

Unicompartmental knee arthroplasty: an exemplar of surgical and engineering collaboration

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Unicompartmental knee arthroplasty (UKA) offers some considerable benefits compared to total knee arthroplasty (TKA). With the recent death of John O'Connor (1934 to 2024), who, together with John Goodfellow (1926 to 2011), researched the biomechanics of the knee^{1,2} and designed the most widely used UKA implant,^{3,4} it is timely to reflect on what UKA offers and how it remains relevant to contemporary and future treatment of knee osteoarthritis (OA).

Distinctive phenotypes of knee OA occur, characterized by patterns of damage to the articular surfaces and surrounding tissues. Anteromedial osteoarthritis (AMOA), described by White et al,⁵ includes a highly repeatable pattern of full-thickness cartilage loss in the anterior medial compartment, full-thickness cartilage retention in the lateral compartment, and an intact anterior cruciate ligament (ACL). Stoddart et al⁶ performed a meta-analysis (n = 3,786 knees) to determine the compartmental distribution of knee OA. The authors reported that prevalence rates were single compartment (50%), bicompartmental (33%), and tricompartmental (17%). Isolated medial compartment disease was the most common, occurring in 27%. This prevalent pattern of medial knee OA agrees with the concepts that mechanical loading plays a significant role in development of OA.^{7,8} Due to the bipedal nature of human locomotion, the medial compartment generally carries a greater share of the forces acting at the tibiofemoral joint.^{9,10} Hence, joint arthroplasty using UKA in the medial compartment is generally more common than in the lateral compartment.

It is generally accepted that the complex interplay between the articular surfaces and the soft-tissues give rise to the patterns of kinematic motion exhibited by the natural knee.¹¹ In particular, the cruciate ligaments control the relative tibiofemoral motion in the sagittal plane,¹² most lower limb functional activities involve motion of the knee joint in the sagittal plane. One of the aims of knee joint arthroplasty has been to replicate the natural patterns of motion of the healthy knee, ensuring appropriate muscle function.

In AMOA, the damage is essentially limited to the medial compartment. With appropriately performed UKA, the function of the other structures is maintained. Performing TKA generally requires sacrifice of the ACL. In vivo fluoroscopy studies have demonstrated that knee joint kinematics after UKA are close to those for healthy normal knees, while kinematics after TKA are grossly abnormal.¹³⁻¹⁵ This restoration of kinematics is associated with higher functional outcomes for UKA, as reported by Wilson et al¹⁶ based on a systematic review and meta-analysis of 60 studies comparing UKA and TKA.

Wilson et al¹⁶ also reported higher revision rates for UKA compared to TKA. This is consistent with the meta-analysis performed by Evans et al,¹⁷ who estimated that 70% of UKAs last for 25 years, while 82% of TKAs last for 25 years. Revision rates are impacted by a number of factors, age and surgeon caseload are two key factors. National Joint Registry data show that the median age of patients receiving TKA is 70 years, while the median age of those receiving

UKA is 64 years.¹⁸ There is marked difference in revision rates between low-volume surgeons (82.8% ten-year survival) and high-volume surgeons (90.0% ten-year survival).¹⁹ This may be addressed by refined patient selection, by having UKA centralized to high-volume surgeons and units, and by the use of enhanced technology.²⁰ While revision rates are higher for UKA than TKA, mortality at all timepoints is significantly higher for TKA.^{21,22} TKA also has longer length of stay (LoS), as well as higher complication and readmission rates than UKA.^{21,23–25}

Cost has become an increasingly important issue for healthcare systems worldwide, and an area of major focus is on reducing LoS. UKA surgery has led the way for day-case joint arthroplasty surgery. Wainwright²⁶ analyzed hospital episode data from all hip, TKA, and UKA operations performed in English NHS providers from July 2018 to June 2019: day-case rates were 0.55% for hip arthroplasty, 0.52% for TKA, and 5.44% for UKA. Overall day-case surgery rates in the NHS are low compared to international comparators; however, there is now considerable activity to embed daycase surgery in the NHS.²⁷ A recent systematic review (data from 8,843 day-case surgeries) has shown that successful same-day discharge was achieved in 88% of cases, and concluded that UKA can be performed safely as a same-day discharge procedure.²⁸ Beard et al²⁹ reported on a large-scale randomized study comparing UKA and TKA (TOPKAT trial), and found that UKA was more effective and less expensive than TKA during five years of follow-up, attributed to better outcomes, lower cost of surgery, and lower follow-up costs for UKA.

Awareness of the overall climate impact of healthcare has grown, with the NHS stating a target of 80% reduction in carbon emissions by 2032.³⁰ Joint arthroplasty implants carry a high burden of embedded carbon, a large proportion of which is due to the production of metal stock material,^{31,32} with a considerable contribution due to the waste generated from surgery.^{33,34} UKA implants typically contain less than one-third of the mass of metal contained in a TKA implant. Delaie et al³² estimated that the overall life cycle carbon footprint of a single TKA is approximately 190 kg of CO₂. Joint arthroplasty implants using less metal, requiring fewer instruments and shorter operating times, as well as shorter LoS,³⁵ have substantial potential to significantly reduce the climate impact of orthopaedic surgery.

It is clear that there are considerable challenges facing healthcare provision. Knee OA incidence is projected to increase between 75%³⁶ to over 100%³⁷ in the next three decades relative to current levels. OA incidence is linked to ageing and obesity,³⁸ and as the population ages and becomes more obese, this will drive an increased demand for treatment. UKA is an effective treatment for unicompartmental knee OA, which is the most common presentation of knee disease, is appropriate for both younger patients and the elderly, and is safe as a day-case procedure. Patients treated with UKA have better functional outcomes. While there is a higher revision rate for UKA, it has lower mortality and complications than TKA. UKA is also more cost-effective than TKA. UKA thus remains relevant to current practice while offering opportunities for reducing costs, LoS, and climate impact.

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