Orthopedic & Muscular System: Current Research

Murphy and Levine, Orthopedic Muscul Sys 2014, 3:2
DOI: 10.4172/2161-0533-3-1000152

Review Article Open Access

Modern Arthroplasty Treatment Options for Osteoarthritis of the Knee

Joshua Murphy and Brett Levine*

Assistant Professor, Rush University Medical Center, Orthopaedics, Chicago, USA

***Corresponding author:** Brett Levine, Residency Program Director and Assistant Professor, Rush University Medical Center Orthopaedics, 1611 W. Harrison St., STE 300, Chicago , IL 60612, USA, Tel: 312-432-2466; E-mail: brettlevinemd@gmail.com

Received date: Dec 10, 2013, **Accepted date:** May 29, 2014, **Published date:** June 04, 2014

Abstract

Osteoarthritis of the knee is a commonly treated orthopaedic condition that can be quite disabling, often leading to significantly reduced activity levels. Non-operative treatment is the first line of management with non-steroidal anti-inflammatory agents, intra-articular injections, knee braces, weight loss and activity modification. While there has been a growing interest in topical agents, stem cell/platelet-rich-plasma injections and shoe modifications, the overall efficacy of such modalities in relationship to the relative cost remains a question. Surgical options typically include total knee arthroplasty, unicompartmental knee arthroplasty and patellofemoral joint arthroplasty, depending on the extent and location of the degenerative joint disease. Arthroplasty options provide excellent long-term outcomes in appropriately indicated patients. Modern total knee arthroplasty components are well-designed and if put in appropriately in a patient that is willing to do their physical therapy, excellent results are commonly found. Unicompartmental knee arthroplasty has also experienced a resurgence with the push for less invasive surgery and more rapid rehabilitation. Successful results can be achieved with meticulous surgical techique and appropriately indicated patients. The following is a thorough review of the modern options for the management of knee degenerative joint disease, focusing on the latest arthroplasty procedures.

Keywords: Osteoarthritis; Arthroplasty; Orthopaedic

Introduction

Osteoarthritis [OA] of the knee is one of the most common diagnoses encountered by practicing orthopaedic surgeons. Knee OA causes significant pain and dysfunction that can be debilitating and alter one's quality of life. Patients often present with pain that can be limited to the medial, lateral or patellofemoral compartments of the knee; however, it is more commonly found globally throughout the knee. Weakness of the quadriceps muscle often results from guarding of the patellofemoral joint, and manifests itself as atrophy, reduced exercise tolerance and decreased thigh circumference. Other common physical findings are a quadriceps avoidance gait, varus/valgus alignment, reduced arc of motion, flexion contracture, effusion and crepitus with range of motion. Radiographic findings of knee OA were described by Fairbanks et al. and include narrowing of radiographic joint space, flattening of the femoral condyles, and ridge formation [1]. Plain radiography is the first diagnostic step in evaluation and if significant OA is found then no further testing is necessary. When radiographs are normal in the setting of significant pain, then advanced imaging studies maybe obtained, including, MRI, CT scan or scintigraphy tests.

Non-operative treatment options

The American Academy of Orthopedic Surgeons [AAOS] released a set of clinical practice guidelines for the treatment of osteoarthritis of the knee in 2013 [an update to the original guidelines published in 2008] based on the systematic review of currently available data and literature [2]. In general, the reviewers felt that non-operative treatment options for knee OA although limited, should be exhausted prior to arthroplasty surgical intervention. Systemic nonsteroidal anti-inflammatory drugs [NSAID's] can be beneficial in decreasing the synovitis associated with osteoarthritis. NSAID's include non-selective cyclooxygenase inhibitors such as ibuprofen or naproxen sodium and selective cyclooxygenase [COX-2] inhibitors. AAOS clinical practice guidelines gave a strong recommendation for the use of NSAID's in treatment of symptomatic knee OA [2]. In patients with coronal malalignment, unloader bracing in addition to medial arch supports and lateral heel wedges can improve the overall alignment of the limb and offload the more diseased compartment [medial or lateral]. This is a commonly utilized treatment option for symptomatic patients with a significant correctable deformity, however the AAOS clinical guidelines do not support routine use of this modality [2]. Physical therapy aimed at quadriceps strengthening is a common non-invasive intervention, which can improve patient strength. Enhanced strength may lead to a reduced intensity of the symptoms while increasing mobility and functional status; however, in advanced stages of OA this is typically not well tolerated. The AAOS clinical practice guideline also gives a strong recommendation for the use of self-management programs, strengthening, low-impact aerobic activities and neuromuscular activities [2]. Intra-articular injections are used commonly in the treatment of knee OA. Injections are broadly classified into corticosteroid, viscosupplementation modalities, and growth factors/platelet rich plasma. Intra-articular corticosteroid injections can diminish the synovitis and inflammation associated with knee OA but does not alter the disease process. Viscosupplementation injections that are naturally occurring and synthetic forms of hyaluronic acid have been utilized to a great extent, however, the AAOS Clinical practice Guidelines give a strong recommendation against the use of such injections in the treatment of knee OA [2]. Of note, corticosteroid and growth factor/PRP injections were given an inconclusive recommendation suggesting that although these modalities may be of benefit, strong scientific data does not exist supporting these modalities [2].

When non-operative management of knee OA has failed to relieve patient symptoms operative management may be indicated. In general, arthroscopic intervention in the setting of OA is not indicated and should be reserved for patients with true mechanical symptoms [catching, locking] suggestive of the presence of a meniscus tear or loose body that is mobile causing dynamic symptoms during range of motion. Mosely et al. in the New England Journal of Medicine in 2002 published the results of randomized and blinded study of arthroscopic intervention for knee OA. They noted no difference in clinical outcomes between patients undergoing arthroscopic debridement, arthroscopic lavage only, and a placebo group wherein patients received only arthroscopic portal incisions [so-called "sham surgery"] without insertion of an arthroscope or instruments [3]. The AAOS clinical practice guidelines give a strong recommendation against arthroscopic lavage or debridement and an inconclusive recommendation in the use of partial arthroscopic meniscectomy for a torn meniscus in the setting of OA [2].

Arthoplasty treatment options

Unicompartmental knee arthroplasty

In select patients with isolated medial or lateral compartment arthrosis, unicompartmental knee arthroplasty [UKA] may be indicated. UKA has evolved over the last three decades with respect to expanding indications, outcomes and overall utilization. Early studies on UKA demonstrated poor patient satisfaction and high failure rates [often related to overcorrection of the anatomic deformity] as compared to conventional total knee arthroplasty [TKA] [4,5]. The early zeal for overcorrection of the deformity led to rapid degeneration in the adjacent compartments of the knee and UKA subsequently fell out of favor. However, there has been a resurgence of UKA use in the United States and worldwide with UKA now representing an estimated 8-10% of all knee arthroplasty surgeries [6]. Contrary to this recent trend in a report of over 4000 patients undergoing TKA, only 4.3% met the clinical and radiographic criteria for UKA [7]. The rationale behind such an increase is found in surgeon comfort level with the procedure, a drive for less invasive surgery and expanding surgical indications.

UKA is often considered a less invasive option for patients' with single compartment degenerative joint disease. Additionally, because the anterior and posterior cruciate ligaments are preserved, patients are more likely to have a "normal" feeling knee and be able to return to pre-operative lifestyle and activities. Reports have demonstrated a higher percentage of patients with flexion greater than 120 degrees and a greater number rating their outcome as excellent in comparison to TKA [8].

The classic indications for UKA as published by Kozinn and Scott include non-obese patients [< 82 kg] with lower functional demands, age greater than 60 years, no pain at rest [only with walking and weight bearing], at least 90 degree flexion arc with < 5 degree flexion contracture, and minimal angular deformity [< 10 degree varus or < 15 degree valgus] correctable at the time of surgery [9]. More recently, the indications have expanded leading to an overall increased utilization of UKA. Pennington et al. reported on 45 patients less than 60 years old undergoing medial UKA, noting a 92% eleven-year survival rate and 93% reporting excellent HSS scores [10]. Berend et al. reported no difference in outcomes of patients greater than 82 kg; < 60 years of age or with patellofemoral radiographic changes in 318 UKA's performed with the Oxford implants [Biomet, Warsaw, IN] [11]. Most recently Della Valle reported on 85 fixed bearings UKA's. In this cohort with a mean age of 49 years, there was a significant increase in the pre-operative knee society score with an estimated 96.5% survivorship at 10 years [12].

Since the resurgence of UKA more reports have become available on newer prostheses and surgical techniques. Berger et al. reported 80% excellent results in 49 knees undergoing fixed bearing procedures with the Miller-Galante [Zimmer, Wars IN] UKA [13]. The same study found 98% ten-year survival and 95.7% 13-year survival rates. Murray et al. have extensively reviewed a mobile bearing UKA design reporting a 97.7% cumulative survival rate in their series [14]. Emerson et al. reported an 85% ten-year survival for patients undergoing medial UKA with a similar mobile bearing prosthesis [15]. Some modern day options that are available, but with limited clinical data include, robot-assisted UKA and custom cutting guides. While intriguing in their utility these modalities have not been sufficiently evaluated in vivo and can be quite costly.

Recently there has been concern that with a greater prevalence of UKAs in the population we may see a greater number of those needing conversion to a TKA annually. Furthermore, it is a common misconception that the revision of a UKA to a TKA is an easy conversion that leaves the patient with the equivalent outcome and satisfaction as a primary TKA. Reports from the New Zealand Joint Registry do not support this misconception [16]. In fact a significant difference exists in the Oxford Knee Score between primary TKA and UKA revised to TKA with the latter being closer to a TKA revision. Moreover, the revision rate of UKA's that have been revised to a TKA is more than four times the revision rate of a standard primary TKA. Based on this data it is important to have a detailed discussion with patients prior to surgery and the authors suggest conservative indications be followed.

Patellofemoral Arthroplasty

In patients with isolated patellofemoral arthritis a patellofemoral arthroplasty [PFA] may be indicated. Isolated patellofemoral OA is a rare entity seen in approximately 13% of men and 15% of women over the age of 60 [17]. Indications for PFA should be limited to not only patients with isolated radiographic arthritic changes of the patellofemoral joint, but also to anterior knee symptomatology, such as pain associated with stair climbing, arising from a seated position and squatting. Patients with patellofemoral arthritis should undergo a detailed examination and work-up in order to identify causative factors for their pathology, which is often related to patella maltracking. Patients with Q angle abnormalities should be considered for tibial tubercle re-alignment in conjunction with PFA. A limited amount of patella tilt can be addressed with lateral retinacular release at the time of surgery; while, subluxation or frank instability will need a more formal realignment procedure.

Patients thought to have isolated patellofemoral arthritis should be carefully scrutinized on history, physical examination, and radiographic evaluation and at the time of surgery for presence of other etiologies of anterior knee pain and the presence of tibiofemoral arthritis. Further a history of meniscal injuries or arthroscopy should be considered prior to moving forward with PFA.

Outcomes of isolated PFA vary largely based on design. Onlay designs have demonstrated better clinical outcomes with fewer revisions for mechanical catching associated with prosthetic designs. Lonner has extensively reviewed PFA emphasizing the importance of prosthetic selection and accurately addressing patellar tracking issues in order to affect better clinical outcomes [18]. Several studies have looked at survivorship of isolated PFA. Cartier in 2005 reported 75% of 79 PFA's performed during a 16-year period were still functioning at a minimum of 6-year follow-up with average follow-up of 10 years [19. Kooijman et al. reported their PFA experience in 2003 [20]. In 45 knees at mean follow-up of 17 years they reported 86% good or excellent clinical results based on Knee Society score and patient satisfaction reporting. They noted that two knees underwent subsequent high tibial osteotomy and ten patients underwent conversion to TKA for progressive tibiofemoral degenerative changes, at a mean of 15.6-years post-op [20]. Ackroyd et al. in 2007 reviewed 109 consecutive PFA's with a minimum of 5-year follow-up finding a 95.8% survivorship with revision surgery as the end point. They reported 80% success based on Bristol Pain Score and noted that their main complication was progression of tibiofemoral arthritis, which occurred in 28% of their patients [21]. Aregenson et al. reported on 66 PFA's performed over an 18-year period. Mean patient age at the time of surgery was 57 years and mean follow-up was 16.2 years. At 16 years, survivorship was noted to be 58% with the number one reason for revision surgery being progression of tibiofemoral arthritis [22]. More recently Davies et al. reviewed the results of 52 consecutive PFA's utilizing the Femoro-patella vialla [FPV, Wright Medical, Arlington, TN] with a minimum 2-year follow-up. They noted that 25% of patients obtained an excellent clinical outcome with near or complete resolution of pre-operative symptoms while 21% of patients received little or no relief in their symptoms. Seven patients had been revised to TKA for ongoing pain or arthritic progression [23].

As with UKA it is important to consider the outcome of PFA when converted to TKA during surgical discussion and decision-making. There is limited literature available on PFA conversion to TKA. Lonner et al. published their results on 12 knees in 10 patients who underwent revision of PFA to TKA at a mean of 4 years after their index surgery. They noted that no stems or augments were necessary at the time of revision surgery and all patients were revised to a posterior stabilized prosthesis. At 3 years follow-up none had underwent further revision surgery and pre-revision Knee Society scores improved from 57 to 96 for clinical and from 51 to 91 for function [24]. Hutt et al. compared 21 patients undergoing PFA revision to TKA to 21 matched controls undergoing primary TKA and noted at mean follow-up of 2.4 years that primary TKA had significantly better Oxford Knee Scores, WOMAC scores, pain visual analog scores, and EQ-5D scores [25].

Total Knee Arthroplasty

Total Knee Arthroplasty [TKA] is a reproducible and predictable operation with reliable patient outcomes and excellent long-term survivorship. The published literature on modern TKA is both robust and complex. There are many variables to consider when assessing TKA publications and thus careful scrutiny of study methodology should be considered when evaluating outcomes. First, outcomes can be reported as survivorship of implants or can be reported as clinical, functional or patient satisfaction scores. Secondly, the type of implant, surgical approach, anesthesia utilized peri-operatively, and rehabilitative efforts may all influence patient satisfaction and short-term outcomes.

Early reports on long-term outcomes demonstrated excellent results and survivorship. Rand et al. reported a 97% survivorship at 5 and 10 years on 9200 TKA's performed between 1971 and 1987 [26]. In 1993, Ranawat et al. report a clinical survival of 94.1% at 15 years in 112 TKA's being followed from 1974 [27]. Ritter et al. reported on 418 cruciate retaining TKA's performed between 1975 and 1983 noting a 96.8% [Kaplan-Meier survival] and 98.1% [crude survival estimate] survivorship at a mean of 8-year follow-up [28]. In a separate publication on compression molded polyethylene in cruciate retaining TKA, Ritter et al. reported the results from 3 institutions on 2001 TKA's noting a 98% 10-year survivorship [29]. Schai et al. reported on 235 TKA's with a 90% survivorship at 10 years [30]. The results of 4583 anatomic graduated component TKA's were reported as 98.86% survival at 15 years [31]. Pavone et al. reported their results of 120 total condylar arthroplasty operations performed between 1977 and 1983. In 26 patients with 34 arthroplasties they reported a 91% survivorship at 23-years [32]. These are reports on results of early TKA designs noting greater than 90% long-term survival in all studies when revision is selected as the end point.

Despite excellent long-term survivorship of early TKA, designs have been modified over time in an attempt to further improve function and survivorship. Key design differences should be considered carefully including fixed versus mobile bearings, cruciate retaining versus cruciate sacrificing [posterior stabilized] prostheses and cemented versus cementless fixation.

Fixed bearing TKA refers to a bearing surface [predominantly polyethylene] that is secured to a tibial base plate or a monoblock tibial component, both of which allow joint motion only at the articular surface interface between the femoral component and the bearing surface. Fixed-bearing TKA is dichotomized into posterior cruciate ligament [PCL] retaining [CR] designs and PCL sacrificing [PS] designs wherein a post from the tibial articular surface inserts into a CAM on the femoral component. The latter design depends on the CAM and post to convey anterior-posterior stability normally provided by the PCL, which is either deficient or sacrificed at the time of surgery.

Mobile-bearing TKA allows motion at two separate interfaces. Rolling of the femoral component occurs at the interface with polyethylene insert. Unlike it's fixed counterpart, the polyethylene insert of the mobile-bearing TKA has motion on the tibial base plate allowing more freedom in motion while also introducing an additional wear producing interface. The rotating platform allows a more congruent polyethylene to be used and in theory would lower wear rates at the articular surface; however, this difference has not been borne out in clinical trials.

In a review of the available literature, a large number of studies evaluate PS and CR TKA. In 2008, Dalury et al. reported on their experience with PFC TKA system demonstrating a 97.2% survival at a median 7.3-year follow-up in 1970 knees [33]. In the same year, Dalury et al. reported a mean ROM of 123 degrees in 284 PFC TKA's [96% were CR, 4% were PS] [34]. In 2005, Bertin reported his experience with 251 consecutive CR TKA's at 5-7 year follow-up. His results showed 98% survival at 5-7 year follow-up with a mean range of motion of 123 degrees [35]. Laskin in 2001 studied 100 consecutive TKA's, both CR and PS. In their CR group the mean ROM was 117 degrees, 10-year survival was 96%, 76% had an excellent clinical result and 20% had a good clinical result. In the PS group, the mean ROM was 114 degrees; 10-year survival was 97%, 75% had excellent clinical results and 23% had a good clinical result [36]. A Cochrane database systematic review demonstrated no appreciable difference in outcomes between CR and PS designs, published initially in 2005 and updated in 2013 [37,38].

The published results reported with fixed bearing CR and PS TKA are essentially equivocal. No study has demonstrated clear clinical superiority in PS or CR TKA; therefore, utility of PS versus CR designs is largely based on surgeon training and experience.

Mobile-bearing TKA's have demonstrated equivalent results as that of fixed-bearing designs. Buechel et al. reported on 373 mobile bearing TKA's. He noted a 97.9% good or excellent clinical result with greater than 97% survivorship at 10 years [39]. Huang et al. report in 88.1% survivorship at 15 years on 495 consecutive mobile bearing TKA's performed in Taiwan [40]. Sorrells et al. reported a twelve-year survivorship of 89.5% in 528 uncemented Low Contact Stress rotating platform TKA's [41]. Mohoney et al., in 2012, performed a prospective randomized study that demonstrated no functional benefit to a mobile bearing TKA over a fixed bearing device. However, survivorship was lower in the mobile bearing group [90.1%] than the fixed bearing group [94.2%] at 6 years post-op [42]. In an extensive literature review Post et al. demonstrated no clinical or survivorship difference between mobile bearing and fixed bearing TKA [43]. In a prospective randomized trial Gioe et al. once again demonstrated clinical equivalence of a rotating platform TKA and an all-polyethylene PS TKA [44]. In an evaluation of 108 young patients [age less than 51] with OA receiving a fixed bearing TKA on one side and a rotating platform TKA on the contralateral, no functional difference was found. At 16.8 year of follow-up using Kaplan-Meier analysis survivorship was 95% for the fixed bearing devices and 97% for the mobile bearing devices [45]. Bhan et al. showed no functional difference in 32 patients with a fixed bearing TKA on one side and mobile bearing on the contralateral at 4.5 years follow-up [46]. A Cochrane database systematic review demonstrated no superiority of mobile bearing or fixed bearing designs in functional performance or range of motion [47].

Despite many publications demonstrating what appears to be good clinical outcomes with mobile bearing TKA's, Namba et al. using joint registry data found that LCS mobile bearing TKA is an independent risk for aseptic revision [48]. Reports from the Norwegian joint registry on over 17,000 TKA's suggest that risk of revision surgery for aseptic loosening of TKA components is related to prosthetic design [49].

For primary TKA procedures, although controversial [anatomic alignment], it is paramount to restore the natural mechanical axis, maintain good component fixation and achieve ligamentous balance. Accurate cuts are vital and less-invasive techniques may compromise this accuracy leading to component malpositioning and difficulty with soft tissue balancing [50,51]. Bone cuts can be achieved with intramedullary, extramedullary, custom cutting guides and/or computer navigation with acceptable levels of accuracy and success [52-54]. However, most recently, there has been a call to question whether the anatomic axis [kinematic alignment] is more important than the mechanical axis [55]. Therefore, at this time it is not perfectly clear what axis and degree of alignment we should be shooting for and will this vary amongst patients.

Ultimately an equal determinant for a successful outcome is the attention to detail in soft tissue balancing, while minimizing the level of constraint inherent to the components. Appropriate osseous and soft tissue technique should re-establish nearly normal kinematics with a medial pivot during midflexion and bicondylar posterior rollback with deep knee flexion [56]. While restoring the appropriate kinematics during TKA, the overall outcomes vary often based upon patient factors, which may not be as closely related to the overall limb alignment as once thought [57]. This concept has lead to the use of sensors and accelerometers to determine the force and contact points of the femoral component on the polyethylene insert in real time. This technology can be expensive and has limited clinical data, but may lead to the intra-operative data we need to truly restore patient kinematics [58]. As more clinical data is collected the future of navigation, custom-cutting guides and accelerometer technology will ultimately be determined.

Summary

Degenerative joint disease of the knee is a common problem in the United States with indicated measures of conservative management to treat patients including medications, physical therapy, activity modification and intra-articular injections. When such non-operative options no longer provide adequate pain relief and return to function then surgical options can be considered. Partial knee replacements include resurfacing a single compartment of the knee individually and with the appropriate indications and surgical technique can lead to highly successful outcomes. When more global degeneration of the knee is found a TKA is indicated. Surgical technique, implant design and component fixation can be variable with relatively similar outcomes and is typically selected based upon surgeon preference. Long-term results of TKA are outstanding and have come a long way in restoring the quality of life to many individuals suffering from OA of the knee.

References

1. FAIRBANK TJ (1948) Knee joint changes after meniscectomy. J Bone Joint Surg Br 30B: 664-670.
2. Jevsevar DS. Treatment of osteoarthritis of the knee: evidence-based guideline, 2nd edition. J Am Acad Orthop Surg. 2013 Sep;21(9):571-6.
3. Moseley JB, O'Malley K, Petersen NJ, Menke TJ, Brody BA, (2002) A controlled trial of arthroscopic surgery for osteoarthritis of the knee. N Engl J Med 347: 81-88.
4. Insall J, Aglietti P (1980) A five to seven-year follow-up of unicondylar arthroplasty. J Bone Joint Surg Am 62: 1329-1337.
5. Laskin RS (1978) Unicompartmental tibiofemoral resurfacing arthroplasty. J Bone Joint Surg Am 60: 182-185.
6. Riddle DL, Jiranek WA, McGlynn FJ (2008) Yearly incidence of unicompartmental knee arthroplasty in the United States. J Arthroplasty 23: 408-412.
7. Ritter MA, Faris PM, Thong AE, Davis KE, Meding JB, (2004) Intra-operative findings in varus osteoarthritis of the knee. An analysis of pre-operative alignment in potential candidates for unicompartmental arthroplasty. J Bone Joint Surg Br 86: 43-47.
8. Newman JH, Ackroyd CE, Shah NA (1998) Unicompartmental or total knee replacement? Five-year results of a prospective, randomised trial of 102 osteoarthritic knees with unicompartmental arthritis. J Bone Joint Surg Br 80: 862-865.
9. Kozinn SC, Scott R (1989) Unicondylar knee arthroplasty. J Bone Joint Surg Am 71: 145-150.
10. Pennington DW, Swienckowski JJ, Lutes WB, Drake GN (2003) Unicompartmental knee arthroplasty in patients sixty years of age or younger. J Bone Joint Surg Am 85-85A: 1968-73.
11. Berend KR, Lombardi AV Jr, Adams JB (2007) Obesity, young age, patellofemoral disease, and anterior knee pain: identifying the unicondylar arthroplasty patient in the United States. Orthopedics 30: 19-23.
12. Biswas D, Van Thiel GS, Wetters NG, Pack BJ, Berger RA, (2014) Medial unicompartmental knee arthroplasty in patients less than 55 years old: minimum of two years of follow-up. J Arthroplasty 29: 101-105.
13. Berger RA, Meneghini RM, Jacobs JJ, Sheinkop MB, Della Valle CJ, (2005) Results of unicompartmental knee arthroplasty at a minimum of ten years of follow-up. J Bone Joint Surg Am 87: 999-1006.

14. Murray DW, Goodfellow JW, O'Connor JJ (1998) The Oxford medial unicompartmental arthroplasty: a ten-year survival study. J Bone Joint Surg Br 80: 983-989.

15. Emerson RH Jr, Higgins LL (2008) Unicompartmental knee arthroplasty with the oxford prosthesis in patients with medial compartment arthritis. J Bone Joint Surg Am 90: 118-122.

16. Pearse AJ, Hooper GJ, Rothwell A, Frampton C (2010) Survival and functional outcome after revision of a unicompartmental to a total knee replacement: the New Zealand National Joint Registry. J Bone Joint Surg Br 92: 508-512.

17. Davies AP, Vince AS, Shepstone L, Donell ST, Glasgow MM (2002) The radiologic prevalence of patellofemoral osteoarthritis. Clin Orthop Relat Res : 206-212.

18. Lonner JH (2008) Patellofemoral arthroplasty: the impact of design on outcomes. Orthop Clin North Am 39: 347-354, vi.

19. Cartier P, Sanouiller JL, Khefacha A (2005) Long-term results with the first patellofemoral prosthesis. Clin Orthop Relat Res : 47-54.

20. Kooijman HJ, Driessen AP, van Horn JR (2003) Long-term results of patellofemoral arthroplasty. A report of 56 arthroplasties with 17 years of follow-up. J Bone Joint Surg Br 85: 836-840.

21. Ackroyd CE, Newman JH, Evans R, Eldridge JD, Joslin CC (2007) The Avon patellofemoral arthroplasty: five-year survivorship and functional results. J Bone Joint Surg Br 89: 310-315.

22. Argenson JN, Flecher X, Parratte S, Aubaniac JM (2005) Patellofemoral arthroplasty: an update. Clin Orthop Relat Res 440: 50-53.

23. Davies AP (2013) High early revision rate with the FPV patello-femoral unicompartmental arthroplasty. Knee 20: 482-484.

24. Lonner JH, Jasko JG, Booth RE Jr (2006) Revision of a failed patellofemoral arthroplasty to a total knee arthroplasty. J Bone Joint Surg Am 88: 2337-2342.

25. Hutt J, Dodd M, Bourke H, Bell J (2013) Outcomes of total knee replacement after patellofemoral arthroplasty. J Knee Surg 26: 219-223.

26. Rand JA, Ilstrup DM (1991) Survivorship analysis of total knee arthroplasty. Cumulative rates of survival of 9200 total knee arthroplasties. J Bone Joint Surg Am 73: 397-409.

27. Ranawat CS, Flynn WF Jr, Saddler S, Hansraj KK, Maynard MJ (1993) Long-term results of the total condylar knee arthroplasty. A 15-year survivorship study. Clin Orthop Relat Res : 94-102.

28. Ritter MA, Herbst SA, Keating EM, Faris PM, Meding JB (1994) Long-term survival analysis of a posterior cruciate-retaining total condylar total knee arthroplasty. Clin Orthop Relat Res : 136-145.

29. Ritter MA, Worland R, Saliski J, Helphenstine JV, Edmondson KL, (1995) Flat-on-flat, nonconstrained, compression molded polyethylene total knee replacement. Clin Orthop Relat Res : 79-85.

30. Schai PA, Thornhill TS, Scott RD (1998) Total knee arthroplasty with the PFC system. Results at a minimum of ten years and survivorship analysis. J Bone Joint Surg Br 80: 850-858.

31. Ritter MA, Berend ME, Meding JB, Keating EM, Faris PM, (2001) Long-term followup of anatomic graduated components posterior cruciate-retaining total knee replacement. Clin Orthop Relat Res : 51-57.

32. Pavone V, Boettner F, Fickert S, Sculco TP (2001) Total condylar knee arthroplasty: a long-term followup. Clin Orthop Relat Res : 18-25.

33. Dalury DF, Gonzales RA, Adams MJ, Gruen TA, Trier K (2008) Midterm results with the PFC Sigma total knee arthroplasty system. J Arthroplasty 23: 175-181.

34. Dalury DF, Barrett WP, Mason JB, Goldstein WM, Murphy JA, (2008) Midterm survival of a contemporary modular total knee replacement: a multicentre study of 1970 knees. J Bone Joint Surg Br 90: 1594-1596.

35. Bertin KC (2005) Cruciate-retaining total knee arthroplasty at 5 to 7 years followup. Clin Orthop Relat Res : 177-183.

36. Laskin RS (2001) The Genesis total knee prosthesis: a 10-year followup study. Clin Orthop Relat Res : 95-102.

37. Verra WC, van den Boom LG, Jacobs W, Clement DJ, Wymenga AA, Nelissen RG. Retention versus sacrifice of the posterior cruciate ligament in total knee arthroplasty for treating osteoarthritis. Cochrane Database Syst Rev. 2013 Oct 11;10:CD004803.

38. Jacobs WC, Clement DJ, Wymenga AB. Retention versus sacrifice of the posterior cruciate ligament in total knee replacement for treatment of osteoarthritis and rheumatoid arthritis. Cochrane Database Syst Rev. 2005 Oct 19;(4):CD004803.

39. Buechel FF Sr, Buechel FF Jr, Pappas MJ, D'Alessio J (2001) Twenty-year evaluation of meniscal bearing and rotating platform knee replacements. Clin Orthop Relat Res : 41-50.

40. Huang CH, Ma HM, Lee YM, Ho FY (2003) Long-term results of low contact stress mobile-bearing total knee replacements. Clin Orthop Relat Res : 265-270.

41. Sorrells RB, Voorhorst PE, Murphy JA, Bauschka MP, Greenwald AS (2004) Uncemented rotating-platform total knee replacement: a five to twelve-year follow-up study. J Bone Joint Surg Am 86-86A: 2156-62.

42. Mahoney OM, Kinsey TL, D'Errico TJ, Shen J (2012) The John Insall Award: no functional advantage of a mobile bearing posterior stabilized TKA. Clin Orthop Relat Res 470: 33-44.

43. Post ZD, Matar WY, van de Leur T, Grossman EL, Austin MS (2010) Mobile-bearing total knee arthroplasty: better than a fixed-bearing? J Arthroplasty 25: 998-1003.

44. Gioe TJ, Glynn J, Sembrano J, Suthers K, Santos ER, (2009) Mobile and fixed-bearing (all-polyethylene tibial component) total knee arthroplasty designs. A prospective randomized trial. J Bone Joint Surg Am 91: 2104-2112.

45. Kim YH, Kim JS, Choe JW, Kim HJ (2012) Long-term comparison of fixed-bearing and mobile-bearing total knee replacements in patients younger than fifty-one years of age with osteoarthritis. J Bone Joint Surg Am 94: 866-873.

46. Bhan S, Malhotra R, Kiran EK, Shukla S, Bijjawara M (2005) A comparison of fixed-bearing and mobile-bearing total knee arthroplasty at a minimum follow-up of 4.5 years. J Bone Joint Surg Am 87: 2290-2296.

47. Gøthesen O, Espehaug B, Havelin L, Petursson G, Lygre S, (2013) Survival rates and causes of revision in cemented primary total knee replacement: a report from the Norwegian Arthroplasty Register 1994-2009. Bone Joint J 95-95B: 636-42.

48. Namba RS, Cafri G, Khatod M, Inacio MC, Brox TW, (2013) Risk factors for total knee arthroplasty aseptic revision. J Arthroplasty 28: 122-127.

49. Jacobs W, Anderson P, Limbeek J, Wymenga A (2004) Mobile bearing vs fixed bearing prostheses for total knee arthroplasty for post-operative functional status in patients with osteoarthritis and rheumatoid arthritis. Cochrane Database Syst Rev : CD003130.

50. Lin WP, Lin J, Horng LC, Chang SM, Jiang CC (2009) Quadriceps-sparing, minimal-incision total knee arthroplasty: a comparative study. J Arthroplasty 24: 1024-1032.

51. Matsumoto T, Muratsu H, Kubo S, Mizuno K, Kinoshita K, (2011) Soft tissue balance measurement in minimal incision surgery compared to conventional total knee arthroplasty. Knee Surg Sports Traumatol Arthrosc 19: 880-886.

52. Boonen B, Schotanus MG, Kort NP (2012) Preliminary experience with the patient-specific templating total knee arthroplasty. Acta Orthop 83: 387-393.

53. Meding JB, Berend ME, Ritter MA, Galley MR, Malinzak RA (2011) Intramedullary vs extramedullary femoral alignment guides: a 15-year follow-up of survivorship. J Arthroplasty 26: 591-595.

54. Rottman SJ, Dvorkin M, Gold D (2005) Extramedullary versus intramedullary tibial alignment guides for total knee arthroplasty. Orthopedics 28: 1445-1448.

55. Howell SM, Papadopoulos S, Kuznik KT, Hull ML (2013) Accurate alignment and high function after kinematically aligned TKA performed with generic instruments. Knee Surg Sports Traumatol Arthrosc 21: 2271-2280.

56. Horiuchi H, Akizuki S, Tomita T, Sugamoto K, Yamazaki T (2012) In vivo kinematic analysis of cruciate-retaining total knee arthroplasty during weight-bearing and non-weight-bearing deep knee bending. J Arthroplasty 27: 1196-1202.

57. Parratte S, Pagnano MW, Trousdale RT, Berry DJ (2010) Effect of postoperative mechanical axis alignment on the fifteen-year survival of modern, cemented total knee replacements. J Bone Joint Surg Am 92: 2143-2149.

58. Nam D, Cody EA, Nguyen JT, Figgie MP, Mayman DJ (2014) Extramedullary guides versus portable, accelerometer-based navigation for tibial alignment in total knee arthroplasty: a randomized, controlled trial: winner of the 2013 HAP PAUL award. J Arthroplasty 29: 288-294.