Cementless fixation in total knee arthroplasty

In this study we present our experience with four generations of uncemented total knee arthroplasty (TKA) from Smith & Nephew: Tricon M, Tricon LS, Tricon II and Profix, focusing on the failure rates correlating with each design change. Beginning in 1984, 380 Tricon M, 435 Tricon LS, 306 Tricon 2 and 588 Profix were implanted by the senior author. The rate of revision for loosening was 1.1% for the Tricon M, 1.1% for the Tricon LS, 0.5% for the Tricon 2 with a HA coated tibial component, and 1.3% for the Profix TKA. No loosening of the femoral component was seen with the Tricon M, Tricon LS or Tricon 2, with no loosening seen of the tibial component with the Profix TKA. Regarding revision for wear, the incidence was 13.1% for the Tricon M, 6.6% for the Tricon LS, 2.3% for the Tricon 2, and 0% for the Profix. These results demonstrate that improvements in the design of uncemented components, including increased polyethylene thickness, improved polyethylene quality, and the introduction of hydroxyapatite coating, has improved the outcomes of uncemented TKA over time.

The long term follow up of cemented total knee arthroplasty (TKA) has shown excellent longevity and clinical outcomes, with low rates of aseptic loosening. Technically, using cement can be advantageous, as cement can be used to fill any defects between bone and prosthesis in the event of imperfect bone cuts. However, cement is known to have weak resistance to tension and shear forces, and may deform and disintegrate under constant pressure, while osteolysis has been observed at the cement bone interface in young patients. Uncemented prostheses were designed to provide ostointegration between implant and bone, especially in younger patients, in the hope that this biological bond would eliminate osteolysis that had been seen in cemented TKA. Furthermore, eliminating the use of cement can reduce operating and tourniquet times, potentially reducing the risk of infection. Uncemented TKA was thought to offer great potential for young patients with high demand activity.

Kreamer et al, investigating the effect of axial, torsional, and shear loads on cementless tibial components, demonstrated that the factors affecting bone ingrowth included the amount of bone exposed to porous surfaces, interconnection pore sizes, and the degree of implant micromotion. The most influential factor affecting component stability was micromotion. Excessive micromotion may frustrate bony ingrowth and result in a fibrous membrane surrounding the porous coat. As a result, all uncemented implants are designed to increase stability, and especially to prevent lift-off of the tibial tray during eccentric loading conditions. Aseptic loosening is the primary mode of failure of cementless implants, which may be the result of fibrous rather than bony ingrowth between the prostheses and bone; this often correlates with the appearance of complete radiolucent lines, and risks mechanical failure and the development of osteolysis.

In order to increase the degree of bony ongrowth and thus increase stability, hydroxyapatite (HA) has been used to coat the surface of uncemented components. Hydroxyapatite coating, in comparison to press fit fixation or porous coating, has osteoconductive properties which can accelerate bony ongrowth, and encourage the biological growth of the bone even in the presence of gaps or partially unstable conditions. The recommended HA coating thickness is 50μm, with a high level of crystallinity; this allows primary stability during the time period when the process of dissolution and bony ongrowth is occurring. Long term follow up has shown no significant difference in regards stability of the tibial component (migration), implant survival or clinical outcome scores between HA coated uncemented TKA, and cemented TKA.
this study we present the senior author’s experience with four generations of uncemented total knee replacements from Smith & Nephew (Memphis, Tennessee): Tricon M, Tricon LS, Tricon II and Profix, focusing on the failure rates correlating with each design change.

**Patients and methods**

All cases were taken by the senior author (HC) and have been followed clinically and radiologically looking for loosening and osteolysis. For the purpose of this report, the endpoint chosen was revision for any reason. There were four cohorts defined by the type of implant; Tricon M, Tricon LS, Tricon II, and the Profix.

**Tricon M.** First developed by Smith & Nephew in 1983, the Tricon M was a tricompartmental, partially constrained, posterior cruciate sparing, condylar prosthesis (Fig. 1). The femoral component was made of cobalt-chrome molybdenum, and was available in three sizes and two widths. The femoral component had a broad trochlear facet with two condylar facets; the medial condyle was 20% broader than the lateral.\(^25\) The tibial component, fabricated from ultra-high molecular weight polyethylene, was available in three different circumferences, and in 4 mm increments of thickness, beginning at 6 mm and extending to 22 mm. The tibial component was metal-backed with a cobalt-chrome alloy base plate, the undersurface of which was covered with sintered layers of beads, similar to those on the distal aspect of the femoral component. The polyethylene extended distally through the metal plate as two flanged ‘flex-lock’ pegs similar to those on the femoral component, while the articular surface had asymmetrical medial and lateral facets matching those on the femoral component. The tibial articular surface sloped posteriorly 7°; the patellar component had no facets and was symmetric.\(^25\)

**Tricon LS.** The Tricon LS (Long Stem) had identical geometry to the Tricon M; the new feature was a metaphyseal stem (Fig. 2). This was an I-beam configuration which was sloped posteriorly in order to match the slope of the posterior tibial metaphysis. The same ‘flex-lock’ pegs were retained in order to provide immediate stability.

**Tricon II.** The Tricon II knee prosthesis had the same femoral geometry as the Tricon M and Tricon LS, but some were
available with HA coating (applied by plasma spraying) as opposed to porous coating (Fig. 3). The tibial component was a titanium alloy, coated with either grit-blasted titanium or HA, in order to determine which coating had a better outcome. In retrospect, this was probably a mistake, as the comparison should have been between HA and porous coating. For initial fixation, the tibial component had the option of ‘flex-lock’ plastic pegs, compression screws or nothing. The tibial component was cannulated in order to allow the attachment of the diaphyseal stem; the objective was to determine the optimal stem length, with options of 75 mm, 120 mm, and 200 mm available. Strain gauge analysis of the tibia had shown the senior author and other designers that, when loaded vertically, the tibia bent medially and laterally, as opposed to anterior-posterior; the stem was therefore split distally in the sagittal plane to reduce medial-lateral bending stiffness. The stems were highly polished to prevent osteointegration, as the objective of the stem to provide stability, not fixation.

**Profix.** The Profix Total Knee System was introduced in 1994, with the goal of reducing polyethylene wear and simplifying instrumentation. Profix features an anatomic, cobalt-chrome femoral component; it has parallel sides as opposed to the usual 3° wedge (Fig. 4). The tibial component is asymmetric, semi-constrained and moderately conforming, with polyethylene tibial articular inserts. The use of a dished tibial insert allows for sacrifice of the posterior cruciate ligament. The tibial component has a Morse taper male connection which allows the addition of a variety of stems, both metaphyseal and diaphyseal. The connection is offset medially, as the centre of the tibia diaphysis is medial to the center of the metaphysis. The stem has a very rough, titanium, fluted Wagner type metaphyseal stem, which gives an extraordinary initial grip.

**Results**

**Tricon M.** The senior author’s series began in 1984. There were 380 cases; four were revised for loosening (1.1%), all of which were for the tibial component. Five were revised for late sepsis, with an additional three requiring surgery for late supracondylar fractures. Of the total number of Tricon M TKA implanted, 50 (13.1%) were revised for wear. In this system the poly was poor and too thin at 6 mm.

**Tricon LS.** This series of patients began in 1986. There were 435 cases, with five (1.1%) requiring revision for loosening; again tibial component loosening accounted for all of these cases. Three patients required revision for end stem pain, and five patients had late supracondylar fractures (1.1%). Of the total number of patients, 29 (6.6%) required revision for wear.

**Tricon 2.** This series of patients began in 1987, with a total of 305 cases. Of the femoral components used, 51 were HA coated while 254 were porous coated. Of the tibial components, 118 were grit blasted while the other 187 tibias were HA coated. The tibial components all had stems of varying length. Of the 305 cases, only one (0.5%) HA coated tibial components required revision, with five (4.2%) grit blasted
tibias requiring revision; yet again there was no loosening of the femoral component. In the Tricon-2 TKA, wear was no longer a major issue, with only seven (2.3%) cases requiring revision. The poly was better quality, and the minimal thickness was now 8 mm.

Profix. This series of patients began in 1995, with a total of 588 cases performed. A total of 520 femoral components were cementless porous coated and 68 (11.6%) were cemented, due to concerns with initial fixation. No tibial components were cemented in this series. A total of 7 (1.3%) cases were revised for loosening; with the Profix TKA loosening was only seen with the femoral component. There were no loose tibial components, and no cases were revised for wear, however there were three revisions for late supracondylar fractures, and three for late sepsis.

Discussion
Cemented and cementless TKA are similar in respect to the requirements for acceptable alignment, accurate bone cuts, and ligament balancing. However, in order to achieve durable fixation, cementless fixation may require greater surgical precision than cemented TKA. Cementless TKA was originally developed in an attempt to obtain more durable component fixation in younger patients. Because of their longer life expectancy and generally higher physically activity, younger patients place far higher demands and stresses on their implants; as a consequence the revision rates for younger patients are significantly higher. The challenge today is to design implants and modes of fixation that will last very long times in younger patients.

Studies looking at the results of the cementless Tricon and Profix prostheses have consistently demonstrated good to excellent results. Nilsson et al24 in a randomised trial, compared the porous coated Tricon M prosthesis with and without cement in patients with both osteoarthritis and rheumatoid arthritis; there were no difference in outcome between these two groups. Laskin25 compared the cementless Tricon M to a cemented prosthesis in 82 patients with osteoarthritis and rheumatoid arthritis, only affecting the tibial component. There was no difference in outcome, comparing the porous coated Tricon M prosthesis with diaphyseal stems. Our study using cementless Tricon II showed a 0.5% revision rate for loosening, only affecting the tibial component. In our report of patients with Tricon M and Tricon LS TKA, a 1.1% incidence of revision for loosening was seen in both groups, again affecting only the tibial component.

A consecutive series of 115 cementless Profix TKAs was performed in 113 patients with 8 to 10 year follow up, with patient overall satisfaction excellent or good in 91.3% of cases, and a 10 year survival rate of 97.1%. A systematic review of 1152 knees using the Profix prosthesis in primary TKA demonstrated an overall estimated implant survival of 98.6% at five years and 94.2% at ten years with revision for any reason as an endpoint; survival was 100% at both time points with radiological loosening as an endpoint.33 Whiteside et al,16 using the uncemented Profix, compared a group of 167 patients whose age was younger than 55 years and whose weight was greater than 90 kg, with a gender-matched series of 167 patients who were 65 years of age or older and who weighed less than 80 kg. At a minimum five year follow up, the mean Knee Society Scores and pain scores were similar for both groups, however function scores were better for the young, heavier patients. No loosening was seen in either group, however one patient in the young, heavy group underwent polyethylene component revision for wear. In our study of 588 uncemented Profix TKA, 1.3% cases were revised for loosening of the femoral component. No tibial loosening was seen at long term follow-up.

The literature comparing cemented to cementless fixation of different prosthesis in TKA show good to excellent results of cementless fixation with regards to all clinical and radiological parameters. In a recent publication, Park and Kim34 compared the long-term survival of cemented and cementless TKA (NexGen CR, Zimmer) in 50 bilateral TKA. The 14 year survival rate, using loosening or revision for all causes as the endpoint, were 100% for the cemented femoral, the cemented tibial, and the cementless femoral component, and 98% for the cementless tibial component; all other measurements including range of motion and satisfaction rates were the same. Cossetto and Gouda35 presented a 5.7 year follow up of 205 TKAs with a cementless fixed-bearing tibial tray (DePuy, Warsaw, Indiana). None of the patients had significant polyethylene wear or osteolysis, and the tibial trays had evidence of bony ingrowth in all but one case; survivorship was calculated as 98.85%. Bassett,36 in an evaluation of 1000 cemented and cementless Performance Knees (Biomet-Kirschner, Warsaw, Indiana), demonstrated an equal rate of survivorship of all components (99%) at a mean follow-up of 5.2 years.

Data from the Norwegian Arthroplasty Register37 reveals that, overall, 87% of the TKAs implanted were cemented [80% in Sweden], with a 10% rate of hybrid prostheses using uncemented porous-coated femoral components and cemented tibial components. Interestingly, uncemented prostheses were used more often than cemented or hybrid TKA in younger patients. Comparison
of the results of all prostheses showed no difference in revision rates between cemented and cementless TKA, even in patients less than 60 years of age. However, the Swedish register shows a 1.4 times higher risk of revision of uncemented tibial components (p = 0.01). A meta-analysis in 2009 compared the survival and clinical outcomes of cemented and cemented primary TKA, showing no statistically significant difference in the mean Knee Society Score, and that cemented fixation offered equivalent clinical outcomes and at least as good as, if not better, survival than uncemented fixation at medium-term follow-up (two to 11 years).

In summary, radiological and clinical studies have shown minimal or no difference between cemented and cementless TKA’s. The senior author (HC) prefers working with the cementless prostheses where possible, and has had good to excellent results in long term follow up.

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References