Comparison of Cemented and Uncemented Fixation in Total Knee Arthroplasty

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Educational Objectives

As a result of reading this article, physicians should be able to:

1. Understand the rationale behind using uncemented fixation in total knee arthroplasty.
2. Discuss the current literature comparing cemented and uncemented total knee arthroplasty.
3. Describe the value of radiostereographic analysis in assessing implant stability.
4. Appreciate the limitations in the available literature advocating 1 mode of fixation in total knee arthroplasty.

Abstract

Total knee arthroplasty performed worldwide uses either cemented, cementless, or hybrid (cementless femur with a cemented tibia) fixation of the components. No recent literature review concerning the outcomes of cemented vs noncemented components has been performed. Noncemented components offer the potential advantage of a biologic interface between the bone and implants, which could demonstrate the greatest advantage in long-term durable fixation in the follow-up of young patients undergoing arthroplasty. Several advances have been made in the backing of the tibial components that have not been available long enough to yield long-term comparative follow-up studies. Short-term

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radiostereographic analysis studies have yielded differing results. Although long-term, high-quality studies are still needed, material advances in biologic fixation surfaces, such as trabecular metal and hydroxyapatite, may offer promising results for young and active patients undergoing total knee arthroplasty when compared with traditional cemented options.

Total knee arthroplasty (TKA) is being performed in increasing numbers, and the patient population is becoming younger. Several authors have shown that the mean age of patients undergoing TKA is decreasing and the proportion of the patients younger than 65 years is increasing. Young patients constitute a challenge to orthopedic surgeons because they expect their activity level to be higher postoperatively and their life expectancy is longer. A 55-year-old is more likely to be interested in the 30-year survival rate of the implant than its 10- to 20-year survival rate. Moreover, because the younger patients’ activity level is higher, greater stress will be placed on the implant, and revision surgery is a likely consequence.

For that reason, the TKA needs to provide good function and longevity and preserve as much bone as possible. Uncemented fixation of orthopedic implants is well tested and works well in several areas. The bond between the implant and bone is physiologic, and it is a living interface that responds to stress in a physiologic manner. Uncemented fixation of knee implants has not been the standard of care because several press-fit implant designs failed and many did not show superiority over cemented fixation. However, as materials and design have evolved, uncemented fixation is again being preferred by many surgeons, mainly because of the changing demographics of the TKA population.

Although cemented vs uncemented total hip arthroplasty has been compared, no reviews have compared cemented and uncemented TKA. The evidence for TKA in the young population was recently reviewed and found to be deficient in several aspects. In the young population, the chief concerns are whether patients gain acceptable pain relief and function and the survival of the implant. Most studies use the Knee Society Score as an outcome parameter and report increases in Knee Society Scores comparable with those in studies on older patients. However, Keeney et al documented that most studies do not include patient-reported outcomes and that long-term follow-up is deficient. Many studies that are often quoted do not provide a long-term follow-up for all of their patients. For example, the study by Diduch et al is often referenced as evidence for the success of TKA in the young population. However, although the study reports a follow-up of 3 to 18 years, the mean follow-up was 8 years, and only 33% of the patients were followed for more than 10 years. Thus, the fate of the TKA in the young population is undocumented, and for that reason the issue of fixation becomes more relevant. Cemented fixation is known to provide good initial fixation, but the uncemented interface between bone and metal forms a biologic bond that may provide better long-term results.

RESULTS

In a recent analysis of 32,000 TKAs performed between 1997 and 2003 reported in the Finnish Arthroplasty Register, 3% of the TKAs were cementless and 6% were hybrid fixations. In a report on hip and knee replacements in England, Sibanda et al reported revision rates for 69,000 cemented TKAs and 6000 uncemented TKAs, which implies that uncemented TKAs constitute approximately 8% of all TKAs in England. The 3-year revision rate was 1.4% for cemented and 1.5% for uncemented TKAs. In Scandinavia, uncemented TKA (including hybrid fixation) constituted 2% in Sweden, 14% in Norway, and 22% in Denmark between 1997 and 2007. Data on the use of uncemented knees in the United States is hard to evaluate because no national registry exists to provide knowledge in this regard.

Clinical Outcome

Dixon et al compared the clinical outcome of a cementless hydroxyapatite-coated prosthesis at 5 years postoperatively in patients 75 years and older and those younger than 75 years and found no difference in Knee Society Clinical rating. The authors concluded that the prosthesis does just as well in older patients as in younger patients.

Bioactive Coating

A bioactive coating may be sprayed onto the surface of the implant to increase the speed of bony ingrowth. It is thought that the hydroxyapatite coating acts by providing anchorage across any motion-induced fibrous membrane between the implant and the bony surface. In a study of 32 Miller-Galante II (Zimmer, Warsaw, Indiana) hydroxyapatite-coated arthroplasties, Akizuki et al found that the clear zones around the implant were common 1 month postoperatively but disappeared completely after 6 months postoperatively. The authors retrieved an arthroplasty that had been implanted for 2 years during autopsy. Sections of the implant-bone interface showed osteogenesis in all parts of the fiber metal and that bone tissue comprised 77% of the interface.

Cost

Uncemented implants are more expensive than cemented implants, but determining the cost of implants is complicated. Prices vary between countries; companies are reluctant to disclose prices; and prices are negotiable. A recent informal request for prices from various companies in Norway revealed that most companies charge 30% to 40% more for their uncemented implants. However, prices vary between companies, and it is possible to
find well-known uncemented implants for the price of a cemented implant from a different provider. The price of cement has to be deducted, as well as the possibility of saving some operative time. A cost-benefit analysis is needed. Kamath et al. \(^{16}\) found that, in their institution, it cost $596 more to use the NexGen (Zimmer) uncemented tantalum metal vs the cemented posterior stabilized tibial component. However, when accounting for operative time, cement, and mixing equipment, the difference in cost was only $150 more for the NexGen implant. \(^{16}\)

**Screw Fixation Vs No Screws**

In a study on the Natural Knee system (Zimmer), 58 tibias with additional 6.5-mm screw fixation were compared with 58 tibias without screws. \(^{17}\) No difference in clinical or radiographic outcome was found, and the authors concluded that screw fixation of a tibial baseplate was not necessary to achieve secure fixation. \(^{17}\)

**Femur Vs Tibia**

Several studies on hybrid fixation confirm excellent results of an uncemented femoral component. \(^{18-20}\) Radiostereographic analysis studies have confirmed that no increased risk of loosening of the femoral component is found when using uncemented techniques. \(^{21-23}\)

**Radiostereographic Analysis Studies**

Radiostereographic analysis is a technique in which the movement between implants and bone may be measured. \(^{24}\) Radiopaque beads are scattered in the area of interest, and cameras record their position at time intervals. Thus, small changes in position may be recorded and, due to the high level of precision, small numbers of participants are needed to detect meaningful differences between implants or surgical techniques. In the realm of implant research, continuous movement between implants and bone at 2 years is regarded as predictive of late aseptic loosening of the implant. For this reason, radiostereographic analysis studies have claimed to have the ability to detect changes earlier than what would have been possible by following the implants for the necessary time span to detect loosening. \(^{25}\)

Nilsson et al. \(^{26}\) reported 97 Profix knees (Smith & Nephew, Memphis, Tennessee) in a prospective randomized radioste- rographic analysis study. The authors noted that cemented tibias did not stabilize in the course of the 2-year follow-up. Hydroxyapatite-coated implants migrated as much as the cemented implants, but these implants displayed all of their migration within the first 3 months. Additional fixation of the tibia with screws was not helpful. Nilsson et al. \(^{26}\) concluded in a randomized, controlled trial that hydroxyapatite coated implants are significantly more stable than both noncoated and ce- mented implants; a recently published 10-year follow-up of these patients revealed that the effect of hydroxyapatite coating lasts. \(^{27,28}\) These researchers used a cruciate-retaining implant and followed their patients for 2 years. In a study published in 2005, Carlsson et al. \(^{29}\) reported that a cemented tibia was more stable than an uncemented tibia (press-fit condylar modular, posterior cruciate-retaining prosthe- sis; Johnson & Johnson Orthopaedics, New Milton, United Kingdom), whether coated or uncoated with hydroxyapatite. However, in the uncemented group, the hydroxyapatite-coated tibias were significantly more stable than the uncoated ones, a finding that is supported by a previous study. \(^{30}\) The favorable results in patients with a bioactive coating were confirmed in a small study in which less migration was observed in implants with a bioactive coating (Duracon; Stryker Howmedica) than in implants without coating. \(^{31}\) However, the beneficial effect of peripatite coating was not confirmed in a radioste- rographic analysis study on patients with rheumatoid arthritis. \(^{32}\) In this prospective randomized study on coated and noncoated Duracon (Stryker, Montreux, Switzerland) implants, a trend was observed toward less migration in implants covered with bioactive material, but the differences were not statistically significant.

**Trabecular Metal**

Trabecular Metal (Zimmer) is a relatively novel material that has elastic characteristics that resemble those of bone and has favorable potential for bony in growth due to its high level of porosity. \(^{33}\) For that reason, it has been thought that Trabecular Metal should be used in TKA for fixation of the tibial component. In a radioste- rographic analysis study by Henricson et al. \(^{34}\) Trabecular Metal Monoblock Tibial components were compared with cemented tibias from the same manufacturer (NexGen). The investigators found that the Trabecular Metal components migrated during the first 3 months and then became stable, whereas the cemented tibias did not stabilize within the 2-year follow-up period. \(^{34}\)

Dunbar et al. \(^{35}\) studied 49 participants in a prospective randomized trial in which a cemented tibial tray (NexGen) was compared with a Trabecular Metal uncem- ented tray with a 2-year follow-up. Using radioste- rographic analysis, the authors found that all 28 Trabecular Metal trays stabilized within 1 year and none were considered at risk for aseptic loosening. Of the 21 cemented tibias, 4 were considered at risk for loosening, and the authors reported a significantly higher movement for these implants between 12 and 24 months postoperatively. \(^{35}\) The beneficial effect of Trabecular Metal was maintained after 5-year follow-up. \(^{36}\) It has also been shown that “Trabecular Metal implants appear to maintain tibial bone mineral density in a parallel fashion to the nonoperative limb in this population and better than historical controls.” \(^{37}\)

Most radioste- rographic analysis studies detect longitudinal changes over the time span of months and years, but it is also possible to study acute changes in
the position of the implant. By applying a load to the implant or extremity and recording the changes in position, the actual movement of a well-fixed implant may be depicted. Several authors have studied the inducible changes in position under various conditions, and a relatively larger inducible displacement is considered a poor prognostic sign of an implant.38-57 To the authors’ knowledge, only 1 study compares the inducible change of uncemented tibias to that of cemented tibias; Wilson et al38 showed that uncemented Trabecular Metal components had a lower inducible change than its cemented counterparts.

The former clinical elements are summarized in the Table.

**Literature Review**

Pertinent literature on cemented vs uncemented TKAs is systematically reviewed and categorized by the scientific rigor of the available publications: Cochrane analysis, meta-analysis, randomized, controlled trials, observational studies, and comparative nonrandomized studies.

**Cochrane Analysis.** When seeking evidence on a clinical topic, it is recommended to look for reviews in the Cochrane Library. In this database, 1 protocol was identified,59 but no review on the topic in question was available. Nakama et al58 have proposed to perform a review focusing on the differences in outcome after cemented vs uncemented TKA.

**Meta-analysis.** It was possible to identify 1 meta-analysis on the topic,59 Gandhi et al59 published their study in 2009, based on 5 randomized, controlled trials and 10 observational studies. When pooling all data, the authors found improved survival of cemented implants compared with uncemented implants. No significant difference existed in clinical outcome as measured by the mean Knee Society Score. However, when the authors pooled data from only randomized, controlled trials, no significant difference existed between the 2 groups. Several interesting aspects are associated with this study.

The primary endpoint was survival of the implant free of aseptic loosening at a minimum of 2 years. Of the 5 randomized, controlled trials, 1 study had a mean follow-up of 7 years,61 one had 5 years,62 and 3 had 2 years.63-65 Bearing in mind that cementless fixation was introduced to improve long-term survival, the studies in this meta-analysis are not helpful to that end. It should be noted that 1 randomized controlled trial with a 15-year follow-up was available.61 This study was discarded in favor of a previous report on the same patient cohort with a 10-year follow-up; this was done to avoid excessive heterogeneity between the studies.

The second interesting aspect relates to the types of implants used in the studies. Although a variety of implants were used, none were hydroxypatite coated, which was unfortunate because radiostereographic analysis studies have demonstrated greater initial stability of hydroxypatite-coated implants compared with noncoated implants, and hydroxypatite-coated implants are regarded by some as the implant of choice.26

Voigt and Mosier66 performed a systematic review and meta-analysis of trials involving tibial components that were either hydroxypatite coated, porous coated, or cemented. The authors found evidence that the hydroxypatite coated components were more stable after 2 years, and no difference was found in revision rates at 2- and 8- to 10-years follow-up. The authors also found no difference between the groups regarding clinical outcome or adverse events, which led the authors to conclude that hydroxypatite coated tibial components might be the implant of choice in patients older than 65 years and that further studies are needed to assess the ideal component choice in younger, more active patients.

<table>
<thead>
<tr>
<th>Topic</th>
<th>Summary</th>
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<tr>
<td>Use</td>
<td>Not able to evaluate in the United States Registry data but indicates generally 2% to 8% of TKA are uncemented, with the exception of Norway (14%) and Denmark (22%).</td>
</tr>
<tr>
<td>Clinical outcome</td>
<td>Age does not appear to unduly influence outcome of cementless TKA in elderly patients.</td>
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<tr>
<td>Bioactive coating</td>
<td>HA coating shows improved fixation over noncoated implants. The common radiographic lucencies and micro motion commonly resolves within the first year.</td>
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<tr>
<td>Cost</td>
<td>More for press-fit implants, but considering time, equipment, and cement, may be as little as $150.</td>
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<tr>
<td>Additional screw fixation</td>
<td>Screw fixation does not appear beneficial.</td>
</tr>
<tr>
<td>Uncemented femoral components</td>
<td>Excellent clinical results without evidence of increased loosening.</td>
</tr>
<tr>
<td>Radiostereographic analysis studies</td>
<td>Uncemented HA-coated show more micro motion early, whereas cemented micro motion persisted. HA coating and TM show decreased micro motion compared with traditional press-fit.</td>
</tr>
<tr>
<td>Trabecular Metal</td>
<td>Favorable characteristics of bony ingrowth and maintaining bone density. Initial micro motion seems to stabilize within 3 months to 1 year.</td>
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*Abbreviations: HA, hydroxyapatite; TM, trabecular metal. Zimmer, Warsaw, Indiana.*
Randomized Controlled Trials. In a randomized, controlled trial of the press-fit condylar posterior cruciate ligament–retaining knee (Johnson & Johnson, Raynham, Massachusetts) with a mean follow-up of 15 years, Baker et al.\(^6\) found no difference in revision rates and survival between the cemented and uncemented prostheses. They did find a significant sex difference in revision rates, with men having an increased risk of revision in the cemented group but not in the cementless group and women having the same revision rates in the 2 groups. The revision rates were 8.7% in the cemented group and 8.9% for the uncemented knees, counting exchange of the femoral component, the tibial plateau, or the tibial insert. Interestingly, the authors report a large reduction in survival at 10- to 15-years follow-up from 91.7% to 80.7% in the cemented group and from 93.3% to 75.3% in the uncemented group. The difference between the knees was not statistically significant.\(^6\) The press-fit condylar knee prosthesis is a cobalt-chrome femoral component articulating with a polyethylene insert that is mounted on a titanium tibial tray with a cruciform stem. None of the components were hydroxyapatite-coated.

Observational Studies. Watanabe et al.\(^6\) reported a 10-year survival rate of 100% in 76 Osteonics 3000 (Stryker Orthopaedics, Mahwah, New Jersey) TKAs, a cobalt-chrome beaded implant that uses a cruciate retaining technique. One knee was subsequently revised, causing the survival rate to decrease to 96.7% at 13 years postoperatively. However, they also reported tibial radioluencies in 20% of the knees, indicating no bony ingrowth.\(^6\)

In a recent report on 175 patients in whom a hydroxyapatite-coated fixed bearing cruciate-retaining design was used, Cossetto and Gouda\(^6\) found bone ingrowth in all but 1 case. This tibial tray (Duofix; DePuy, Warsaw, Indiana) was used in conjunction with an uncemented femoral implant (press-fit condylar Sigma; Johnson & Johnson) and consisted of a central polished stem and 4 hydroxyapatite-coated smaller pegs. Radiolucent lines were found in 9 patients, but none were progressive or extended around the peripheral pegs. The mean follow-up in this study was 5 years. These results are supported by a report by Cooke et al.,\(^7\) who reviewed the early results in 200 cases operated on with the same implant, in which bony ingrowth was found in all cases. Chana et al.\(^7\) reported on 186 cementless Duracon knees (Stryker Orthopaedics, Mahwah, New Jersey) on which periapatite was used for enhanced bone ingrowth. In this report, only 1 component was revised for aseptic loosening after 5 to 8 years.

In a study reporting 255 TKAs that were followed for 15 to 18 years, Whiteside\(^7\) recommended cementless, patella-sparing, and posterior cruciate ligament–retaining techniques, asserting that the results are comparable with the best series reported with cemented fixation. In an earlier study, Whiteside\(^7\) found a 94% survival of 31 TKAs after 10 years that considered all modes of failure. In a sex-matched series of 122 knees, Whiteside and Viganò\(^7\) found that young and heavy patients performed as well as older patients using the cementless fixation (5- to 10-year follow-up). Ritter and Meneghini\(^7\) reported a 96.8% survivorship of the uncemented AGC monoblock tibial component (Biomet, Warsaw, Indiana) after 20 years. Reviewing the initial experience using the New Jersey Low Contact Stress meniscal bearing and rotating platform knees (DePuy, Warsaw, Indiana), Buechel et al.\(^7\) found a 98.3% survivorship after 18 years for the cementless rotating platform knees when revision for any mechanical reason or poor clinical knee score was used as an endpoint. In a separate report, the same authors found nearly identical survival rates for cementless (98.3%) and cemented (97.7%) implants after 18 to 20 years using the rotating platform.\(^7\)

Hofmann et al.\(^7\) implanted the cementless Natural Knee (Zimmer, Warsaw, Indiana) in 300 knees and reviewed 176 knees 12 years postoperatively. Excluding revisions for infections and simple polyethylene exchanges, 2 femoral and 1 tibial component required revision, for a cumulative survival rate of 95.1%. Eriksen et al.\(^7\) reported the 20-year results of 114 AGC 2000 (Biomet) porous coated knees. Due to early tibial and late patellar revisions, the cumulative survival rate when all revisions were included was 85%. The isolated survival rate for the tibial component was 97.2% and 100%, excluding the failures from the femoral and patellar components, for the femoral component. In a prospective observational study, the Profix cementless knee (Smith & Nephew, Memphis, TN) was followed for 8 to 10 years.\(^8\) Of 115 knees, 2 tibial components were revised: 1 for a perioperative medial plateau fracture and 1 for aseptic loosening after 6 years. The cumulative survival rate after 10 years was 97.1%.\(^8\) Kamath et al.\(^8\) found no radiographic evidence of loosening in 100 consecutive tantalum monoblock uncemented tibial components (NexGen; Zimmer) with a minimum 5-year follow-up in patients younger than 55 years. Woo et al.\(^8\) reviewed the results from 3 types of cementless posterior cruciate ligament–retaining semiconstrained prostheses in patients with rheumatoid arthritis. They had an average follow up of 10.1 years, and Kaplan Meier analysis showed a 96.8% survival rate at the post-operative 15.5-year follow-up.\(^8\) Eskola et al.\(^8\) found no statistically significant difference in clinical outcome scores between uncemented knees in patients with osteoarthritis vs rheumatoid arthritis. This study evaluated 92 knees, with 42 patients with rheumatoid arthritis. Two tibial baseplates had lucencies greater than 2 mm, both found in patients with rheumatoid arthritis. No clinically evident loosening was observed.\(^8\)

In a prospective study of young active patients, Tai and Cross\(^8\) followed 118
knees with a stemless hydroxyapatite-coated implant (Active; DJ Ortho, Sydney, Australia) for 5 to 12 years. Two tibial revisions for aseptic loosening and 1 polyethylene exchange were performed. The cumulative survival rate was 92.1% (including polyethylene exchange). Cross and Parish\(^7\) reported a 99.14% cumulative survival rate in 1000 knees with a cementless, hydroxyapatite-coated cruciate-retaining implant followed for 10 years. They performed 5 revisions, of which 4 were due to septic loosening. Epinette and Manley\(^8\) reported a 98% survival rate after 10 to 15 years in a series of 146 TKAs using implants that were partially or completely hydroxyapatite coated. According to their report, hydroxyapatite coating appeared to encourage filling of gaps that remained after the initial surgery.

In a study on the migration of an uncemented, hydroxyapatite-coated tibial component fixed with 4 screws, Fukuoka et al\(^9\) reported a migration of 60.7 µm during the first 6 months, after which all components remained stable. They emphasized the importance of achieving initial stability.

**Comparative Nonrandomized Studies.** Comparing porous-coated anatomic (Howmedica, Rutherford, New Jersey) to Duracon implants, Gruber et al\(^10\) reported that uncemented implants had slightly better results than cemented knees.

**Discussion**

Currently, the majority of implants for TKA worldwide use either cemented or hybrid components. In reviewing the current literature, the authors came to the following conclusions. The results for cemented and noncemented femoral components were equivocal. Although observational studies report favorable results with noncemented tibial components without a bioactive coating, randomized, controlled trials and meta-analyses failed to show significant differences when compared with cemented components. Tibial components with bioactive coatings had less migration in radiostereographic analysis studies than those without coatings. Radiostereographic analysis studies have shown differing results when evaluating hydroxyapatite-coated noncemented tibial components compared to cemented tibial components. Due to multiple variables and the limited information available, it was not possible to reach a conclusion about the ultimate cost of cemented vs noncemented components.

Long-term outcomes of TKA in the young population are still somewhat unknown. Multiple technological advances regarding the surface of press-fit implants have been promising. These advances are relatively recent and, therefore, lack long-term follow-up. However, there is hope that this will enable a more biologic bone-implant interface than traditional cemented implants. If so, the greatest benefit would likely be felt by younger patients undergoing TKA who place greater demands for longer periods of time on their implants. High quality studies investigating the long-term success and patient satisfaction is needed in the subset of patients undergoing TKA who are young, particularly in evaluating results of tibial implants with a bioactive coating and comparing these with cemented components. Similar studies are also needed in comparing modern press-fit tibias of different designs (rotating platform vs cruciate retaining vs cruciate substituting).

**References**


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