EOR | VOLUME 6 | OCTOBER 2021
DOI: 10.1302/2058-5241.6.200156
www.efortopenreviews.org

EFORT open reviews

Patellar management during total knee arthroplasty: a review

Kara McConaghy[1]
Tabitha Derr[2]
Robert M. Molloy[3]
Alison K. Klika[3]
Steven Kurtz[2,4]
Nicolas S. Piuzzi[3]

- 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

Cite this article: *EFORT Open Rev* 2021;6:861-871.
DOI: 10.1302/2058-5241.6.200156

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 prothesis. Additionally,

Downloaded from Bioscientifica.com at 08/29/2023 12:07:04PM
via free access

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 pad[26]

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]

Downloaded from Bioscientifica.com at 08/29/2023 12:07:04PM
via free access

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.

Downloaded from Bioscientifica.com at 08/29/2023 12:07:04PM
via free access

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.

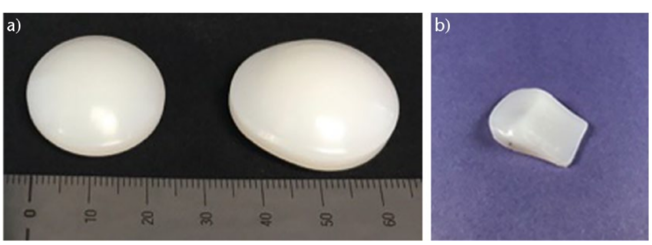

Fig. 1 The patellar component comes in various shapes: (a) shows a symmetric (left) and asymmetric (right) patellar component which attempts to better reflect the naturally occurring asymmetric shape of the patella; (b) shows a different asymmetric component design.

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]

Downloaded from Bioscientifica.com at 08/29/2023 12:07:04PM
via free access

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]

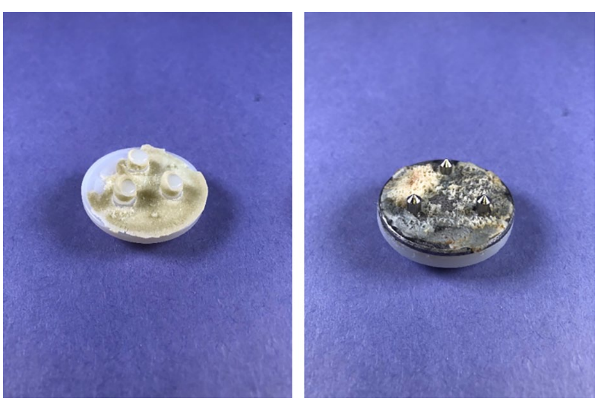

Fig. 2 Two explanted patellar components: a cemented patellar component (left) and a porous metal-backed patellar component (right).

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]

Downloaded from Bioscientifica.com at 08/29/2023 12:07:04PM
via free access

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

Downloaded from Bioscientifica.com at 08/29/2023 12:07:04PM
via free access

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.

AUTHOR INFORMATION

[1]Case Western Reserve University School of Medicine, Cleveland, Ohio, USA.
[2]Implant Research Core, School of Biomedical Engineering, Science, and Health Systems, Drexel University, Philadelphia, Pennsylvania, USA.
[3]Cleveland Clinic, Department of Orthopedic Surgery, Cleveland, Ohio, USA.
[4]Exponent, Philadelphia, Pennsylvania, USA.

Correspondence should be sent to: Nicolas S. Piuzzi, MD, Cleveland Clinic, Orthopaedic and Rheumatology Institute, 9500 Euclid Ave, A41, Cleveland, OH 44195.
Email: piuzzin@ccf.org

ICMJE CONFLICT OF INTEREST STATEMENT

TD reports grants pending to their Institution from Stryker Orthopaedics, for relevant financial activities outside the submitted work.
RMM reports consulting fees paid by Stryker Orthopaedics pertinent to the work under consideration for publication, and also consultancy fees from the same for relevant financial activities outside the submitted work.
SK reports various monies (consultancy, expert testimony, payment for manuscript preparation) paid by Exponent, for relevant financial activities outside the submitted work. They also report grants from Zimmer Biomet, Stryker, Lima Corporate, Osteal, Ferring, Orthoplastics, Wright Medical Technology, DJO, CarbofixSINTX, Celanese, Invibio and Ceramtec – again for relevant financial activities outside the submitted work.
All authors declare no conflicts of interest relevant to this work.

FUNDING STATEMENT

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

OPEN ACCESS

© 2021 The author(s)
This article is distributed under the terms of the Creative Commons Attribution-Non Commercial 4.0 International (CC BY-NC 4.0) licence (https://creativecommons.org/licenses/by-nc/4.0/) which permits non-commercial use, reproduction and distribution of the work without further permission provided the original work is attributed.

REFERENCES

1. **Helmy N, Anglin C, Greidanus NV, Masri BA.** To resurface or not to resurface the patella in total knee arthroplasty. *Clinical orthopaedics and related research*. Volume 466. New York: Springer New, 2008:2775–2783.

2. **Longo UG, Ciuffreda M, Mannering N, D'Andrea V, Cimmino M, Denaro V.** Patellar resurfacing in total knee arthroplasty: systematic review and meta-analysis. *J Arthroplasty* 2018;33:620–632.

3. **Chen K, Li G, Fu D, Yuan C, Zhang Q, Cai Z.** Patellar resurfacing versus nonresurfacing in total knee arthroplasty: a meta-analysis of randomised controlled trials. *Int Orthop* 2013;37:1075–1083.

4. **Li S, Chen Y, Su W, Zhao J, He S, Luo X.** Systematic review of patellar resurfacing in total knee arthroplasty. *Int Orthop* 2011;35:305–316.

5. **Abdel MP, Parratte S, Budhiparama NC.** The patella in total knee arthroplasty: to resurface or not is the question. *Current reviews in musculoskeletal medicine*. Volume 7. New York, Humana Press Inc, 2014:117–124.

6. **Fraser JF, Spangehl MJ.** International rates of patellar resurfacing in primary total knee arthroplasty, 2004–2014. *J Arthroplasty* 2017;32:83–86.

7. **Migliorini F, Eschweiler J, Niewiera M, El Mansy Y, Tingart M, Rath B.** Better outcomes with patellar resurfacing during primary total knee arthroplasty: a meta-analysis study. *Arch Orthop Trauma Surg* 2019;139:1445–1454.

8. **Vertullo CJ, Graves SE, Cuthbert AR, Lewis PL.** The effect of surgeon preference for selective patellar resurfacing on revision risk in total knee replacement: an instrumental variable analysis of 136,116 procedures from the Australian Orthopaedic Association National Joint Replacement Registry. *J Bone Joint Surg [Am]* 2019;101-A:1261–1270.

9. **Clements WJ, Miller L, Whitehouse SL, Graves SE, Ryan P, Crawford RW.** Early outcomes of patella resurfacing in total knee arthroplasty. *Acta Orthop* 2010;81:108–113.

10. **Vertullo CJ, Grimbeek PM, Graves SE, Lewis PL.** Surgeon's preference in total knee replacement: a quantitative examination of attributes, reasons for alteration, and barriers to change. *J Arthroplasty* 2017;32:2980–2989.

11. **Albrecht DC, Ottersbach A.** Retrospective 5-year analysis of revision rate and functional outcome of TKA with and without patella implant. *Orthopedics* 2016;39:S31–S35.

12. **Maney AJ, Koh CK, Frampton CM, Young SW.** Usually, selectively, or rarely resurfacing the patella during primary total knee arthroplasty: determining the best strategy. *J Bone Joint Surg [Am]* 2019;101-A:412–420.

13. **Coory JA, Tan KG, Whitehouse SL, Hatton A, Graves SE, Crawford RW.** The outcome of total knee arthroplasty with and without patellar resurfacing up to 17 years: a report from the Australian Orthopaedic Association National Joint Replacement Registry. *J Arthroplasty* 2020;35:132–138.

14. **Weeks CA, Marsh JD, MacDonald SJ, Graves S, Vasarhelyi EM.** Patellar resurfacing in total knee arthroplasty: a cost-effectiveness analysis. *J Arthroplasty* 2018;33:3412–3415.

15. **Pakos EE, Ntzani EE, Trikalinos TA.** Patellar resurfacing in total knee arthroplasty: a meta-analysis. *J Bone Joint Surg [Am]* 2005;87-A:1438–1445.

16. **Kaseb MH, Tahmasebi MN, Mortazavi SJ, Sobhan MR, Nabian MH.** Comparison of clinical results between patellar resurfacing and non-resurfacing in total knee arthroplasty: a short term evaluation. *Arch Bone Jt Surg* 2018;6:124–129.

17. **Parvizi J, Rapuri VR, Saleh KJ, Kuskowski MA, Sharkey PF, Mont MA.** Failure to resurface the patella during total knee arthroplasty may result in more knee pain and secondary surgery. *Clin Orthop Relat Res* 2005;438:191–196.

18. **He JY, Jiang LS, Dai LY.** Is patellar resurfacing superior than nonresurfacing in total knee arthroplasty? A meta-analysis of randomized trials. *Knee* 2011;18:137–144.

19. **Nizard RS, Biau D, Porcher R, et al.** A meta-analysis of patellar replacement in total knee arthroplasty. *Clin Orthop Relat Res* 2005;432:196–203.

Downloaded from Bioscientifica.com at 08/29/2023 12:07:04PM
via free access

20. **Pavlou G, Meyer C, Leonidou A, As-Sultany M, West R, Tsiridis E.** Patellar resurfacing in total knee arthroplasty: does design matter? A meta-analysis of 7075 cases. *J Bone Joint Surg [Am]* 2011;93-A:1301–1309.

21. **Pilling RWD, Moulder E, Allgar V, Messner J, Sun Z, Mohsen A.** Patellar resurfacing in primary total knee replacement: a meta-analysis. *J Bone Joint Surg [Am]* 2012;94-A:2270–2278.

22. **Garneti N, Mahadeva D, Khalil A, McLaren CA.** Patellar resurfacing versus no resurfacing in Scorpio total knee arthroplasty. *J Knee Surg* 2008;21:97–100.

23. **Meding JB, Fish MD, Berend ME, Ritter MA, Keating EM.** Predicting patellar failure after total knee arthroplasty. *Clinical orthopaedics and related research*. Volume 466. New York: Springer New York, 2008:2769–2774.

24. **Khan A, Pradhan N.** Results of total knee replacement with/without resurfacing of the patella. *Acta Ortop Bras* 2012;20:300–302.

25. **Zaffagnini S, Dejour D, Grassi A, et al.** Patellofemoral anatomy and biomechanics: current concepts. *Joints* 2013;1:15–20.

26. **Loudon JK.** Biomechanics and pathomechanics of the patellofemoral joint. *Int J Sports Phys Ther* 2016;11:820–830.

27. **Jibri Z, Jamieson P, Rakhra KS, Sampaio ML, Dervin G.** Patellar maltracking: an update on the diagnosis and treatment strategies. *Insights Imaging* 2019;10:65.

28. **Insall J, Salvati E.** Patella position in the normal knee joint. *Radiology* 1971;101: 101–104.

29. **Powers CM, Ward SR, Fredericson M, Guillet M, Shellock FG.** Patellofemoral kinematics during weight-bearing and non-weight-bearing knee extension in persons with lateral subluxation of the patella: a preliminary study. *J Orthop Sports Phys Ther* 2003;33: 677–685.

30. **Zhang DH, Wu ZQ, Zuo XC, Li JW, Huang CL.** Diagnosis and treatment of excessive lateral pressure syndrome of the patellofemoral joint caused by military training. *Orthop Surg* 2011;3:35–39.

31. **Morrison JB.** The mechanics of the knee joint in relation to normal walking. *J Biomech* 1970;3:51–61.

32. **Ellis MI, Seedhom BB, Wright V.** Forces in the knee joint whilst rising from a seated position. *J Biomed Eng* 1984;6:113–120.

33. **Cleather DJ, Goodwin JE, Bull AMJ.** Hip and knee joint loading during vertical jumping and push jerking. *Clin Biomech (Bristol, Avon)* 2013;28:98–103.

34. **Goudakos IG, König C, Schöttle PB, et al.** Stair climbing results in more challenging patellofemoral contact mechanics and kinematics than walking at early knee flexion under physiological-like quadriceps loading. *J Biomech* 2009;42:2590–2596.

35. **Trepczynski A, Kutzner I, Kornaropoulos E, et al.** Patellofemoral joint contact forces during activities with high knee flexion. *J Orthop Res* 2012;30:408–415.

36. **Iranpour F, Merican AM, Amis AA, Cobb JP.** The width:thickness ratio of the patella: an aid in knee arthroplasty. *Clin Orthop Relat Res* 2008;466:1198–1203.

37. **Lie DTT, Gloria N, Amis AA, Lee BPH, Yeo SJ, Chou SM.** Patellar resection during total knee arthroplasty: effect on bone strain and fracture risk. *Knee Surg Sports Traumatol Arthrosc* 2005;13:203–208.

38. **Bengs BC, Scott RD.** The effect of patellar thickness on intraoperative knee flexion and patellar tracking in total knee arthroplasty. *J Arthroplasty* 2006;21:650–655.

39. **Anglin C, Fu C, Hodgson AJ, Helmy N, Greidanus NV, Masri BA.** Finding and defining the ideal patellar resection plane in total knee arthroplasty. *J Biomech* 2009;42:2307–2312.

40. **Putman S, Boureau F, Girard J, Migaud H, Pasquier G.** Patellar complications after total knee arthroplasty. *Orthop Traumatol Surg Res* 2019;105:S43–S51.

41. **Pagnano MW, Trousdale RT.** Asymmetric patella resurfacing in total knee arthroplasty. *Am J Knee Surg* 2000;13:228–233.

42. **Breeman S, Campbell M, Dakin H, et al.** Patellar resurfacing in total knee replacement: five-year clinical and economic results of a large randomized controlled trial. *J Bone Joint Surg [Am]* 2011;93-A:1473–1481.

43. **Schiavone Panni A, Cerciello S, Del Regno C, Felici A, Vasso M.** Patellar resurfacing complications in total knee arthroplasty. *Int Orthop* 2014;38:313–317.

44. **Huang AB, Qi YS, Song CH, Zhang JY, Yang YQ, Yu JK.** Novel customized template designing for patellar resurfacing in total knee arthroplasty. *J Orthop Res* 2016;34:1798–1803.

45. **DeOrio JK, Peden JP.** Accuracy of haptic assessment of patellar symmetry in total knee arthroplasty. *J Arthroplasty* 2004;19:629–634.

46. **Camp CL, Martin JR, Krych AJ, Taunton MJ, Spencer-Gardner L, Trousdale RT.** Resection technique does affect resection symmetry and thickness of the patella during total knee arthroplasty: a prospective randomized trial. *J Arthroplasty* 2015;30:2110–2115.

47. **Assiotis A, Ng Man, Sun S, Mordecai S, Hollingdale J.** A novel freehand method for patellar resurfacing in total knee replacement. *Acta Orthop Belg* 2015;81:340–343.

48. **Lombardi AV Jr, Mallory TH, Maitino PD, Herrington SM, Kefauver CA.** Freehand resection of the patella in total knee arthroplasty referencing the attachments of the quadriceps tendon and patellar tendon. *J Arthroplasty* 1998;13:788–792.

49. **Ledger M, Shakespeare D, Scaddan M.** Accuracy of patellar resection in total knee replacement: a study using the medial pivot knee. *Knee* 2005;12:13–19.

50. **Greenfield MA, Insall JN, Case GC, Kelly MA.** Instrumentation of the patellar osteotomy in total knee arthroplasty: the relationship of patellar thickness and lateral retinacular release. *Am J Knee Surg* 1996;9:129–131.

51. **Fu CK, Wai J, Lee E, et al.** Computer-assisted patellar resection system: development and insights. *J Orthop Res* 2012;30:535–540.

52. **Yuan F, Sun Z, Wang H, Chen Y, Yu J.** Clinical and radiologic outcomes of two patellar resection techniques during total knee arthroplasty: a prospective randomized controlled study. *Int Orthop* 2019;43:2293–2301.

53. **Stryker LS, Odum SM, Springer BD, Fehring TK.** Role of patellofemoral offset in total knee arthroplasty: a randomized trial. *Orthop Clin North Am* 2017;48:1–7.

54. **Lee RH, Jeong HW, Lee JK, Choi CH.** Should the position of the patellar component replicate the vertical median ridge of the native patella? *Knee* 2017;24:82–90.

55. **Lachiewicz PF, Soileau ES.** Patella maltracking in posterior-stabilized total knee arthroplasty. *Clinical orthopaedics and related research*. Volume 452. Philadelphia, PA: Lippincott Williams and Wilkins, 2006:155–158.

56. **Brick GW, Scott RD.** The patellofemoral component of total knee arthroplasty. *Clin Orthop Relat Res* 1988;231:163–178.

57. **Lee TQ, Budoff JE, Glaser FE.** Patellar component positioning in total knee arthroplasty. *Clin Orthop Relat Res* 1999;366:274–281.

58. **Hofmann AA, Tkach TK, Evanich CJ, Camargo MP, Zhang Y.** Patellar component medialization in total knee arthroplasty. *J Arthroplasty* 1997;12:155–160.

59. **Anglin C, Brimacombe JM, Wilson DR, et al.** Biomechanical consequences of patellar component medialization in total knee arthroplasty. *J Arthroplasty* 2010;25: 793–802.

Downloaded from Bioscientifica.com at 08/29/2023 12:07:04PM
via free access

60. **Kawano T, Miura H, Nagamine R, et al.** Factors affecting patellar tracking after total knee arthroplasty. *J Arthroplasty* 2002;17:942–947.

61. **Nikolaus OB, Larson DR, Hanssen AD, Trousdale RT, Sierra RJ.** Lateral patellar facet impingement after primary total knee arthroplasty: it does exist. *J Arthroplasty* 2014;29:970–976.

62. **Luring C, Perlick L, Tingart M, Grifka J.** *The effect of femoral component rotation on patellar tracking in total knee arthroplasty*. Volume 30. 2007. www.ORTHOSuperSite.com (accessed 19 December 2020).

63. **Berger RA, Crossett LS, Jacobs JJ, Rubash HE.** Malrotation causing patellofemoral complications after total knee arthroplasty. *Clinical orthopaedics and related research*. Philadelphia, PA: Lippincott Williams and Wilkins, 1998:144–153.

64. **Farrokhi S, Keyak JH, Powers CM.** Individuals with patellofemoral pain exhibit greater patellofemoral joint stress: a finite element analysis study. *Osteoarthritis Cartilage* 2011;19:287–294.

65. **Nakamura S, Tanaka Y, Kuriyama S, et al.** Superior-inferior position of patellar component affects patellofemoral kinematics and contact forces in computer simulation. *Clin Biomech (Bristol, Avon)* 2017;45:19–24.

66. **Brar AS, Howell SM, Hull ML, Mahfouz MR.** Does kinematic alignment and flexion of a femoral component designed for mechanical alignment reduce the proximal and lateral reach of the trochlea? *J Arthroplasty* 2016;31:1808–1813.

67. **Lozano R, Campanelli V, Howell S, Hull M.** Kinematic alignment more closely restores the groove location and the sulcus angle of the native trochlea than mechanical alignment: implications for prosthetic design. *Knee Surg Sports Traumatol Arthrosc* 2019;27:1504–1513.

68. **Dossett HG, Estrada NA, Swartz GJ, LeFevre GW, Kwasman BG.** A randomised controlled trial of kinematically and mechanically aligned total knee replacements: two-year clinical results. *J Bone Joint Surg [Br]* 2014;96-B:907–913.

69. **Keshmiri A, Maderbacher G, Baier C, Benditz A, Grifka J, Greimel F.** Kinematic alignment in total knee arthroplasty leads to a better restoration of patellar kinematics compared to mechanic alignment. *Knee Surg Sports Traumatol Arthrosc* 2019;27:1529–1534.

70. **Nam D, Nunley RM, Barrack RL.** Patient dissatisfaction following total knee replacement: a growing concern? *J Bone Joint Surg [Br]* 2014;96-B:96–100.

71. **Steinbrück A, Schröder C, Woiczinski M, et al.** Influence of tibial rotation in total knee arthroplasty on knee kinematics and retropatellar pressure: an in vitro study. *Knee Surg Sports Traumatol Arthrosc* 2016;24:2395–2401.

72. **Feczko PZ, Pijls BG, van Steijn MJ, van Rhijn LW, Arts JJ, Emans PJ.** Tibial component rotation in total knee arthroplasty. *BMC Musculoskelet Disord* 2016;17:87.

73. **Gromov K, Korchi M, Thomsen MG, Husted H, Troelsen A.** What is the optimal alignment of the tibial and femoral components in knee arthroplasty? An overview of the literature. *Acta Orthopaedica* 2014;85:480–487.

74. **Bindelglass DF, Dorr LD.** Current concepts review: symmetry versus asymmetry in the design of total knee femoral components – an unresolved controversy. *J Arthroplasty* 1998;13:939–944.

75. **Stoddard JE, Deehan DJ, Bull AMJ, McCaskie AW, Amis AA.** No difference in patellar tracking between symmetrical and asymmetrical femoral component designs in TKA. *Knee Surg Sports Traumatol Arthrosc* 2014;22:534–542.

76. **Barink M, Meijerink H, Verdonschot N, van Kampen A, de Waal Malefijt M.** Asymmetrical total knee arthroplasty does not improve patella tracking: a study without patella resurfacing. *Knee Surg Sports Traumatol Arthrosc* 2007;15:184–191.

77. **Petersilge WJ, Oishi CS, Kaufman KR, Irby SE, Colwell CW Jr.** The effect of trochlear design on patellofemoral shear and compressive forces in total knee arthroplasty. *Clin Orthop Relat Res* 1994;309:124–130.

78. **Boyd AD, Ewald FC, Thomas WH, Poss R, Sledge CB.** Long-term complications after total knee arthroplasty with or without resurfacing of the patella. *J Bone Joint Surg [Am]* 1993;75-A:674–681.

79. **Smith AJ, Wood DJ, Li MG.** Total knee replacement with and without patellar resurfacing: a prospective, randomised trial using the Profix total knee system. *J Bone Joint Surg [Br]* 2008;90-B:43–49.

80. **Schindler OS.** The controversy of patellar resurfacing in total knee arthroplasty: ibisne in medio tutissimus? *Knee Surg Sports Traumatol Arthrosc* 2012;20:1227–1244.

81. **Wood DJ, Smith AJ, Collopy D, White B, Brankov B, Bulsara MK.** Patellar resurfacing in total knee arthroplasty: a prospective, randomized trial. *J Bone Joint Surg [Am]* 2002;84-A:187–193.

82. **Gharaibeh MA, Chen DB, Wood JA, MacDessi SJ.** Characteristics of three different patellar implant designs in total knee arthroplasty. *ANZ J Surg* 2020;90:1303–1309.

83. **Smith AJ, Lloyd DG, Wood DJ.** A kinematic and kinetic analysis of walking after total knee arthroplasty with and without patellar resurfacing. *Clin Biomech (Bristol, Avon)* 2006;21:379–386.

84. **O'Brien S, Spence DJ, Ogonda LO, Beverland DE.** LCS mobile bearing total knee arthroplasty without patellar resurfacing: does the unresurfaced patella affect outcome? Survivorship at a minimum 10-year follow-up. *Knee* 2012;19:335–338.

85. **Bourne RB, Burnett RSJ.** The consequences of not resurfacing the patella. *Clinical orthopaedics and related research*. Philadelphia, PA: Lippincott Williams and Wilkins, 2004:166–169.

86. **Ma HM, Lu YC, Kwok TG, Ho FY, Huang CY, Huang CH.** The effect of the design of the femoral component on the conformity of the patellofemoral joint in total knee replacement. *J Bone Joint Surg [Br]* 2007;89-B:408–412.

87. **Matsuda S, Ishinishi T, White SE, Whiteside LA.** Patellofemoral joint after total knee arthroplasty: effect on contact area and contact stress. *J Arthroplasty* 1997;12:790–797.

88. **Theiss SM, Kitziger KJ, Lotke PS, Lotke PA.** Component design affecting patellofemoral complications after total knee arthroplasty. *Clin Orthop Relat Res* 1996;326:183–187.

89. **Huang CH, Hsu LI, Chang TK, et al.** Stress distribution of the patellofemoral joint in the anatomic V-shape and curved dome-shape femoral component: a comparison of resurfaced and unresurfaced patellae. *Knee Surg Sports Traumatol Arthrosc* 2017;25:263–271.

90. **Ali AA, Mannen EM, Rullkoetter PJ, Shelburne KB.** In vivo comparison of medialized dome and anatomic patellofemoral geometries using subject-specific computational modeling. *J Orthop Res* 2018;36:1910–1918.

91. **Burroughs BR, Rubash HE, Estok D, Jasty M, Krevolin J, Muratoglu OK.** Comparison of conventional and highly crosslinked UHMWPE patellae evaluated by a new in vitro patellofemoral joint simulator. *J Biomed Mater Res B Appl Biomater* 2006;79:268–274.

92. **Medel FJ, Kurtz SM, Hozack WJ, et al.** Gamma inert sterilization: a solution to polyethylene oxidation? *J Bone Joint Surg [Am]* 2009;91-A:839–849.

93. **Yu B-f, Yang G-j, Wang W-l, Zhang L, Lin X-p.** Cross-linked versus conventional polyethylene for total knee arthroplasty: a meta-analysis. *J Orthop Surg Res* 2016;11:39.

94. **Lachiewicz PF, Soileau ES.** Is there a benefit to highly crosslinked polyethylene in posterior-stabilized total knee arthroplasty? A randomized trial. *Clin Orthop Relat Res* 2016;474:88–95.

Downloaded from Bioscientifica.com at 08/29/2023 12:07:04PM
via free access

95. Lachiewicz PF, Geyer MR. The use of highly cross-linked polyethylene in total knee arthroplasty. *J Am Acad Orthop Surg* 2011;19:143–151.

96. Asano T, Akagi M, Clarke IC, Masuda S, Ishii T, Nakamura T. Dose effects of cross-linking polyethylene for total knee arthroplasty on wear performance and mechanical properties. *J Biomed Mater Res B Appl Biomater* 2007;83:615–622.

97. Bradford L, Baker D, Ries MD, Pruitt LA. Fatigue crack propagation resistance of highly crosslinked polyethylene. *Clinical orthopaedics and related research*. Philadelphia, PA: Lippincott Williams and Wilkins, 2004:68–72.

98. Ries MD, Pruitt L. Effect of cross-linking on the microstructure and mechanical properties of ultra-high molecular weight polyethylene. *Clinical orthopaedics and related research*. Volume 440. Philadelphia, PA: Lippincott Williams and Wilkins, 2005:149–156.

99. Gencur SJ, Rimnac CM, Kurtz SM. Fatigue crack propagation resistance of virgin and highly crosslinked, thermally treated ultra-high molecular weight polyethylene. *Biomaterials* 2006;27:1550–1557.

100. Hambright DS, Watters TS, Kaufman AM, Lachiewicz PF, Bolognesi MP. Fracture of highly cross-linked all-polyethylene patella after total knee arthroplasty. *J Knee Surg* 2010;23:237–240.

101. Stulberg BN, Wright TM, Stoller AP, Mimnaugh KL, Mason JJ. Bilateral patellar component shear failure of highly cross-linked polyethylene components: report of a case and laboratory analysis of failure mechanisms. *J Arthroplasty* 2012;27:789–796.

102. Goldstein MJ, Ast MP, Dimaio FR. Acute posttraumatic catastrophic failure of a second-generation, highly cross-linked ultra-high-molecular-weight polyethylene patellar component. *Orthopedics* 2012;35:e1119–e1121.

103. Ries MD. Highly cross-linked polyethylene: the debate is over––in opposition. *J Arthroplasty* 2005;20:59–62.

104. Nam D, Kopinski JE, Meyer Z, Rames RD, Nunley RM, Barrack RL. Perioperative and early postoperative comparison of a modern cemented and cementless total knee arthroplasty of the same design. *J Arthroplasty* 2017;32:2151–2155.

105. Ranawat CS, Flynn WF Jr, Saddler S, Hansraj KK, Maynard MJ. Long-term results of the total condylar knee arthroplasty: a 15-year survivorship study. *Clin Orthop Relat Res* 1993;286:94–102.

106. Nguyen LCL, Lehil MS, Bozic KJ. Trends in total knee arthroplasty implant utilization in the United States. *J Arthroplasty* 2015;30:1292.

107. Healy WL, Wasilewski SA, Takei R, Oberlander M. Patellofemoral complications following total knee arthroplasty: correlation with implant design and patient risk factors. *J Arthroplasty* 1995;10:197–201.

108. Rosenberg AG, Andriacchi TP, Barden R, Galante JO. Patellar component failure in cementless total knee arthroplasty. *Clin Orthop Relat Res* 1988;236:106–114.

109. Stulberg SD, Stulberg BN, Hamati Y, Tsao A. Failure mechanisms of metal-backed patellar components. *Clin Orthop Relat Res* 1988;236:88–105.

110. Andersen HN, Ernst C, Frandsen PA. Polyethylene failure of metal-backed patellar components: 111 AGC total knees followed for 7–22 months. *Acta Orthop Scand* 1991;62:1–3.

111. Ritter MA, Meneghini RM. Twenty-year survivorship of cementless anatomic graduated component total knee arthroplasty. *J Arthroplasty* 2010;25:507–513.

112. Newman JM, Sodhi N, Dekis JC, et al. Survivorship and functional outcomes of cementless versus cemented total knee arthroplasty: a meta-analysis. *J Knee Surg* 2020;33:270–278.

113. Mont MA, Gwam C, Newman JM, et al. Outcomes of a newer-generation cementless total knee arthroplasty design in patients less than 50 years of age. *Ann Transl Med* 2017;5:S24.

114. Valdivia GG, Dunbar MJ, Jenkinson RJ, Macdonald SJ, Rorabeck CH, Bourne RB. Press-fit versus cemented all-polyethylene patellar component midterm results. *J Arthroplasty* 2002;17:20–25.

115. Harwin SF, DeGouveia W, Sodhi N, et al. Outcomes of cementless-backed patellar components. *J Knee Surg* 2020;33:856–861.

116. Cohen RG, Sherman NC, James SL. Early clinical outcomes of a new cementless total knee arthroplasty design. *Orthopedics* 2018;41:e765–e771.

117. Rath NK, Dudhniwala AG, White SP, Forster MC. Aseptic loosening of the patellar component at the cement-implant interface. *Knee* 2012;19:823–826.

118. Kwong LM, Nielsen ESN, Ruiz DR, Hsu AH, Dines MD, Mellano CM. Cementless total knee replacement fixation: a contemporary durable solution – affirms. *J Bone Joint Surg [Br]* 2014;96-B:87–92.

119. Chan JY, Giori NJ. Uncemented metal-backed tantalum patellar components in total knee arthroplasty have a high fracture rate at midterm follow-up. *J Arthroplasty* 2017;32:2427–2430.

120. Dye SF. The pathophysiology of patellofemoral pain: a tissue homeostasis perspective. *Clinical orthopaedics and related research*. Philadelphia, PA: Lippincott Williams and Wilkins, 2005:100–110.

121. Witoński D, Wagrowska-Danielewicz M. Distribution of substance-P nerve fibers in the knee joint in patients with anterior knee pain syndrome: a preliminary report. *Knee Surg Sports Traumatol Arthrosc* 1999;7:177–183.

122. Wojtys EM, Beaman DN, Glover RA, Janda D. Innervation of the human knee joint by substance-P fibers. *Arthroscopy* 1990;6:254–263.

123. Motififard M, Nazem K, Zarfeshani A, Zarfeshani K. Effect of patellar electrocautery neurectomy on postoperative pain among patients referred for total knee arthroplasty. *Adv Biomed Res* 2018;7:9.

124. Budhiparama NC, Hidayat H, Novito K, Utomo DN, Lumban-Gaol I, Nelissen RGHH. Does circumferential patellar denervation result in decreased knee pain and improved patient-reported outcomes in patients undergoing non-resurfaced, simultaneous bilateral total knee arthroplasty? *Clin Orthop Relat Res* 2020; 478:2020–2033.

125. Alomran A. Effect of patellar denervation on mid-term results after non-resurfaced total knee arthroplasty: a randomised, controlled trial. *Acta Orthop Belg* 2015;81:609–613.

126. Zhang P, Liu H, Yan WS, Wang WL. Is patellar denervation necessary in total knee arthroplasty without patellar resurfacing? *Knee Surg Sports Traumatol Arthrosc* 2016;24:2541–2549.

127. Xie X, Pei F, Huang Z, Tan Z, Yang Z, Kang P. Does patellar denervation reduce post-operative anterior knee pain after total knee arthroplasty? *Knee Surg Sports Traumatol Arthrosc* 2015;23:1808–1815.

128. Pulavarti RS, Raut VV, McLauchlan GJ. Patella denervation in primary total knee arthroplasty: a randomized controlled trial with 2 years of follow-up. *J Arthroplasty* 2014;29:977–981.

129. Duan G, Liu C, Lin W, et al. Different factors conduct anterior knee pain following primary total knee arthroplasty: a systematic review and meta-analysis. *J Arthroplasty* 2018;33:1962–1971.e3.

130. Kwon SK, Nguku L, Han CD, Koh YG, Kim DW, Park KK. Is electrocautery of patella useful in patella non-resurfacing total knee arthroplasty? A prospective randomized controlled study. *J Arthroplasty* 2015;30:2125–2127.

Downloaded from Bioscientifica.com at 08/29/2023 12:07:04PM
via free access

131. van Jonbergen H-PW, Barnaart AFW, Verheyen CCPM. A Dutch survey on circumpatellar electrocautery in total knee arthroplasty. *Open Orthop J* 2010;4:201–203.

132. Spencer BA, Cherian JJ, Margetas G, et al. Patellar resurfacing versus circumferential denervation of the patella in total knee arthroplasty. *Orthopedics* 2016;39:e1019–e1023.

133. Dong Y, Li T, Zheng Z, Xiang S, Weng X. Adding patella resurfacing after circumpatellar electrocautery did not improve the clinical outcome in bilateral total knee arthroplasty in Chinese population: a prospective randomized study. *J Arthroplasty* 2018;33:1057–1061.

134. Findlay I, Wong F, Smith C, Back D, Davies A, Ajuied A. Non-resurfacing techniques in the management of the patella at total knee arthroplasty: a systematic review and meta-analysis. *Knee* 2016;23:191–197.

135. Goicoechea N, Hinarejos P, Torres-Claramunt R, Leal-Blanquet J, Sánchez-Soler J, Monllau JC. Patellar denervation does not reduce post-operative anterior knee pain after primary total knee arthroplasty with patellar resurfacing. *Knee Surgery, Sport Traumatol Arthrosc* 2020. doi:10.1007/s00167-020-06164-5 [Epub ahead of print].

136. Cerciello S, Robin J, Lustig S, Maccauro G, Heyse TJ, Neyret P. The role of patelloplasty in total knee arthroplasty. *Arch Orthop Trauma Surg* 2016;136:1607–1613.

137. Antinolfi P, Manfreda F, Placella G, Teodori J, Cerulli G, Caraffa A. The challenge of managing the 'third-space' in total knee arthroplasty: review of current concepts. *Joints* 2018;6:204–210.

138. Keblish PA, Varma AK, Greenwald AS. Patellar resurfacing or retention in total knee arthroplasty: a prospective study of patents with bilateral re-placements. *J Bone Joint Surg [Br]* 1994;76-B:930–937.

139. Sun YQ, Yang B, Tong SL, Sun J, Zhu YC. Patelloplasty versus traditional total knee arthroplasty for osteoarthritis. *Orthopedics* 2012;35:e343–e348.

140. Župan A, Snoj Ž, Antolič V, Pompe B. Better results with patelloplasty compared to traditional total knee arthroplasty. *Int Orthop* 2014;38:1621–1625.

141. Burnett RS, Haydon CM, Rorabeck CH, Bourne RB. The John Insall Award: patella resurfacing versus nonresurfacing in total knee arthroplasty. *Clin Orthop Relat Res* 2004;428:12–25.

142. Agarwala S, Shetty V, Karumuri LK, Vijayvargiya M. Patellar resurfacing versus nonresurfacing with patellaplasty in total knee arthroplasty. *Indian J Orthop* 2018;52:393–398.

143. Liu ZT, Fu PL, Wu HS, Zhu Y. Patellar reshaping versus resurfacing in total knee arthroplasty: results of a randomized prospective trial at a minimum of 7 years' follow-up. *Knee* 2012;19:198–202.

144. Li B, Bai L, Fu Y, Wang G, He M, Wang J. Comparison of clinical outcomes between patellar resurfacing and nonresurfacing in total knee arthroplasty: retrospective study of 130 cases. *J Int Med Res* 2012;40:1794–1803.

145. Hwang BH, Yang IH, Han CD. Comparison of patellar retention versus resurfacing in LCS mobile-bearing total knee arthroplasty. *Knee Surg Sports Traumatol Arthrosc* 2012;20:524–531.

Downloaded from Bioscientifica.com at 08/29/2023 12:07:04PM
via free access