Patellar malalignment treatment in total knee arthroplasty

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Summary

The patella, with or without resurfacing, plays a fundamental role in the success of a total knee arthroplasty (TKA). Patellofemoral joint complications are due to problems related to the patient, to the surgical technique, or to the design of the components. Patellar tracking is influenced by several factors: a severe preoperative valgus, the presence of pre-existing patellofemoral dysplasia, the design of the femoral component, the surgical approach, the Q angle, the mechanical alignment of the limb, the tightness of the lateral retinaculum, the positioning of the patellar component in the proximal-distal and medial-lateral directions, the patella height, the patella (native or resurfaced) thickness, the size of the femoral and the tibial components, and the alignment and rotation of the components. Several factors are crucial to prevent patellar maltracking in TKA: the use of an anatomical femoral component, a meticulous surgical technique, careful dynamic intraoperative assessment of patellar tracking, and, if necessary, the achievement of an adequate lateral release.

Key-words: *patellofemoral joint, total knee arthroplasty, alignment*

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Introduction

The patella, with or without resurfacing, plays a fundamental role in the success of a total knee arthroplasty (TKA). Complications such as anterior knee pain, maltracking, subluxation or dislocation of the patella, abnormal wear and ultimately loosening of a polyethylene patellar component (if implanted), and fracture of the patella are usually due to problems related to the patient, to the surgical technique, to the design of the components, or to a combination of these factors (1).

For the patellofemoral (PF) joint to be congruent, the patella should track centrally in the trochlear groove. Patellar tracking is conditioned by a combination of static and dynamic factors. The former determine the position of the patella in relation to the femoral component and include the shape of the trochlear prosthetic groove, the three-dimensional positioning of the femoral component, and the balance of the soft tissues. The dynamic factors consist of direction and intensity of the quadriceps action during movement. Therefore, treating PF malalignment during TKA, actually means preventing an incongruence, however slight, of the PF joint, first of all choosing a suitable prosthetic design and, intraoperatively, dynamically monitoring the spatial relationship between the three components, and also the patellar tracking. Indeed, mere revision of the PF joint will lead to a suboptimal result (2,3). Patellar tracking is influenced by every step of the surgical procedure. Patellar maltracking is often due to a major surgical mistake or to a combination of several minor errors. If encountered, it should be taken as a warning signal, and prompt reassessment of the size, rotation, translation and balance of each component should be considered (4).

The basic principles in prosthetic knee surgery are the proper execution of bone resections and the achievement of a correct ligament balance, of both the femorotibial and the PF joint. Several factors have been shown to influence patellar tracking: a severe preoperative valgus, the presence of pre-existing PF dysplasia, the design of the femoral component, the type of approach, the Q angle, the mechanical alignment of the limb, the tightness of the lateral retinaculum, the positioning of the patellar component in the proximal-distal and medial-lateral directions, the patella height, the patella (native or resurfaced) thickness, the size of the femoral and tibial components, and the alignment and rotation of the components (5-8). The surgical approach can also influence patellar tracking: a lower incidence of lateral release has been demonstrated with the midvastus and subvastus approaches, compared with the medial parapatellar approach (9,10). Maltracking can cause extensor mechanism problems (1,5,11-13), patellar subluxation, dislocation or fracture, a localized increase of the contact forces, which, in turn, may lead to excessive pressure on the native patella or, in the case of a resurfaced patella, to rapid wear of the patellar component.

Patella kinematics depends on a complex relationship between the extensor mechanism and the femorotibial joint. Its function as a fulcrum in the extensor mechanism is influenced by the design of the implant, the relationship between the patellar, femoral and tibial components, the joint line, the Q angle, and the overall limb alignment (14). The surgeon's intraoperative choices can compensate for or exacerbate implant design limitations. Ultimately, the achievement of proper PF mechanical function depends on an adequate surgical technique and on a full understanding of the biomechanical principles of TKA. However, the impossibility, even in the presence of correct implant selection and the use of an adequate surgical technique, of predicting with certainty the likelihood that a patient (with or without patellar resurfacing) will develop anterior knee pain remains an issue that needs to be addressed.

Biomechanical principles

The native patella does not fit perfectly with the femoral trochlea. The contact areas between the patella and femur vary at different degrees of knee flexion (15,16). The distal pole of the patella makes contact with the femoral trochlea at 20° of knee flexion (16,17); as flexion progresses, the contact surface increases and shifts to the upper pole of the patella. The main function of the patella is to increase the lever arm of the extensor mechanism (18); indeed, patellectomy reduces quadriceps strength by 30-40% (19). The PF joint reaction force is equal to 0.5 times an individual's body weight during walking on level ground; on going up or down stairs, it reaches 6.5 to 7.6 times the individual's body weight (20). It can be reduced to 21% after TKA (21). The resurfaced patella moves medially during flexion, rather than laterally as the native patella does.

The modified kinematics and the reduced PF contact area resulting from arthroplasty may contribute to the onset of patellofemoral complications. The increase in the knee flexion angle that is obtained through arthroplasty increases PF contact forces (17,22,23). Bone thickness reduction, in combination with osteopenia resulting from the patella resurfacing contributes to the risk of patellar fracture. This risk increases when a lateral release is simultaneously performed (24).

Causes of malalignment

Patellar malalignment can generally be attributed to factors related to the patient, to the implant design, or to the surgical technique. The patient-related factors (preoperative valgus malalignment, patellar subluxation, severe PF degenerative changes) have all been associated with an increased prevalence of lateral retinacular release and postoperative patellar malalignment. Therefore, they must be recognized at the time of preoperative planning and properly managed during surgery.

The effect of implant design on PF stability is well recognized. Femoral components featuring a symmetrical and shallow trochlear groove with an abrupt sagittal radius have been shown to create abnormal patellar kinematics and increase the risk of patellar maltracking. In a series reviewing 289 TKAs with a shallow and narrow trochlea, patellar maltracking was found to be the reason for PF revision in 14 out of 20 cases receiving this surgery (25).

Errors in surgical procedure are the most frequent cause of patellar maltracking. Residual valgus limb malalignment, patella alta, excessive internal rotation of the femoral and/or tibial component, medial placement of the femoral component, valgus alignment of the femoral component (even if the overall alignment of the limb is neutral), asymmetrical patellar resection, lateral positioning or excessive thickness of the patellar button, incorrect soft-tissue balancing and missing or insufficient lateral release, have all been shown to have a negative effect on patellar tracking (5,7,26,27). Failure to recognize and correct these problems during surgery unavoidably leads to PF complications.

Implant design

Most of the femoral components are designed to articulate with a designated patellar prosthesis (28,29). Articulation between the native patella and prosthetic femur can cause potential problems in terms of abnormal contact and tracking. Anatomical femoral components appear to be particularly suitable for articulation with a non-resurfaced patella, and are thus called "patella-friendly". They provide better congruence with the native patella and require minimum patellar remodeling. The proximal extension of the femoral flange will help to engage the patella during the initial stages of flexion. Asymmetrical trochlear grooves provide for early patellar engagement through the protrusion of the lateral flange and decrease the prevailing in-valgus force vector, reducing the shear forces exerted on the patella. In a randomized controlled trial (30), a relatively patella-unfriendly design was used, featuring flat condyles with a shallow and angular trochlear groove; in a second study by the same institution, carried out using the same methodology (31), a relatively patella-friendly design was used, characterized by a deepened trochlear groove which curved gently toward the femoral condyles. Comparison of the outcome for patients with unresurfaced patellae showed that, in the second study, the rate of anterior knee pain decreased from 31% to 21% and the reoperation rate for PF complications from 12% to 1.2%, while the Knee Society score increased by 11 points.

Intraoperative assessment of the patellar tracking

Following implantation of the trial components (the tibial insert must have the correct thickness to ensure a good medial-lateral balance both in extension and at various degrees of flexion) patellar tracking must be evaluated. This is done with the patellar component in position (if one has been implanted) or with the native patella cleared of osteophytes and, if necessary, remodeled. Clearly, dynamic forces can also influence patellar tracking, but these cannot be assessed intraoperatively (6).

During the "no-thumb test" (32) with the tourniquet deflated and the medial capsule open, the patella should track with its medial edge in contact with the medial femoral component throughout the range of motion without the surgeon having to keep it in this position manually. Tourniquet deflation offers a more realistic assessment of patellar tracking and has been shown to reduce the number of lateral releases, otherwise performed in more than 31% of cases (33,34). Some authors have criticized this technique, suggesting that it may overestimate the problem when the medial parapatellar approach is used (4,35,36).

Alternatively, the "kissing rule" has been described: if, in maximal flexion, the medial surface of the patella does not make contact with the medial condyle of the femoral component, patellofemoral congruence may be considered insufficient (7).

Another method for checking lateral retinaculum tightness is to medially subluxate the patella, resurfaced or not, with the knee in extension and the trial components *in situ*. If the patella crosses the medial prosthetic condyle for half of its diameter, the retinaculum is not too tight.

Surgical technique: axial limb alignment

The key is to reestablish physiological limb alignment, which varies between 5° and 7° of anatomical valgus (37). Any increase in valgus angle beyond 7° will increase the Q angle and contribute to patellar maltracking. Several long-term follow-up studies have shown that prosthetic survival is not compromised if limb alignment is kept within 2.4°-7.2° of anatomical valgus (38). The femoral component is more likely to be placed in excessive valgus if the knee presents preoperative valgus malalignment, and especially if associated with hypoplasia of the lateral femoral condyle is (4). Even if the tibial component is placed in varus in an attempt to compensate for this, the problem is still likely to create abnormal patellofemoral kinematics.

Surgical technique: femoral positioning

It is generally accepted that placing the femoral component in approximately 3° to 5° of external rotation, relative to the posterior condylar axis, improves patellar tracking and proximal engagement (39). External rotation moves the trochlear groove toward the natural position of the patella, thereby relaxing the lateral retinacular structures and reducing the lateral force vector acting on the patella.
Alignment of the femoral component in the sagittal plane also requires attention. Placing the femoral component in flexion creates liftoff of the anterior flange and patellar impingement with the proximal lip of the trochlear groove; excessive extension of the femoral implant will displace the extensor mechanism anteriorly, increasing retinacular tension and patellofemoral compressive force (14).
In the frontal plane, lateral positioning of the femoral component was found to result in improved patellar tracking compared with central or medial placement (40). The ideal position can be achieved by placing the center of the femoral component immediately lateral to the midline of the intercondylar notch.

Surgical technique: tibial positioning

Rotational alignment of the tibial component is equally important in preventing patellar maltracking and instability (41). The center of the anterior portion of the tibial baseplate should be aligned with the medial third of the tibial tubercle. This will externally rotate the tibial component, thus relatively medializing the tibial tubercle and decreasing the Q angle. In patients suffering from anterior knee pain after TKA, the tibial component was found to be, on average, in 6.2° of internal rotation, compared with 0.4° in the control group (1).
Lateral translation of the tibial component helps to medialize the tibial tubercle and to decrease the Q angle.

Surgical technique: patellar resurfacing

The patellar bone should be resected parallel to its anterior surface to create a uniformly thick remnant, which usually requires removal of considerably more bone from the medial aspect of the patella. Correct patellar exposure and appropriate removal of surrounding soft tissues will allow for better visualization and assessment of the level of resection. Failure to appreciate the asymmetry of the patella may lead to the removal of equal amounts of bone from the medial and lateral facets, creating an oblique resection surface. Such errors in preparation have been shown to increase the risk of patellar tilt and maltracking (42-44). In a series of 300 TKAs, 21 of these had the patella asymmetrically resurfaced. At a mean follow-up of 7.5 years, 11 (51%) of these patients were affected by PF complications requiring revision (45).
Placement of the patellar component in a more medial position relative to the center of the retropatellar surface is considered beneficial because it replicates the medialized position of the native median eminence. In clinical series, the rate of lateral retinacular release was 13%-17% when the patellar component was placed medially, compared with 46%-48% when it was placed centrally (46,47). Radiographic results of medialized insertion of patellar prostheses have confirmed its effect on lateralization of the bony structure of the patella: it is thought to decrease lateral shear forces and decrease the likelihood of patellar subluxation. A significant reduction of PF contact force above 60° of knee flexion occurred with increasing medialization of the patellar component (48). At the same time, however, the more the patellar component was medialized, the more the patella tended to tilt laterally

relative to the femur. Hence, is recommended to medialize the patella by no more than 2.5 mm (49). Moreover, an equivalent effect to medialization of the patella implant may, in many respects, be achievable by lateralizing the femoral component.

It is essential to re-create physiological patella thickness after resurfacing, which is constant in both sexes, having values ranging from 22 to 24 mm (50). Particular problems have been observed when the thickness of the patella-button complex exceeds preoperative values. This will create overstuffing of the PF joint, and a subsequent increase in retinacular tension, leading to patellar tilt and subluxation (51); furthermore, overall flexion may be reduced and the risk of patellar component failure or patella fracture may be increased (52-54). By ensuring that the overall patellar thickness was less than or equal to that of the native patella, the incidence of lateral retinacular release has been reduced from 55% to 12% (55). Reducing the overall thickness by 1-2 mm in an attempt to improve patellar tracking has been recommended by some, with biomechanical data supporting this concept (4). Ideally, one should aim to preserve approximately 15 mm of patellar bone, but many surgeons appear to consider 12 mm to be the cutoff point, below which the patella cannot be resurfaced (56).

Maintenance of the patellar height has been shown to be an important factor in re-creating normal PF kinematics (57); it depends on femoral and tibial resections. Raising or lowering the joint line will create secondary patella infera or alta, respectively. In cases of patella infera, the PF compressive forces will be increased during early knee flexion and overall range of motion is often compromised. Patella alta is generally less common and often developmental rather than secondary to surgery. It is associated with patellar instability and subluxation.

Surgical technique: native patella remodeling

The normal patella has an asymmetrical shape with a prominent median ridge, which separates the medial and lateral facets; if it is decided not to resurface the patella, it is essential to implant a "patella-friendly" femoral component with a trochlear groove which, suiting this shape, will accommodate and guide the patellar ridge. Furthermore, to improve congruence, all osteophytes are resected and, if necessary, the patella is remodeled using the trochlea of the femoral trial component as the negative mold. After implantation of the definitive components, during the cement polymerization phase, with the knee extended and the patella everted, the femoral trochlea of the trial implant is positioned and rotated over the patella, thus simulating full range of motion. In this way, it is possible to check how the patella fits into the trochlea at various degrees of flexion and, if necessary, to remodel it progressively in order to achieve optimal congruence.

Surgical technique: lateral retinaculum release

A lateral release may become necessary if, after placement of all the implant components, the patella shows a tendency to lateral tracking or subluxation; the lateral retinaculum release procedure is indicated when has first been ascertained that there are no errors of alignment in rotation, translation, or angulation of all the prosthetic components. A certain degree of release is reportedly necessary in around 40% of cases, while complete release is generally deemed necessary in approximately 6% (58). Although the technique is easy to perform, there are conflicting opinions about its potential morbidity, including: wound-healing problems, avascular necrosis and patellar fracture (27,59-62). The procedure itself carries some minor morbidity, including postoperative swelling, hematoma and hemarthrosis, most of which is related to inadequate hemostasis. Most surgeons routinely release the lateral patellofemoral ligament (LPFL) when using a medial parapatellar approach because it helps with exposure and eversion of the patella and allows for the preventive correction of minor tracking abnormalities (63).

For correct execution of a lateral release it is essential to be familiar with the anatomy of the lateral retinaculum, which has been described by several authors (64,65). Keeping the retinaculum under tension helps to define the various soft tissue planes and may assist in identifying the lateral superior and inferior genicular arteries. The release is performed step by step, assessing patellar tracking in stages and tailoring the amount of tissue released to the real requirements (66). The LPFL is the first structure released

from the deep aspect. Subsequently, if necessary, the superior genicular artery, which can be found distally to the lower edge of the vastus lateralis, at the level of the superior pole of the patella, is isolated and, through blunt dissection, protected (62). Much has been written about the importance of preserving patellar perfusion when performing a lateral release, in particular the lateral superior genicular artery, which is the main source of blood supply to the patella (67); however, it is not always possible to preserve this artery and, at the same time, provide adequate release. In such cases, it may be advantageous to leave the lateral skin flap intact (i.e. avoid separating the skin from the subcutaneous tissue) in order to preserve the superficial vessels and ensure blood supply to the patellar bone from the overlying skin (68). Accessory blood supply through the anterior vascular plexus, Hoffa's fat pad, and patellar and quadriceps tendons should be sufficient to maintain patellar viability (60). Consequences arising from the sacrifice of the lateral genicular vessels are: avascular necrosis, patellar fracture and wound-healing problems (69,70). In a series of 1146 TKAs, a 5.4% rate of patella fractures was observed in patients who had undergone lateral release, compared with 2.4% in those who had not (13).
Once the artery has been isolated, the surgeon performs the lateral retinaculum release proceeding from the inside to outside; the incision starts distally to the superior genicular artery, approximately 1 to 2 cm lateral to the patellar margin, and divides the synovium, capsule, and retinacular fibers up to the subcutaneous fat. The release is gradually extended distally, parallel to the lateral margin of the patella and, if necessary, along the edge of the patellar tendon (remaining 2.5 cm from it) as far as the Gerdy tubercle, involving fibrous expansions of the iliotibial tract.
An alternative surgical procedure has been described: lateral patellar osteotomy (71). The lateral patellar facet is exposed through eversion of the patella, 7 to 9 mm of the lateral border is resected using an oscillating saw, and the bony fragment is removed by subperiosteal dissection. The lateral patellar ligamentous structures are thus decompressed, relaxing the lateral retinaculum and making a formal release unnecessary. In a series of 76 patients, none required a lateral retinacular release, but 15% presented a degree of lateral patellar tilt (71).

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