Technical Note

Standard Versus Dysplastic Inlay Implant for Patellofemoral Arthroplasty: Surgical Technique and Decision-Making

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Abstract: Patellofemoral arthroplasty (PFA) has emerged as an alternative bone-preserving surgical option for treating isolated symptomatic patellofemoral osteoarthritis that better replicates the natural knee kinematics compared with total knee arthroplasty. Achieving successful outcomes in PFA relies on meticulous patient selection, proper surgical technique, and appropriate implant choice and placement. Recent advancements in inlay trochlea implants, allowing for customized and anatomic joint line reconstruction with less bone resection, have demonstrated significant improvements in functional outcome scores and pain relief. This Technical Note aims to provide insights into the surgical technique of PFA with inlay implants, highlighting key considerations and potential challenges. It also assists surgeons in making informed decisions regarding the choice between standard and dysplastic inlay implants, while suggesting concurrent procedures to optimize tracking and overall outcomes.

Isolated patellofemoral osteoarthritis (PFOA) affects approximately 10% of individuals over 40 years old, with a higher occurrence in women compared with men. Among individuals aged 55 years and older, PFOA affects 2% to 11% of men and 8% to 24% of women.[1,2] PFOA can arise from various factors, including malalignment (such as abnormal tilt, Q angle, and torsion), instability, trauma, inflammatory arthritis, obesity, and osteoarthritis.[1-4] Trochlear dysplasia is also a strong risk factor for isolated PFOA, with the degree of arthritis significantly correlating with the degree of dysplasia.[5]

The initial approach to managing PFOA involves nonoperative interventions, such as physical therapy, bracing, weight loss, injections, and activity modification. When conservative treatments prove ineffective, surgical interventions become necessary. Joint-preserving procedures, including arthroscopic releases, chondroplasty debridement, microfracture, cartilage restoration procedures, and tibial tubercle osteotomy, are commonly employed.[6] While total knee arthroplasty (TKA) has conventionally been considered the "gold standard" for end-stage osteoarthritis, it may not be ideal for patients with isolated PFOA. Instead, patellofemoral arthroplasty (PFA) has emerged as an alternative bone-preserving surgical option that better replicates the natural knee kinematics compared with TKA, leading to improved functional outcomes and minimizing the risk of complications associated with more extensive joint replacement procedures.[7] Furthermore, PFA offers the potential for a more rapid recovery, reduced postoperative pain, and improved patient satisfaction.[8]

Over the years, surgical techniques and prosthetic designs for PFA have evolved.[7,9] First-generation "inlay" implants involved implanting the trochlear component flush with the surrounding cartilage, after creating a bone bed within the trochlea, while second-generation "onlay" designs replaced the entire anterior compartment. Initially, onlay designs were favored due to better outcomes, but the introduction of a new-

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generation inlay design offered promising advantages.[9] The new inlay design better maintains the natural biomechanics of the joint and allows personalized and anatomic trochlear resurfacing, reducing complications, improving stability, preserving soft tissue tension, and minimizing overstuffing.[9-14]

After meticulous patient selection, the crux of PFA success lies in the accurate choice of prosthesis and the precise execution of surgical procedures, especially in cases where trochlear dysplasia is present.[1] In this Technical Note, we provide insights on the proper technique for proper inlay implant positioning and describe the intraoperative parameters to guide the surgeon in selecting and positioning standard versus dysplastic inlay implants.

Technique

Indications and Contraindications

This technique is indicated for patients presenting with isolated PFOA with or without trochlear dysplasia (Table 1). Additionally, this system is suitable for patients with a history of patellar dislocation or patellar fracture, as well as individuals who have experienced persistent pain, deformity, or dysfunction despite previous surgical interventions such as arthroscopy, tibial tubercle elevation, or lateral release. Certain absolute contraindications should be considered, including (1) nonlocalized defects; (2) inflammatory degenerative joint disease, including conditions such as rheumatoid arthritis, infection, sepsis, or osteomyelitis, which can interfere with the success of the procedure; and (3) known material sensitivity: individuals who have a documented sensitivity or allergy to the materials commonly employed in orthopaedic prosthetic devices or bone cements.[1,2]

Radiographic Evaluation

Radiographic evaluation included (1) a full-weightbearing long-leg standing anteroposterior x-ray, to determine the femorotibial angle of the extremity; (2) the Schuss or Rosenberg radiographic view,[15] to evaluate the joint line space; (3) a lateral non-weightbearing radiography of the knee at 30° of flexion, to measure the patellar height (Fig 1 A and B); (4) a Merchant view (skyline view with the knee flexed to 45°), to calculate the lateral patellar tilt and the severity of PFOA; and (5) magnetic resonance imaging (MRI) (Fig 1 C and D), which, together with the lateral x-ray, allowed to evaluate the trochlear dysplasia according to Dejour's classification.[16] Furthermore, in cases of severe dysplasia, it becomes crucial to measure the width of the trochlear groove, as the dysplastic inlay implant variant necessitates a minimum width of 43 mm for proper mediolateral positioning.

Table 1. Intraoperative Parameters for Standard and Dysplastic PFA

	Inlay PF Implant	
	Standard (HemiCAP^{Wave})	Dysplastic (HemiCap^{Kahuna})
Indication	Isolated symptomatic patellofemoral osteoarthritis with moderate trochlear dysplasia, after failed conservative treatment. Normal alignment and tibiofemoral joint space.	Isolated symptomatic patellofemoral osteoarthritis with severe trochlear dysplasia, after failed conservative treatment. Normal alignment and tibiofemoral joint space.
When one or the other?	Implant seats inlay perfect regarding upper trochlear groove.	■ If anterior bony bump appears over standard trial implant, proceed to extra anterior reaming for dysplastic inlay PF implant. ■ Also recommended in case of nondysplastic large femurs.
Objective	Restore original joint line. Implant seats inlay 0.5 mm under surrounding cartilage.	Metallic lateral built up to reconstruct the anatomic joint line. Implant seats inlay 0.5 mm under surrounding cartilage.
Imaging	■ X-ray: Rosenberg view: normal tibiofemoral joint space; lateral view: dysplasia type A, B, or C (Dejour's classification). ■ MRI: isolated patellofemoral arthritis grade IV ICRS.	■ X-Ray: Rosenberg view: normal tibiofemoral joint space; lateral view: dysplasia type D (Dejour's classification). ■ MRI: isolated patellofemoral arthritis grade IV ICRS.
Limit size factors	A minimum 35-mm trochlear width required.	A minimum 42-mm trochlear width required.
Trochlear component	■ 7/8.5/10/11.5-mm SI offset.* ■ 4/5-mm depth. ■ Cemented or noncemented.	■ 7/8.5/10-mm SI offset.* ■ 5-mm depth. Cemented or noncemented.
Patellar component	■ Anatomic: 25 × 9 mm; button: 30 × 7 mm; and Dom: 30 × 9 mm.	■ Anatomic: 25 × 9 mm; button: 30 × 7 mm; and Dom: 30 × 9 mm.
Reaming steps	Central + anterior + posterior reaming.	Central + anterior + posterior reaming (+ extra supratrochlear reaming).

ICRS, International Cartilage Repair Society; MRI, magnetic resonance imaging; PF, patellofemoral; SI, superior-to-inferior.

*SI offsets (trochlear groove curvature) are positive while medial-to-lateral offset (trochlear depth) values are negative. In addition, higher numbers indicates lower radius of curvature.

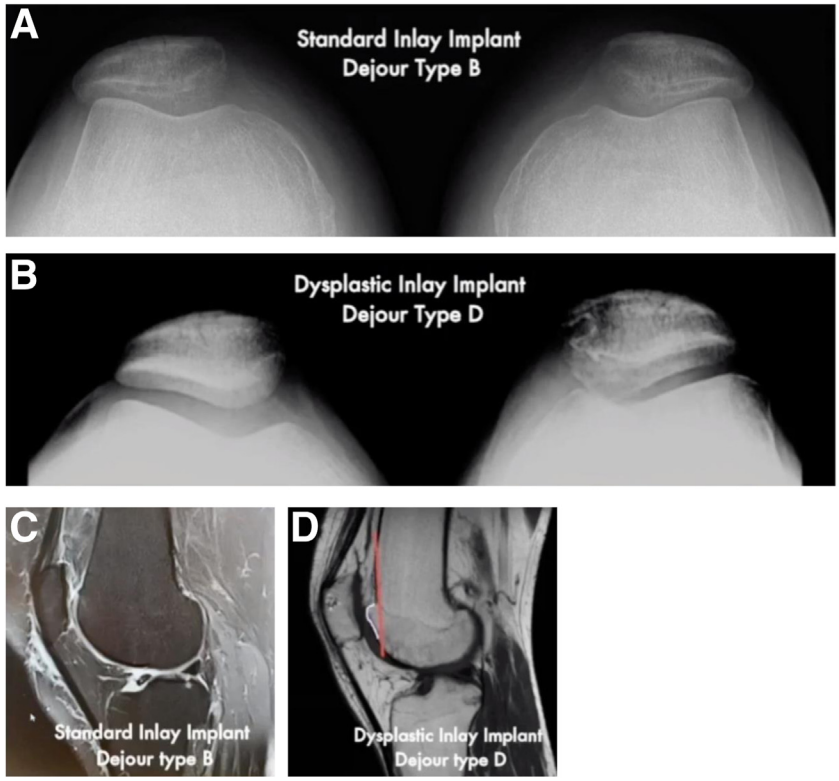

Fig 1. Lesion evaluation. X-ray axial view images (A, B, supine position) at a 30° flexion angle and magnetic resonance images (C, D, sagittal view) showing type B (A, C) and type D (B, D) dysplastic trochleas, according to Dejour's classification.

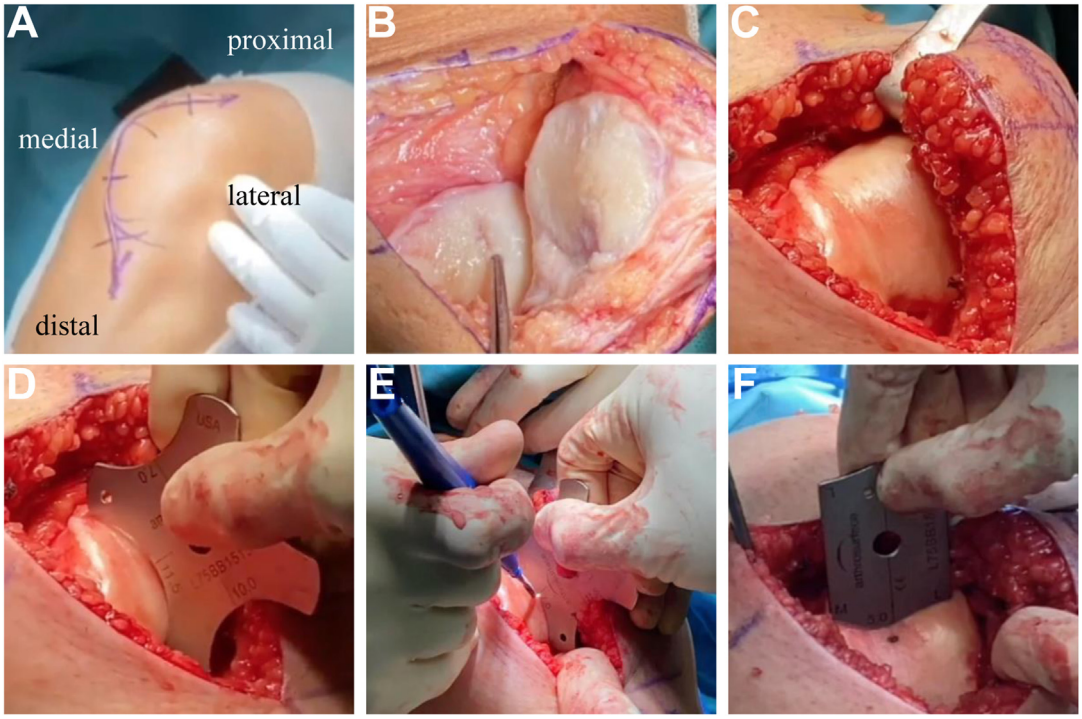

Fig 2. Lesion exploration and sizing. Images A to F depict a left knee. The patient is positioned in a supine position, and a medial parapatellar arthrotomy is performed (A). Once the knee is accessed, a thorough visual examination is conducted to confirm the presence of isolated patellofemoral osteoarthritis and assess any accompanying mirror lesion or trochlear dysplasia (B, corresponding to Dejour type B; C, corresponding to Dejour type D). The optimal implant option is determined by first measuring the superior-to-inferior offset of the trochlea with sizing templates (D). Subsequently, the trochlea's center is precisely marked using an electric scalpel (E), and the medial-to-lateral offset is measured with reference to this marked point (F).

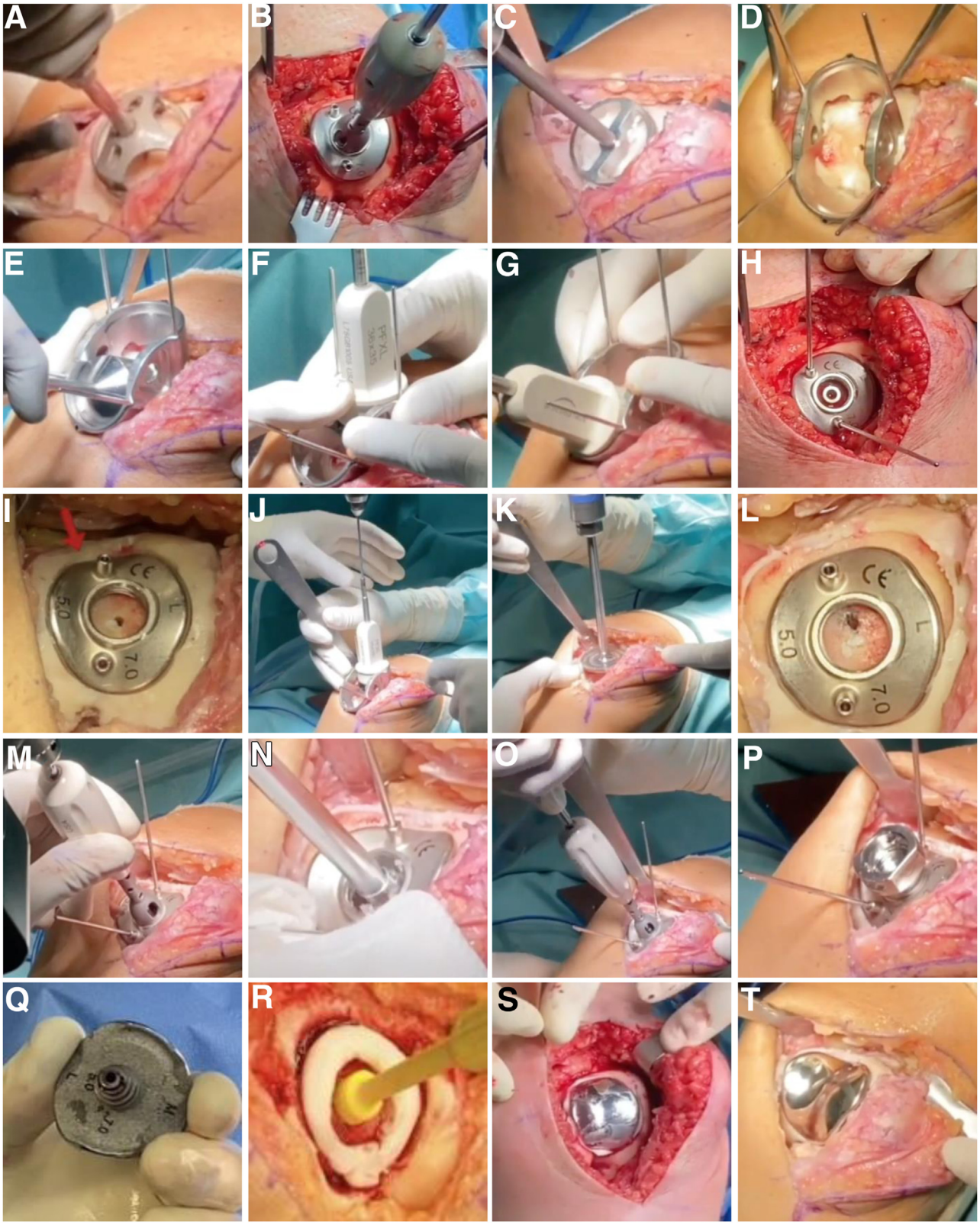

Fig 3. Trochlear implant positioning. Images A to T depict a left knee. To prepare the femoral implant bed, a working axis for instrumentation is established perpendicular to the center of the trochlear articular surface using the guide pin (A) and the drill guide (B). The central reamer is progressed along the guide pin until the etched mark on the side of the reamer is flush with the medial/lateral (C). The appropriate guide block is selected based on previous sizing, aligned according to the medial and lateral indicator laser marks, and secured onto the trochlear groove using 2.5-mm guide pins (D). Then, the circular scalpel is inserted in

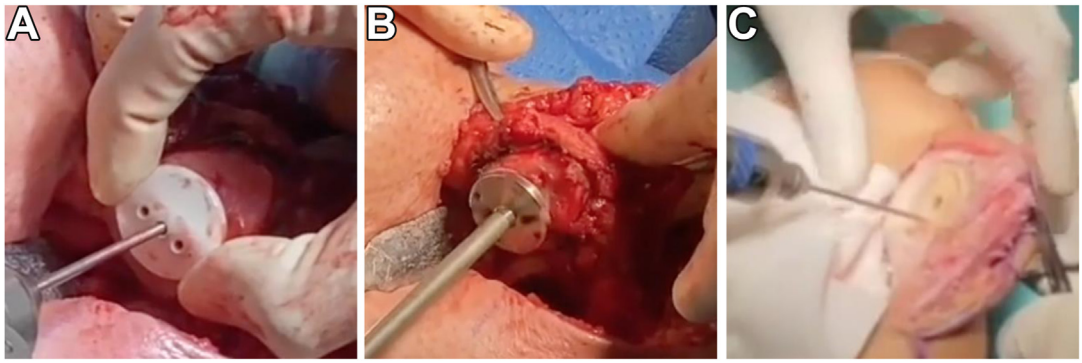

Fig 4. Patella implant positioning. For individuals with smaller knees, an anatomic implant version is recommended (A). Ensure proper positioning by reaming until the trial seats below the surrounding cartilage (B). Enhance cement fixation by drilling 1.5-mm holes (C).

Implants and Surgical Technique

Details of the technique are shown in Video 1 and Figures 2 to 4. Additionally, Table 2 provides a comprehensive list of tips for performing PFA with inlay implants, both with and without trochlear dysplasia.

The general procedure of this technique has been previously described by others.[10,11,17] The inlay standard and dysplastic trochlear and patellar components used here were the HemiCAP PF Wave and Kahuna system implants (Arthrosurface), respectively. The trochlear components are available with different superior-to-inferior (SI) and medial-to-lateral (ML) offset curvatures (Table 1), while the patellar component allows to choose among 3 different shape options.

The choice of surgical approach for PFA depends on various factors, such as the surgeon's preference, the patient's surgical history, and the underlying pathology. The patient is positioned in a supine position, with a thigh tourniquet, and a longitudinal incision is made over the patella (Fig 2A). The subcutaneous tissue and fascia are reflected, allowing access to the patella. According to the surgeon's preference, medial or lateral arthrotomy is performed and the patella is everted. Once the knee is accessed, a thorough visual examination is conducted to confirm the presence of isolated PFOA and assess any accompanying mirror lesion or trochlear dysplasia (Fig 2 B and C). To determine the optimal implant option that will be used later in the procedure, the SI (Fig 2D) and ML (Fig 2F) offsets of the trochlea are measured with sizing templates (tips 1 and 2), and the trochlea's center is marked using an electric scalpel (Fig 2E).

To prepare the femoral implant bed, a working axis for instrumentation is first established perpendicular to the center of the trochlear articular surface using the guide pin (Fig 3A) and the drill guide (Fig 3B, tips 3 and 4). Once the guide pin is positioned, the central reamer (either the 4- or 5-mm version depending on the type of implant) is progressed along the guide pin until the etched mark on the side of the reamer is flush with the medial/lateral facets (Fig 3C, tip 5). Choose the appropriate guide block based on the offset determined from the SI mapping point, aligning it according to the medial and lateral indicator laser marks, and secure it onto the trochlear groove using 2.5-mm guide pins (Fig 3D, tips 6 and 7). Then, insert the circular scalpel into the upper/lower bores of the guide block and onto the articular surface (Fig 3E). Use a twisting motion to advance and create a cut through the articular surface, creating healthy cartilage margins and defining the area where the implant will settle. Following that, proceed to the anteroposterior reaming. Place the outer reamer into the superior guide block bore (Fig 3F), and gradually advance the reamer into the bone until the depth mark on the reamer shaft is reached. Repeat the reaming process using the lower bore of the guide block (Fig 3G), and then proceed with the edge reamer (tip 8). To ensure congruity of the implant and to

the guide block and advanced using a twisting motion to create healthy cartilage margins (E). Following that, proceed to the anteroposterior reaming (F and G). To ensure congruity of the implant and to accommodate the taper post, a suitable sizing trial is assembled onto the trial handle and placed into the previously reamed area, ensuring that the sizing trial fits properly (H). If a bony-cartilage protrusion is present (I, red arrow), it is advisable to consider a dysplastic implant and proceed to an extra reaming step (J, K). Extra bony-cartilage resection can be observed in (L). The appropriate trial implant is selected and securely fastened with 2 short pins, followed by preparing the taper post bed using the drill guide (M), the step drill (N), and the tap (O). Verification of correct positioning using a placement gauge (P). In cases involving severe osteoporotic patients, preassembling the implants on the table is recommended (Q). Final implantation involves a noncemented approach for good bone quality, or surface cement application (R) for osteoporotic patients. Apply firm mallet strikes to the impactor until the femoral component is fully seated (S, standard implant; T, dysplastic implant).

Table 2. Tips for Patellofemoral Arthroplasty Using Inlay Implants With and Without Trochlear Dysplasia

Stage	Tip	Recommendation
SI sizing	1	To ensure proper SI sizing, position the template along the trochlear groove, ensuring continuous contact at both the upper and lower ends, as well as in the central part, which may exhibit less contact due to a higher likelihood of damage, and ensuring that the template is positioned at least 3 mm above the intercondylar notch.
		Severe trochlear dysplasia: the SI offset measurement should be taken on the lateral condyle.
ML sizing	2	Trochlear dysplasia: the ML offset is set at 5 mm, due to the increased thickness of the dysplastic implant, which necessitates a minimum of 43 mm for proper ML seating. If there is uncertainty regarding depth sizing, it is advisable to proceed with the understanding that these steps may need to be repeated if we initially choose a depth of 4 mm and ultimately require the dysplastic version.
Drilling	3	Advance the guide pin into the bone, ensuring that the drill guide is correctly positioned on the curved surface in such a way that all 4 points of contact are established on the articular surface.
Working axis	4	As an alternative technique to positioning the guide pin, once the joint measurement has been made, we can select the corresponding trial implant and position it, using the threaded knob to center it at the medial-lateral level while ensuring a minimum distance of 3 mm above the femoral notch. We place then the guide pin through the trial implant and the pilot drill. The final position of the pin usually coincides with the mark previously made with the electric scalpel. This option of the trial implant assembly can simply be used as a double check of the correct positioning of the future implant on the femur.
Central reaming	5	Exceed the etched mark of the reamer to ensure the "inlay" position of the implant.
Guide block positioning	6a	In case of SI swinging, choose a lower curvature radius guide block (i.e., higher number). In case of ML swinging (instability), generally caused by the proximal and distal fins of the guide block touching the prepared surface before the body of the guide block is correctly settled in the central part, select a guide block with a higher curvature (i.e., lower number).
		Trochlear dysplasia: in cases where the trochlea is dysplastic (flat or dome-shaped trochlea), the guide block may not fit perfectly against the reamed area (it could happen that even the block with the higher radius of curvature [number 7] remains unstable at the medial-lateral level). To address this, use an osteotome to create slots in the bone that can accommodate the proximal and distal fins of the guide block. By creating these slots, the guide block will be able to sit flush against the reamed area.
	6b	Alternatively, gently mallet the proximal fin of the guide block until the guide block feet penetrate into the trochlea.
	6c	After positioning the guide block on the reamed area, it is crucial to reconfirm the block's depth level. To achieve this, verify that the 4/5-mm indicator laser mark on the central body of the guide block is exceeded significantly. This ensures that the implant is positioned correctly for an inlay placement.
Guide block securing	7	Ensuring a secure position for the guide block onto the femur is crucial, and it should be firmly fastened using 4 guide pins, as opposed to the 2 pins mentioned in some techniques. This becomes particularly important when dealing with osteoporotic bone, as it effectively prevents instability and guarantees precise reaming throughout the procedure.
Upper/lower reaming	8	Due to the convergent insertion of the guide pins, it is highly recommended to apply firm downward pressure on the guide block while reaming to prevent any unwanted ejection or improper movement of the guide block.
		Trochlear dysplasia: for dysplastic trochlea, an extra reaming stage is necessary. Place the guide pin into the superior position using the outer reamer in the guide bushing. Remove the guide block and proceed to ream over the guide pin using the Kahuna reamer until the reamer bottoms out on the central part of the previously reamed surface. This technique facilitates proper seating of the dysplastic inlay implant, which replicates the lateral wing of the anatomic femoral trochlea. As a result, it reconstructs the femoral groove to optimize femoral-patellar tracking.
Sizing trial positioning	9	Assessing the presence of bony protrusions in the adjacent supratrochlear area is vital before placing the implant. If such a bump is found, it is recommended to opt for a dysplastic implant. If the central reaming was not initially set to a depth of 5 mm, which is the requirement for the dysplastic implant, it is necessary to repeat all steps with a depth of 5 mm.
Sizing trial securing	10	Insert the pins only up to the laser mark to prevent them from destabilizing the implant and from interacting with the drilling process.

Stage	Tip	Recommendation
Step drilling	11	It is advisable to check the advancement of the step drill versus the sizing trial, ending the drilling when the proximal limit of the step drill fins is flush with the last thread gap of the trial implant, the one closest to the trochlear bone.
Taper post implantation	12	When screwing the taper post, the audible indication of the bone yielding to the screw is a characteristic sound that confirms the correct execution of the procedure (refer to Video 1).
Inserting placement gauge	13	To ensure the taper post is correctly positioned for engaging the implant femoral component, check the proper depth of the taper post by inserting the placement gauge into the sizing trial.
Lavage	14	Remove any bone particles around the taper post and lavage thoroughly.
Cementation	15	Typically, a small amount of bone cement is applied to the trochlear reamed surface, except in cases where the patient is young (usually male) and presumed to have good bone quality (Fig 1D). Direct application of cement to the implant is not advised as it masks the lateral etched mark, potentially compromising the accurate final orientation of the implant.
Taper post preassemble	16	In situations where osteoporotic bone is suspected and may potentially lead to taper post instability, it is recommended to preassemble the threadless stud with the implant femoral component on the surgical table. Ensure the protection of the articular face of the implant femoral component by gently impacting with a mallet to properly seat the morse taper of the threadless stud onto the implant femoral component. Proceed to cementation as in tip 15.
Patellar implant	17	Based on our experience, the anatomic patellar implant is commonly used in females with smaller knees. When employing the anatomic patella, it is crucial to align it with the patella crest. Prior to reaming, we highly recommend marking the alignment. Additionally, it is essential to ensure that reaming is carried out parallel to the articular surface of the patella, continuously verifying the progress with the trial to achieve an inlay of at least 70% of the implant.

ML, medial-to-lateral; SI, superior-to-inferior.

accommodate the taper post, a sizing trial that corresponds to the offset profile specified during sizing is assembled onto the trial handle and placed into the previously reamed area (Fig 3H). Ensure that the sizing trial fits properly, with all margins congruent or slightly recessed to the edge of the surrounding articular surface. If needed, trim the transition areas between the reamed surfaces to ensure the sizing trial is fully seated. In this sense, it is crucial to assess the presence of bony protrusions in the adjacent supratrochlear area where the implant is intended to be placed. In case such a bump is present (Fig 3I), it is advisable to consider a dysplastic implant and proceed to an extra reaming step (Fig 3 J-L, tip 9). Fix the sizing trial in place with 2 pins while keeping it firmly positioned (tip 10). The pilot drill is then inserted through the center of the guide handle and advanced up to the laser mark (Fig 3M). Progress the step drill over the pilot drill (Fig 3N, tip 11). Then remove the step drill and advance the tap by applying only a 360° turn (Fig 3O). Remove the tap and pilot drill. Verify the correct positioning using a placement gauge (Fig 3P). Put the taper post into the morse taper of the trial handle and secure it to the sizing trial. Then, pass the hex driver through the trial handle and gradually advance the taper post until the stop on the hex driver shaft makes contact with the rear of the trial handle (tips 12 to 14). Position the femoral component ensuring that the medial etch mark faces the medial aspect of the knee and the lateral mark faces the lateral plane (Fig 3Q, tip 15). Insert it securely into the taper of the taper post (Fig 1F). Apply firm mallet strikes to the impactor until the femoral component is fully seated (Fig 3 S and T, tip 16). Proceed then to the patella component as usual, choosing the proper patellar implant among the different options (button, anatomic, or dome) (Fig 4 A-C, tip 17).

Postoperative and Rehabilitation Protocol

Postoperative x-ray examination is necessary (Fig 5 A and B). During the first and second weeks following surgery, it is advised to engage in passive range of motion exercises, starting the first day after the operation. The extent of weightbearing can be adjusted based on symptoms such as pain and joint effusion. Partial weightbearing of up to 20 kg is permitted, with the use of a brace in full extension. Isometric quad exercises should also be performed. In the third and fourth weeks, weightbearing can be gradually increased by 20 kg per week. A physiotherapist-designed protocol should be followed to enhance the strength of the quadriceps and hamstrings. By the sixth week, full active range of motion can be achieved. However, it is important to avoid high-impact sports at this stage. Instead, activities like cycling and swimming are recommended. After 6 months, patients can gradually resume their normal daily activities.

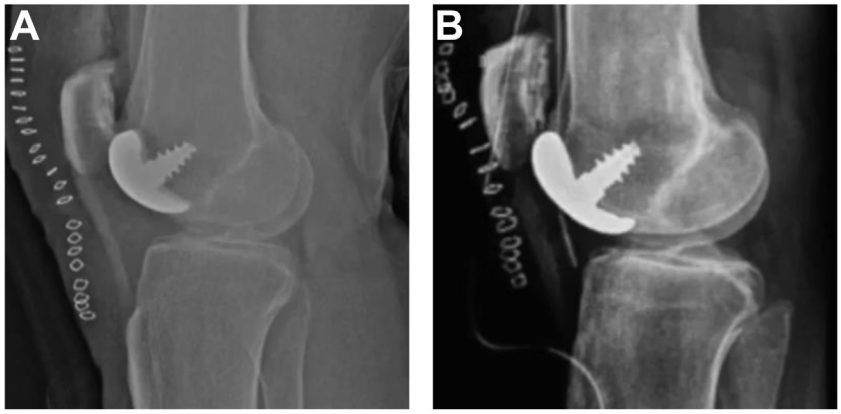

Fig 5. Postoperative lateral x-rays are acquired to verify the positioning of both standard (A) and dysplastic (B) inlay implants.

Discussion

Successful outcomes in PFA rely on meticulous patient selection, proper surgical technique, and appropriate implant choice and positioning.[1] When it comes to implant options, the use of new-generation inlay implants facilitates joint line reconstruction with minimal bone resection.[9,17] With various implant curvatures and convexities available, they enable restoration of the unique articular surface geometry of both the femoral trochlear groove and the patella. This restoration creates a congruent pathway for smooth joint movement and ensures an anatomic fit, leading to enhanced performance.[18] This aspect is particularly important in cases of trochlear dysplasia, a commonly observed condition in PFA. In severe dysplastic cases, such as Dejour type D, larger design implants may be necessary to address the broad and shallow trochlear pathomorphology.[10] Furthermore, surgeons should also ensure a seamless transition from the native anatomy to the implant, which may involve resection or smoothing of a supratrochlear bump.[10] Additionally, for older patients with isolated PFOA undergoing PFA, considering cement-based fixation augmentation at the trochlear bone-implant interface can be beneficial.[10]

Intraoperatively, factors considered highly relevant and described in this technique include (1) accurate trochlear groove sizing, since this will conditionate the curvature and convexity of the implant and ultimately

Table 3. Advantages, Risks, and Limitations of Patellofemoral Arthroplasty Technique With Inlay Implants

Advantages of the Inlay vs Onlay Implants	
Bone preservation	The inlay implant contributes to bone preservation by minimizing the need to remove healthy bone tissue during the procedure.
Long-term stability	Theoretical advantages for implant stability are derived from the integration of prosthetic stability and fixation into the overall joint surface, contrasting with exposed onlay prosthetic devices.
Reduced joint wear	It helps reduce joint wear by more naturally replicating the biomechanics of the joint.
Minimization of overstuffing	Onlay implants have been associated with higher risk of overstuffing.
Advantages of having the option to choose between the standard and dysplastic inlay implant	
Customization	It allows for greater customization according to the specific needs of the patient and the complexity of the clinical situation.
Adaptability to anatomy	The availability of standard and dysplastic options facilitates adaptation to each patient's unique anatomy.
Improved outcomes	The ability to choose between different types of implants contributes to more satisfactory and precise results.
Risks/limitations based on femur size and the possibility of adapting the dysplastic implant	
Anatomic limitations	Femur size may impose limitations on implant selection, especially in cases where anatomy is atypical (dysplastic cases).
Need for detailed evaluation	The adaptability of the dysplastic implant requires a detailed evaluation of the patient's anatomy to avoid potential complications.
Preoperative considerations	Meticulous preoperative considerations are necessary to ensure the suitability and safety of adapting the dysplastic implant.
Considerations regarding other implant characteristics	
Material type	The choice of implant material and cementation technique can influence biocompatibility and long-term stability.
Healing process	Considerations about how the implant affects the healing process and integration with surrounding tissues.

the implant correct fit; (2) an adequate preparation of the femoral implant bed, taking into account the specific requirements of the dysplastic implant, which necessitates additional depth for mediolateral positioning and supratrochlear reaming; (3) taking precautions during drilling and reaming processes, particularly in cases of dysplasia or osteoporotic bones, being sure that this process is firmly secured (including the proper fixation of the guiding block and trial implant); and finally, (4) appropriately positioning and securing the taper post. Taken together, we believe that the technical tips provided in this Technical Note will assist surgeons in improving the success of PFA procedures, especially in cases of dysplastic trochlea. Table 3 includes a summary of the advantages, risks, and limitations of PFA technique with inlay implants.

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Disclosures

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