



Patellar management during total knee arthroplasty: a review

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- The optimal management of the patella during total knee arthroplasty (TKA) remains controversial and surgeons tend to approach the patella with one of three general mindsets: always resurface the patella, never resurface the patella, or selectively resurface the patella based on specific patient or patellar criteria.
- Studies comparing resurfacing and non-resurfacing of the patella during TKA have reported inconsistent and contradictory findings.
- When resurfacing the patella is chosen, there are a number of available patellar component designs, materials, and techniques for cutting and fixation.
- When patellar non-resurfacing is chosen, several alternatives are available, including patellar denervation, lateral retinacular release, and patelloplasty. Surgeons may choose to perform any of these alone, or together in some combination.
- Prospective randomized studies are needed to better understand which patellar management techniques contribute to superior postoperative outcomes. Until then, this remains a controversial topic, and options for patellar management will need to be weighed on an individual basis per patient.

Keywords: non-resurfacing; patella; resurfacing

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The management of the patella during total knee arthroplasty (TKA) has been a matter of considerable debate in the orthopaedic community.¹⁻⁴ Surgeons tend to approach the patella with one of three general mindsets: always resurface the patella, never resurface the patella, or selectively resurface the patella based on specific patient or

patellar criteria. However, the choice in approach depends largely on location and training, as there is insufficient consensus in the literature to justify the implementation of a standard practice. Surgeons in the United States routinely resurface the patella, with some studies reporting a resurfacing rate of > 80%.^{5,6} Countries such as Norway and Sweden lie at the other end of the spectrum, with only about 2–4% of surgeons opting to resurface the patella,⁵⁻⁷ while resurfacing rates in Australia are more moderate at about 43–59%, with the majority of surgeons preferring selective resurfacing.^{6,8,9} As a result of conflicting recommendations in the literature, surgeon preference is largely driven by education, training, and personal experience with better reproducibility or functional outcomes following TKA.^{5,8,10}

Advocates of patellar resurfacing argue that resurfacing decreases postoperative anterior knee pain, reduces revision rate, and improves patient-reported outcomes while remaining cost-effective.^{1,2,7,11-15} However, other studies have failed to find any significant difference in the rates of anterior knee pain or patient satisfaction,^{3,6,16-21} and thus some surgeons claim that resurfacing the patella is not worth the increased risk of complication associated with patellar resurfacing.^{2,4,22-24} Because numerous well-done randomized control trials and meta-analyses have published directly contradictory findings, there is much controversy surrounding resurfacing the patella.

Lack of standardization in surgical technique undoubtedly contributes to the largely disparate outcomes. For surgeons who choose to resurface the patella, there are a number of available component designs including symmetric, asymmetric, and ‘patella-friendly’ implants. The patellar component may be made of traditional polyethylene or highly crosslinked polyethylene, and surgeons may choose to cement or press-fit the prosthesis. Additionally,

there are a number of cutting techniques, using either guides or a freehand approach. Patellar non-resurfacing also presents a variety of options, including circumpatellar electrocautery, lateral retinacular release, or patelloplasty. Surgeons may choose to perform any of these alone or may use several in any number of combinations. However, many studies examining postsurgical outcomes do not address these possibly confounding differences in patellar management.

Therefore, the purpose of this review was to summarize current clinical studies that have investigated the effect of commonly used materials and techniques on outcomes of TKA with or without patellar resurfacing. Analysing outcomes of TKA based on the specific techniques and materials used for patellar management may allow us to better understand what factors contribute to superior postoperative outcomes and possibly identify targets for improved surgical management.

Patellar anatomy and biomechanics

Due to the numerous muscular and ligamentous structures acting dynamically on the patella, the patellofemoral joint is considered one of the most biomechanically complex joints in the human body.²⁵ The patellofemoral joint is a diarthrodial plane joint between the posterior surface of the patella and the trochlear surface of the distal femur.²⁶ A major vertical ridge divides the posterior surface of the patella into medial and lateral halves, which are not symmetric. The medial facet is small and steeply angled, while the lateral facet is larger with a shallow angle.^{26,27} The sagittal plane patellar position is commonly measured using the Insall–Salvati ratio, which describes the relative length of the patellar tendon compared to the patellar height when the knee is flexed to around 30 degrees.²⁸ A 1:1 ratio is considered normal, while a ratio of less than 0.8 or greater than 1.2 is termed ‘patella baja’ or ‘patella alta’, respectively.²⁸ Those with patella alta are at increased risk of subluxation, because in this position the patella is less constrained by the bony femoral trochlea.²⁶ In the frontal plane, the patella sits midway between the two femoral condyles, with a slight lateral deviation.²⁹ In the transverse plane, the medial and lateral borders should be equidistant from the femur.²⁶ Lateral tilt (when the lateral border is lower than the medial border) can lead to patellofemoral compression syndrome.³⁰ The superior and inferior borders of the patella should also be equidistant from the femur, as an inferiorly tilted patella may irritate the infrapatellar fat pad²⁶

Biomechanically, the patellofemoral joint acts as an anatomic pulley to provide mechanical advantage for knee extension, as well as to reduce friction between the extensor mechanism and the femur.²⁷ The articular surface area of the patella changes with joint position, with

the contact surface on the patella becoming more proximal as the knee progresses through flexion.^{25–27} Therefore, patellofemoral pressure increases with knee flexion, peaking at about 90–120 degrees.²⁶ Since the 1970s and ’80s, biomechanical modelling studies of the natural knee have consistently predicted extremely high patellar loads during a range of high-flexion activities.^{31,32} In these models, the patella is predicted to experience about 5–7 × body weight when rising from a chair, 2–3 × body weight when going up stairs, and 20 × body weight when jumping.^{31–34} Prior to the advent of in vivo-implanted sensors, it was not possible to validate these biomechanical models. Now validated with in vivo data in patients with telemetric TKAs, recent models still predict the patellofemoral forces to be elevated, but somewhat lower than previously thought in high-flexion activities.³⁵ These models predict patellar loads to be about three-times body weight during stair climbing, getting out of a chair, and squatting and one-times body weight during normal level walking.³⁵ Based on research with in vivo telemeterized implants, interpatient variation in the patellofemoral contact forces is also observed.³⁵ Due to the potentially high loads transmitted across the patellofemoral joint, biomechanical dysfunction at this articulation may result in pain, instability, and impaired function, especially during high-flexion activities of normal daily living.^{25,26}

Patella resurfacing management

Cutting techniques

When resurfacing, the goal is to restore patellar thickness by matching the amount of patella resected to the thickness of the patellar implant. Therefore, it is important to assess the thickness of patella before resurfacing in order to prevent under-resection or overstuffing of the patellofemoral joint. The average male patella is 25 mm thick, whereas that of the female is 22 mm.³⁶ In general, the patella should not be cut to a thickness of less than 12 to 15 mm (Table 1).^{37,38}

Asymmetric resurfacing of the patella, defined as a greater than 2-mm difference in thickness when comparing the medial and lateral edges of the patella,^{39,40} has been associated with increased anterior knee pain, bony impingement, patellar fracture, patellar maltracking, instability, and revision rate.^{21,40–43} However, identifying and defining an ideal resection plane during surgery can be difficult due to the irregular shape and small size of the patella.^{39,44} As a result, a number of techniques have been developed to improve patellar symmetry and patient outcomes.

Many surgeons favour a freehand technique, in which haptic feedback or anatomic landmarks are used to estimate the patellar resection thickness and symmetry.^{45–48}

Table 1. Patellar resection errors and associated risks

Too little resection	Too much resection
Increased patellofemoral compression and shear forces	Increased strain on the anterior patellar surface
Maltracking, subluxation, and wear	Mechanical weakness of the patella
Decreased or limited flexion	Increased risk of patellar fracture
Altered biomechanics of the quadriceps	Patellar implant failure
Challenging wound closure due to overstretched extensor retinaculum	Increased risk of patellar clunk syndrome and crepitus
May increase postoperative pain	Risk of extensor mechanism disruption

Others prefer to use standard cutting guides or a reamer, as they assist with producing a flat patellar cut.^{49,50} A study by Camp et al compared the accuracy of freehand techniques versus cutting guides, and found that freehand techniques produced the most symmetric patellar resections and were able to more reproducibly achieve goal patellar thickness.⁴⁶ While cutting guides provided smooth and even cuts, their utility was effectively limited by the surgeon’s ability to apply the guide at the appropriate depth and obliquity. Additionally, freehand cutting allowed for easier assessment of thickness and symmetry of the patella compared to the guide. However, other techniques using computer-aided preoperative planning and customized design guides have shown improvement in symmetric patellae resurfacing compared to the conventional cutting guide technique.^{44,51}

Though there are many studies describing the effect of various methods of patellar resection on intraoperative measurements and radiography, few studies have directly examined the effect of different patellar resection techniques on postoperative outcomes. A study by Yuan et al in 2019 found no significant difference in rates of anterior knee pain, patellofemoral functional capacity or clinical outcomes between resections performed using the freehand and the cutting guide technique.⁵² Another study examining significance of patellofemoral height found that using different resection techniques did not reduce anterior knee pain or improve function following TKA.⁵³ Though limited, the available literature seems to indicate that cutting technique does not play a significant role in determining patient outcomes, as long as patellar resection symmetry is ultimately achieved.

Component alignment

Appropriate component alignment and positioning is critical to accurate patellar tracking in TKA.⁵⁴ If there is maltracking of the patella, TKA patients are more likely to have complications such as subluxation, dislocation, and chronic pain.⁵⁵

Traditionally, medialization of the patellar prosthesis has been recommended.^{56,57} Using this technique, the

patellar component is placed medial to the centre in order to reproduce the normal high point at the median ridge.⁵⁸ Compared to placing the patellar component centrally on the osteotomized patella, medialization has been demonstrated to reduce lateral retinacular tension, decrease patellofemoral contact force, and decrease the rate of lateral retinacular release.⁵⁴ However, this technique may not be appropriate for all patients. In patients with a small medial facet, positioning the patellar component based on the median ridge may cause lateral tilt, which can lead to impingement and erosion of the prosthesis.^{59–61} Therefore, preoperative assessment of patients’ native anatomy and kinematics of the patellofemoral joint is necessary for determining optimal patellar component positioning.

Malalignment of the femoral component can also contribute to patellar maltracking and anterior knee pain. Malrotation is a well-documented risk factor for postoperative patellofemoral complications; however, there is some debate regarding how to achieve the correct rotational orientation.^{62–65} Implants can be positioned using kinematic alignment (KA) or mechanical alignment (MA). The goal of KA is to correct the arthritic deformity and restore native knee kinematics by matching the amount of cartilage and bone resected to the thickness of the implant.^{66–68} Some studies have found that this individualized approach provides a better overall restoration of patellar kinematics.⁶⁹ On the other hand, MA is based on an average alignment paradigm, with a goal of restoring the lower limb alignment to zero degrees.^{66,67} MA is the conventional and most utilized method of component alignment; however, interest in KA has grown in recent years.^{68,70} In either case, excessive internal rotation of the femoral component is to be avoided, as this has been directly correlated with the severity of postoperative patellofemoral complications.^{63,64}

Internal rotation of the tibial component should also be avoided. When the tibial component is internally rotated, there is a significant increase in retropatellar pressure that may lead to maltracking and anterior knee pain.⁷¹ However, there are no standard guidelines for the rotational placement of the tibial component in TKA.^{71,72} There are many anatomical landmarks that can be used to align the tibial component, including the medial border of the tibial tuberosity, the medial third of the tibial tuberosity, the anterior tibial crest, the posterior tibial condylar line, and the first webspace of the foot.⁷² Other intraoperative methods of determining tibial component rotation include anatomical placement of an asymmetric tibial tray on the cut surface or rotation the tibial component into alignment following the femoral component during extension.⁷³ Further study is needed to determine which method most effectively optimizes tibial component positioning and reduces the risk of postoperative complications.

Implant design

Prior to the late 1970s, most TKAs utilized femoral components with a symmetric patellar groove.⁷⁴ However, over time the use of laterally oriented, asymmetric patellar grooves became more common as they were believed to be more anatomical and improve patellofemoral function.^{74–77} Several studies conducted in the 1990s claimed that the less anatomic articular geometry of the symmetric components led to increases in shear force and poor knee extension function following TKA.^{77–79} However, more recent studies have found that the modern asymmetrical prostheses do not provide more anatomical patellar kinetics or stability compared to the older symmetrical designs (Fig. 1).^{75,76}

However, implant designs have continued to evolve and there are many aspects of implant design that may affect clinical outcomes beyond symmetry. In addition to a lateralized trochlear groove, implants that feature an extended anterior flange, deepened patellar groove and deepened distal extent of the trochlea are considered more ‘patella-friendly’, whereas ‘unfriendly’ patellar designs feature flat-shaped condyles with a shallow and angular trochlear groove.^{20,80} There is some disagreement in the literature regarding the clinical benefit of patella-friendly designs.^{20,81,82}

Several studies have found that choosing a patella-friendly prosthesis is especially important when the patella is left unresurfaced. A group of researchers from the University of Western Australia conducted two randomized controlled studies where the only major variable was the type of prosthesis used.⁸⁰ Comparing the outcome of non-resurfaced patients between both studies demonstrated a significant decrease in both anterior knee pain and reoperation rate.^{81,83} O’Brien et al conducted a study of 600 unresurfaced TKAs utilizing a patella-friendly implant. This study reported a survivorship of 97.8% at a minimum of 10 years with only 1.5% of cases requiring resurfacing for anterior knee pain, leading the authors to conclude that non-resurfacing of the patella does not adversely affect outcomes of TKA when patella-friendly

designs are used.⁸⁴ These results are consistent with a number of prior studies that found patella-friendly femoral components to improve outcomes when the patella is left unresurfaced.^{85–88} Other studies have examined the kinematics of patella-friendly designs compared to non-patella-friendly designs in unresurfaced TKA and found superior stress distribution on the patellofemoral joint in designs that utilized deeper trochlear grooves.^{89,90}

Conversely, other studies found no significant difference in clinical outcomes relative to implant design. Gharaibeh et al compared three different designs in terms of intraoperative characteristics and patient-reported outcomes and found no difference between implants.⁸² Additionally, Pavlou et al conducted a meta-analysis of 7075 cases of resurfacing and non-resurfacing TKA using both patella-friendly and non-patella-friendly designs. The authors found no difference in the incidence of reoperation or anterior knee pain between patellar-friendly and unfriendly designs regardless of resurfacing status, and concluded that prosthetic design had no effect of clinical outcome of TKA.²⁰ However, it was suggested that the authors’ broad definition of ‘patella-friendly’ may have affected these results, as most implants were considered friendly.

Patellar implant material

Prior to the mid 1990s, patellar components were composed of conventional polyethylene gamma sterilized in air. However, polyethylene gamma sterilized in air is subject to long-term oxidative degradation, and was eventually discovered to reduce the yield and tensile strength of the patellar components.⁹¹ After this discovery, gamma sterilization in inert gas was developed in an effort to limit oxidative damage to the components. This process produces patellar components with less oxidation potential than those gamma sterilized in air, but they still undergo mechanisms of in vivo oxidation to a lesser extent.⁹² As a result, advances in polyethylene fabrication have led to the development of highly crosslinked polyethylene, a modified form of conventional polyethylene that is irradiated and subsequently melted in order to achieve a higher crosslink density.^{91,93} Highly crosslinked polyethylene is increasingly being used for tibial inserts; however, it has not been accepted for routine use in patellar components.^{94,95} There is little data published on the clinical performance of highly crosslinked patellar components, and the available studies have reported inconsistent results.

The goal of introducing highly crosslinked patellar components is to reduce wear; however, there is some concern that these components show reduced fracture toughness compared to conventional polyethylene. Some reports suggest that the additional irradiation and thermal treatment of highly crosslinked polyethylene can lead to reduced mechanical strength and fatigue resistance.^{96–99}



Fig. 1 The patellar component comes in various shapes: (a) shows a symmetric (left) and asymmetric (right) patellar component which attempts to better reflect the naturally occurring asymmetric shape of the patella; (b) shows a different asymmetric component design.

Additionally, there have been three publications describing four cases of mechanical failure and fracture of patellar prostheses made of highly crosslinked polyethylene.^{100–102} Three of the components were examined for visual wear on the articulating surface. In one study, no wear was observed on the patellar component; however, the other study found mild wear on one component and severe wear on the other component. Concerns regarding the possibility of mechanical failure have led some to recommend against the use of highly crosslinked polyethylene in TKA.¹⁰³

However, other studies have suggested that highly crosslinked patellar components have increased damage resistance compared to conventional polyethylene. A study by Burroughs et al found that highly crosslinked patellar components were more resistant to delamination and cracking than conventional polyethylene under in vitro simulated aggressive physiological conditions.⁹¹ The authors suggest that these findings are the result of the high-dose irradiation eliminating free radicals, and thus reducing oxidative degradation of the implant.⁹¹

Cemented or cementless patellar components?

Presently, most surgeons choose to use a cemented patellar component due to their history of excellent survivorship and outcomes.^{104–106} Additionally, early cementless designs had poor results, and frequently reported early failure.^{107–111} However, advances in materials and bioactive surface coatings have led to the development of a new generation of cementless implants that demonstrate improved survivorship.^{112,113} As a result, cementless components have grown in popularity in recent years (Fig. 2).

In 2002, Valdivia et al compared midterm results between press-fit and cemented patellar components. Radiographic data showed that the incidence of maltracking was significantly higher with cement fixation, but the two components provided equivalent clinical results.¹¹⁴

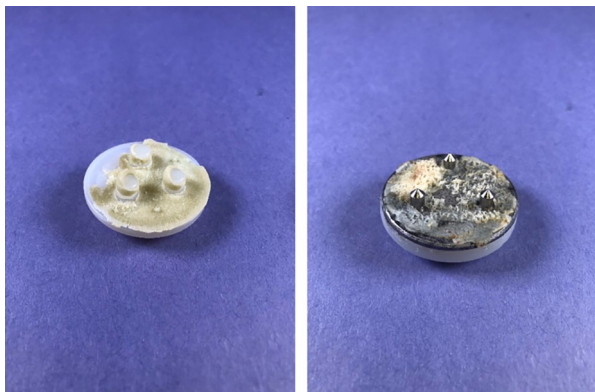


Fig. 2 Two explanted patellar components: a cemented patellar component (left) and a porous metal-backed patellar component (right).

More recently, Harwin et al evaluated implant survivorship, complications, and radiographic outcomes in a large cohort of patients with cementless TKA. The authors reported a 98% success rate with minimal reported complications at a mean 4.5 years follow-up, and concluded that cementless patellar fixation can be considered a safe technique.¹¹⁵ Another study, by Cohen et al, compared 72 TKAs using uncemented patellar components to a matched cohort of cemented TKAs. All patellar components appeared well-fixed radiographically and there were no reported patellar complications.¹¹⁶ Kwong et al also reported that the use of new implant designs and biomaterials appears to have addressed prior reported problems with high rates of patellar component failure. With increased concern about aseptic loosening, tension, and osteolysis at the bone–cement interface for cemented components, these studies suggest that uncemented patellar designs could provide a reasonable alternative.^{115,117,118} However, Chan et al reported a minimum 20% rate of component fracture at an average of 5.4 years following cementless TKA, and thus the authors recommended continued monitoring and investigation of cementless patellar designs.¹¹⁹

Patellar non-resurfacing management

Patellar denervation

The patella is innervated by a network of superficial sensory nerves that pass through the peripatellar soft tissue. This tissue is rich in substance P nerve fibres, and has been suggested as a possible source of anterior knee pain following TKA.^{120–122} As a result, patellar denervation with electrocautery has been proposed as a technique to reduce this pain.^{123–125} A number of studies have tested this premise; however, there has been some disagreement on the efficacy of the procedure.

There have been a number of promising results from studies examining the effect of patellar denervation in TKA without patellar resurfacing. Since 2015, two studies have demonstrated significantly improved anterior knee pain and functional outcomes in patients who received circumpatellar electrocautery.^{125,126} However, some studies have suggested that these improvements may not be lasting.^{123,127,128} While Motififard et al found a statistically significant improvement in postoperative anterior knee pain following patellar denervation at three-week follow-up, this effect disappeared by the three-month follow-up.¹²³ Likewise, a study by Xie et al concluded that the beneficial effect of patellar denervation on anterior knee pain was limited to the 12 months following TKA.¹²⁷ However, a more recent meta-analysis by Duan et al found that patellar denervation decreased the incidence of anterior knee pain both before and after 12 months of follow-up, in contrast to the study by Xie et al.^{127,129}

Other studies have found no significant improvement in anterior knee pain following unresurfaced circumpatellar electrocautery. In 2015, a prospective randomized controlled study by Kwon et al found no difference in anterior knee pain, knee function, or complication rates between the electrocautery and non-electrocautery cohorts up to five years after TKA.¹³⁰ The same findings were reported in a 2020 study by Budhiparama et al that analysed patients who underwent non-resurfaced, simultaneous, bilateral primary TKA with a minimum of two years of follow-up.¹²⁴ The authors suggested that the absence of a standardized circumferential patellar cauterization technique might contribute to the conflicting outcomes of patellar denervation reported in the literature.¹²⁴

While less common, about 32% of orthopaedic surgeons also choose to use circumpatellar electrocautery when resurfacing the patella.¹³¹ Unlike when used with the unresurfaced patella, the literature on this topic is relatively in agreement. Several studies have shown equivalent clinical results with or without circumpatellar electrocautery.^{132–135} In the most recent of these studies, Goicoechea et al found no significant difference in anterior knee pain or knee function scores in primary TKA with patellar resurfacing compared to patellar replacement without denervation.¹³⁵ Therefore, based on current results, patellar denervation cannot be recommended when patellar resurfacing is performed in TKA.¹³⁵

Patelloplasty

When choosing not to resurface the patella, surgeons may perform a patelloplasty, defined as any surgical intervention aimed at improving the congruency between the native patella and the trochlea of the femoral component.^{136,137} This definition is fairly non-specific and may include patellar decompression, lateral patellectomy, patellar reshaping with or without resection of the cartilage layer, osteophyte removal, or some combination of these procedures.^{136,138} This lack of standardization can make it challenging to compare results between studies.

There are few studies that directly compare non-resurfacing of the patella with and without patelloplasty. In the last ten years, two studies have compared patelloplasty – defined as osteophyte removal, denervation, patellar cartilage resection, and reshaping of the patellar facets – to osteophyte removal and denervation alone.^{139,140} The first study done in 2012 found that the patelloplasty group had significantly better functional scores and patient satisfaction, but there was no difference in postoperative anterior knee pain.¹³⁹ The following study, conducted in 2014, found significantly improved Knee Injury and Osteoarthritis Outcome Scores and Oxford Knee Scores in the patelloplasty group compared to traditional management; however, there was no significant difference in Knee Society Function or Pain Scores.¹⁴⁰

In both studies, the authors concluded that patelloplasty was better than traditional patellar retention in improving knee function and quality of life.

Studies comparing patelloplasty to patellar resurfacing have almost unanimously reported no significant difference in outcomes between these two procedures. Since 2004, six studies have found no difference between these two groups in regard to functional ability, clinical rating scores, patient satisfaction, anterior knee pain, revision, reoperation, or radiographic outcomes.^{79,141–145} As a result, several authors recommended patellar non-resurfacing with patelloplasty as it preserves bone stock and allows for conversion to patellar replacement if anterior knee pain reoccurs.^{143,144} However, in 2016, Cerciello et al performed a systematic review of the available literature concerning patelloplasty and found that the global rate of anterior knee pain after patelloplasty was increased compared to patellar replacement (12.2% and 7.9% respectively).¹³⁶ As a result of these conflicting results, further study is required before definitive recommendations can be made.

Conclusion

Whether or not to resurface the patella during TKA is a contentious topic in orthopaedic surgery (Table 2). Without clear evidence that any one method is superior, most surgeons choose their technique based on local preference, training, and personal experience. This has led to a wide variety of different surgical approaches, components, and materials being utilized for patellar management. With this lack of standardization, it is difficult to compare results between studies, as differences in surgical technique could have a confounding effect on postoperative outcomes.

A limited number of studies have examined the individual effects of component design, component material, cutting technique, cementing, circumpatellar electrocautery, lateral retinacular release, and patelloplasty on postoperative outcomes of TKA. Reports on some topics show relatively consistent results. For example, the majority of studies agree that patellar denervation and patelloplasty

Table 2. Arguments for patellar resurfacing versus non-resurfacing

Arguments for resurfacing	Arguments for non-resurfacing
Improved technology has reduced the rate of resurfacing complications	Avoids complications related to patellar resurfacing
Reduced rate of secondary resurfacing and reoperation	Conservation of patellar bone
Has been associated with lower risk of anterior knee pain	No definitive evidence of overall improved postoperative pain or function
Improved patient-reported outcomes	Ability to withstand higher forces
	More physiologic patellofemoral kinematics
	No cost

do not improve clinical outcomes after TKA with patellar resurfacing. However, studies on most other interventions continue to produce inconsistent and contradictory findings. Future studies should continue to investigate how outcomes of TKA are affected by the specific methods used for patellar management, which has received only cursory attention to date. Until then, this remains a controversial topic, and options for patellar management will need to be weighed on an individual basis per patient, considering the patient's age, diagnosis and patellar anatomy.

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