

Modern Trends in Total Knee Arthroplasty

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Abstract

Knee arthritis is a common disease that causes pain and disability. Non-surgical treatments include NSAIDs, low-impact exercise, physical therapy, ambulatory assist devices and intra-articular injections. When these treatments fail to alleviate pain and restore knee function, such as in severe cases of knee osteoarthritis, total knee arthroplasty (TKA) may be necessary. Modern TKA has evolved significantly from its first incarnation and success rates are high. Various types of implants have the potential to allow more knee flexion and improved range of motion, but current studies show high-flexion devices do not conclusively improve function. Computer-assisted navigation during surgery allows greater accuracy in alignment, but may not ultimately improve survival rate or function. Complications during TKA surgery can involve infection, pain, and blood loss; intra-articular tranexamic acid can be used to decrease blood loss, while wound drains may increase blood loss. TKA patients under regional anesthesia appear to have fewer complications than patients under general endotracheal anesthesia.

Keywords: TKA surgery; Endotracheal anesthesia; Arthroplasty

Knee Osteoarthritis

Knee osteoarthritis is the most common joint disorder causing knee arthritis [1-4]. The incidence of knee osteoarthritis increases with age, and with an incidence of 240 out of every 100,000 person-years, which is more than twice the incidence of either hand osteoarthritis or hip osteoarthritis [4]. Knee osteoarthritis is often comorbid with obesity, another common chronic disease; obesity can increase the risk and severity of knee osteoarthritis due to increased joint loading, less physical activity, and loss of protective muscle strength [5]. The risk of having osteoarthritis is increased by minor trauma at a younger age, such as sports-related meniscal tear and ligamentous injuries, which can account for up to 40-50% of all knee osteoarthritis [3]. Other diseases that can result in knee arthritis, and may require total knee arthroplasty (TKA), include inflammatory arthritis, such as spondyloarthritis, rheumatoid arthritis, and psoriatic arthritis [6,7]. Knee arthritis involves degeneration of the knee, resulting in loss of articular cartilage, capsular stretching, ligament laxity, formation of osteophytes, subchondral cysts and sclerosis, weakness of the associated muscles, and pain (Figure 1) [7,8].

The source of knee pain is multi-faceted; the pain is an indication of the severity of the arthritis and can be accessed via different questionnaires commonly used in joint-related studies, including a visual analog scale (VAS), health assessment questionnaires (HAQ),

Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), the Knee Society Score (KSS), and the EuroQol five-dimensions questionnaire (EQ-5D) [9-12]. Osteoarthritis can occur unilaterally or bilaterally, thus affecting pain levels and knee function [13]. In a study comparing patients with unilateral severe knee pain versus bilateral severe knee pain, the unilateral group had lower WOMAC scores, averaging 19.9, while patients with bilateral knee pain, with at least one knee rated as severe, had WOMAC scores ranging from 25.3 to 28.9 [13].

Non-Surgical Treatment for Knee Arthritis

Low impact-exercise and physical therapy is often used to manage knee arthritis-related pain and improve function in patients with knee arthritis [14-18]. Fatigue of the quadriceps femoris muscle was found at a much higher rate in patients with knee OA. Reduced knee flexion and major difficulty standing was found to have a significant association with knee OA as well [16,17]. In a study by Knoop et al., improvements of 24% in activity limitations, 34% in pain, and 21% in muscle strength after 12 weeks of exercise therapy were achieved in patients with knee osteoarthritis [16]. Iannitti et al. found pulsed electromagnetic field therapy also significantly decreased WOMAC scores and VAS scores in elderly patients with knee osteoarthritis [18].

A currently widely used method of alleviating knee pain non-surgically is through intra-articular injections, including corticosteroids and hyaluronic acid [19-28]. Corticosteroids have significant pain reducing effects on patients; however, there have not been any identified predictors of response to intra-articular corticosteroid injections [19,20]. In a study by Habib et al., a hiccup reflex occurring following an intra-articular corticosteroid injection was reported, and the authors recommended avoiding corticosteroid injections if this phenomenon is known to happen in a patient [21].

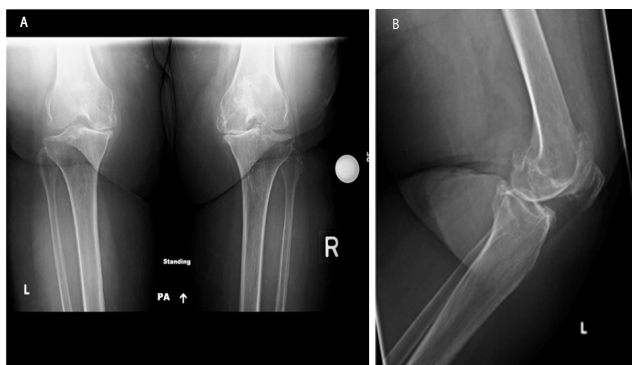


Figure 1a,b: Anteroposterior and lateral radiographs of a severely degenerative osteoarthritic knee; exhibiting osteophyte formation, loss of joint space, subchondral cysts and subchondral sclerosis.

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A meta-analysis and systematic review focused on injection technique itself, determining whether the accuracy of intra-articular knee injections varied and if the accuracy and site of injection was connected to the efficacy of the treatment [22]. The results suggested that intra-articular knee injections were most accurate (87%) at the superolateral patellar bursae site when they were not image-guided; image-guided injections were more accurate than blinded injections; however, these studies were performed with caretakers who were not orthopaedic surgeons [22].

Studies involving intra-articular hyaluronic acid are widespread, alluding to anti-inflammatory and chondroprotective properties that give hyaluronic acid the theoretical potential to reduce pain [23,24,27,28]. However, the recently published clinical practice guidelines (CPG) for treatment of OA by the AAOS does not recommend the use of hyaluronic acid in patients with knee OA [25,26]. Studies that support the use of hyaluronic acid exist and continue to be produced, including one study by Bellamy et al. that showed an improvement of 26% in pain rating and 23% in function in the 4 to 14-week post-injection period, and another study by Chevalier et al. that also showed statistically significant improvement in pain rating compared to baseline measurements of knee pain and function [23,24]. However, the CPG has found that while outcomes with higher molecular weight hyaluronic acid preparations were statistically significant, they were not clinically significant and lacked minimal clinical important improvement [25,26]. The CPG believes literature on visco-supplementation to be biased, with studies that show negative results less likely to be published than studies with positive results; thus, literature supporting hyaluronic acid should be carefully considered [25,26].

History of Tka

In the 1890's, Theophilus Gluck performed one of the earliest total knee arthroplasties with an ivory-hinged implant fixed with plaster of Paris and colophony [29]. TKA results in the first half of the 1900's had 20-48% failure rates, with only 11-20% 'good' results [29]. In 1954, Leslie Gordon Percival Shiers published his preliminary report on knee arthroplasty [29]. Shiers' goal was to improve knee arthroplasty, especially the design of the prosthesis in three categories – to permit flexion, to limit extension, and preserve lateral stability [29]. Designing and experimenting to make the prosthesis took five years, and the first two patients were operated on with the new design in 1953[29]. Shiers says of his prosthesis: "This is a hinge." [29]. Similar to the basic devices previously used, Shiers' prosthesis was a simple hinge that permits flexion and extension up to 180 degrees, preserved lateral stability, and was made of non-electrolytic and reverse-plated stainless steel [29].

The condylar knee was first designed by Frank Guston and later popularized by orthopaedic surgeons at the Mayo Clinic [30]. The condylar knee more closely replicated the way the biological knee works and preserved the cruciate ligaments and was fixed to the tibiofemoral condylar surfaces with cement [30]. Soon after, more condylar knee prostheses were designed to allow modularity and noncemented fixation, and either preserving or sacrificing the cruciate ligaments became common place [30]. The Duocondylar and the Uniccondylar designs were developed in 1971 by Chitranjan Ranawat, Allan Inglis, John Insall, and Peter Walker; the Duocondylar was a true condylar design, preserving both cruciates and having two separate tibial components [30]. In 1974, the same team created the Duo patella design, which included the patellofemoral joint and retained the posterior cruciate ligament [30]. In that same period of time, a team that included Mark Coventry, Roderick Turner, and Robert Averill

designed the Geomedic condylar knee, which had pegs on the tibial component to improve fixation with the use of bone cement [30]. However, loosening was still an issue [30].

In the late 1970s, Good fellow and O'Connor in Oxford, England, designed the first mobile-bearing implant, which permitted slightly greater rotation medially and laterally [30]. Soon after, Beuchal and Pappas in New Jersey designed a meniscal bearing mobile rotating platform implant, which both provided more rotational freedom and decreased the wear on the components [30]. In 1975, the same team designed a low-contact-stress knee implant which replaced all three knee articulations; this implant is still seen in patients today [31,32]. Modern implants have the same basic design structures as the implants previously mentioned (Figure 2), with fixed-bearing vs mobile-bearing designs and posterior-stabilized vs cruciate-retaining vs unicompartmental designs. This review will also look at recent studies comparing these designs.

Modern Design and Tka Outcomes

Ideally, patients who undergo TKA will regain function and flexion in their knees, necessary for everyday activities such as walking, kneeling, and traversing stairs. Some devices are designed to allow high flexion beyond 125 degrees [33]. Designs with mobile bearings, rotating platforms in the tibial component, and fixed-bearing devices are also available; these designs theoretically permit more tibial rotation during flexion and assist in higher degrees of flexion [33,34]. In osteoarthritis patients who require TKA, the above-mentioned design features have not resulted in a clear increase in flexion and function compared to fixed-bearing designs, and may have associated complications and pain, as shown in recent meta-analyses and studies [33,35-38].

Survival rates of Low Contact Stress TKA, fixed, and mobile-bearing TKAs are high [31,32,39]. In a long-term study by Sharma et al., uncemented Low Contact Stress TKA patients were followed at time-points of 12.9 years and 22 years, the survival rate was 94% and 88.9% respectively, mean knee range of motion was 104 degrees and 105 degrees respectively [31,32]. Another long-term study by Bistolfi et al. compared fixed and mobile-bearing TKAs, and found there were no significant differences in clinical outcome and implant survival at the 9-year follow up time-point [39].

Kalisvaart et al. performed a five-year study comparing different rotating-platform and fixed-bearing total knee designs and found that knee range of motion, function (measured via Knee Society Score and



Figure 2a,b: Anteroposterior and lateral radiographs of a knee status post total knee arthroplasty.

stair-climbing scores), and durability were not significantly different at 2 year and 5 year time points [38]. Range of motion for the all-polyethylene fixed bearing, modular-metal-backed fixed-bearing, and rotating-platform designs averaged 111 degrees, 111 degrees, and 110 degree at 2 years, and 110 degrees, 109 degrees, and 109 degrees at 5 years, respectively [38]. Knee Society scores averaged 90, 91, and 91 at 2 years and 88, 89, and 88 at 5 years, respectively [38].

High-flexion devices aim to provide maximum flexion, but the increase in range of motion compared to other designs has not yet been conclusively shown [33,34,37]. A study by Dennis et al., comparing a posterior-stabilized high-flexion device to a posterior-stabilized standard device, found that non-weight-bearing passive flexion was significantly superior in the high-flexion device group, especially for patients who had less pre-operative flexion [34]. A separate study by Nutton et al. also found that non-weight-bearing flexion was increased in the high-flexion rotating-platform group (113 degrees compared to 107 degrees); however, they also found that weight-bearing flexion was four degrees lower in the rotating-platform group, and the post-operative WOMAC pain score was significantly higher in that group [33]. One year after surgery, patients with the rotating-platform implant also reported more pain and that the additional non-weight-bearing flexion did not assist their daily activities [33]. Thus, while the high-flexion devices can increase passive flexion in some designs, their clinical benefits are inconclusive, as they do not conclusively improve function or decrease post-operative pain.

Computer-Assisted Navigation Surgery

Recently, computer-assisted navigation has been employed in TKA to attempt to improve the alignment, accuracy, and clinical function of the implants [40-45]. Alignment errors greater than 3 degrees in either tibial, femoral, or mechanical axis alignment have been associated with higher risks of implant failure and post-surgical prosthetic loosening in some studies [40,41,46]. In a meta-analysis with 2541 patients, Hetaimish et al. found that significantly fewer patients in the computer-navigated group had misalignment greater than both the 3 degree threshold and the 2 degree threshold [40]. With computer-assisted navigation, alignment accuracy within 1 degree can be routinely obtained and variance is decreased [40,41,45].

This 3 degree alignment standard was introduced by Jeffery et al., but some studies found it to be an arbitrary figure that may more accurately represent the reproducibility that an arthroplasty surgeon can obtain rather than have any correlation with function and survival of the total knee arthroplasty [46,44,47,48]. A study by Parratte et al. found a post-operative alignment axis between 0 degrees and 3 degrees did not improve the 15-year implant survival rates compared to knees with mechanical axis of greater than 3 degrees [48,49].

However, although alignment is improved in the computer-navigated cohorts, other studies have shown that computer-assisted navigation TKA and patient-specific instruments may not result in improved clinical function for patients while costing more money and time [43-45]. In a prospective randomized trial by Young-Hoo Kim et al., either computer-assisted navigation TKA or conventional TKA was performed on 536 patients, they found that preoperative and postoperative range of motion and Knee Society scores, as well as radiographic and computed tomographic (CT) results to be similar in both groups [43]. In fact, they found the average operative time and tourniquet time to be significantly longer for the computer-assisted navigation TKA cohort, while length of incision, blood loss during surgery, drainage, and transfusion volume did not significantly differ

between the cohorts [43]. Another study by Nunley et al. found similar tourniquet times between computer navigation and conventional TKA, but found a significant decrease in overall time in the operating room when patient-specific instruments were used [44]. However, the cost of the imaging and instruments associated with patient-specific instruments outweighed the cost-benefit from decrease OR time [44]. In addition, patient-specific instruments are more costly, with the imaging study costing around \$500-\$1,000 and the instrument fabrication around \$1000-\$1,500 [45].

Complications

Complications arising from TKA surgery can include joint infection, compartment syndrome, and nerve injury [50-52]. A recent study by Zmistowski et al. of 10,633 patients who underwent either TKA or total hip arthroplasty (THA) found that 5.3% of patients were readmitted to the hospital within 90 days after surgery, with the most common cause being joint-related infection [49]. Manifestation of pain associated with the prosthesis after surgery also occurs; Wylde et al. found 44% of TKA patients reported having persistent postsurgical pain, and 15% of TKA patients reported severe to extreme pain [52,53]. In addition, TKA patients who have different etiologies causing knee arthritis also respond differently to TKA; patients with rheumatoid arthritis have a higher risk of infection after TKA and require more careful management of perioperative and postoperative medications compared to patients with osteoarthritis [7,54].

TKA is also associated with post-operative blood loss that can necessitate blood transfusions, possibly leading to immunological problems, higher risk of infection, and viral infection risks [55,56]. Kumar et al. found that 84% of total lost blood occurred in the first 12 hours after surgery, thus immediate actions to reduce bleeding should be taken [57]. To reduce blood loss, tourniquets and tranexamic acid are often used [58-62]. In a meta-analysis of tourniquet use by Alcelik et al., tourniquet use was found to be associated with less total and intraoperative blood loss, but also more minor complications [58]. Tranexamic acid is an antifibrinolytic drug used to restrict bleeding and reduce total blood loss during surgeries; usually administered locally/topically or intravenously, it may require multiple doses, possibly affecting the post-operative treatment [59-62]. Roy et al. found that intra-articular tranexamic acid also reduces drain output 48 hours after surgery and helped conserve red blood cells as compared to a control group without tranexamic acid [62]. However, the study included a small cohort, and did not compare intra-articular tranexamic acid results with intravenous administration results [62].

Post-surgical methods, such as wound draining and autologous blood transfusions, are also used to reduce blood loss and risk of transfusion-related infections and reactions [63-66]. Wound draining after TKA is still controversial, as some studies emphasize the risk of bacterial infection with a wound drain while others find wound drains reduce the risk of hematomas [57,63,64]. Recent studies have found no significant difference in complications, infections, and range of motion in TKA patients with and without wound drains; however, wound drains were associated with requiring more blood transfusions [63,64]. In a meta-analysis by Zhang et al. of 1361 TKA patients, the results indicate that wound drainage can also reduce necessity for dressing reinforcement and incidence of soft tissue ecchymosis [63]. Wound drain clamping was also assessed and found to have the potential to decrease blood loss, but the advantage of clamping versus non clamping drainage after TKA could not be confirmed [65,66].

Complications may also arise from the anesthesia during the surgery; these include nausea, vomiting, hematoma, and nerve injury [50,51,67-69]. Femoral nerve blocks are associated with traumatic injuries, such as mobile-bearing dislocation or ligamentous rupture after a fall, in 1.6% of patients, femoral neuritis in 0.59% of patients, 0.2% risk of permanent nerve injury, and a fall risk of 0.7% [70,71]. When combined with a sciatic nerve block or periarticular anesthetic infiltration, no significant differences in knee flexion, patient-reported functional scores and pain scores, or complications were found; however, one study by Pumberger et al. found the incidence of complications with epidural/spinal anesthesia was higher than previously reported [50,69].

Two commonly used anesthesia methods are general endotracheal anesthesia and regional epidural/spinal anesthesia; however, general endotracheal anesthesia has been associated with more complications than regional epidural/spinal anesthesia [71-73]. Mitchell et al. evaluated the effects of regional versus general anesthesia in a small randomized cohort and found that while operative time, blood loss, number of units transfused, and hematocrit did not differ significantly between the two groups, proximal vein thrombosis was 18% more likely to occur in the general anesthesia group [71]. A database search by Pugely et al. of over 14,000 patients who had either TKA performed under spinal anesthesia or general anesthesia found that general anesthesia resulted in a small but significant increase in complication risks [72]. In the general anesthesia group, frequency of superficial wound infections increased by 0.24%, blood transfusions increased by 1.05%, and overall complications increased by 1.62%; the length of surgery was also increased by 4 minutes and the length of hospital stay was increased by .32 days [72]. Pugely et al. also found the difference in risks was greatest for patients with comorbidities [72]. Studner et al. compared regional versus general anesthesia in patients undergoing simultaneous bilateral TKA; blood transfusion requirement was significantly less in the regional anesthesia group, and in-hospital mortality, 30-day mortality, and complication rates tended to be lower in the regional anesthesia group [73].

Summary

Knee arthritis can be caused by osteoarthritis, the most common joint disorder, rheumatoid arthritis, and other factors [1,4,6,7]. It involves degeneration of the knee cartilage, causing deformity and laxity, muscle weakness, and pain [7,8]. Knee pain questionnaires are used as an indication of severity of the disease and also to assess if treatment methods improve pain and symptoms [9-12].

Prior to surgery, knee arthritis symptoms can be ameliorated via methods such as exercise, physical therapy, ambulatory assist devices, NSAIDs, and intra-articular injections [14-28]. Exercise therapy was found to improve pain levels by 34%, while the new AAOS guidelines for treatment of knee OA no longer supports intra-articular hyaluronic acid injections, as they believe the studies supporting hyaluronic acid to be publication-biased, and that the results were not clinically significant [6,22,25,26].

TKA devices have improved significantly since the first hinged design was implanted in the 1890's [29,30]. Condylar knee designs with mobile-bearing, fixed-bearing, and rotating-platform options allow more freedom in medial/lateral movement, while high-flexion devices aim to improve flexion; however, although high-flexion devices increased passive flexion by 6 degrees, they do not conclusively improve weight-bearing flexion or function [33,34,38].

TKA surgeries can now employ computer-assisted navigation rather

than traditional TKA to improve the alignment, accuracy, and clinical function of the prosthetic [40-45]. While alignment is improved, with accuracy routinely within 1 degrees, clinical function and outcome have not been shown to improve with computer-navigated TKA [43-45]. In addition, computer-assisted TKA patients had longer operative and tourniquet time [43].

Complications of TKA can include joint infection, nerve injury, hematomas, blood loss, instability, loosening, and wear [49,68-73]. Joint infection was the most common cause of readmittance to the hospital, with 5.3% of patients readmitted within 90 days of surgery [49]. Post-operative blood loss can lead to more complications, such as infection, immunological problems, and viral infections from necessary blood transfusions [55,60]. Tranexamic acid, traditionally used intravenously, was injected intra-articularly and resulted in decreased drain output compared to non-tranexamic acid patients [62]. Wound drains also are used to decrease hematoma formation, but are associated with requiring more blood transfusions [63,64]. Anesthesia-related complications from TKA surgery can result from femoral nerve blocks, while regional spinal/spinal epidural anesthesia has been shown to have better results than general endotracheal anesthesia in TKA [70-73]. However, epidural/spinal anesthesia in TKA was found to have a higher incidence of complications than previously reported [50,69].

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