Knee arthroplasty: growing trends and future problems

Total knee arthroplasty, as practiced in the early 21st century, is a product of almost 150 years of understanding the biomechanics of the knee as well as the development of prosthetic materials and surgical techniques, with good long-term results. Patient expectations after total knee arthroplasty have changed; patients undergo total knee arthroplasty hoping to restore their quality of life, which sometimes includes activities requiring high physical demand. Both cemented and uncemented knees provide long-lasting fixation. Minimally invasive surgery limits soft-tissue damage and may facilitate faster rehabilitation. Better materials and implant designs have increased the range of motion and decreased wear. Computer-assisted navigation surgery will render more accurate placement of implants. This article discusses developments in selected topics related to adult knee reconstruction to provide stable and durable implants. Finally, health economics will dictate what is affordable and cost effective in any healthcare system.

KEYWORDS: bearing surfaces ▪ computer-assisted navigation ▪ fixation ▪ minimally invasive ▪ pain management ▪ total knee arthroplasty

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In 1861, Ferguson reported a resection arthroplasty as treatment for severe arthritis of the knee [1]. To our knowledge this was the first report of a surgical intervention to treat arthritis. In the late 18th century, Verneuil performed an interposition arthroplasty of the knee, when he used flaps of joint capsule to cover resected articular surfaces in an attempt to decrease the pain and increase the quality of life of patients [2]. Subsequent to these two papers, many other materials, including skin, muscle, fat, chromicized pig bladder, cellophane and nylon, were tried as interposition materials in the 'resurfacing' of diseased articular surfaces.

Stimulated by the success of Smith-Petersen [3] with mold arthroplasty of the hip, Campbell and Boyd performed the first mold arthroplasty of the knee [4]. In 1971, Gunston reported good early results with a metal femoral component and a high-density polyethylene tibial component fixed to the bone with polymethylmethacrylate (PMMA) using the polycentric knee [5]. In 1973, Insall and others at the Hospital for Special Surgery (NY, USA) developed total condylar prosthesis that dramatically improved the standards for survivorship of total knee arthroplasty (TKA). Insall, Ranawat and colleagues reported 94% efficacy with a knee system that evolved from that original design at 15-year follow-up [6].

In 2008, approximately 550,000 TKAs were performed in the USA. The total expenditures on this procedure alone exceeded US$18 billion. It is now expected that by 2030 the number of primary TKAs will reach 3.48 million annually [7]. We have previously reported on the cost–effectiveness of TKA [8]. In most cases, this procedure restores function and motion and provides significant pain relief. When compared with other surgical and medical interventions its cost–utility profile makes it one of the most effective procedures in medicine (Figure 1).

Fixation

In the early history of TKA, most TKAs were implanted with PMMA. The first few reported series with poor results reflected mostly implant design failures [9]. Gunston introduced a hinge-like TKA design that did well at 12 months [10]. Over the longer follow-up it became clear that the mechanics of the knee were much more complex than a simple hinge. The designs evolved and most knee systems used in 2010 are fundamentally based on the total condylar design. In the late 1980s, Hungerford and colleagues published a landmark paper describing 'cement disease' around hip replacements [11]. This group then went on to develop the first knee design that did not require bone cement to fix it to bone. This 'revolutionary' technology to biologically fix implants to bone became popular in the USA and Europe. Excellent results were reported at the 24-month follow-up mark with this technique [12]. During that time in the history of arthroplasty, several porous surfaces

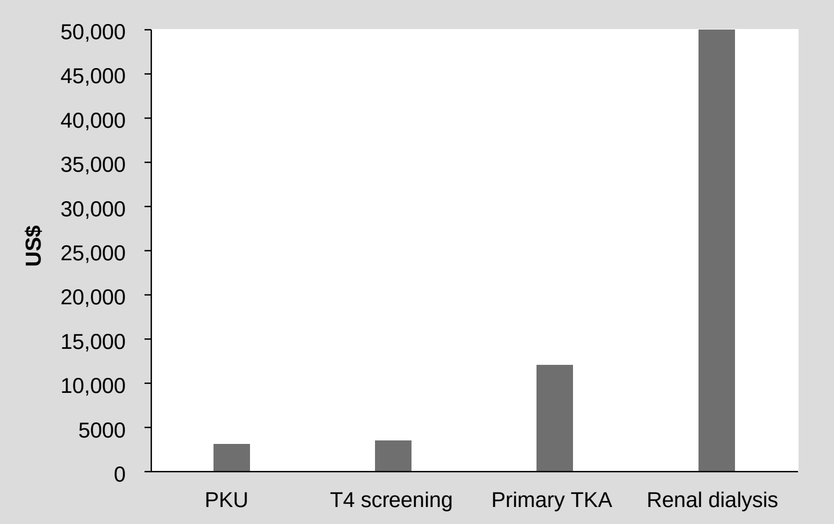

Figure 1. Cost per quality-adjusted life-years for various medical interventions.
PKU: Phenylketonuria; TKA: Total knee arthroplasty.

that allowed bone fixation to grow into and onto them were being widely used in hip and knee arthroplasty.

The development of porous metals and coatings to 'biologically' fix metal to bone revolutionized the field of orthopedics. Initially, the most popular surfaces were: metal beads, wire pieces (fiber mesh) and plasma sprayed surfaces. In their early development all these surfaces had problems. Sintered spherical (Figure 2) structures applied with improper heat treatments broke off. Davey and Harris (ten cases from 70 implantations) concluded that the sintering technique used in the manufacture of these implants did not prevent loosening of cobalt chrome beads from porous-coated cobalt chrome acetabular components [13]. This 'bead-shedding' phenomena created three-body wear and caused early failure of some components. In addition, some of the early sintering techniques weakened the base metals and several hundred implants fractured with repeated use [14–16].

A histological study documented that titanium plasma spray coated on (Figure 3) titanium alloy implants showed greater thickening of ingrown trabeculae than a smooth-sided titanium implant [17]. This phenomenon was observed in the bone–material interface as early as 4 weeks postimplantation and seen to increase with time after implantation.

Other coating utilized was the fiber mesh (Figure 4). Although very successful around the hip joint, particularly in acetabular components, the surface was not very effective in eliciting good long-term function around knee replacement implants. In a small prospective, randomized study, 34 patients were randomized to receive a cemented or cementless Ti alloy tibial plate with four pegs and fiber-mesh undersurface [18]. A radiographic analysis performed 2 years after TKA showed a significant increase in sagittal rotation in the cementless group. This corresponded to increased subsidence medially or laterally in the uncemented knees. This article started the clinical decline of porous surfaces in TKA. Owing to multiple large series documenting high failure rates for porous total knee implants, most surgeons returned to using PMMA for fixation in primary arthroplasty [19,20].

Recent advances

For more than 60 years the potential use of tantalum in humans and animals has been studied [21–23]. Tantalum hip implants were introduced in 1997. These porous tantalum acetabular and femoral components have surfaces so similar to trabecular bone that they are often referred to as 'trabecular metal'. They have been utilized in a wide variety of clinical applications such as treatment of avascular necrosis of the femoral head, reconstruction after tumor resection and joint arthroplasty [24]. Trabecular Metal™ (Zimmer, Warsaw, IN, USA) tibial tray implants made of tantalum are now available for TKA (Figure 5).

Trabecular metal has a 75–85% porosity allowing for two- or three-times greater bone ingrowth compared with conventional porous coatings [25]. Its modulus of elasticity is similar to that of host bone facilitating load transfer and helps minimize stress shielding [26,27]. In a prospective study of 103 patients (105 knees) undergoing TKA using the NexGen (Zimmer) prosthesis with a trabecular metal monoblock tibial component [28], it showed significant improvement after TKA in the Oxford Knee Scores and the Short Form-12 scores at mean follow-up of 44 months (range: 36–56 months). There was only one revision at 27 months after a patient sustained a fall 2 months after knee arthroplasty. In a prospective study of 101 primary TKAs, a monoblock tibial component was implanted in 86 knees and a cemented tibial baseplate was implanted in 29 knees [24]. No differences in Knee Society Scores were recorded at 2-year follow-up between groups. Regardless of the encouraging short-term results, long-term data are needed to support the benefits of porous tantalum knee components. This metal could herald the return of biological fixation to TKA.

Significant advances in the last 15 years have been achieved in the instrumentation to implant the knees and stronger alloys have been developed. Broken knee implants are now rare unless accompanied by malposition of components in the face of a very high BMI [29]. Modern cementing techniques have been developed to implant the knees. We now clean the cancellous surfaces with pulsed lavage or gas and drill the very sclerotic bone to allow bone cement penetration and proper interdigitation – in some centers a gun is used to pressurize the cement. Cemented fixation remains the gold standard in primary knee replacement in 2010 [30,31]. In 2010, over 95% of the knee arthroplasties carried out in the USA are implanted with PMMA. Several long-term series in young patients have been published with over 20-year follow-up in which aseptic loosening rates are around the range of 15%. These knees were implanted over 20 years ago with fewer sizes, older plastic and older instrumentation [32,33].

Minimally invasive

Total knee replacement has traditionally resulted in lengthy recuperative periods [34–36]. To expedite this process minimally invasive or smaller incision approaches were developed in the mid-1990s. Most minimally invasive TKAs include:

- Decreased skin incision length
- Minimal disruption quadriceps muscle
- Lack of patellar evertion
- Pain protocol
- Rapid rehab protocols
- Lower profile instrumentation

Supporters of minimally invasive knee arthroplasty have adopted these techniques to provide faster recovery times, shorter hospital stays and improved short-term functional outcomes [37–42]. However, concerns have been raised with regards to implant malposition and the length of the learning curve [43]. Schorer *et al.* compared implant positioning in 50 patients undergoing TKA with either a medial parapatellar or the mini-subvastus approach [44] with the use of CT scans. They reported an increased accuracy in tibial alignment with the mini-subvastus approach. However, there was greater variance in average coronal femoral component alignment. In a study comparing the first 100 minimally invasive TKAs with the use of the quadriceps-sparing approach performed by a single high-volume arthroplasty surgeon and his last 50 TKAs performed through a medial parapatellar approach, the authors found significant longer operative times in the first 25 patients with the minimally invasive approach [45]. After the first 25 patients, there were no differences in operative times between procedures. Patients in the minimally invasive group had significantly lower length of stay, discharge disposition, less use of narcotics postoperatively and lower need for an assistance device to walk at 2 weeks post-implatation. Although minimally invasive TKA has achieved some good short-term outcomes [46,47], level I prospective, randomized studies have found no differences in pain, blood loss and hospital stay between minimally invasive and standard TKA [48–53]. In addition, increases have been seen in malpositioned implants [43,54] and revision rates [55]. Most large centers no longer perform these 'quad-sparing' procedures since the few benefits appear to be short-term only. We do not recommend the small incision, 'quad-sparing' approaches. However, the pain management protocols that have accompanied these approaches have been extremely beneficial. The length of stay with these pain management protocols accompanied by 'rapid' physical therapy has dropped in our unit from 6 to 4.1 days.

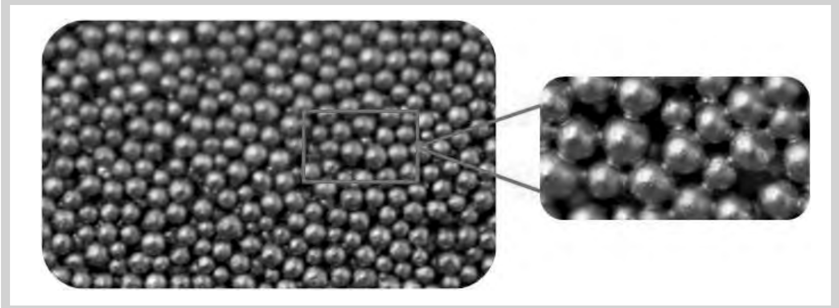

Figure 2. Beaded structure. Magnification 5×.

Pain management

Pain control after total joint arthroplasty has been a key concern for most orthopedic surgeons. Proper analgesia, in addition to making the perioperative period tolerable, directly impacts the perceived, functional outcomes,

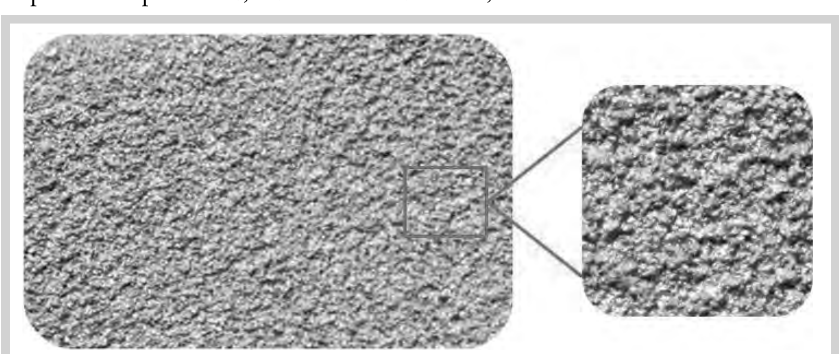

Figure 3. Plasma sprayed surface. Magnification 5×.

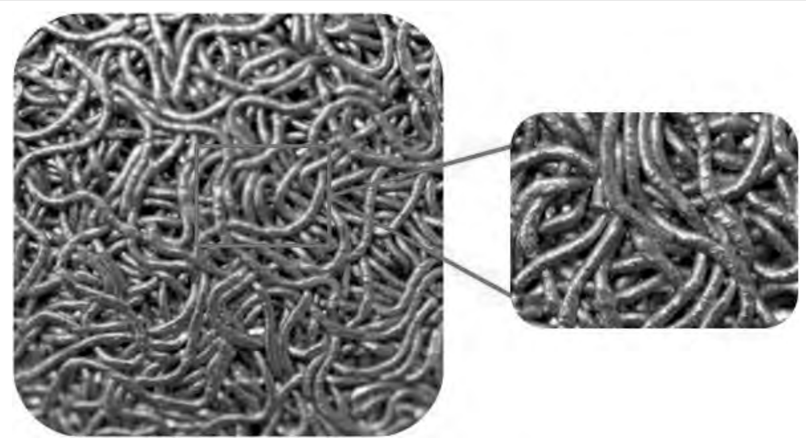

Figure 4. Fiber mesh. Magnification 5×.

and economic expenditure long after the procedure [56]. The consequences of severe immediate postoperative pain are longer hospital stays, increased numbers of readmissions, increased cases of arthrofibrosis and increased opioid use with subsequent increase in side effects such as nausea and vomiting, resulting in lower patient satisfaction [57]. We reported a lower range of motion and a higher rate of arthrofibrosis when multimodal pain management was not used [56]. These improvements in pain management have been one of the most important advances in total joint arthroplasty [58–61]. Although treatment options include the use of oral, intramuscular and intravenous medications, and regional anesthesia with or without the use of opioids, a gold standard has not been established [58,60–64].

Preemptive analgesia incorporates the delivery of medication before the insult and before severe pain spikes (Figure 6), reducing the use of analgesics given once the inflammatory process develops (Figure 7). First described in 1993 as a method of improving outcome after colon surgery [65], the multimodal approach is dependent on understanding the multiple pathways of pain. It combines different drugs collectively affecting the CNS, the afferent pathways and the peripheral wound sites. Pain centers in the CNS are treated with regional anesthetics, the afferent pathways are treated with systemic opioids and the peripheral wound sites are managed with local anesthetics and anti-inflammatory drugs [59].

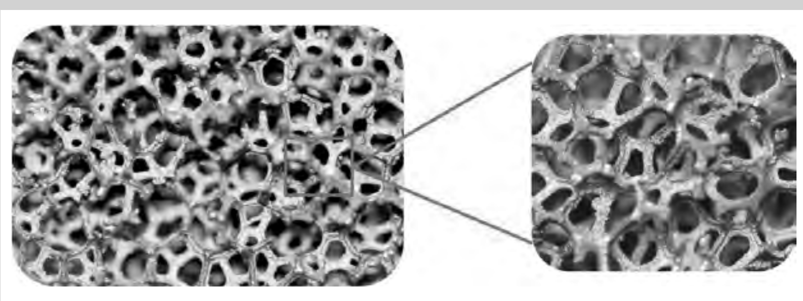

Figure 5. Porous tantalum material. Magnification 5×.

Preemptive analgesia can be achieved with the use of a combination of drugs such as nonsteroidal anti-inflammatory drugs, cyclooxygenase (COX)-2 inhibitors, anticonvulsants and ketamine. The use of nonsteroidal anti-inflammatory drugs and COX-2 inhibitors has an opioid-sparing effect and may reduce the opioid-induced hyperalgesia seen after surgery [66]. The use of COX-2 inhibitors 24 and 1 h before surgery has shown significant reduction in pain scores, reduced opioid requirements, faster time to physical rehabilitation and greater patient satisfaction after TKA [67]. Gabapentin and pregabaline are antiepileptic drugs that have also been successfully used for the treatment of chronic pain. These agents bind the presynaptic voltage-gated calcium channels in the dorsal root ganglia and the spinal cord, inhibiting the release of excitatory neurotransmitters. A recent review found that both drugs reduced pain and opioid consumption after surgery [68] when compared with placebo. Studies have also found a synergistic effect of gabapentin and COX-2 inhibitors, helping to reduce postoperative pain and morphine consumption at 24 h after spinal fusion [69]. Among the receptors implicated in the nocioceptive transmission, the *N*-methyl-D-aspartate receptor plays a critical role in the sensitization and intensity of perceived postoperative pain [70]. Ketamine is a noncompetitive antagonist of *N*-methyl-D-aspartate receptors. In a prospective, randomized, double-blinded study, the ketamine group required significantly less morphine and allowed faster postoperative knee rehabilitation than the placebo group [71].

In the perioperative period, peripheral nerve blocks are increasingly used as a method for anesthesia and pain management in TKA. In a small, prospective, randomized study, patients with femoral nerve block and epidural anesthesia had lower pain scores and faster knee rehabilitation 6 weeks after TKA compared with the use of patient-controlled analgesia [72]. In addition, a lower incidence of side effects was seen in patients with the use of femoral nerve block. Although peripheral nerve blocks can be achieved with the use of a single injection of a local anesthetic, a continuous infusion may offer better analgesia, as reported by Salinas *et al.* [73]. They found that a continuous femoral nerve block was associated with significantly lower pain scores and lower opioid consumption after TKA when compared with single-injection femoral nerve block. However, they found no difference in length of stay and functional recovery at 12 weeks after surgery. We recently reported a marked decrease in postoperative cases of arthrofibrosis using a multimodal pain protocol [56].

Patient-controlled anesthesia (PCA) is the most common form of postoperative analgesia after TKA [74]. PCA delivers patient-activated fixed and small doses of opioids, usually morphine, hydroxymorphone or fentanyl, on demand. Intravenous drug delivery is the most widely used form of PCA; however, less invasive techniques such as transdermal PCA allows postoperative delivery of drugs without the need for venous access or external infusion pumps [75]. Transdermal PCA uses ionthophoresis technology to deliver drugs through the skin by use of an external electrical field. A prospective, randomized study conducted in patients undergoing abdominal or orthopedic surgery found that the fentanyl transdermal system was as effective as intravenous PCA using morphine [76]. However, the transdermal system appeared to be easy for patients to use and for the staff to care for.

Bearing surfaces

Knee arthroplasty in younger more demanding patients with increased functional requirements and the desire to participate in impact activities will pose a significant challenge for designers. Increased wear debris-induced osteolysis will probably occur and cause early failure in these very demanding patients. The accumulation of polyethylene wear debris over time in periprosthetic tissue will lead to an increased incidence of osteolysis [77,78]. Although many potential sources of wear particles have been identified, in most TKAs the greatest contribution results from motion that occurs between the two primary bearing surfaces (prosthetic femoral component against the polyethylene knee insert). Wear accounts for most of the change in the surface of a polyethylene bearing over the longer term [79,80]. Many variables affect the polyethylene wear and these include: wear resistance of the materials and their loads, lubrication, motion pattern, implantation techniques, type of use of the joint and sliding distance. Wear resistance of polyethylene is a function of the base resin, the manufacturing and the method of sterilization of the polyethylene component [81–83]. Until recently γ-irradiation was the most common method of sterilization in the orthopedic industry. A time-dependent increase in the amount of oxidation can result from γ-irradiation in air, which decreases the resistance of polyethylene bearings to fatigue, leading to higher rates of wear. This method breaks molecular bonds in the long polyethylene chains, giving rise to free radicals. Levels of oxidation typically occur approximately 1–2 mm below the surface of a polyethylene component. As the oxidation increases, so does the occurrence of fatigue cracking and delamination, as has been observed in retrieved tibial components [81,82,84]. When free radicals are formed in polyethylene, such as by γ-irradiation, crosslinking

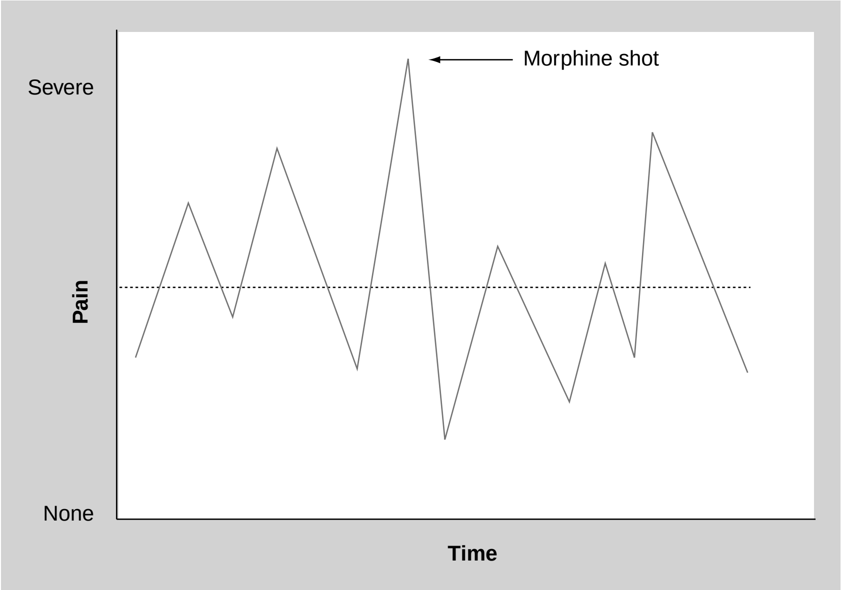

Figure 6. Traditional pain management.

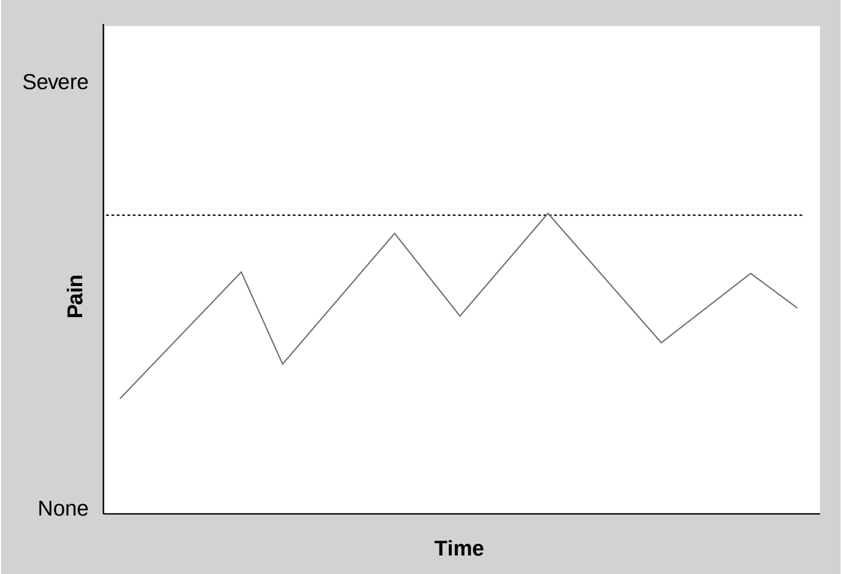

Figure 7. Multimodal pain management.

of polyethylene molecules is a competing reaction to oxidation. Crosslinking also changes the material properties of polyethylene, but it can improve the resistance to wear. In general, as oxidation increases, crosslinking decreases and *vice versa* [85]. Methods for controlled crosslinking include the use of chemicals (peroxide), variable-dose γ-irradiation and electron-beam irradiation. Clinical studies have indicated a substantial reduction in wear associated with crosslinked polyethylene around hip replacements [79,86]. Crosslinking may not have the same degree of benefit in total knee replacement owing to the more complex loading mechanism that exists in the knee joint [87].

Knee implant designs

Ritter examined the 20-year survival of the cemented anatomical graduated component (Biomet, Warsaw, IN, USA) total knee replacement. Over 20 years, 36 knees were followed with a survival rate of the tibial and femoral components together of 97.8% – no implants were revised for polyethylene wear or osteolysis [88]. The author attributes the success of the anatomical graduated component implant to its relatively unconstrained articular geometry and the durability of a nonmodular metal-backed tibial component with compression-molded polyethylene. Dixon *et al.* in a consecutive series of 139 TKAs (modular fixed-bearing posterior cruciate-retaining total knee prosthesis) in 109 patients, examined 45 patients (59 knees) at a minimum of 15 years postimplantation [89]. At 15 years, the survival rate without revision or need for any reoperation was 92.6%. The mean Knee Society score and functional score at 15 years were 96 and 78 points, respectively. The prevalence of radiolucent lines was 13%, with 2% around the femur, 11% around the tibia and none around the patella. No lines were clinically relevant. In this series, this prosthesis had good clinical and radiographic results with excellent survivorship for up to 15 years. These results are similar to those found in long-term studies of posterior stabilized implants and of prostheses with mobile-bearing and nonmodular tibial inserts.

Knee replacement with severe deformity and ligamentous deficiency requires a device with some inherent stability. The use of a hinged design may be preferable to standard condylar implants, even when using models with constraint [90,91]. Fixed-hinged designs implanted in the middle of last century led to a high failure rate and new modular designs with rotational systems were developed to address this issue [92]. However, older designs of rotating hinged designs gave poor results and are no longer used [93–95]. These newer mobile-bearing hinged knee prosthesis are routinely used for knee arthroplasty after the resection of large neoplasms. Important improvements in these designs, such as the ability of the implant to rotate and the introduction of metal wedge augmentation and modular fluted stems with variable offset to improve the alignment and allow cementless fixation, have been promising [90,96–98]. A recent report by Hernandez-Vaquero *et al.* on 26 patients (five primary) who underwent knee arthroplasty due to severe collateral ligament deficiency with the use of a rotating hinged prosthesis (Stryker Orthopedics, Mahwah, NJ, USA) found that at a mean follow-up of 46 months, there was a significant improvement in the Knee Society pain score as well as in the range of motion postoperatively [91]. A radiographic analysis of this same series showed no implant loosening.

Knee replacements with a symmetric fixed-bearing design have yielded good long-term results, but there have been some problems related to the locking mechanism (the plastic onto the metal tibial tray), resulting in severe backside wear [99]. Engh *et al.* reported significant micromotion between these 'fixed bearings' and the tibial tray. To address these issues and to be able to increase the surface contact areas, mobile-bearing knee prostheses were developed [100]. In addition, it was postulated that the mobile-bearing prosthesis would minimize bone–prosthesis stress at the tibial surface and improve the contact stresses in cases of malrotation between the femoral and tibial components at the time of implantation [101,102].

Various studies for both mobile-bearing and fixed-bearing prostheses have documented results that are comparable in terms of performance and survival, with overall revision rates of approximately 1% per year for both types of implants [103]. However, failure has been documented depending on the mobile-bearing knee design. Some of the most common mechanisms of failure include increased wear [104], dislocation [105,106], meniscal bearing dislodgments and 'spin outs' of the rotating platforms [107]. Mobile bearing dissociation/dislodgment is a unique failure mode that is not present in fixed-bearing designs. Overall in the long-term series, these mobile-bearing systems did not provide any advantage over the fixed-bearing designs.

In recent years, gender-specific implants have been released. The concept of a female-specific total knee implant design is based on the theory that there are clinically important morphologic differences between male and female knees that traditional designs have failed to address [108]. The most important anatomic differences are the medial–lateral and anterior–posterior femoral condylar aspect ratios [109]. Some studies suggest women have worse results than their male counterparts [109], while others claim there is no difference [110] with the use of conventional implants. In a prospective, randomized, blinded study of 138 female patients who received a standard NexGen CR-flex (Zimmer) prosthesis in one knee and a gender-specific NexGen CR-flex (Zimmer) in the other knee, the authors reported no difference in clinical and radiographic results, patient satisfaction and complication rate between the two groups at 3 years after TKA [111]. In spite of the lack of evidence that any implant changes or modifications related to gender result in a clinical improvement to patient outcomes, the added options in terms of more 'sizes' make these implants attractive. These 'extra' sizes that are now available improve the coverage available and decrease the 'overhang' that occurs in some patients in the femoral side.

Innovative bearing materials have also been recently introduced in the field of arthroplasty. Oxidized zirconium is a relatively new material used for femoral components in knee prosthesis. Thermally driven oxygen diffusion transforms the metallic zirconium alloy surface into a durable low-friction oxide. It has been suggested that oxidized zirconium provides superior resistance to abrasion without the risk of brittle or fracture, thereby combining the benefits of metals and ceramics [112]. Lewis *et al.* reported on a prospective randomized study of 100 patients and their mid-term clinical outcomes after implantation of oxidized zirconium (Oxinium™, Smith & Nephew, Memphis, TN, USA) versus cobalt-chrome femoral heads in total hip arthroplasty (THA) [113]. At a minimum follow-up of 2 years, stem survival was 98% for both groups. Clinical outcomes (Harris Hip score, Western Ontario and McMaster Universities Osteoarthritis Index [WOMAC] scores, SF-12 physical and mental component scores) for THA procedures using oxinium and cobalt–chrome femoral heads also appeared to be equivalent. However, there are concerns regarding damage of oxidized zirconium femoral heads subsequent to hip arthroplasty dislocation [114]. Although oxidized zirconium knees are now available and early reports are encouraging [115,116], long-term follow-up of over 15 years would be necessary to demonstrate efficacy.

Preoperative planning

Careful preoperative templating of an adequate set of radiographs is a key part of modern preoperative planning for hip and knee arthroplasty. Conventional templating uses common radiographs in which surgeons determine the size, position and number of implants based on blueprinted diagrams of the actual implants printed on acetate films provided by the manufacturers that are overlaid on radiographs (FIGURE 8). Acetate templates provided by most prosthesis manufacturers often come with a 10–20% magnification and cannot be adjusted for variations in radiograph magnification, potentially increasing the risk for inaccurate measurements [117]. Carter *et al.* reported that with the use of acetate templates a senior orthopedic surgeon was able to predict the size of a noncemented stem in 94.6% of cases undergoing primary THA, compared with 87.8–82.4% for four- and second-year orthopedic residents, respectively [118].

Digital templating (FIGURE 9) uses either digitized images obtained by scanning radiographic films or digital radiographs. The software calibrates the images and templates are scaled to the correct magnification factor. The surgeon selects the appropriate template from a library and digitally overlays them on the image. Several steps are involved in using digital templating. Bono *et al.* described seven steps for using a digital templating algorithm for THA that will facilitate the surgeon to preoperative determine the appropriate cup size, stem size, neck length, head size and the amount of bone resection to reestablish the limb length and femoral offset [119].

Variable results have been reported with the use of conventional and digital templating for hip and knee arthroplasty. A study by Iorio *et al.* found that digital templating was not more accurate than acetate templating for primary THA [120]. Bertram *et al.* found that digital templating was more accurate in predicting the correct size of the acetabular component and produced better results in the postoperative radiological assessment of the acetabular and femoral components [121]. Regarding TKA, Specht *et al.* showed that digital templating was more accurate in predicting the tibial component size; no differences were found between techniques for the femoral component [122].

Indications for surgery

Indications for TKA have changed along with the evolution of component design. Originally, surgical interventions had a very high risk of infection. Even short-term success was around 50% [123].

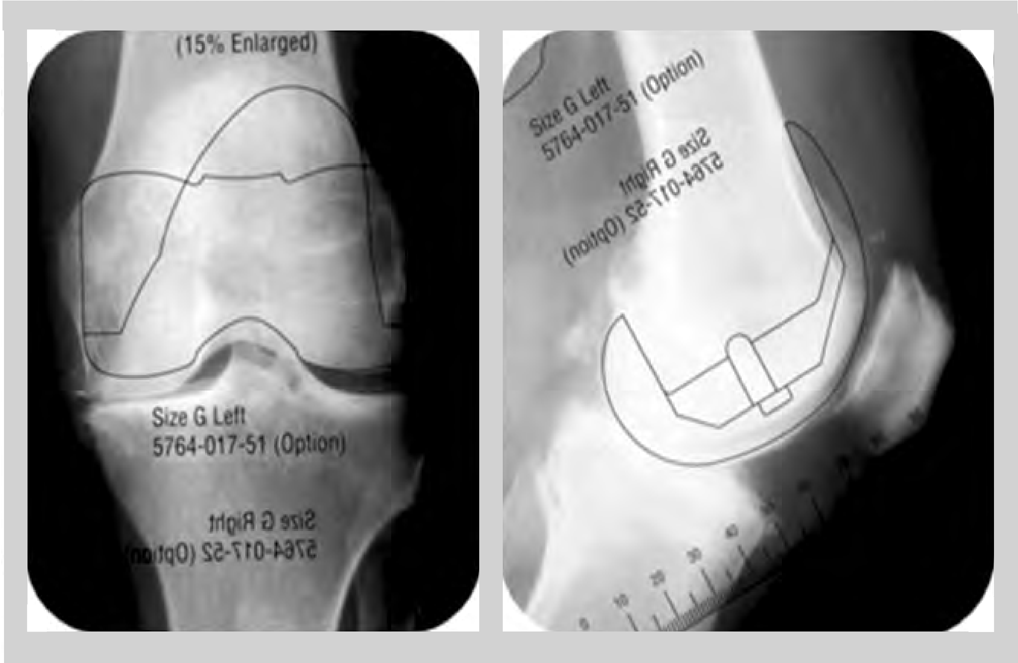

Figure 8. Preoperative knee templating using acetate templates.

With the advent of the total condylar design and aseptic technique the short-/mid-term results got better. In the early 1980s, a TKA was offered with trepidation and mostly to physiologically older patients. In 2010, a significant decrease in quality of life constitutes a valid indication for TKA. The survival of a modern day TKA can be predicted based on two data points: laboratory simulators and clinical series with over 20 years of follow-up.

Sophisticated laboratory simulators exist that can subject TKA to complex loads [124]. These simulators can cycle actual specimens in complex

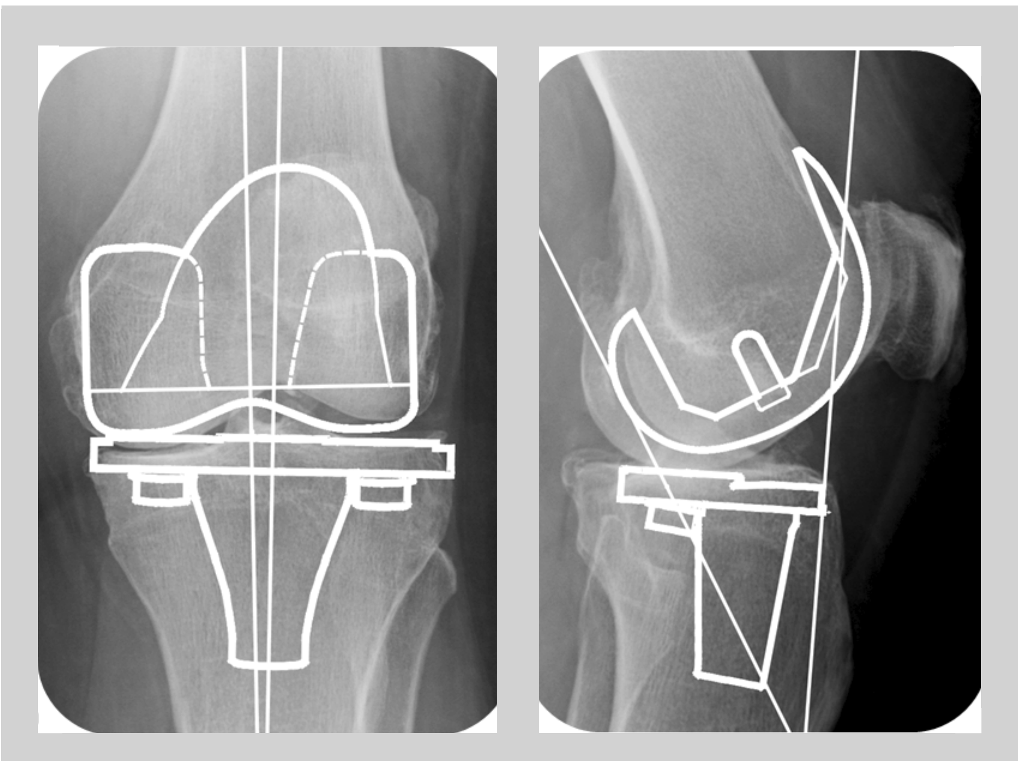

Figure 9. Preoperative knee templating using digital templates.

loading schemes for over 25 million cycles. The articulating surfaces can then be measured for wear and, after assuming a certain activity level, we can predict the estimated life of these devices. Investigators have published data on cohorts of young active patients followed for almost 20 years [125–127]. The survival curves for these cohorts have 80% longevity. The clinical and laboratory data combined can be interpreted to predict that 85% of the TKAs carried out in 2010 will probably last over 25 years. Younger patients are now seeking high-performance knee implants that will allow them to perform high impact activities for longer lengths of times. New developments in TKA have been directed at reducing failure rates while addressing the needs of young patients with a high activity profile. Modern components must provide durable fixation and bearing surfaces must show low wear.

Identification of clinical and patient-reported characteristics that can help identify those individuals who will have low functional levels after surgery may help surgeons plan more appropriate interventions. Fortin *et al.* noted that patients presenting for knee and hip arthroplasty with low preoperative function and pain scores did not improve 6 months postoperatively to the same magnitude as their counterparts who had less pain and a higher function capacity [128].

Total knee arthroplasty following osteotomy is considered to be more technically demanding than TKA in the absence of prior osteotomy. The basic premise of osteotomies is to redirect the mechanical axis from a degenerated area to the relatively well-preserved compartment. At the knee joint, in most cases, the transfer of weight-bearing load is from a worn medial compartment through the healthier cartilage of the lateral joint space. The most common indication is the treatment of unicompartmental varus or valgus osteoarthritis in physically active individuals; however, it can also be effective in unloading pressure on the focal cartilage lesions, such as in osteonecrosis and adult osteochondritis dissecans [129].

Insall and Aglietti suggested that the most important factor that can contribute to deterioration after this procedure is time [130]. Osteotomy should not be perceived to be the ultimate solution of joint degeneration; rather, it is a procedure that can delay the need for total knee replacement.

Some authors have reported that prior high tibial osteotomy has no adverse affect on TKA outcomes [131,132]. Others have reported that the results of TKA are inferior following high tibial osteotomy [133,134]. It appears that knee osteotomies, both proximal tibial and distal femoral, have become relatively infrequent [135]. Encouraging mid-term and long-term outcomes in young active patient populations in which artificial knee implants have been utilized could explain the shifting in these tendencies [136,137].

We reported a study that suggested that performing arthroplasty earlier may result in better surgical outcomes [138]. We found that individuals who start out with poorer scores before surgery, even though they show large improvements in self-reported functional measures, end up with lower scores 3 years after surgery when compared with those patients who had higher functional levels before the arthroplasty (Figures 10 & 11). These individuals never 'catch up' to their counterparts who had surgery at higher functional levels.

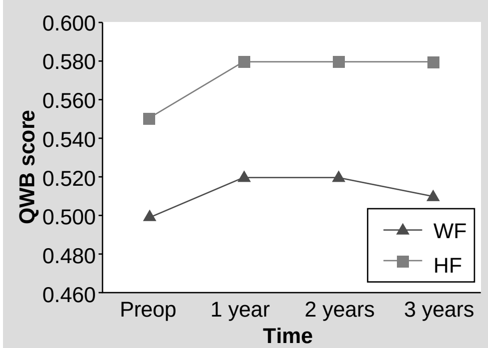

Figure 10. The Quality of Well Being Index for both groups within total knee arthroplasty over time.
HF: Higher functioning group; QWB: Quality of Well Being Index; WF: Worse functioning group.

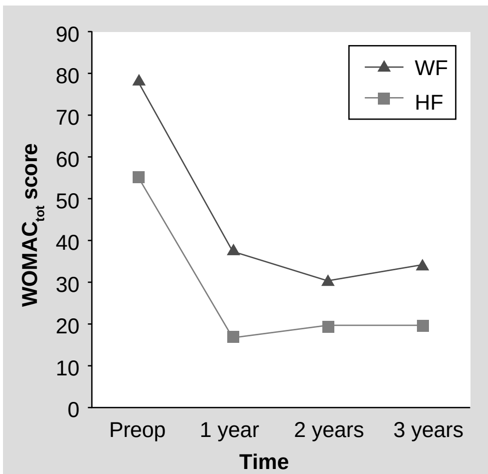

Figure 11. The WOMAC total score for both groups within total knee arthroplasty over time.
HF: Higher functioning group; WF: Worse functioning group; WOMAC$_{tot}$ score: Total score of Western Ontario and McMaster Universities Osteoarthritis Index.

Gold standard in 2010

The long-term success of total knee replacement is multifactorial and includes factors related to patient, implant and surgeon. It is widely agreed that a cemented fixed bearing total knee replacement performed through a standard approach by an experienced surgeon with modern alloys (Co–Cr femur and Ti-6 Al-4 Va) and a polyethylene-beating surface is the current gold standard in arthroplasty of the knee.

Navigation

Recently, there has been increased interest in computer-assisted surgical navigation systems. Kim *et al.* assessed whether TKA with use of computer-assisted surgical navigation is superior to conventional TKA with regard to the precision of implant positioning [139]. In the study 170 consecutive patients undergoing primary bilateral sequential TKAs (340 knees) were prospectively enrolled. Each patient had a TKA with use of computer-assisted surgical navigation in one knee and conventional TKA in the other. The two methods were compared for accuracy of orientation and alignment of the components, as determined by radiographs and CT scans. The mean duration of follow-up was 3.4 years. Pre- and post-operative ranges of motion of the knees were similar in both groups. The operating and tourniquet times were significantly longer in the computer-assisted TKA group than in the conventional TKA group ($p < 0.001$). The groups were not significantly different with regard to the accuracy of component positioning and the number of outliers for the various radiographic parameters ($p > 0.05$). Their data demonstrated that TKA with use of computer-assisted surgical navigation did not result in more accurate implant positioning than that achieved in conventional TKA. Similar results have been found in numerous prospective, randomized studies regarding component alignment [140,141], complications [142,143] and clinical outcomes [144,145]. However, the evolution of these techniques in which computers assist the surgeon will probably render them extremely useful in the future.

Robotics

Recent technical innovations in unicondylar knee arthroplasty (UKA) have included the use of computer-assisted navigation technology. This has been shown to improve postoperative leg alignment compared with conventional UKAs [146–148]. However, a direct improvement of the implant positioning itself has not been demonstrated. Pearle *et al.* reported the first clinical series of UKA using a semiactive robotic system (MAKO Tactile Guidance System™; MAKO Surgical Corp, Fort Lauderdale, FL, USA) for the implantation of an inlay UKA [149]; ten patients were selected for this study. The planned and intraoperative tibiofemoral angle was within 1°. The postoperative long leg axis radiographs were within 1.6°. The authors concluded that haptic guidance in combination with a navigation module allowed for precise planning and execution of both inlay components in UKA.

These 'semiactive' systems give the surgeon active control over the robot. Based on preoperative computed tomography-based planning, active surgeon-controlled cutting becomes possible with the added benefit of control features such as robot-imposed limitations on the areas that may be resected such that iatrogenic complications may be reduced. There is no doubt that precision surgery is part of the future of TKA.

Future perspective

Over the next 5–10 years and due to the aging of baby boomers, TKA will be performed in younger and more active patients. This has led to the reintroduction of cementless knee devices. Historically, cementless fixation in TKA has not yielded good results [19]. Early designs had high failure rates due to factors other than component fixation, such as failure of the metal-backed patellar components with subsequent metallosis [150,151]. Despite these early failures, some cementless TKA designs in the hands of selected surgeons have demonstrated results equivalent to cemented TKA [152–155].

Cementless femoral and tibial components were designed to provide bone osteointegration into the implant. Although cemented and cementless TKA share the same requirements for alignment, ligament balancing and bone preparation, cementless designs avoid the use of acrylic cement in the reconstruction, which should increase the life of the TKAs [156]. The introduction of 'precision surgery' using robots and perhaps computer-assisted surgery combined with the reintroduction of tantalum for biological fixation may allow biological fixation to become the future gold standard.

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Executive summary

Fixation

- The development of porous metals and coatings to 'biologically' fix metal to bone revolutionized the field of orthopedics.
- Short-term studies encourage the use of porous tantalum in total knee arthroplasty (TKA).
- Cemented fixation remains the gold standard in primary knee replacement in 2010.

Minimally invasive procedures

- Most large centers no longer perform these minimally invasive procedures since the few benefits appear to be short-term only.

Pain management

- The preemptive analgesia incorporates the delivery of medication before the insult and before severe pain spikes, reducing the use of analgesics.
- Patient-controlled anesthesia is the most common form of postoperative analgesia after TKA, delivering small doses of opioids on demand.

Bearing surfaces

- The use of highly crosslinked polyethylene is associated with a reduction of wear in TKA.

Knee implant designs

- Mobile-bearing designs have not provided any advantages over the fixed-bearing designs in long-term series.
- Gender-specific implants have failed to improve clinical outcomes compared with standard knee implants.
- Although oxidized zirconium knees have been associated with decreased wear, long-term studies are needed to demonstrate efficacy.

Navigation

- Several studies have found no difference in clinical and radiographic outcomes with the use of computer-assisted surgical navigation in TKA.

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