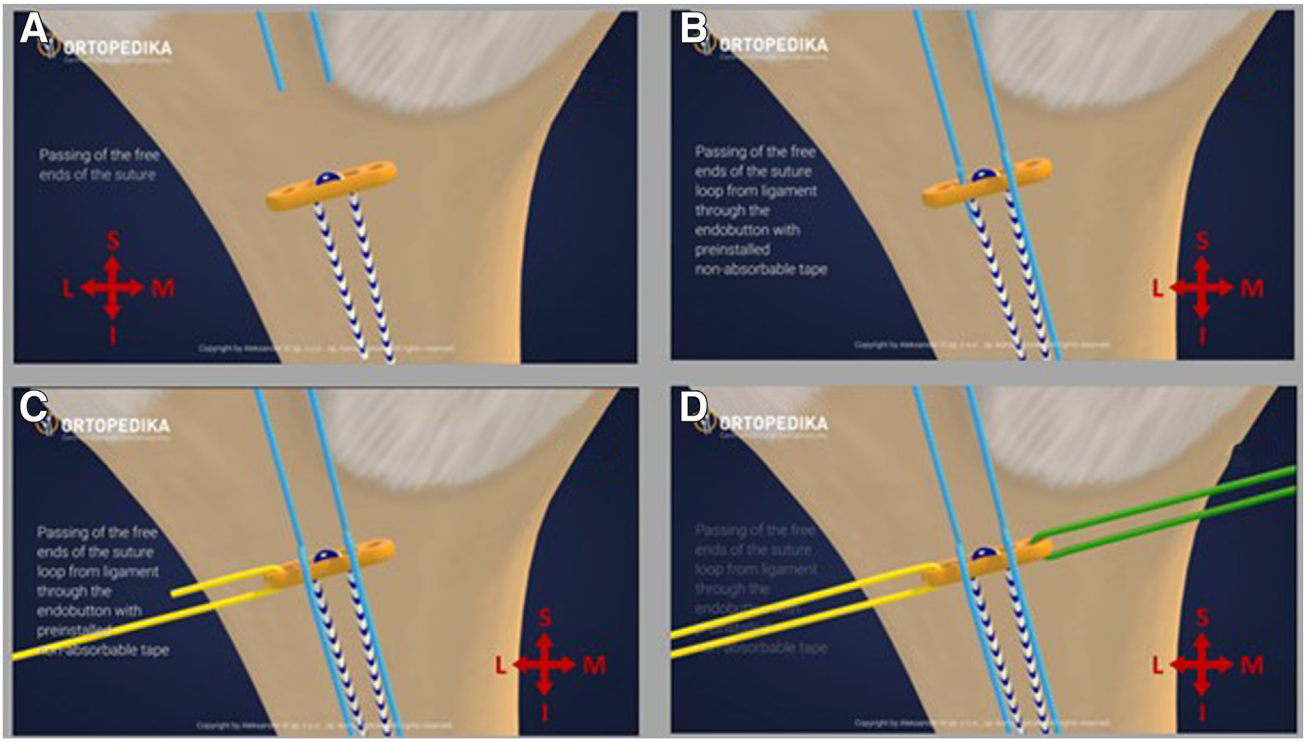

Fig 11. One of the steps of the arthroscopic primary ACL repair technique with polyester suture tape augmentation. The 4-hole cortical button is armed. The FiberTape (Arthrex) is inserted into 2 middle holes of the cortical button. (A) Both free ends should be the same length and directed distally. This tape will serve as a stabilizer for the ACL (white with blue stripes). (B) Next, the ACL lasso end of the looped wire is inserted into both middle holes. The direction should start from the downside through the hole and back downside (light blue). The outer two are armed with 2 sutures (yellow and green). Those sutures are crucial to direct and pull the button through both canals. (C, D) The loose ends of the sutures should be the same length. (ACL, anterior cruciate ligament.)

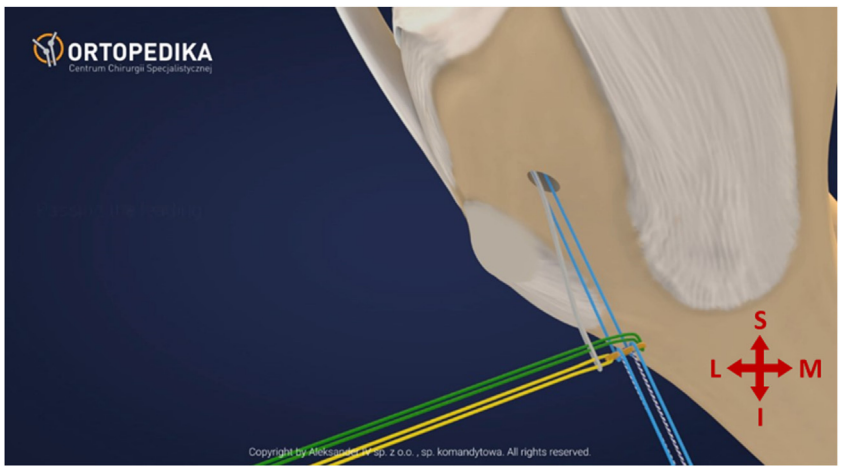

Fig 12. One of the steps of the arthroscopic primary anterior cruciate ligament repair technique with polyester suture tape augmentation. View from the medial side of the right knee. The medial and lateral directional sutures are driven through the lasso end of the looped wire mounted in the previous step (Fig 11).

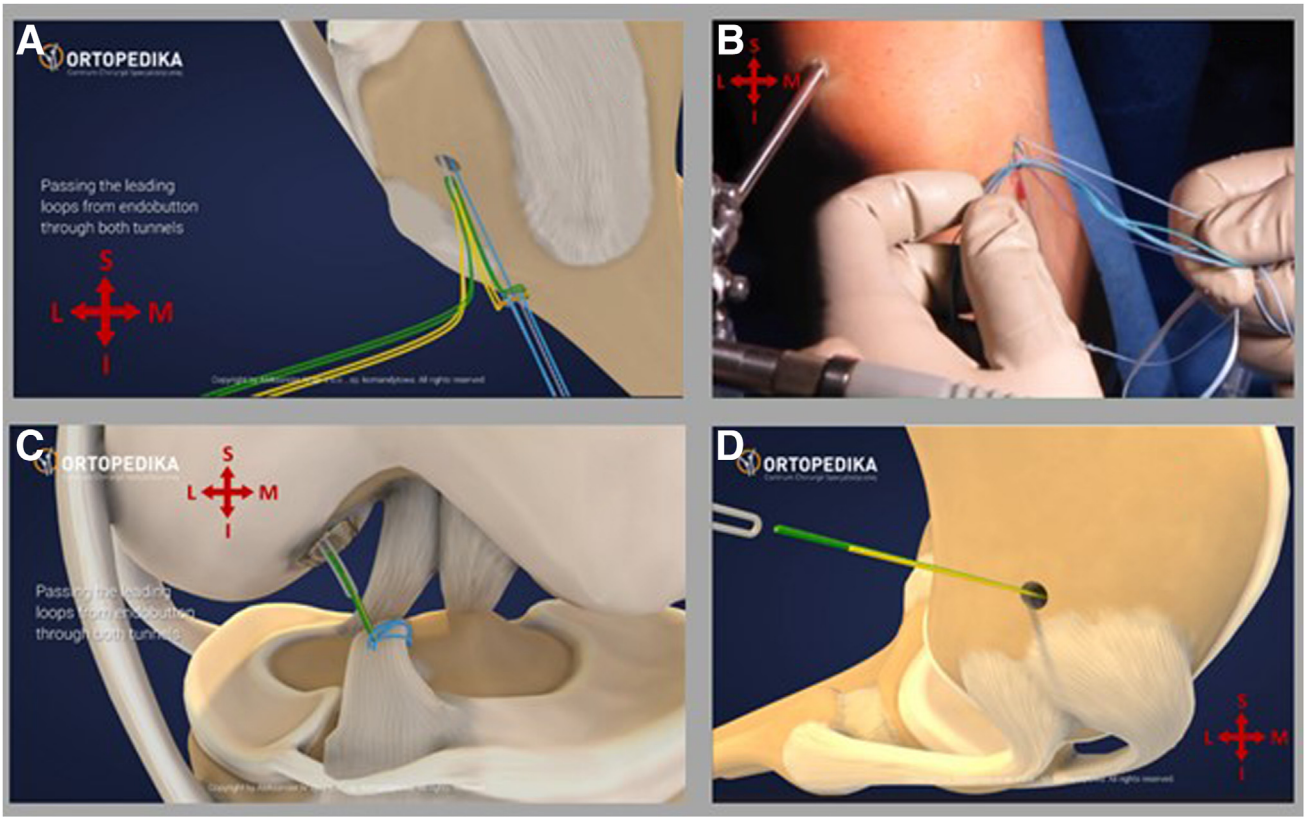

Fig 13. One of the steps of the arthroscopic primary anterior cruciate ligament repair technique with polyester suture tape augmentation. (A-C) View from the medial side of the right knee. (D) Lateral view of the picture. The lasso end of the looped wire mounted in step 10 is pulled by the loose ends protruding from the portal over the femoral canal, dragging the sutures through both canals.

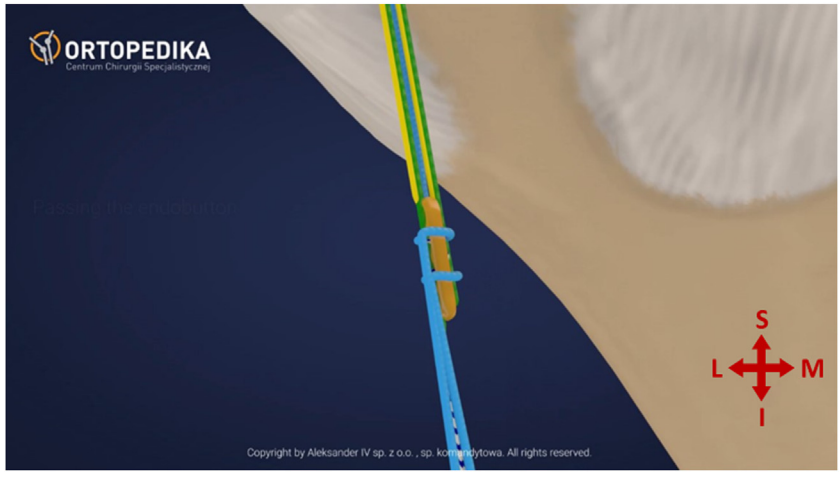

Fig 14. One of the steps of the arthroscopic primary anterior cruciate ligament repair technique with polyester suture tape augmentation. View of the armed cortical button from the medial side of the right leg. By pulling one of the directional (green, yellow) sutures tighter, the button is flipped, allowing to stall it through both canals. There is no difference in which suture will be overtensioned.

Fig 15. One of the steps of the arthroscopic primary anterior cruciate ligament repair technique with polyester suture tape augmentation. View from the lateral side of the right knee. When the button is armed and flipped to the vertical position, the directional sutures are pulled by loose ends protruding from the portal over the femoral canal.

finding. Nevertheless, the target of limiting the anterior tibial translation in elderly patients with ACL tear is accomplished.

Strassman et al.[12] have presented an interesting variant of ACL repair using a retensionable all-suture—based construct. Three sutures for ACL stump are used in this technique, and it seems to allow a more anatomic repair.

Another ACL repair technique is described by Peng et al.,[13] who presented a continuous bundle suture technique with simplified suture passing. This method may be preferable when suture management is targeted to be less complex. More clinical data seem necessary to prove the relevant superiority of any of the mentioned techniques.[6]

Disclosures

All other authors (A.M., M.W., W.B., M.N., J.S., G.K.) declare that they have no known competing financial

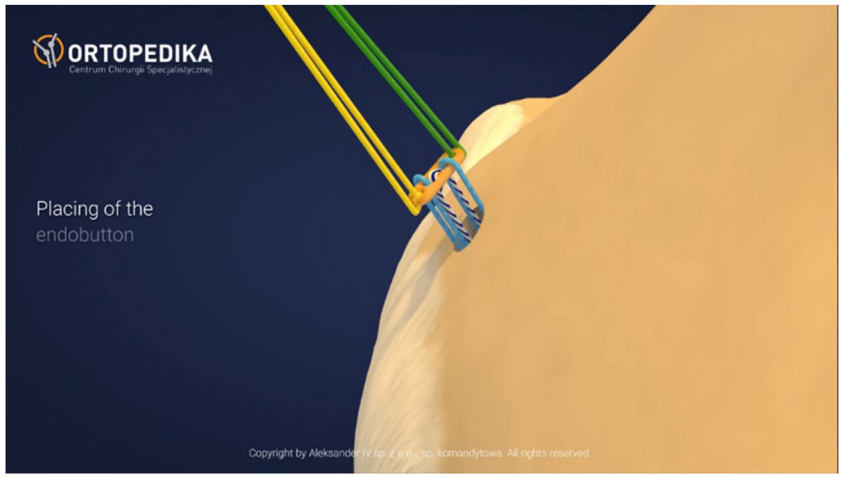

Fig 16. One of the steps of the arthroscopic primary anterior cruciate ligament repair technique with polyester suture tape augmentation. View from the lateral side of the femoral canal opening of the right knee. The cortical button is flipped and anchored on the femoral cortex over the femoral canal. This is achieved by pulling the directional suture contralateral to the one overtensioned in previous steps. The position of the cortical button can be controlled by C-arm examination or by direct visualization from a small incision. When the button is placed on the femoral cortex, the sutures can be cut at the level of the portal.

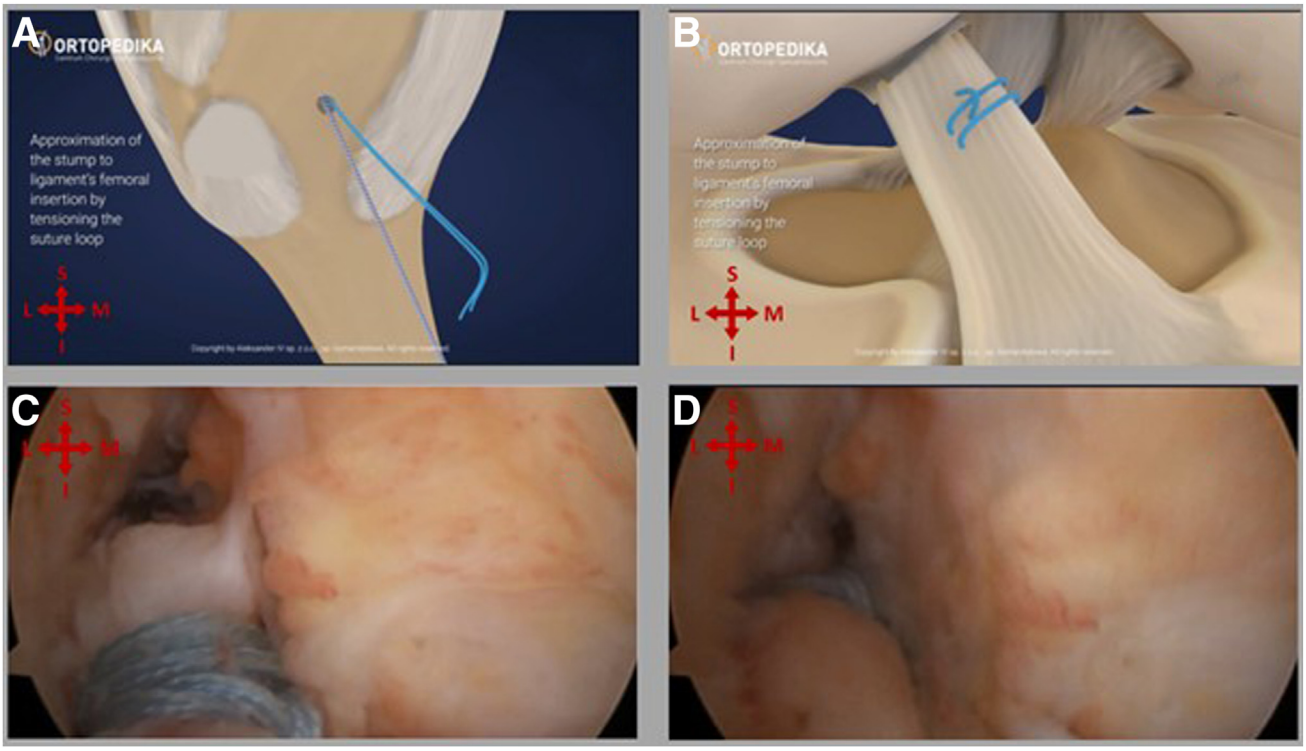

Fig 17. One of the steps of the arthroscopic primary ACL repair technique with polyester suture tape augmentation. (A-D) View from the middle side of the knee. After the cortical button is placed, the ACL portions are approximated. This is achieved by tensioning the ACL suture (light blue in A and B). (C, D) The approximation should be controlled by arthroscopic visualization. (ACL, anterior cruciate ligament.)

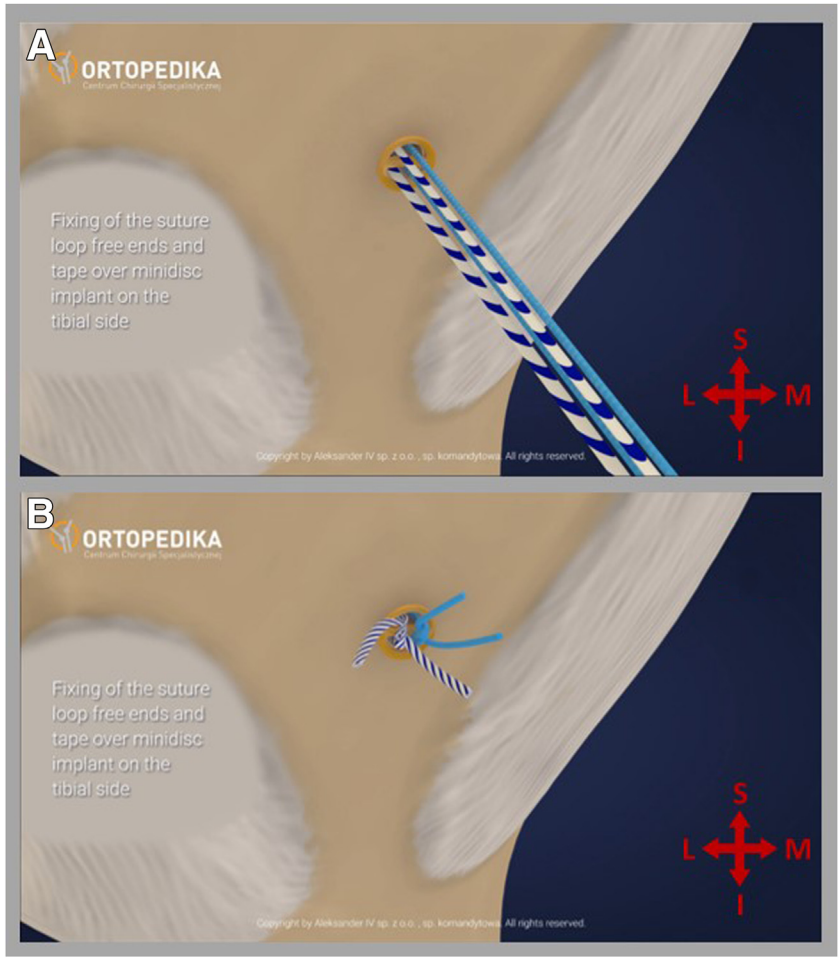

Fig 18. One of the steps of the arthroscopic primary ACL repair technique with polyester suture tape augmentation. (A, B) View at the level of the external opening of the tibial canal from the medial side of the right knee. Both sutures are tensioned and fixed on the tibial button. After assessment of the ACL stability, the instrumentation can be pulled out and the portal closed. (ACL, anterior cruciate ligament.)

interests or personal relationships that could have appeared to influence the work reported in this paper.

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