Comparison of Cementless and Hybrid Cemented Total Knee Arthroplasty

RICHARD LASS, MD; BERND KUBISTA, MD; JOHANNES HOLINKA, MD; MARTIN PFEIFFER, MD; SPIRO SCHULLER, MD; SANDRA STENICKA, MD; REINHARD WINDHAGER, MD; ALEXANDER GIUREA, MD

abstract

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Cementless total knee arthroplasty (TKA) implants were designed to provide long-term fixation without the risk of cement-associated complications. The purpose of this study was to evaluate the outcome of titanium-coated cementless implants compared with hybrid TKA implants with a cemented tibial and a cementless femoral component. The authors performed a case-control, single-center study of 120 TKAs performed between 2003 and 2007, including 60 cementless and 60 hybrid cemented TKAs. The authors prospectively analyzed the radiographic and clinical data and the survivorship of the implants at a minimum follow-up of 5 years. Ninety patients who underwent TKA completed the 5-year assessment. Knee Society Scores increased significantly in both groups ($P < .001$). In both groups, 2 patients underwent revision due to aseptic tibial component loosening, resulting in a 96% implant survival rate. Radiographs showed significantly less radiolucent lines around the tibial baseplate in the cementless group (n=12) than in the hybrid cemented group (n=26) ($P = .009$).

At 6-year mean follow-up, no significant difference existed between the cementless and hybrid cemented tibial components in TKA in terms of clinical and functional results and postoperative complications. The significantly smaller number of radiolucent lines in the cementless group is an indicator of primary stability with the benefit of long-term fixation durability of TKA.

The authors are from the Department of Orthopaedics, Vienna Medical University, Vienna General Hospital, Vienna, Austria.

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Correspondence should be addressed to: Richard Lass, MD, Department of Orthopaedics, Vienna Medical University, Vienna General Hospital, Währinger Gürtel 18-20, 1090 Vienna, Austria (richard.lass@meduniwien.ac.at).

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Early condylar total knee arthroplasty (TKA) implant designs most commonly used an all-polyethylene cemented tibial component.\textsuperscript{1,2} Since the mid 1980s, modular, metal-backed tibial trays have dominated the TKA implant market based on finite-element analysis studies that reported superior force distribution compared with conventional all-polyethylene components.\textsuperscript{3} These implants provided long-term fixation, with prosthetic survival rates ranging from 77% to 94% at 16 to 20 years postoperatively.\textsuperscript{4,5} However, aseptic tibial component loosening was a reason for failure in these implants.\textsuperscript{6,7} In 2005, the demand for primary TKA was projected to increase from 450,000 to 3.48 million procedures in the United States by 2030.\textsuperscript{8} As condylar TKA became increasingly successful, the age for indication steadily decreased. Increasing life expectancy has raised the concern that cemented TKAs may not withstand prolonged use, particularly in younger patients.\textsuperscript{9,10} Patients younger than 65 years are projected to account for more than 50% of patients undergoing TKA by 2016 and to more than 50% of patients undergoing revision surgery by 2011.\textsuperscript{11} The number of total knee revisions in the United States is expected to increase from 38,300 in 2005 to 268,200 in 2030.\textsuperscript{12}

Cementless TKA implants were designed as an alternative to cemented implants. They were expected to provide long-term fixation without the risk of cement debris particle generation and cement degradation resulting in late prosthetic loosening and failure.\textsuperscript{13,14} They were envisioned as a superior solution for TKA in younger patients.\textsuperscript{15,16} Titanium-coated implants have been used successfully in joint arthroplasty since 1986.\textsuperscript{17,18} This rough surface is optimal for bone ingrowth and enhances primary stability.\textsuperscript{19,20} Interest has also increased in prostheses coated with bioactive materials to promote osseous ingrowth and, thus, biological fixation.\textsuperscript{21,22} Furthermore, cementless techniques offer advantages in terms of shorter operating and tourniquet times. However, they may cause complications, such as poor initial fixation, aseptic loosening, and osteolysis. Cemented and hybrid cemented prostheses continue to yield excellent results.\textsuperscript{5,6,10,26} However, it has not been clearly shown whether the functional and clinical results of cementless implants are comparable with those of hybrid cemented implants. This study collected and analyzed clinical data on mobile bearing cementless implants coated with a titanium plasma-sprayed layer and with a thin bioactive calcium phosphate (µ-CaP) surface layer to enhance bone ingrowth and prevent implant-related incidents. The purpose of this study was to establish whether this combination leads to successful results comparable with the gold standard of a cemented implantation.

**Materials and Methods**

Between July 2003 and January 2007, the authors prospectively collected data on 111 consecutive patients (120 knees) with idiopathic, posttraumatic, or rheumatoid arthritis who underwent primary TKA. Exclusion criteria were previous revision surgery, a history of joint sepsis, primary or secondary carcinoma in the past 5 years, psychosocial disorders limiting rehabilitation, more than 20° of valgus or varus deformity, and extension loss of more than 20°.

Sixty TKAs were performed with a hybrid fixation technique using a cemented tibial tray and a cementless femoral component as the standard procedure. The other 60 TKAs were uncemented. The fixation technique choice was determined by the surgeon’s preference; 2 surgeons preferred the cementless technique and performed most of the cementless implantations. The other surgeons preferred the hybrid cemented implantation but also performed at least 1 cementless operation. In total, more than 10 surgeons were included. Nine patients underwent bilateral TKA, 3 of whom underwent simultaneous bilateral TKA. The patella was replaced and cemented in all cases. Mean operative time was 123 minutes (range, 70-140 minutes). The primary diagnoses were idiopathic arthritis (n = 106; 88.3%), posttraumatic arthritis (n = 8; 5.0%), rheumatoid arthritis (n = 4; 3.3%), and avascular necrosis (n = 1; 0.8%). Eighty-one (72.9%) patients were women. Average age was 66.9 years (range, 35-90 years), and mean body mass index (BMI) at operation was 30.28 kg/m².

No significant difference existed in preoperative Knee Society Scores or demographic characteristics (ie, age, sex, primary diagnosis, or BMI) between the cementless and hybrid cemented groups (Table 1).

**Surgical Technique**

The uncemented e.motion knee prosthesis (Aesculap, Tuttinglen, Germany), a posterior cruciate-retaining prosthesis with a mobile polyethylene bearing on a metal tibial platform, was used for all patients. All implantations were performed using an image-free navigation system (OrthoPilot; Aesculap). All surgeons used a standard surgical technique involving a midline incision, medial parapatellar exposure, and a tourniquet after prophylactic antibiotics were administered for a maximum tourniquette duration of 120 minutes. Sixty TKAs were fully uncemented using the uncemented e.motion knee prosthesis with a 350-µm plasma-sprayed titanium coating. The implants were coated with a layer of fine titanium powder applied in a plasma spray process under vacuum and with a thin bioactive dicalcium phosphate (µ-CaP) dihydrate surface layer. The Plasmapore (Aesculap AG, Tuttinglen, Germany) pore sizes ranged from 50 to 200 µm, with a microporosity of 35% and a thickness of 0.35 mm. In the hybrid ce-
mented group, 60 TKAs were performed with a hybrid fixation technique using a cemented tibial tray and a cementless femoral component. In these patients, the cement was placed only on the tibial plateau but not down the tibial medullary canal. The patella was replaced, and the polyethylene patellar component was cemented in all patients. The cement used in all patients was Palacos R (Heraeus Medical GmbH, Wehrheim, Germany). The implant design was the same in all patients except the surface of the uncremented tibial tray as mentioned above. Postoperative management consisted of early range of motion exercises and walking aids for the first 6 postoperative weeks with partial weight bearing on the operated leg in both groups.

Study Parameters

To characterize the study population preoperatively, the following parameters were collected from each patient: primary diagnosis, age, sex, weight, height, BMI, operation date, and operative side. After discharge, patients were followed up at 6 weeks, 3 and 6 months, and annually thereafter. To assess the clinical and functional outcome, the Knee Society Score was calculated pre- and postoperatively at each follow-up.

Radiographs were obtained pre- and postoperatively at each follow-up (Figure 1). The analysis was conducted by an investigator (S.S.) who was not an operating surgeon; the results were evaluated with the roentgenographic knee evaluation system endorsed by the Knee Society. The system has a numerical score for the prosthetic interface that assesses fixation quality. The tibial interface is examined and evaluated in the anteroposterior and lateral views, the femoral interface in the lateral view, and the patella in the skyline view with the help of digital radiograph tools. The total score for each component is calculated by measuring the cumulative width in millimeters of the radiolucent lines in all zones of the component. Five to 7 zones may be assigned to the tibia and femur and 3 to 5 zones may be assigned to the patella. For a 7-zone tibial component on the anteroposterior view, the score can be rated as follows: 4 or less and nonprogressive, probably not significant; 5-9, should be closely followed for progression; and 10 or greater, signifies possible or impending failure regardless of symptoms. Osteolysis was defined as a lytic lesion greater than 5 mm² that was not present on immediate postoperative radiographs.

Statistical Analysis

Statistical analysis for comparing age and BMI at baseline as well as the radiological numerical scores and pre- and postoperative knee scores at last follow-up for the 2 groups was performed with the 2-tailed independent t test. Chi-squared analyses were performed to compare sets of categorical data, such as sex, operative side, or revision rates with regard to prosthetic-related incidents. The authors used Kaplan-Meier curves in the analysis of the survival rate of the prostheses with revi-

### Table 1: Patient Demographics

<table>
<thead>
<tr>
<th>Demographic Data</th>
<th>Cementless Group</th>
<th>Hybrid Cemented Group</th>
<th>Total</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of TKAs</td>
<td>60</td>
<td>60</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>Sex, M:F</td>
<td>25:35</td>
<td>14:46</td>
<td>39:81</td>
<td>.32†</td>
</tr>
<tr>
<td>Mean BMI (range), kg/m²</td>
<td>30.0 (19-44)</td>
<td>30.5 (23-51)</td>
<td>30.3 (19-51)</td>
<td>.61*</td>
</tr>
<tr>
<td>Mean age (range), y</td>
<td>65.7 (43-85)</td>
<td>68.1 (35-90)</td>
<td>66.9 (35-90)</td>
<td>.19*</td>
</tr>
<tr>
<td>L:R knees</td>
<td>29:31</td>
<td>27:33</td>
<td>56:64</td>
<td>.71†</td>
</tr>
<tr>
<td>Primary diagnosis (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Idiopathic arthritis</td>
<td>52 (86.7)</td>
<td>54 (91.6)</td>
<td>106 (88.3)</td>
<td></td>
</tr>
<tr>
<td>Posttraumatic arthritis</td>
<td>5 (8.3)</td>
<td>1 (1.6)</td>
<td>6 (5)</td>
<td></td>
</tr>
<tr>
<td>Rheumatoid arthritis</td>
<td>2 (3.3)</td>
<td>2 (3.3)</td>
<td>4 (3.3)</td>
<td></td>
</tr>
<tr>
<td>Avascular necrosis</td>
<td>1 (1.6)</td>
<td>0 (0)</td>
<td>1 (0.8)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
<td>3 (5)</td>
<td>3 (2.5)</td>
<td></td>
</tr>
<tr>
<td>TKAs lost to follow-up</td>
<td>5 (8.3)</td>
<td>8 (13.3)</td>
<td>13 (10.8)</td>
<td></td>
</tr>
<tr>
<td>Patients deceased</td>
<td>3 (5)</td>
<td>1 (1.6)</td>
<td>4 (3.3)</td>
<td></td>
</tr>
<tr>
<td>Patients not examinable</td>
<td>3 (3.3)</td>
<td>0 (0)</td>
<td>3 (2.5)</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index; L, left; R, right; TKA, total knee arthroplasty.

*Two-tailed independent t test.
†Chi-square test.

Figure 1: Standard anteroposterior radiographs at minimum 5-year follow-up showing radiolucent lines of 1 to 2 mm after cementless (A) and hybrid cemented (B) total knee arthroplasty.

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1A 1B
sion for aseptic loosening of a component or revision for any reason as the endpoint. Statistical analysis was performed with SPSS version 15.0 software (SPSS, Inc, Chicago, Illinois). Statistical significance was set at a $P$ value less than .05 for all analyses.

### Results

#### Evaluable Cases

Eighty-one patients who underwent 90 TKAs (75%) completed the 5-year follow-up. Of the 90 TKAs, 43 (48%) were cementless and 47 (52%) were hybrid cemented. During the study, 4 (3.3%) patients died due to causes not related to the index procedure. Two patients who had undergone 3 TKAs did not complete 5-year follow-up because of bad health due to concomitant diseases. One patient sustained a major stroke 2 years postoperatively and 1 patient had progressive Parkinson’s disease, but both patients had good clinical results at last follow-up at 18 and 6 months, respectively. Thirteen patients (13 TKAs; 10.8%) were lost to follow-up (Table 1).

#### Outcome

Ninety operated knees in 81 patients were analyzed for a minimum of 5 years postoperatively. Mean follow-up was 6, 2 years (range, 5.0-8.5). Knee Society Scores increased significantly in both groups ($P<.001$). Mean total Knee Society Score increased from 93.3 to 184.2 in the cementless group and from 91.5 to 179.7 in the hybrid cemented group. Thus, the total Knee Society Score improvement was 91.9 points in the cementless group and 88.2 points in the hybrid cemented group ($P=.538$). No statistically significant difference existed in Knee Society Score between the groups (Table 2).

#### Radiological Measurement

In the radiological evaluation, no osteolysis was found, but radiolucent lines of less than 1 mm were found in 10 (23.2%) patients in the cementless group and in 14 (29.7%) patients in the hybrid cemented group. Radiolucent lines between 1 and 2 mm were found in 2 (4.6%) patients in the cementless group and in 12 (25.5%) patients in the hybrid cemented group (Figures 1A, B). The authors calculated anteroposterior tibial scores higher than 4 in 6 cases and higher than 9 in 2 cases in the cemented group, but none in the cementless group ($P<.001$). In the current study, the authors noted a significant difference in mean anteroposterior tibial scores for the hybrid cemented and cementless groups of 1.83 and 0.43, respectively, ($P<.001$) and in mean lateral tibial scores for the hybrid cemented and cementless groups of 0.35 and 0.07, respectively ($P=.010$) (Table 3).

#### Revisions

Revision surgery was required in 10 (8.3%) patients, with 6 (10%) revisions in the cementless group and 4 revisions (6.7%) in the hybrid cemented group ($P=.509$) (Table 4). In 2 patients with a cementless tibial implant (3.3%), aseptic loosening was the reason for revision. One patient with a BMI of 35 kg/m$^2$ underwent revision 18 months postoperatively, and the other patient underwent revision 3 months after the primary operation but had continuous pain postoperatively. A nickel allergy, which was confirmed by a transcutaneous test in

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**Table 2**

<table>
<thead>
<tr>
<th>KSS Outcome (Range)</th>
<th>Cementless Group</th>
<th>Hybrid Cemented Group</th>
<th>$P^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean clinical</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preoperative</td>
<td>54.1 (10-95)</td>
<td>45.4 (0-100)</td>
<td>.11</td>
</tr>
<tr>
<td>Postoperative</td>
<td>93.0 (55-100)</td>
<td>89.2 (45-100)</td>
<td>.109</td>
</tr>
<tr>
<td>Mean function</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preoperative</td>
<td>42.4 (0-69)</td>
<td>46.1 (10-77)</td>
<td>.180</td>
</tr>
<tr>
<td>Postoperative</td>
<td>91.7 (64-100)</td>
<td>90.5 (63-100)</td>
<td>.492</td>
</tr>
<tr>
<td>Mean total</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preoperative</td>
<td>93.3 (0-153)</td>
<td>91.5 (44-142)</td>
<td>.730</td>
</tr>
<tr>
<td>Postoperative</td>
<td>184.7 (144-200)</td>
<td>179.7 (113-200)</td>
<td>.146</td>
</tr>
<tr>
<td>Improvement</td>
<td>91.9 (6-200)</td>
<td>88.2 (18-155)</td>
<td>.538</td>
</tr>
</tbody>
</table>

$^a$Abbreviation: KSS, Knee Society Score.

$^b$Two-tailed independent $t$ test.

**Table 3**

<table>
<thead>
<tr>
<th>Tibia Radiolucent Lines</th>
<th>Total Score Mean (Range)</th>
<th>$P^b$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anteroposterior</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hybrid cemented</td>
<td>1.83 (0-10)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Cementless</td>
<td>0.43 (0-4)</td>
<td></td>
</tr>
<tr>
<td>Lateral</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hybrid cemented</td>
<td>0.35 (0-3)</td>
<td>.010</td>
</tr>
<tr>
<td>Cementless</td>
<td>0.07 (0-1)</td>
<td></td>
</tr>
</tbody>
</table>


$^b$Two-tailed independent $t$ test.
a qualified laboratory, was the cause of repeated tibial implant loosening. Thus, the implant failure was not attributed to the fixation method. In the other patients, revision with polyethylene-exchange or adhesiolysis was performed to improve range of motion or to treat instability.

In the hybrid cemented group, 2 (3.3%) revisions were required due to tibial part loosening, which was changed in both patients. The first patient with a BMI of 36 kg/m² underwent revision at 29 months postoperatively and the second at 15 months postoperatively. The other 2 patients were revised with a polyethylene liner due to limited range of motion in 1 patient and infection in the other.

Survival data are shown in Figures 2 and 3. Kaplan-Meier survivorship analysis with revision for any reason as the endpoint shows an 88.5% (95% CI, 76.3-94.6) survival rate for cementless TKAs and 93.1% (95% CI, 82.7-97.3) survival rate for hybrid cemented TKAs 8.3 years postoperatively.

All revisions were performed within 2.5 years after implantation (Figure 2). The survivorship analysis with revision for aseptic loosening as endpoint shows a 96.2% (95% CI, 85.8-99.1) survival rate for cementless and 96.5% (95% CI, 86.5-99.1) survival rate for hybrid cemented TKAs (Figure 3).

**DISCUSSION**

The purpose of this case-control study was to evaluate the clinical and radiographic outcome and survivorship with regard to the different tibial fixations in TKA. Debate exists regarding the benefits of cementless and hybrid cemented fixation in joint arthroplasty. It has not been clearly shown whether a cementless or a cemented knee implant results in better clinical outcomes. Nearly as many studies show the superiority of cemented over cementless implants\(^8\),\(^10\),\(^28\),\(^29\) and those that show the opposite\(^17\),\(^30\)-\(^33\) and other studies show results irrespective of the fixation method.\(^5\),\(^34\),\(^35\)

Methylmethacrylate monomer used for cemented implants may be toxic and can damage bone during polymerization.\(^36\)

Signs of osteolytic activity at the cement-bone interface were found in well-fixed cemented implants.\(^36\) In the early generation of cementless designs, failures, such as screw track osteolysis, metal back patellar component failures, and problems with the polyethylene, were determined. Due to recent improvements in biomaterials, particularly highly porous metals and highly crosslinked polyethylene, as well as timesaving advantages and long-term osseointegration renewed interest in cementless fixation occurred.\(^12\)

Encouraging results were also reported after TKAs with hydroxyapatite-coated tibial components were believed to increase bone ingrowth and enhance early fixation.\(^23\),\(^24\),\(^37\)

In the current study, a cementless implant with a titanium plasma-sprayed layer and a thin bioactive dicalcium phosphate dihydrate surface layer (µ-CaP) to enhance bone ingrowth was used. The layer supports the continuous release of calcium and phosphate ions and encourages the formation of new bone structures at the bone-implant interface. Due to the continuous dissolving of the calcium phosphate, the pores of the Plasmapore coating are continuously open for bony ingrowth. The osteoconductive characteristics and the in vivo behavior of dicalcium phosphate dihydrate have been investigated in animal experiments.\(^38\) In contrast, the poorly soluble hydroxyapatite releases only calcium ions from nonhydroxyapatite calcium compounds resulting from the manufacturing process, but almost no phosphate ions.\(^39\),\(^40\)

The reabsorbable tricalcium phosphate stimulates giant cell reactions, which is not optimal for use in orthopedic implants. In orthopedic implants, the transition between primary and secondary implant stability is a continuous process of bone remodeling, characterized by apposition and resorption at the implant surface.\(^41\)-\(^43\)

In the current study, the implant design is exactly the same in all cases except the material character of the surface of the uncemented tibial tray as mentioned above to make the groups comparable.

The current study showed no significant difference between cementless and hybrid cemented TKAs over the 5-year follow-up in terms of clinical and functional results and postoperative complications. The revision rate due to tibial component loosening was identical in both groups (3.3%) but was lower in the cementless group (1.7%) when the revision case associated with allergic reaction to nickel was excluded. Cementless femoral fixation seemed effective because no femoral component loosening occurred in either group. This was supported by Bercovy et al.\(^37\) who prospectively reported a hydroxyapatite-coated femoral component survival rate of 100% at 9 years with no interface radiolucencies. Moore et al.\(^44\) reported radiographic signs of osseointegration in porous-coated acetabular com-

**Table 4**

<table>
<thead>
<tr>
<th>Fixation Method</th>
<th>Follow-up (n)</th>
<th>Reason for Revision</th>
<th>No. (%) of Revisions</th>
<th>(P^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cementless</td>
<td>60</td>
<td>In total</td>
<td>6 (10)</td>
<td>.509</td>
</tr>
<tr>
<td>Cemented</td>
<td>60</td>
<td>Tibial loosening</td>
<td>4 (6.7)</td>
<td></td>
</tr>
<tr>
<td>Cementless</td>
<td>60</td>
<td>Tibial loosening</td>
<td>2 (3.3)</td>
<td>1.000</td>
</tr>
<tr>
<td>Cemented</td>
<td>60</td>
<td>Tibial loosening</td>
<td>2 (3.3)</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)Chi-squared test.
ponents. They reported that the absence of radiolucent lines, presence of superolateral buttresses, and medial stress-shielding were the most sensitive signs for indicating bone ingrowth. Similarly, Aebli et al reported that radiolucent lines might occur due to imperfect cuts of the tibial plateau or due to micromotions leading to the formation of gaps, which may prevent osteointegration in cementless TKAs, inducing the formation of fibrous tissue or regions of osteoporosis. Similarly, Toksvig-Larsen and Ryd reported a 1- to 2-mm gap between the lower- and the uppermost points of the tibial plateau after cutting, which might result in tibial stress shielding. This could be a reason for moderate knee pain. Sadoghi et al reported a significant correlation between continual moderate knee pain and the appearance of tibial radiolucent lines. In the current study, no significant correlation existed between the clinical and functional knee scores, including pain and the presence of radiolucent lines.

In the current radiological evaluation, significantly more radiolucent lines existed in the hybrid cemented group than in the cementless group ($P = .009$). The anteroposterior tibial scores revealed significantly more patients in the hybrid cemented group, which should be followed for progression, at 5-year follow-up. These observations were supported by Bercovy et al and Regner et al from their randomized Radiostereometric Analysis (RSA) study, which indicated superior stability of the hydroxyapatite-coated TKA after a minimum 50-year follow-up. It is unknown whether these radiological signs at 5-year follow-up predict late prosthetic loosening and tibial component failure in the hybrid cemented group in the long term. Bistolfi et al reported a significant correlation between progressive radiolucent lines and failure for a cemented fixed-bearing TKA after an average 13.5-year follow-up.

The findings of the current study are limited by its nature as a nonrandomized, observational case-control study with pre- and postoperative comparisons of cementless and hybrid cemented TKA in a single center, leaving the type of fixation to the surgeon’s preference. Furthermore, because the current study only provided mid-term results, long-term evaluation is required to demonstrate clear benefits in longevity of uncemented fixation.

**Conclusion**

This study illustrates the importance of ideal implant fixation in TKA without clinical or radiological signs of loosening at a minimum 5-year follow-up. No significant differences existed between cementless Plasmapore titanium-coated and hybrid cemented TKA implants in terms of clinical and functional results and postoperative complications. Nevertheless, the significantly smaller number of radiolucent lines in the cementless group in the mid-term results is an indicator of primary stability with benefits for the fixation durability of TKA in the long term.

**References**

4. Schai PA, Thornhill TS, Scott RD. Total knee arthroplasty with the PFC system. Results


