Focus On

Which design of TKR – does it matter?

Introduction

There is presently a spectacular rise in demand for total knee replacement (TKR). More knee than hip replacements are now implanted annually and the trend is likely to continue.[1]

Early designs from the 1950s were hinged prostheses with intramedullary stems. While capable of accommodating ligament insufficiency, torsion-induced loosening was common.[2] Today, rotating-hinge knee replacements are available but their use is limited to cases of unstable primary TKR and revision TKR.[3] Designs of TKR from the 1960s were surface arthroplasties combining a small metallic femoral and polyethylene tibial component. However, as the patellofemoral region was not resurfaced, patellar pain was common.

Total condylar resurfacing emerged in 1973 and has progressed to include a more anatomical trochlear and patellar resurfacing. Subsequently, a dichotomous evolution of prostheses arose with some surgeons retaining, and some sacrificing, the posterior cruciate ligament (PCL). Dysfunction or absence of the PCL was associated with posterior tibial subluxation in flexion. Such instability was countered by constructs containing a tibial post against which a rolling femoral cam could abut, thereby limiting subluxation.

Cruciate-retaining implants with cementless fixation were developed in the 1990s and refined to enable bone integration, some using hydroxyapatite coating. Mobile- bearing prostheses were created to maximise articular conformity throughout flexion. A perceived advantage was the potential for rotational self-alignment of femoral and tibial components, and reduced wear.[4-5]

Today, the selection of a TKR is from a variety of modular surface arthroplasties. A plethora of both major and minor design choices exist, even from the same manufacturer, creating a selection dilemma. One might therefore ask, does it matter what we use?

Cemented *versus* uncemented TKR

The method of fixation of a knee prosthesis is important because loosening is the commonest mode of failure.

Following the initial success of cemented hip replacement (THR), polymethylmethacrylate was adopted as a suitable cement material for early designs of TKR. Today, most TKRs are still cemented. This provides secure fixation, fills gaps in the bone-implant interface and resists compressive forces. Fracture of the interposed cement has the potential to create inflammatory debris and peri-prosthetic osteolysis. Revision surgery is also associated with loss of bone stock during cement removal.

However, over the past two decades, the success of cementless and hydroxyapatite (HA)-coated THR has renewed interest in uncemented TKR.

A recent meta-analysis has certainly confirmed the efficacy of cemented TKR.[6]

Combining observational and randomised trials, cemented knees were less prone to aseptic loosening than uncoated cementless designs. However, when comparing only randomised controlled trials (RCTs), cemented TKRs were not longer lasting. Femoral fixation has been durable without cement and 'hybrid' fixation, combining uncemented femoral and cemented tibial components, has lasted well.[7] Indeed, early uncemented designs failed on the tibial side, in association with inadequate cortical contact and insecure fixation.[8]

Roentgen stereophotogrammetric analysis (RSA) studies demonstrate greater initial subsidence of uncemented TKR implants. However, after 12 months, tibial trays coated with HA stabilised and migrated less than their cemented variants.[9]

The perceived advantages of cementless designs are speed, fewer interfaces for loosening, and easier revision with protection of bone stock. These are all favourable features in a younger population of patients undergoing TKR.

Bassett[10] and Baker et al[11] reported no difference in the survivorship of cemented versus uncoated and uncemented designs at a mean follow-up of five and nine years, respectively. However, cemented TKR demonstrated higher failure rates in younger, heavier men.

Hydroxyapatite coating has the potential to shift surgical preference towards cementless implants. Good results have been achieved with different designs of THR incorporating HA fixation since 1985,[5] despite shear stress on femoral fixation. Evidence supporting the success of HA with the planar fixation surfaces of a TKR is increasing. Gaps of up to 2 mm between bone and prosthesis have the potential to fill with bone within a year. Cross and Parish[8] report a survivorship of 99% at a ten-year follow-up, matching results of the best cemented designs.

Posterior cruciate ligament (PCL): salvage or sacrifice?

Whether the PCL is salvaged or sacrificed at TKR has been much debated.[4]

Posterior glide and roll of the femorotibial contact region with flexion is influenced by the PCL. Isolated removal of the PCL increases the flexion gap. While it may be attractive in gaining

surgical access and subsequent flexion, PCL sacrifice encourages posterior tibial subluxation. A tibial post and femoral cam, or a dished polyethylene insert with raised anterior lip, may resurrect both stability and femorotibial rollback.

Evidence suggests that using PCL-substituting designs increases post-operative knee flexion. This could perhaps be because of more normal kinematics. Fluoroscopic studies demonstrate increased femoral rollback using the cam-post articulation as compared with some PCL-retaining systems.[12] A randomised trial by Maruyama et al,[13] comparing patients with bilateral TKR, identified a greater range of movement with PCL-substituting as compared with PCL-sacrificing TKR. Clark et al[14] noted increased flexion with PCL substitution at two years after surgery. A recent meta-analysis[15] concluded that there was an improvement in flexion of 8° in PCL-substituted designs compared with PCL retention. However, any improvement in flexion seemed limited and not associated with improved function. Other investigators have not detected improved flexion with PCL substitution.[16-18]

The PCL may not function even when a PCL-retaining design is used.[12,19] An MRI study has shown that much of the tibial PCL insertion is resected in PCL-retaining arthroplasty.[14] A Cochrane review[10] indicated no difference in clinical outcome when the PCL was retained or resected even if a PCL-stabilised knee was not used.

Problems with cam and post designs include the risk of wear at the cam-post interface, the need for additional bone resection to accommodate the design and the potential for 'cam over post' jump.

A wear analysis study[20] of retrieved PCL-substituting TKRs concluded that cam-post attrition may create polyethylene debris. Creation of a femoral box in these designs requires resection of significant bone and associated soft tissues from the femur. With younger patients undergoing TKR, a bias towards bone preservation might encourage alternative solutions for PCL insufficiency. Laskin et al[21] demonstrated that deeply dished inserts were as clinically effective as cam and post restraints in PCL-deficient knees. Indeed, surface geometry is probably a more important determinant of tibiofemoral movement.[22]

Mobile or fixed-bearing TKR?

Natural knee flexion involves about 20° of external rotation of the femur on the tibia. This value is diminished if the tibia is itself held in external rotation.[23] Designers of knee replacements who may be concerned about polyethylene wear at the tibiofemoral articulation sought to develop meniscal bearings. The aim was to minimise wear by enabling the insert to rotate and slide on a smooth tibial baseplate.[24,25] Mobile-bearing implants were also developed with the aim of increasing articular conformity throughout flexion. A concern with these designs is their potential for instability created by greater movement of the insert.

Kim, Yoon and Kim[26] compared a mobile-bearing, cruciate-sacrificing TKR with a fixed-bearing, cruciate-retaining design. Patient factors were excluded by using patients undergoing simultaneous bilateral TKR. The authors noted no long-term differences between the designs. Price et al[27] reported a small improvement in knee scores with mobile-bearing TKRs, and less

pain. However, their rate of dislocation of the insert was 2.5%. A large United Kingdom multicentre RCT by the Knee Arthroplasty Trial (KAT) Group, involving 116 surgeons and 2352 patients, established no advantage with the mobile-bearing design.[28] Retrieval analysis shows that mobile inserts have more wear on their underside than fixed, modular, insert designs.[29]

Patellar resurfacing?

Whether to resurface the patella remains an important question. Metal-backed patellar components have significantly higher rates of complications[30] and are now rarely used. Patellar resurfacing does not guarantee a painless patellofemoral joint.[31,32] Malalignment of the patella compromises outcome while tibiofemoral replacement can fail to address any incongruity and tension at the patellofemoral joint. Indeed, very worn patellae might track laterally with an associated patellar tilt unless they are resurfaced. The KAT failed to demonstrate significant benefit from patellar resurfacing.[28]

Other designs

High-flexion designs of TKR were conceived to increase knee flexion after surgery. The geometry of the posterior flange and the offset of the femoral component have been adjusted in order to permit deep flexion. Although cadaver studies[33] of such designs suggest greater flexion, clinical studies have failed to show this.[34,35] Kim, Choi and Kim recently compared high-flexion and standard designs in an RCT and concluded that the former provided no advantage in flexion or clinical outcome.[36]

Gender-specific knees have been proposed by some manufacturers in order to provide women with more congruent femoral components. Studies have failed to prove any difference in outcomes compared with standard versions.[36,37]

All-polyethylene tibial components are cheaper than metal-backed versions. Some evidence suggests equivalent survivorship and function.[28,38,39] The lack of modularity afforded by these and compression-moulded polyethylene designs makes gap sizing more difficult despite their published success and reduced backside wear.[40]

Bicruciate-retaining designs are uncommon but have been used with some success. The integrity of the cruciate ligaments is often compromised in arthritis making such designs difficult to use in all cases.[41]

Conclusion

Which design of TKR to best use remains a difficult question. Available studies are often small and surgeon-reported observational works often only record early results. In 1997, 54% of the 37 knee replacements available on the market had no reported data to support their use.[42] However, which design is used does obviously matter. What is clear is that the consequences of using individual designs are different. Despite possible superior kinematics in flexion, PCL-stabilised versions involve greater bone loss and their cam-post articulations receive high loads. Regardless of their potential for self-alignment, mobile bearings have a greater potential to dislocate and may not demonstrate less wear. At present, HA-coated knee replacements remain more

expensive than cemented alternatives. Results after TKR, however, are clearly not simply a function of prosthetic design. Indeed, patients may be satisfied by most of the commonly available designs.

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