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Cementless fixation in total knee arthroplasty

DOWN THE BOULEVARD OF BROKEN DREAMS – OPPOSES

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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, 305 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.¹⁻⁵ 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.¹ However, cement is known to have weak resistance to tension and shear forces, and may deform and disintegrate under constant pressure,⁶ while osteolysis has been observed at the cement bone interface in young patients.⁷

Uncemented prostheses were designed to provide osteointegration 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.⁸⁻¹⁰ Furthermore, eliminating the use of cement can reduce operating and tourniquet times,¹¹ potentially reducing the risk of infection.¹²⁻¹⁵ Uncemented TKA was thought to offer great potential for young patients with high demand activity.^{9,15,16}

Kreamer et al,¹⁷ 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.¹⁸ 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.¹⁹ 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.²⁰ Aseptic loosening is the primary mode of failure of cementless implants, which may be the result of fibrous rather than bony ingrowth between the prosthesis 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.^{21,22} 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.²³

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.²⁴ In

Fig 1a

Fig 1b

Clinical photograph (a) and radiograph (b) of the Tricon M prosthesis.

Fig 2a

Fig 2b

Fig 2c

Fig 2d

Clinical photographs (a and b) radiographs (c and d) of the Tricon LS prosthesis.

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

Fig. 3a

Fig. 3b

Fig. 3c

Fig. 3d

Clinical photographs (a and b) and radiographs (c and d) of the Tricon II prosthesis.

Fig. 4a

Fig. 4b

Radiographs (a and b) of the Profix prosthesis.

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.²⁶ 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 fracture (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.^{27,28} 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.^{29,30} 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 al,²⁴ 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 rheumatoid arthritis and osteoarthritis; there was no statistical difference between the groups in regards pain, range of motion, stability, or patient satisfaction.

In a later study, Nilsson et al³¹ compared 29 HA coated Tricon II tibial components to 28 cemented tibial components. The HA coating in the Tricon II was seen to promote osteoconduction, accelerated bone ongrowth, and biological fixation by bidirectional bone growth even in the presence of a gap.^{21,22} In this series, one HA coated implant was revised due to early delamination of the HA coating and clinical loosening. The HA coated implants displayed some migration in the first three months after surgery and then stabilised, while the cemented knees had initially lower rates of migration that tended to increase over time; after five years, no differences were detected between the two types of implants. Cameron³² showed good to excellent clinical and radiological results in 121 patients with the Tricon II 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 TKA's 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%.²⁶ 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 TKA's 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],³⁸ 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 uncemented TKA, even in patients less than 60 years of age.^{32,37,39,40} However, the Swedish register shows a 1.4 times higher risk of revision of uncemented tibial components ($p = 0.01$).³⁷ A meta-analysis in 2009¹² compared the survival and clinical outcomes of cemented and uncemented 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

1. Lombardi AV Jr, Berasi CC, Berend KR. Evolution of tibial fixation in total knee arthroplasty. *J Arthroplasty* 2007;22(4 Suppl 1):25–29.
2. Berger RA, Rosenberg AG, Barden RM, et al. Long-term followup of the Miller-Galante total knee replacement. *Clin Orthop Relat Res* 2001;388:5867.
3. Keating EM, Meding JB, Faris PM, Ritter MA. Long-term followup of nonmodular total knee replacements. *Clin Orthop Relat Res* 2002;404:34–39.
4. Font-Rodriguez DE, Scuderi GR, Insall JN. Survivorship of cemented total knee arthroplasty. *Clin Orthop Relat Res* 1997;345:79–86.
5. Ito J, Koshino T, Okamoto R, Saito T. 15-year follow-up study of total knee arthroplasty in patients with rheumatoid arthritis. *J Arthroplasty* 2003;18:984–992.
6. Lewis G. Properties of acrylic bone cement: state of the art review. *J Biomed Mater Res* 1997;38:155–182.
7. Naudie DD, Ammeen DJ, Engh GA, Rorabeck CH. Wear and osteolysis around total knee arthroplasty. *J Am Acad Orthop Surg* 2007;15:53–64.
8. Soballe K, Hansen ES, Brockstedt-Rasmussen H, Bünger C. Hydroxyapatite coating converts fibrous tissue to bone around loaded implants. *J Bone Joint Surg [Br]* 1993;75-B:270–278.
9. Hofmann AA, Heithoff SM, Camargo M. Cementless total knee arthroplasty in patients 50 years or younger. *Clin Orthop Relat Res* 2002;404:102–107.
10. Nelissen RG, Valstar ER, Rozing PM. The effect of hydroxyapatite on the micromotion of total knee prostheses: a prospective, randomized, double-blind study. *J Bone Joint Surg [Am]* 1998;80-A:1665–1672.
11. Gicquel P, Kempf JF, Gastaud F, Schlemmer B, Bonnomet F. Comparative study of fixation mode in total knee arthroplasty with preservation of the posterior cruciate ligament. *Rev Chir Orthop Reparatrice Appar Mot* 2000;86:240–249 (in French).
12. Gandhi R, Tsvetkov D, Davey JR, Mahomed NN. Survival and clinical function of cemented and uncemented prostheses in total knee replacement: a meta-analysis. *J Bone Joint Surg [Br]* 2009;91-B:889–895.
13. Wood JEJ. Uncemented fixation in total knee replacement: a promising future. *Curr Opin Orthop* 2007;18:61–65.
14. Baker PN, Khaw FM, Kirk LM, Esler CN, Gregg PJ. A randomised controlled trial of cemented versus cementless press-fit condylar total knee replacement: 15-year survival analysis. *J Bone Joint Surg [Br]* 2007;89-B:1608–1614.
15. Tai CC, Cross MJ. Five- to 12-year follow-up of a hydroxyapatite-coated, cementless total knee replacement in young, active patients. *J Bone Joint Surg [Br]* 2006;88-B:1158–1163.
16. Whiteside LA, Viganò R. Young and heavy patients with a cementless TKA do as well as older and lightweight patients. *Clin Orthop Relat Res* 2007;464:93–98.
17. Kraemer WJ, Harrington IJ, Hearn TC. Micromotion secondary to axial, torsional, and shear loads in two models of cementless tibial components. *J Arthroplasty* 1995;10:227–235.
18. Haddad RJ Jr, Cook SD, Thomas KA. Biological fixation of porous-coated implants. *J Bone Joint Surg [Am]* 1987;69-A:1459–1466.
19. Pilliar RM, Lee JM, Maniopoulos C. Observations on the effect of movement on bone ingrowth into porous surfaced implants. *Clin Orthop Relat Res* 1986;208:108–113.
20. Volz RG, Nisbet JK, Lee RW, McMurtry MG. The mechanical stability of various noncemented tibial components. *Clin Orthop Relat Res* 1988;226:38–42.
21. Soballe K. Hydroxyapatite ceramic coating for bone implant fixation: mechanical and histological studies in dogs. *Acta Orthop Scand* 1993;255:1–58.
22. Stephenson PK, Freeman MA, Revell PA, et al. The effect of hydroxyapatite coating on ingrowth of bone into cavities in an implant. *J Arthroplasty* 1991;6:51–58.
23. Jaffe WL, Scott DF. Total hip arthroplasty with hydroxyapatite-coated prostheses. *J Bone Joint Surg [Am]* 1996;78-A:1918–1934.
24. Nilsson KG, Kärrholm J, Carlsson L, Dalén T. Hydroxyapatite coating versus cemented fixation of the tibial component in total knee arthroplasty: prospective randomized comparison of hydroxyapatite-coated and cemented tibial components with 5-year follow-up using radiostereometry. *J Arthroplasty* 1999;14:9–20.
25. Laskin RS. Tricon-M uncemented total knee arthroplasty: a review of 96 knees followed for longer than 2 years. *J Arthroplasty* 1988;3:27–38.
26. Hardeman F, Vandenuecker H, Van Lauwe J, Bellemans J. Cementless total knee arthroplasty with Profix: a 8- to 10-year follow-up study. *Knee* 2006;13:419–421.
27. Laskin RS. Session III: total knee replacement in young patients. *Clin Orthop Relat Res* 2002;404:100–101.
28. Robertsson O, Dunbar M, Knutson K, Lidgren L. Past incidence and future need for knee arthroplasty in Sweden: a report from the Swedish Knee Arthroplasty Register regarding the affect of past and future population changes on the number of arthroplasties performed. *Acta Orthop Scand* 2000;71:376–380.
29. Harrysson OL, Robertsson O, Nayfeh JF. Higher cumulative revision rate of knee arthroplasties in younger patients with osteoarthritis. *Clin Orthop Relat Res* 2004;421:162–168.
30. Robertsson O, Knutsson K, Lewold S, Lidgren L. The Swedish Knee Arthroplasty Register 1975-1997: an update with special emphasis on 41,223 knees operated on in 1988-1997. *Acta Orthop Scand* 2001;72:503–513.
31. Nilsson KG, Henricson A, Norgren B, Dalén T. Uncemented HA-coated implant is the optimum fixation for TKA in the young patient. *Clin Orthop Relat Res* 2006;448:129–139.
32. Cameron HU. Clinical and radiologic effects of diaphyseal stem extension in noncemented total knee replacement. *Can J Surg* 1995;38:45–50.
33. Viganò R, Marega L, Breemans E, Miró RL. A systematic literature review of the Profix in primary total knee arthroplasty. *Acta Orthop Belg* 2012;78:55–60.
34. Park JW, Kim YH. Simultaneous cemented and cementless total knee replacement in the same patients: a prospective comparison of long-term outcomes using an identical design of NexGen prosthesis. *J Bone Joint Surg [Br]* 2011;93-B:1479–1486.
35. Cossetto DJ, Gouda AD. Uncemented tibial fixation total knee arthroplasty. *J Arthroplasty* 2011;26:41–44.
36. Bassett RW. Results of 1,000 Performance knees: cementless versus cemented fixation. *J Arthroplasty* 1998;13:409–413.
37. Furnes O, Espehaug B, Lie SA, et al. Early failures among 7,174 primary total knee replacements: a follow-up study from the Norwegian Arthroplasty Register 1994-2000. *Acta Orthop Surg* 2002;73:117–129.
38. Robertsson O, Dunbar M, Pehrsson T, Knutson K, Lidgren L. Patient satisfaction after knee arthroplasty: a report on 27,372 knees operated on between 1981 and 1995 in Sweden. *Acta Orthop Scand* 2000;71:262–267.
39. Onsten I, Nordqvist A, Carlsson AS, Besjakov J, Shott S. Hydroxyapatite augmentation of the porous coating improves fixation of tibial components: a randomised RSA study in 116 patients. *J Bone Joint Surg [Br]* 1998;80:417–425.
40. Havelin L I, Espehaug B, Furnes O. The Norwegian Arthroplasty Register. *Annual Yearbook* 2001.