

The Femoral Sulcus Deepening Trochleoplasty of Lyon



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Abstract: The sulcus deepening trochleoplasty procedure has been described for the management of patellofemoral instability in patients with severe trochlear dysplasia. Here, we describe the updated Lyon sulcus deepening trochleoplasty technique. This technique with a stepwise approach allows one to prepare the trochlea, remove the subchondral bone, osteotomize the articular surface, and fix the facets with 3 anchors while minimizing the risk of complications.

Trochlear dysplasia has been shown to be the first risk factor for patella–femoral instability.^{1,2} This condition is characterized by a modified trochlear shape and an increased overhang of the groove relative to the anterior femoral cortex in high grade trochlear dysplasia. The trochleoplasty is a surgical correction of the trochlear groove shape with the aim of preventing recurrent patellar dislocations.

Three surgical techniques have been proposed to correct an abnormally shaped trochlea: the lateral wedge augmentation trochleoplasty (LWAT), the recession trochleoplasty (RT), and the deepening trochleoplasty (DT). The original techniques have undergone many modifications since their first descriptions. Unlike the LWAT and RT, which modify, respectively, the shape or the prominence, the aim of DT is to alter both features.

The LWAT was developed by Albee in 1915.³ This technique, performed with a lateral opening-wedge osteotomy and bone grafting, has been gradually replaced. The main concern with this procedure is the greater joint reaction force, due to the elevated lateral facet, with an increased risk of pain and secondary osteoarthritis.⁴

The RT, described initially by Goutallier et al.⁵ and later modified by Beaufilet et al.,⁶ reduces the prominence without changing the groove's shape and without any realignment.

The DT was first proposed by Bilton Pollard in 1890.⁷ It was then described by Masse et al. in 1978,⁸ who proposed to remove the subchondral bone and impact the trochlear cartilage with a punch.

The original technique was subsequently modified and standardized by Dejour in 1987, leading to 2 different procedures: the Lyon sulcus deepening trochleoplasty (or thick-flap procedure) and the “Bereiter” deepening trochleoplasty (or thin-flap procedure). The principal difference between the 2 lies in the preservation of cartilage.

In 1990, Dejour et al.⁹ proposed to add an osteotomy of both femoral condyles to create a V-shaped trochlear groove. This procedure was slightly changed by the senior author in 2010,¹⁰ with the addition of the groove lateralization for a “proximal realignment.”

Alternatively, in 1994, after visiting Dejour, Bereiter and Gautier¹¹ developed a U-shaped DT technique. This technique has some technical adaptations to facilitate the procedure and doesn't need trochlear osteotomies to be performed. A burr is used to remove part of the subchondral bone, modifying the shape of the bony sulcus. The osteochondral flap is then depressed and

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The authors report the following potential conflicts of interest or sources of funding: D.H.D. reports royalties from Arthrex. Full ICMJE author disclosure forms are available for this article online, as [supplementary material](#).

Received October 10, 2022; accepted January 18, 2023.

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2212-6287/221336

<https://doi.org/10.1016/j.eats.2023.01.007>

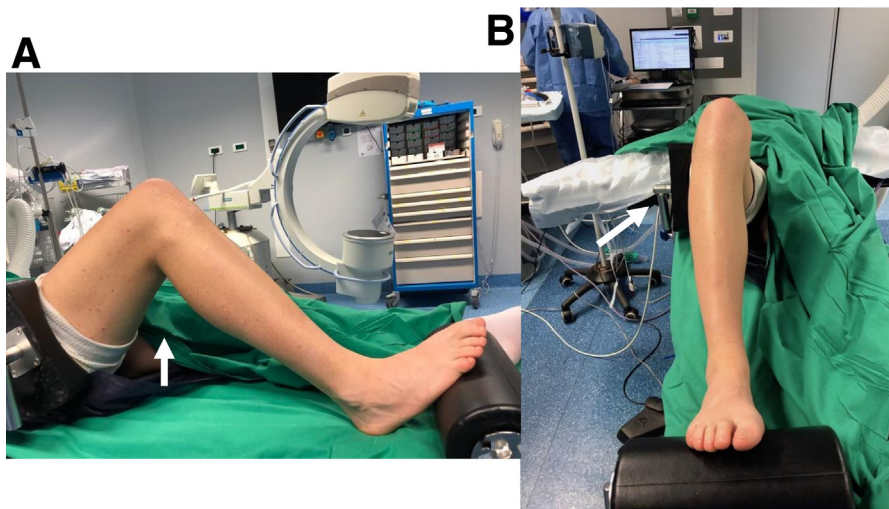


Fig 1. Patient position (right side). The patient is placed in a supine position on the operating table. Two supports, lateral and distal, are used to keep the knee in flexion. A high thigh tourniquet is placed to optimize the knee exposure during surgery. The knee is positioned at 90° of flexion.

fixed to the new bony sulcus with VICRYL tape. In 2010, Blønd and Schöttle¹² described how to perform this technique arthroscopically.

Since then, numerous deepening trochleoplasty techniques have been described, mixing or slightly modifying one of the two.¹³⁻¹⁶ DT, whatever the technique used, finds its rationale in modifying both the prominence and the shape of the trochlea. The technique we describe has been developed through the work of Pollard, Masse, Dejour, and the senior author (D.H.D.).

Table 1. Step-by-Step Details of the Technique

Step 1. Position and examination under anesthesia
- Sedation and regional anesthesia.
- Patient in supine position with 2 supports (lateral and distal).
Step 2. Surgical approach
- 10-cm midline skin incision.
- Transquadriceps tendon approach.
- Supratrochlear synovial membrane incision.
Step 3. Trochlear preparation
- The native groove, the medial and lateral facets lines are marked.
- The new planned groove line is marked.
Step 4. Prominence removal
- A strip of cortex is removed around the femorotrochlear osteochondral junction.
Step 5. Trochlear undersurface preparation
- Multiple convergent tunnels through the trochlear undersurface cancellous bone are performed.
- Bone bridges between the tunnels are removed.
Step 6. Trochlear surface osteotomies
- Cartilage incision with surgical scalpel blade No. 23 along the marked lines.
- Osteochondral cuts with a thin osteotome.
- Facets are rotated slightly to increase the sulcus angle.
Step 7. Fixation
- Fixation with 3 BioComposite Labral SwiveLock Anchors 3.5 mm.
Step 8. Closure
- Fulfill the gaps between the facets with bone.
- Supratrochlear synovium is closed.

Here, we describe the most updated Lyon sulcus deepening trochleoplasty, with tips and tricks and modification to the original technique.

Surgical Technique (With Video Illustration)

Indication for Surgery

The sulcus deepening trochleoplasty is indicated in patients with recurrent patellar dislocation, an abnormal patellar tracking, and high-grade trochlear dysplasia, classified as types B or D according to Dejour et al.¹⁷ with a trochlear prominence greater than 5 mm.¹⁸

Step 1: Position and Examination Under Anesthesia

Sedation and regional anesthesia are required to perform this procedure. The patient is positioned supine on the operating table (Fig 1, Table 1 and Video 1). Two supports, lateral and distal, are used to keep the knee in flexion. A high thigh tourniquet is placed to aid in visualization during surgery. Preprocedural prepping and draping is carried out through the entire lower extremity. Before the incision to be done, the medial tilt test and true patellar glide are assessed.

Step 2: Surgical Approach

The knee is positioned at 90° of flexion. Starting from 5 cm proximal to the upper patellar pole, a longitudinal 10 cm midline skin incision is performed (Fig 2). A transquadriceps tendon approach with medial parapatellar arthrotomy is performed, removing the periosteum from the medial middle third of the anterior surface of the patella, to prepare it for subsequent medial patellofemoral ligament (MPFL) reconstruction, which is carried out systematically.

This approach is therefore preferred, simplifying distal femoral exposure and MPFL reconstruction. No patellar

Fig 2. The skin incision (right side). Starting from 5 cm proximal to the upper patellar pole, a longitudinal 10-cm midline skin incision is performed.

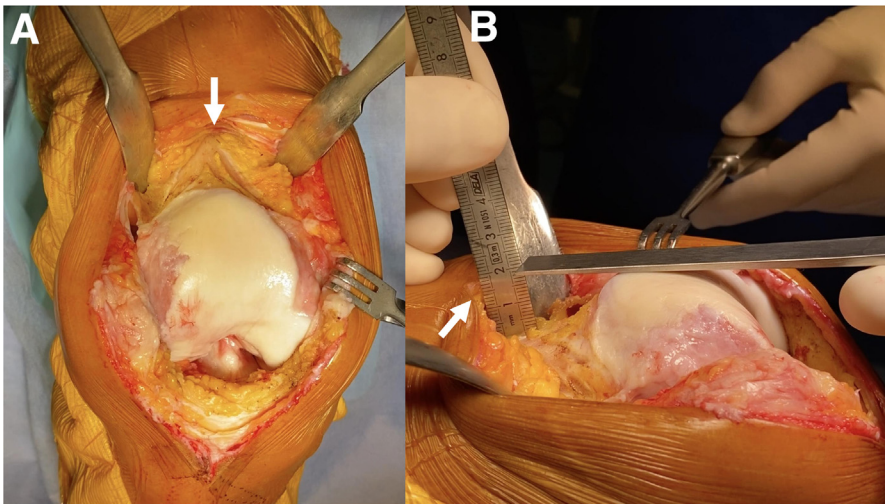
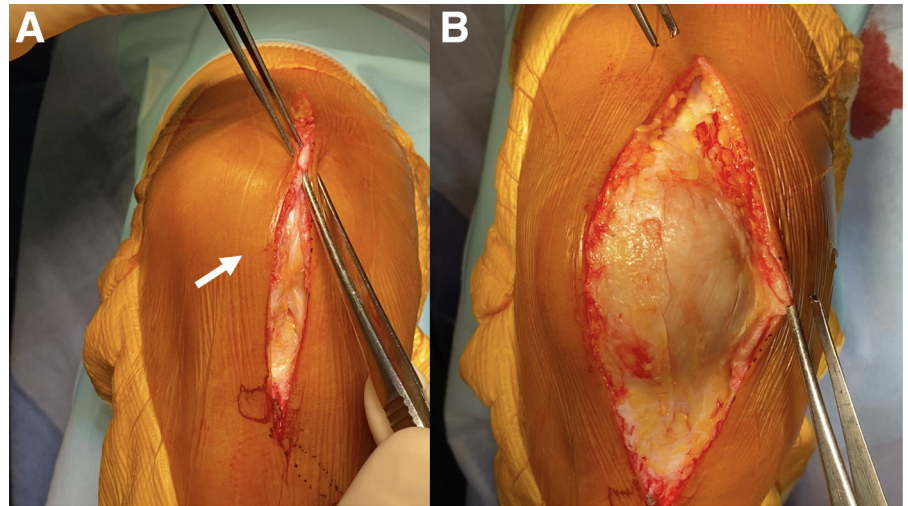


Fig 3. The supratrochlear synovial membrane is incised both longitudinally and along the proximal bone–cartilage transition of the distal femur (A) (right side). The trochlear dysplasia is then assessed, measuring the supratrochlear spur (B).

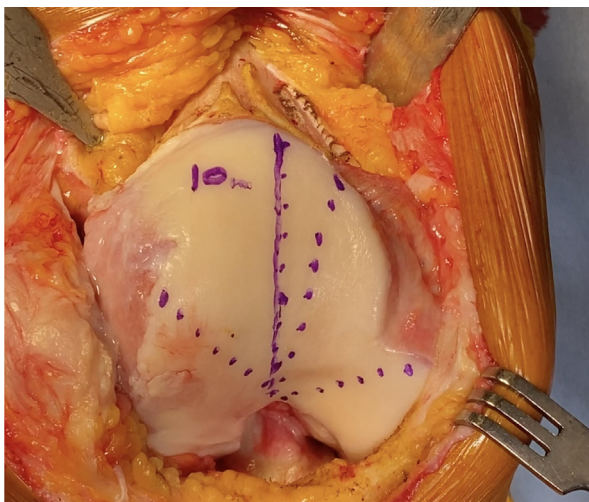


Fig 4. A sterile marking pen is then used to draw 3 dashed lines (representing the native groove and the lateral and medial facets limits) and a continuous line (representing the new planned groove) (right side).

eversion is needed to assess the articular cartilage surface of both the patella and trochlea.

The supratrochlear synovial membrane is incised both longitudinally and along the proximal bone–cartilage transition of the distal femur (Fig 3). A periosteal elevator is then used to reflect it from the anterior femoral cortex. The anterior surface of the distal femur is used as a landmark to determine the amount of bone to be removed, making the new groove flush with it. The trochlear dysplasia is then assessed, measuring the supratrochlear spur and often evaluating an hypoplastic medial facet.

Step 3: Trochlear Preparation

A sterile marking pen is then used to draw 3 dashed lines from the top of the notch, representing the native groove and the lateral and medial facets limits (Fig 4). Frequently in those cases, the native groove goes medially with an abnormal direction. The medial and

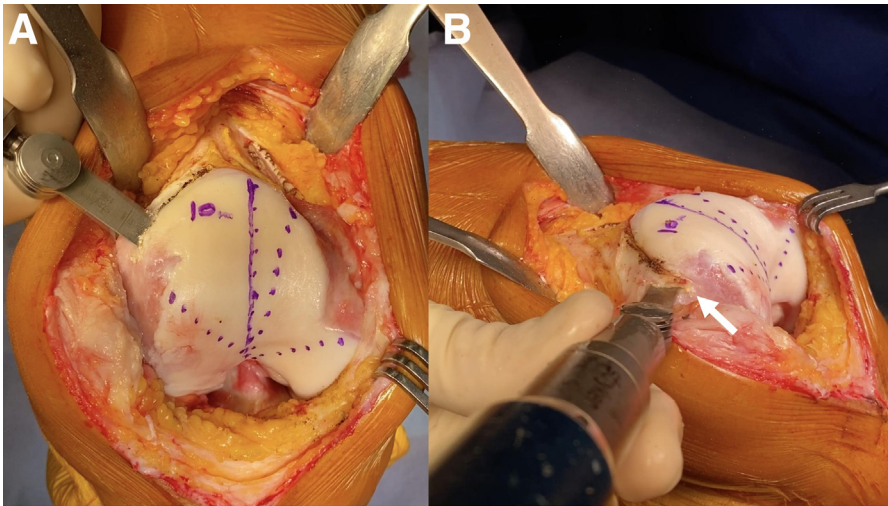


Fig 5. A strip of cortex is removed around the femorotrochlear osteochondral junction with an oscillating saw (A-B) (right side).

Fig 6. The cortical wedge of bone is removed (A) and its height is equal to prominence, cortex (B) (right side).

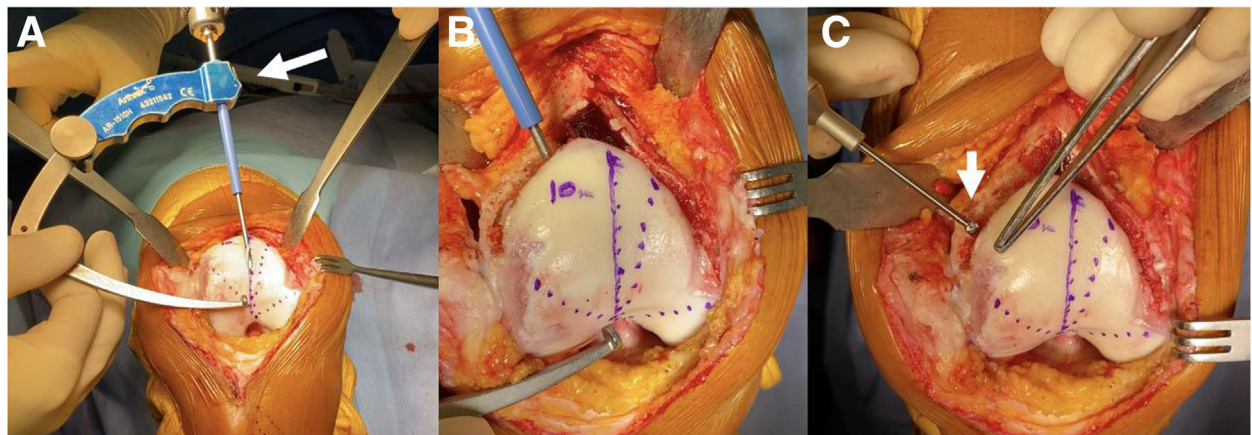
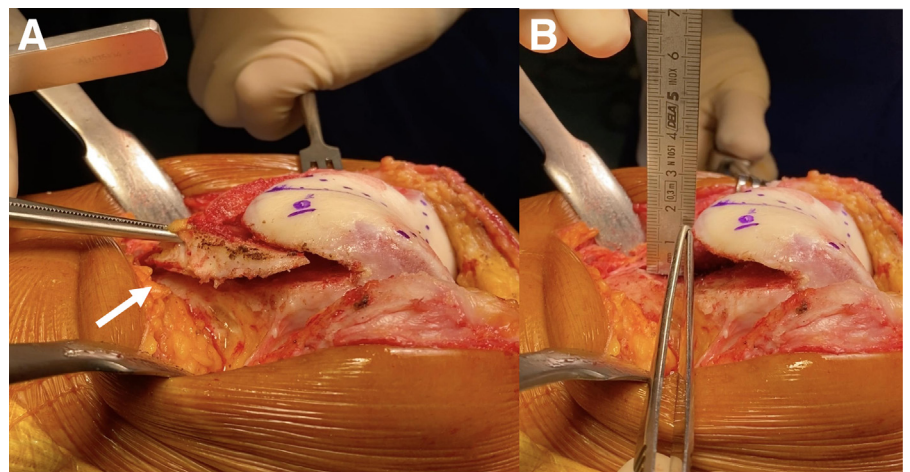


Fig 7. A special drill guide with a 5 mm off-set marking hook (A-B) and a 4-mm egg-shaped high-speed burr (C) are used to prepare the trochlear undersurface (right side). The guide is used to drill multiple convergent tunnels through the trochlear undersurface cancellous bone. The hook is placed at the top of the notch and the tunnels are drilled from proximal to distal. Then, the burr is used to remove the cancellous bone bridges between the tunnels in a proximal-to-distal fashion.

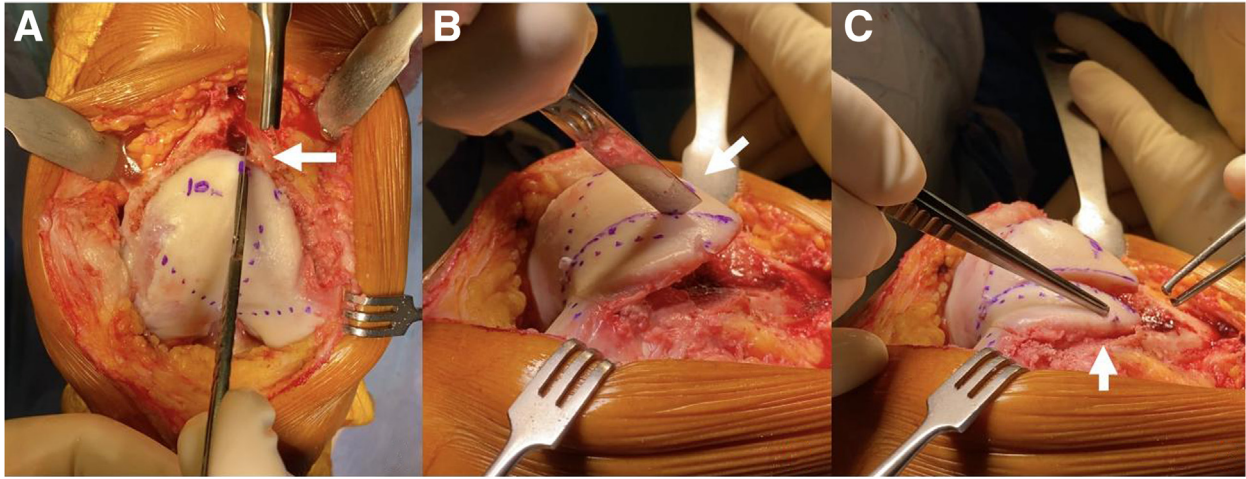


Fig 8. A surgical scalpel blade No. 23 is used for cartilage incision (A) (right side). Three osteochondral cuts along the marked lines are completed with a 45° oriented osteotome (B). With surgical forceps, the facets are pushed to check the trochlea to be flush with the anterior femoral cortex (C).

lateral dashed lines are drawn through the condylotrochlear grooves.

Then the new planned groove is marked with a continuous line in a more lateral position. The new sulcus should be aligned to the femoral anatomical axis and the resultant lateralized position might be adequate therefore to decrease a slightly elevated tibial tuberosity–trochlear groove distance without the need of addressing the tibial side. The distance between the native and new groove lines is then measured to assess the tibial tuberosity–trochlear groove modification.

Step 4: Prominence Removal

A strip of cortex is removed around the femorotrochlear osteochondral junction, either with an oscillating saw or with an osteotome (Fig 5). This cortical wedge of bone thickness is equal to the prominence height, allowing the new groove to be flush with the anterior femoral cortex (Fig 6). The spur removal exposes the trochlear undersurface cancellous bone.

Step 5: Trochlear Undersurface Preparation

A special drill guide with a 5-mm off-set marking hook (Arthrex, Naples, FL) is used to drill multiple convergent tunnels through the trochlear undersurface cancellous bone (Fig 7). The hook is placed at the top of the notch and the tunnels are drilled from proximal to distal. The offset guide enables to create an osteochondral flap of 5 mm, limiting the risk of cartilage damage and allowing for adequate healing. It is fundamental not to go beyond the medial and lateral marked line.

Then, the cancellous bone bridges between the tunnels are removed in a proximal-to-distal fashion with a

4-mm egg-shaped high-speed burr on a Total Performance System (Stryker, Kalamazoo, MI), while irrigating it with physiological saline. The undersurface bone removal is adapted to the shape and the amount of deepness needed. A greater amount of bone is removed in the center midline below the planned sulcus. This would make the new groove flush with the anterior femoral cortex. The cancellous bone is removed from the metaphyseal part of the femur to preserve the trochlear thickness.

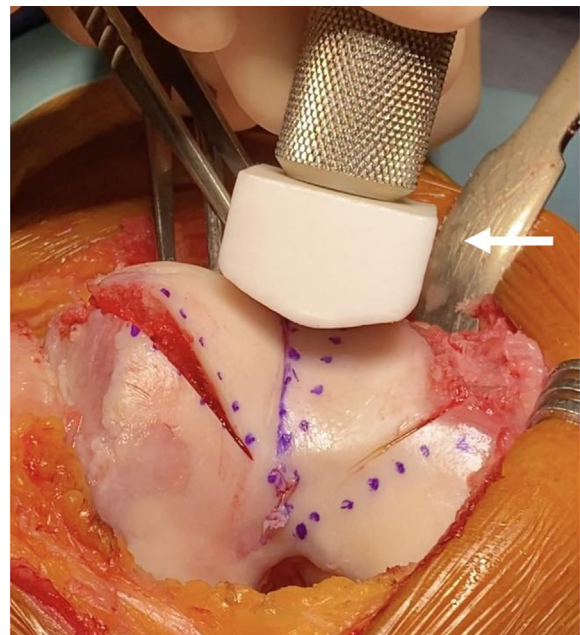


Fig 9. The 145° polyethylene pusher. Light pressure might be applied with a 145° polyethylene pusher to shape the 2 flaps (right side).

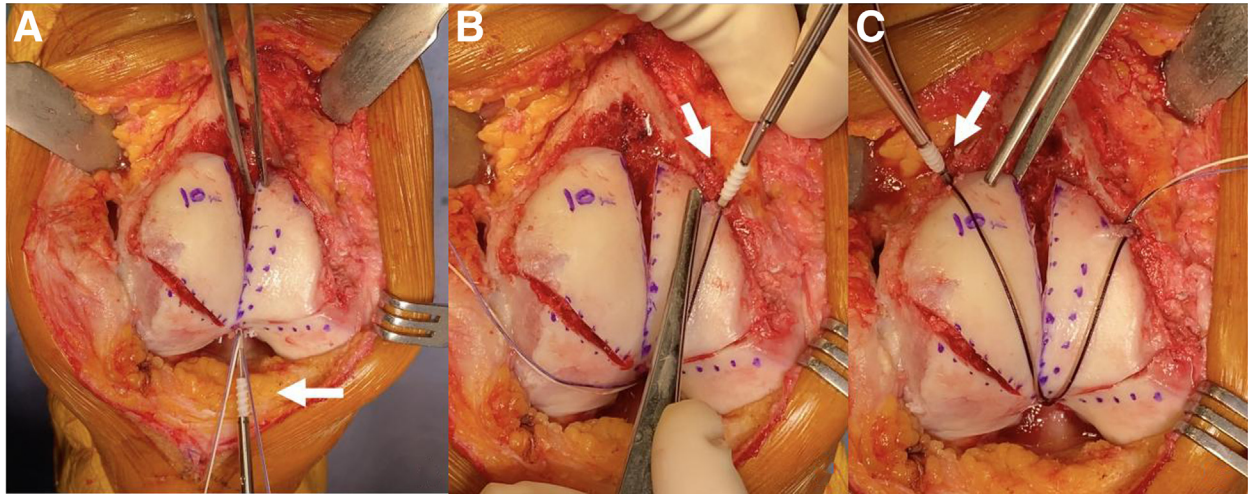


Fig 10. The fixation is performed with 3 BioComposite Labral SwiveLock Anchors, 3.5 mm (Arthrex) (A-C) (right side). The first anchor, loaded with 2 No. 2 VICRYL sutures (Ethicon, Cornelia, GA), is placed at the top of the notch. Each facet is compressed by a single pair of sutures, which are then tensioned and fixed with another BioComposite Labral SwiveLock Anchor, 3.5 mm at the proximal femorotrochlear margin.

Step 6: Trochlear Surface Osteotomies

At this point, the whole trochlea might be mobilized by a pusher depression. It is not flexible enough to be shaped completely without the risk of fracture. A surgical scalpel blade No. 23 is then used for cartilage incision and positioned on the marked new groove and lateral and medial margins (Fig 8). A bone tamp and mallet are used along with the scalpel to perform the incision.

Then, with a very thin osteotome oriented at 45° to trochlea, the 3 osteochondral cuts along the marked lines are completed from proximal to distal to allow greater molding. It is mandatory not to join the osteochondral cuts distally to keep a distal hinge.

With surgical forceps, the facets are pushed to check the trochlea to be flush with the anterior femoral

cortex. Both facets might be rotated slightly to increase the sulcus angle.

Light pressure might be applied with a 145° polyethylene pusher to shape the 2 flaps (Fig 9). Part of the bone removed at the beginning of the procedure might be inserted peripherally under the facets aiding the flaps elevated position. Once the groove is satisfactory and perfectly flush, the fixation might be performed.

Step 7: Fixation

The fixation is performed with 3 BioComposite Labral SwiveLock Anchors, 3.5 mm (Arthrex) (Fig 10). The first anchor, loaded with 2 No. 2 VICRYL sutures (Ethicon, Cornelia, GA) is placed at the top of the

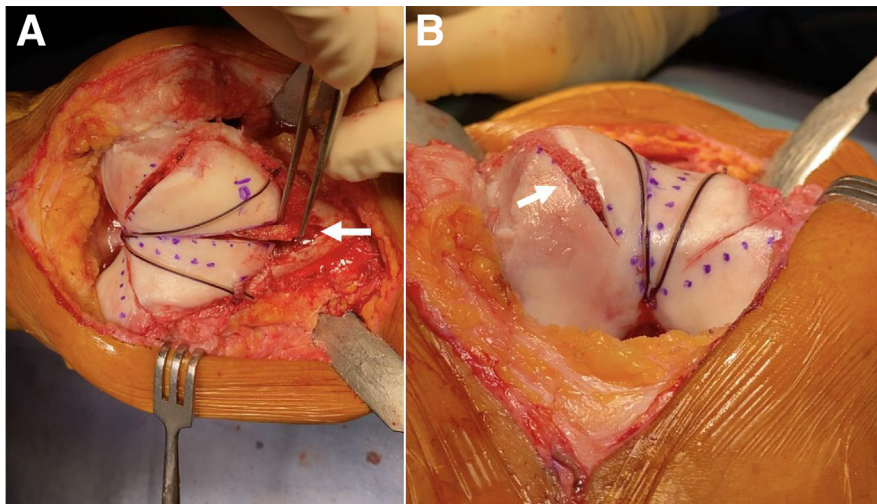


Fig 11. The 3 gaps between are fulfilled with pieces of bone taken from the strip of cortex harvested (A-B) (right side).

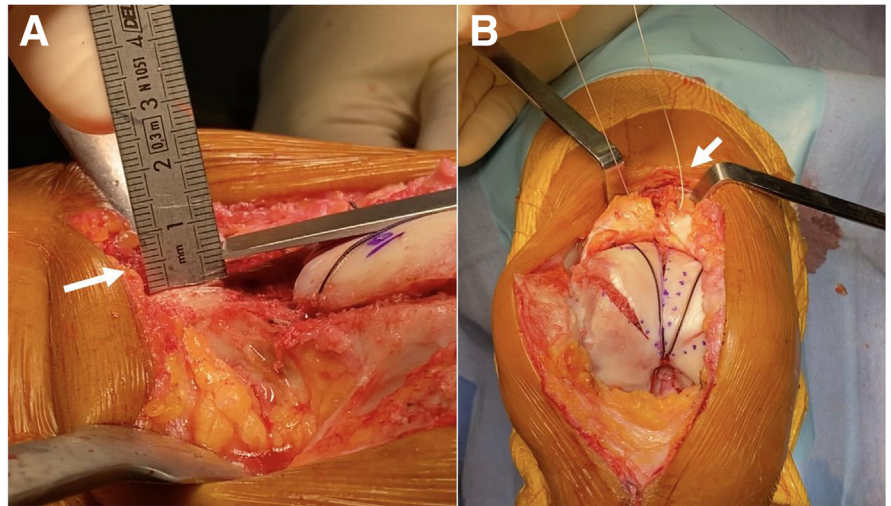


Fig 12. The height of the groove is then measured to evaluate the difference with the prominence assessed at the beginning of the procedure (A) (right side). The supratrochlear synovium is closed (B).

notch. Each facet is compressed by a single pair of sutures, which are then tensioned and fixed with another BioComposite Labral SwiveLock Anchor, 3.5 mm at the proximal femorotrochlear margin. The sutures should be placed without the risk of sliding into the midline osteotomy. The sutures should not be overtensioned as this would increase the risk of anchor pull-out. While placing the anchor, it might be helpful to achieve the right compression, to push the facet with a surgical forceps.

Step 8: Closure

The strip of cortex harvested is then used to create anterior based wedge pieces of bone to fulfill longitudinally the 3 gaps between the facets (Fig 11). The height of the groove is then measured to evaluate the difference with the prominence assessed at the beginning of the procedure (Fig 12). The supratrochlear

synovium is closed. The patellar tracking is then tested before the tibial tubercle osteotomy or MPFL to be performed. The MPFL is reconstructed systematically at the end of the procedure.

Discussion

The trochleoplasty has been shown to be effective in improving clinical outcomes in patients with objective patella instability associated with severe trochlear dysplasia.¹⁹ Furthermore, the redislocation rate is even lower when the procedure is carried out in combination with MPFL reconstruction.^{20,21}

The most recent meta-analysis by Leclerc et al.⁴ evaluated the clinical outcomes of 1,000 trochleoplasties, performed using different techniques. The rate of

Table 2. Pearls and Pitfalls

Pearls

- The supratrochlear synovial membrane should be incised and reflected to determine the amount of bone to be removed.
- Drawing the planned trochlear lines with a sterile marking pen to evaluate before performing the osteotomies the planned trochlear groove.
- The use of the offset guide enables to create an osteochondral flap of 5 mm, limiting the risk of cartilage damage.
- Additional subchondral bone should be removed from the metaphyseal part with the burr to decrease the prominence and mold the trochlear flaps.

Pitfalls

- Breakage of the osteochondral flap while performing the three osteotomies.
- Overtensioning of the sutures might lead to suture cut-through on the cartilage and anchor pull-out and cartilage.
- The osteotomy and slight twist of the osteochondral flap around the distal hinge might create a step, which needs to be removed with the surgical blade.

Table 3. Advantages and Disadvantages of the Femoral Sulcus Deepening Trochleoplasty of Lyon

Advantages

- This technique has shown to be the most effective in reducing recurrence.
- The surgeon has a complete view of the trochlear surface and this makes it easier to modify the shape in very dysplastic trochlae.
- The same anterior approach is used for MPFL reconstruction.
- Removing the undersurface strip of cortex with an oscillating saw is less time-consuming than performing it entirely with a burr.
- Leaving 5 mm of subchondral bone below the articular surface makes it a less-aggressive procedure relative to the cartilage layer.
- Performing 3 osteotomies enables a better reshaping of the trochlear groove.

Disadvantages

- The described technique is not minimally invasive, as it requires a 5- to 10-cm incision.
- Osteochondral flaps with a thickness of 5 mm might be more difficult to mold.
- A split of the trochlear cartilage is required to create the new groove.
- The notch anchor required articular cartilage violation.

MPFL, medial patellofemoral ligament.

recurrent dislocation, instability without dislocation, patellofemoral (PF) osteoarthritis, stiffness, and need for subsequent surgery were respectively: 2.4%, 14%, 27%, 7%, and 17%.

The sulcus deepening trochleoplasty has several advantages compared with the other techniques. It has shown to be the most effective in reducing recurrence, with a rate of 0.28%.^{4,22} Leaving 5 mm of subchondral bone below the articular surface makes it a less-aggressive procedure relative to the cartilage layer. Performing 3 osteotomies enables a better reshaping of the trochlear groove. Pearls and pitfalls and advantages and disadvantages are, respectively, described in Table 2 and Table 3.

Davies et al.²³ reviewed the outcomes of 702 patients undergoing specifically a sulcus-deepening trochleoplasty. The rate of dislocation and persistent apprehension test ranged, respectively, between 0% and 8% and 0% and 29%. Furthermore, up to 83% of patients were able to return to sport.

The results of deepening trochleoplasty might improve over time and beyond 1 year of follow-up. This would clarify the doubts of patients desiring to have a reliable prediction of the postoperative course.²⁴

Controversial is whether this procedure also should be indicated for patients with severe trochlea dysplasia but no history of dislocations. Zimmermann et al.²⁵ treated 15 patients with severe trochlear dysplasia and chronic PF pain with deepening trochleoplasty. The authors showed a reduced pain and improved clinical outcomes in this group of patients. The sulcus deepening trochleoplasty is a technically demanding procedure that has been feared and avoided for long time. The indications previously highlighted might change in the future, including also patients with severe trochlear dysplasia without any history of lateral patellar dislocation.

It reliably protects against recurrent patellar instability, leading to good postoperative clinical outcomes. However, it might not reduce the development of PF osteoarthritis and might lead to residual pain and range of motion limitation.

This article describes a stepwise approach to prepare the trochlea, remove the subchondral bone, osteotomize the articular surface, and fix the facets with 3 anchors while minimizing the risk of complications.

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