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SYMPOSIUM: PAPERS PRESENTED AT THE ANNUAL MEETINGS OF THE KNEE SOCIETY

# All-Polyethylene Tibial Components in Obese Patients Are Associated With Low Failure at Midterm Followup

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**Abstract**
*Background* In the United States, the obese population has increased markedly over the last four decades, and this trend continues. High patient weight places additional stress on TKA components, which may lead to increased polyethylene wear, osteolysis, radiolucencies, and clinical failure. Metal-backed tibial components and all-polyethylene tibial components in the general population have comparable osteolysis and failure, but it is unclear whether these components yield similar osteolysis and failure in obese patients.
*Questions/purposes* We therefore determined the (1) function, (2) occurrence of osteolysis, and (3) complications in a cohort of obese patients receiving all-polyethylene tibial components.
*Patients and Methods* Between September 17, 1996, and December 19, 2002, we implanted all-polyethylene tibial components in 90 obese patients (125 knees); 24 patients (33 knees) died and 13 patients (17 knees) were lost to followup, leaving 53 patients (59%) with 75 knees. All surgeries were cruciate-retaining, tricompartmental TKAs. We evaluated patients with Knee Society Scores and serial radiographs. Minimum followup was 7 years (mean, 10.4 years; range, 7–14 years).
*Results* At latest followup, mean Knee Society Score was 92 points. There were five tibial radiolucencies, all less than 1 mm and characterized as nonprogressive. We observed minimal, nonprogressive osteolysis in one knee. One patient required reoperation after a traumatic event. There were no implant-related failures and no implants at risk of failure.
*Conclusions* At an average 10-year followup, all-polyethylene tibial components were functioning well in this obese group. These findings confirm the effectiveness of all-polyethylene tibial components in obese patients.
*Level of Evidence* Prognostic—Level IV—Case Series, uncontrolled. See Guidelines for Authors for a complete description of levels of evidence.

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Each author certifies that his or her institution approved or waived approval for the reporting of these cases and that all investigations were conducted in conformity with ethical principles of research.
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## Introduction

Obesity continues to be a leading healthcare problem in the United States [17, 34]. The prevalence of adult obesity continues to be high, exceeding 30%, with 32% of adult men and 35% of adult women considered obese [17].

Obesity is a known risk factor for the development and progression of knee osteoarthritis [6, 8–10, 29, 32, 42, 45]. The incidence of knee osteoarthritis continues to rise, perhaps because of the greater proportion of the aging US population combined with the high obesity rates [42].

TKA improves a patient's health-related quality of life [13]. Although a recent study using contemporary TKA implants found overall patient satisfaction was lower than that in earlier reports, overall patient satisfaction was still 81% [7]. The predictors of patient dissatisfaction were expectations not being met, a low 1-year WOMAC, preoperative pain at rest, and postoperative complications. There was no difference between satisfied patients and dissatisfied/neutral patients in terms of body mass index (BMI) [7].

Studies focusing on the obese patient population show most patients show improvements in outcome scores and are satisfied with TKA [1, 2, 12, 18, 19, 24, 26, 30, 33, 37, 43, 44, 48, 49]. However, high body weight amplifies the magnitude of joint load per step and may adversely affect polyethylene wear performance and the rate of aseptic loosening. Increased stress at the bone-prosthesis interface may decrease survivorship of the TKA. On the other hand, these loading force effects may be countered by an obese patient's sedentary lifestyle that decreases the loading cycles per year [46].

Although metal-backed tibial (MBT) components and modern all-polyethylene tibial (APT) components have comparable success [5], little research is available regarding use of the latter in obese patients. Several studies of cemented TKA in obese patients report increased radiolucent lines around the components [2, 12, 24] or increased osteolysis in obese patients [43], whereas others show no radiographic differences between obese and nonobese patients [18, 30, 48]. However, those studies [12, 24] used MBT, not APT, components. Previous reports of APT components have focused mainly on clinical and radiographic evaluation in elderly [11, 22, 27, 35, 36] or sedentary patients [11]. Whether APT components are associated with similar osteolysis and loosening in obese patients is unclear.

We therefore determined the (1) function, (2) occurrence of osteolysis, and (3) complications in a cohort of obese patients receiving APT components.

## Patients and Methods

Between September 17, 1996, and December 19, 2002, we implanted a cemented APT component (PFC/Sigma® TKA; DePuy Orthopaedics Inc, Warsaw, IN) in 273 patients (378 knees). We made the decision to use an APT component intraoperatively based on the patient's age and activity demands. We considered any patient older than 70 years or any patient who had a low functional demand regardless of age for an APT component; patient weight or BMI did not affect this decision. During that same time, we treated a total of 1435 knees with TKA using any type of component. Of the 273 patients who had an APT component, 90 (125 knees) were characterized as obese (BMI of more than 30 kg/m$^2$ as calculated by the standard formula: patient's weight in kilograms divided by the square of his or her height in meters [15]). Of those 90 patients (125 knees), 24 (33 knees) died and 13 (17 knees) were lost to followup before the minimum 7-year followup period. Therefore, the final study group consisted of 53 patients (75 knees). Forty were women (59 knees) and 13 were men (16 knees) with an average age of 72 years (range, 61–83 years) and an average BMI of 34 kg/m$^2$ (range, 30–48 kg/m$^2$). The underlying diagnoses were osteoarthritis (52 patients, 74 knees) and avascular necrosis (one patient, one knee). The minimum followup was 7 years (mean, 10.4 years; range, 7.8–14 years). No patients were recalled specifically for this study; all data were obtained from medical records and radiographs.

All surgeries were performed by the senior author (DFD). All patients received prophylactic antibiotics administered within 1 hour of surgical start time. The senior author used a midline incision along with a medial trivector approach [16], made bone cuts using the appropriate cutting jigs, and performed soft tissue balancing in a standard fashion. All knees were cemented tricompartmental knees. The APT design had a cruciform stem, and all procedures were cruciate retaining. The polyethylene thickness varied: 8 mm (37 knees), 10 mm (34 knees), and 12.5 mm (four knees). The tibial component was implanted, and extruded cement was removed. The femoral component was then cemented, and the patella was resurfaced with an all-polyethylene component (Fig. 1).

The postoperative rehabilitation protocol was identical for all patients. Patients were encouraged to be out of bed and to ambulate with assistance with weightbearing as tolerated starting the day of surgery. Postoperative physical therapy and occupational therapy included five 30-minute sessions beginning on Postoperative Day 1. Physical and occupational therapy in the hospital was supervised. All patients started with a walker and progressed to a cane as tolerated. ROM was active and active assisted. Continuous passive motion machines (optional) were available for all patients. No knee immobilizers or braces were used. Patients were discharged to home or an inpatient rehabilitation facility on Postoperative Day 3 and continued to have in-home, inpatient, or outpatient physical therapy.

We evaluated patients clinically and radiographically preoperatively and postoperatively at 6 weeks, 12 weeks, 1 year, and every other year thereafter. In the clinical evaluation, we used the Knee Society Score (KSS) [25] to

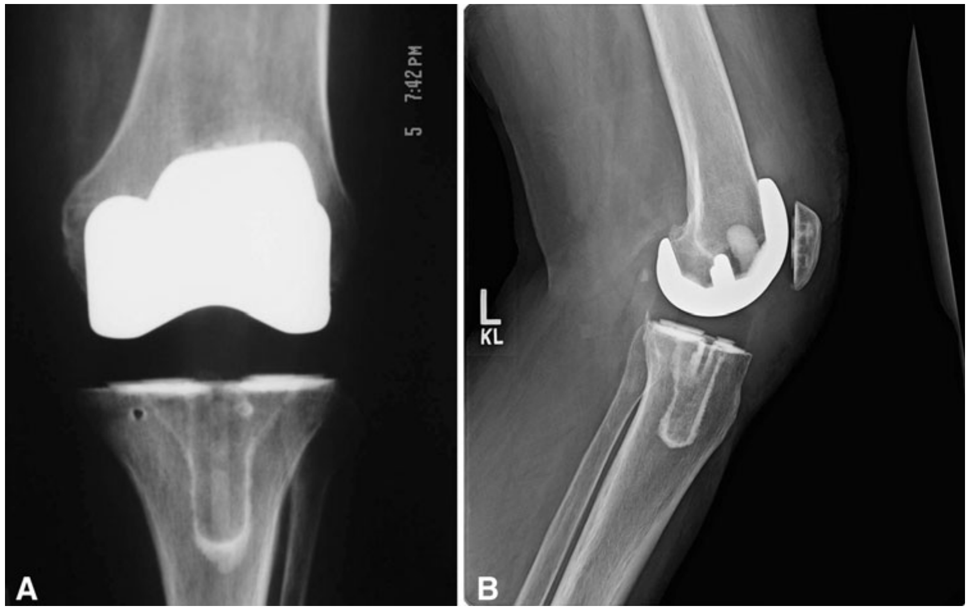


**Fig. 1A–B** (**A**) AP and (**B**) lateral radiographs show the APT component for TKA used in our obese patients.

evaluate pain and function and to generate an overall score. We obtained weightbearing AP, lateral, and Merchant views in all patients.

While the Knee Society Total Knee Arthroplasty Radiographic Evaluation and Scoring System is reportedly associated with low interobserver variability [4], two of us (DFD, TCK) independently evaluated all radiographs for radiolucent lines and osteolysis. We did not measure interobserver variability of the measurements. We recorded any progressive radiolucent line defined as expanding to neighboring zones or increasing in width from previous radiographs or both. Radiolucencies, if identified, were recorded according to the specific component sites. We used criteria of the Knee Society knee radiographic score [14] to assess lucencies and osteolysis.

Of 53 patients (75 knees), complete postoperative clinical KSSs were available for 46 patients (63 knees) and complete postoperative radiographic studies were available for 38 patients (51 knees) with a minimum 7-year followup. The remaining patients who were not considered lost to followup after 7 years but who were missing clinical or radiographic evaluations were still being followed in the same orthopaedic practice and were noted by others in the practice to have well-functioning TKAs without any problems. For the data analysis, we included patients who had complete clinical KSS and complete radiographic evaluation with a minimum 7-year followup.

## Results

The mean KSS was 51.6 points (range, 8–99 points) preoperatively and 92.4 points (range, 45–100 points) at the latest followup (Table 1). Preoperative ROM was similar to postoperative ROM. The mean knee extension was 3.3° (range, 0°–19°) preoperatively and 0.7° (range, 0°–10°) at final followup. The mean knee flexion was similar preoperatively and at last followup: 119.4° (range, 82°–140°) versus 118.2° (range, 75°–135°), respectively.

**Table 1.** Mean preoperative and postoperative KSS and ROM

| Parameter | Preoperative value | Postoperative value | p Value |
|---|---|---|---|
| KSS (points) | | | |
| Pain | 17.9 (0–50) | 46.8 (10–50) | < 0.001 |
| Function | 51.7 (20–100) | 76.7 (0–100) | < 0.001 |
| Total | 51.6 (8–99) | 92.4 (45–100) | < 0.001 |
| Extension (°) | 3.3 (0–19) | 0.7 (0–10) | < 0.001 |
| Flexion (°) | 119.4 (82–140) | 118.2 (75–135) | 0.323 |

Values are expressed as mean, with range in parentheses; KSS = Knee Society Score.

We identified five tibial radiolucencies in four patients, all of which were less than 1 mm and nonprogressive; one femoral radiolucency in each of two patients; and one case of minimal, nonprogressive tibial osteolysis. There were no femoral or patellar zones of osteolysis. No knee was radiographically positioned more than ± 3° relative to the mechanical axis, no femoral component was placed in more than 2° of femoral flexion, and no tibial component was placed in more than 6° of posterior slope. None of our patients had patellar subluxation or dislocation.

One patient required a reoperation after a traumatic event. This patient complained of instability after a fall that resulted in injury to the medial collateral ligament 21 months after the index surgery. The knee was converted

**Table 2.** Summary of published data regarding APT components

| Study | Study type | Number of TKAs | APT group | | | |
|---|---|---|---|---|---|---|
| | | | >BMI or weight* | Followup* | Clinical outcome* | Radiographic outcome |
| Apel et al. [3] (1991) | Retrospective | 131 TKAs; 62 APT versus 69 MBT | Weight: 101–274 (pounds)† | 90.4 months (48–137) | KSS: 86.4 (66–97) | No progressive radiolucencies after first postoperative year |
| L'Insalata et al. [27] (1992) | Retrospective | 98 TKAs; 38 APT versus 60 MBT; all patients, > 80 years old at surgery | NA | 5.4 years (2–12) | 53% excellent, 39% good, 8% poor results | NA |
| Rand [39] (1993) | Retrospective | 78 TKAs; 22 APT versus 56 MBT | Weight: 73 ± 13 kg | 10 years (8–11) | KSS pain: 72 ± 14 KSS function: 75 ± 26 | Radiolucencies present in 59% of APTs, all < 2 mm wide; no progressive radiolucent lines |
| Pomeroy et al. [36] (2000) | Retrospective | 298 TKAs; less active group (> 70 years old) | NA | 35.3 months (24–84) | KSS: 78.9 | Radiographic review revealed optimum fixation with no osteolysis |
| Gioe and Bowman [20] (2000) | Prospective randomized | 213 TKAs; 111 APT versus 102 MBT | All patients: weight: 96 ± 14 kg | 49 months (36–71) | KSS: 84.3 ± 14.2 | Nonprogressive radiolucencies only, all < 2 mm wide; 4% on AP view, 2% on lateral view |
| Udomkiat et al. [47] (2001) | Retrospective | 96 TKAs; 48 APT versus 48 MBT | Weight: 177.5 pounds (130–245) | 38.4 months (24.6–69.1) | KSS: 94 ± 6.9 | Radiolucencies in 4 APT knees; all nonprogressive |
| Rodriguez et al. [40] (2001) | Retrospective | 243 TKAs; 130 APT versus 113 MBT | All patients: weight: 79 kg (52–121) | 5.5 years (5–7) | KSS: 95.1 ± 4 | Radiolucent lines in 16% of APTs; most measured < 1.5 mm wide and were without evidence of progression |
| Najibi et al. [31] (2003) | Retrospective | 98 TKAs; 49 APT versus 49 MBT | BMI: 28.5 (22.2–43.4) | APT: 6.02 years (4–8) | KSS: 89 (40–100) | NA |
| Ma et al. [28] (2005) | Retrospective | 64 TKAs; 28 APTs versus 36 MBTs | All patients: weight: 58 kg (45–78) | All patients: 19 years (17–22) | All patients: HSS: 86 | Radiolucent lines in 10 of 28 APTs; all lines < 4 mm wide |
| Ranawat et al. [38] (2005) | Retrospective | 54 TKAs; APT in active patients < 60 years old | BMI: 29.2 (20.2–48.7) | 5 years (2–11) | Most knees (95%) functioning well with a combined KSS > 170 (162–200) | No radiographic evidence of component loosening, progressive radiolucent lines, or osteolysis; 6 knees with nonprogressive radiolucent lines in Zone 1 on AP view, 1 with a nonprogressive radiolucent line in Zone 1 on lateral view |

**Table 2.** continued

| Study | Study type | Number of TKAs | APT group | | | |
|---|---|---|---|---|---|---|
| | | | >BMI or weight* | Followup* | Clinical outcome* | Radiographic outcome |
| Gioe et al. [23] (2007) | Followup of previous study: prospective, randomized | Remaining 167 TKAs; 97 APT versus 70 MBT | All patients: weight: 96 ± 14 kg; BMI: 36 | 115 months (8–12 years) | Clinical KSS: 92 (83.6 ± 17.3), KSS function: 55 (57.7 ± 28.5) | No circumferential radioluciencies; 2 knees asymptomatic osteolytic defects |
| Shen et al. [41] (2009) | Retrospective | 68 TKAs; 34 APT versus 34 MBT in Chinese patients | Weight: 64.00 ± 5.36 kg | 5.9 years (5–7) | HSS: 85.48 ± 1.88 | 4 tibial components with radiolucent lines, mean width < 2 mm; none symptomatic |
| Dalury et al. [11] (2009) | Retrospective | 120 APT used for patients > 70 years old with a low activity level | NA | 7–10 | KSS: 93.7 ± 8.1; KS function: 68.9 ± 27.6; KS pain: 47 ± 6.7 | No radiographic osteolysis; KS radiographic rating system: 32 knees < 4 points (nonprogressive radioluciencies), 4 knees 5–9 points (radiolucencies requiring observation); no knee with > 10 points (impending failure) |
| Gioe et al. [21] (2009) | Prospective, randomized | 312 TKAs; 136 APT versus 176 RP | APT: BMI: 31.51 ± 6.7 | Minimum 24 months; 42 ± 14.2 months | KSS pain: 44.9 ± 0.8; KSS clinical: 90.4 ± 1.1; KSS function: 55.0 ± 2.4 | No progressive radiolucent lines or osteolysis |
| Dalury et al. (current study) | Retrospective | 53 APT in obese patients | BMI: 34 (30–48) | 10.4 years (7–14) | KSS: 92.4 | 5 tibial radiolucencies, all < 1 mm, nonprogressive; 1 with minimal nonprogressive osteolysis |

* Values are expressed as mean, mean ± SD, and/or range; †no units were listed, but the assumption is pounds; APT = all-polyethylene tibial; BMI = body mass index; MBT = metal-backed tibial; RP = rotating platform; NA = not available; KSS = Knee Society Score; HSS = Hospital for Special Surgery.

to a stabilized implant. There were no implant-related failures or any implants at risk of failure at latest followup.

## Discussion

In the practice of any orthopaedic surgeon, obese individuals comprise a substantial proportion of patients with osteoarthritis. For most obese patients, as for any patient, TKA results in improved pain and function scores with high satisfaction rates [2, 12, 26, 30, 33, 37, 49]. MBT components and modern APT components both have been shown to be successful in the general population; however, the use of APT components specifically in obese patients has not been well studied. We therefore determined the (1) function, (2) occurrence of osteolysis, and (3) complications in a cohort of obese patients receiving APT components.

There are several limitations to our study. First, we had no control group: we did not compare the use of APT and MBT components in the same obese population. A randomized controlled trial would better study this concept. Second, 41% of the patients died or were lost to followup before the 7-year minimum followup. That large a number lost may have affected the findings. At last followup between 6 months and 9 years, none of those patients had any complications or required revision. Third, our indications to use an APT component based on patient age and activity introduce bias to the study: our older patients (average age, 72 years) may have been inherently less active, and the correspondingly fewer cycles on the polyethylene may have produced less wear than might have occurred in a younger, more active obese population. Fourth, our study represents a midterm, not long-term, analysis, and additional followup is necessary. However, despite these limitations, our data may serve as a basis for consideration of choosing an APT component for TKAs in obese patients.

Multiple publications [3, 11, 20–23, 27, 28, 31, 36, 39–41, 47] also document clinical and radiographic success with the use of an APT component (Table 2). Three similar retrospective studies report clinical success with the use of an APT component. Ranawat et al. [38] reported on 54 TKAs using APT components. All patients were 60 years old or younger with an average BMI of 29.2 kg/m$^2$ (range, 20.2–48.7 kg/m$^2$). All knees received posterior-stabilized implants. At an average followup of 5 years (range, 2–11 years), their KSSs improved to 95 points (range, 72–100 points) with only one tibial component loosening secondary to trauma. We found similar KSSs (mean, 92 points), but our population differs from that of Ranawat et al. [38] because (1) our patients were older (mean age, 72 years; range, 61–83 years), (2) all of our patients were considered obese (only some in the other study were obese), and (3) we used a cruciate-retaining prosthesis. Dalury et al. [11] also previously reported midterm clinical findings of APT components in 88 patients (120 TKAs) older than 70 years or who had comorbidities suggestive of a low activity level. Unfortunately, patient BMI was not captured in that study. The average postoperative KSS in that study was 93.7 points. In 2007, Gioe et al. [22] reported on 443 APT components (378 patients) implanted by 12 surgeons in a community registry. The mean age was 77 years (range, 58–94 years), but BMI was also unfortunately not captured in this study for comparison. Although the authors noted APT components performed extremely well, they did not report KSS.

Ranawat et al. [38] reported no radiographic evidence of component loosening, progressive radiolucent lines, osteolysis, or malalignment. Dalury et al. [11] noted 32 of 120 knees with nonprogressive radiolucencies, four knees with progressive radiolucent lines requiring observation, and no knee with impending failure. That study did not reveal osteolysis in any knee. The study by Gioe et al. [22] did not specifically address radiolucencies or osteolysis but noted one knee required revision for aseptic loosening. We found no progressive radiolucent lines, one implant with minimal osteolysis, and no implant-related failures.

The obese population in the United States has increased markedly over the past several decades. At an average 10-year followup, obese patients had satisfactory clinical and radiographic findings with the use of an APT component. These findings support the continued use of an APT component even in the obese population.

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## References

1. Amin AK, Clayton RA, Patton JT, Gaston M, Cook RE, Brenkel IJ. Total knee replacement in morbidly obese patients: results of a prospective, matched study. *J Bone Joint Surg Br*. 2006;88:1321–1326.
2. Amin AK, Patton JT, Cook RE, Brenkel IJ. Does obesity influence the clinical outcome at five years following total knee replacement for osteoarthritis? *J Bone Joint Surg Br*. 2006;88:335–340.
3. Apel DM, Tozzi JM, Dorr LD. Clinical comparison of all-polyethylene and metal-backed tibial components in total knee arthroplasty. *Clin Orthop Relat Res*. 1991;273:243–252.
4. Bach CM, Steingruber IE, Peer S, Nogler M, Wimmer C, Ogon M. Radiographic assessment in total knee arthroplasty. *Clin Orthop Relat Res*. 2001;385:144–150.
5. Bettinson KA, Pinder IM, Moran CG, Weir DJ, Lingard EA. All-polyethylene compared with metal-backed tibial components in total knee arthroplasty at ten years: a prospective, randomized controlled trial. *J Bone Joint Surg Am*. 2009;91:1587–1594.
6. Blagojevic M, Jinks C, Jeffery A, Jordan KP. Risk factors for onset of osteoarthritis of the knee in older adults: a systematic

review and meta-analysis. *Osteoarthritis Cartilage*. 2010;18: 24–33.
7. Bourne RB, Chesworth BM, Davis AM, Mahomed NN, Charron KD. Patient satisfaction after total knee arthroplasty: who is satisfied and who is not? *Clin Orthop Relat Res*. 2010;468:57–63.
8. Brennan SL, Cicuttini FM, Pasco JA, Henry MJ, Wang Y, Kotowicz MA, Nicholson GC, Wluka AE. Does an increase in body mass index over 10 years affect knee structure in a population-based cohort study of adult women? *Arthritis Res Ther*. 2010;12:R139.
9. Buchholz AL, Niesen MC, Gausden EB, Sterken DG, Hetzel SJ, Baum SZ, Squire MW, Kaplan LD. Metabolic activity of osteoarthritic knees correlates with BMI. *Knee*. 2010;17:161–166.
10. Coggon D, Reading I, Croft P, McLaren M, Barrett D, Cooper C. Knee osteoarthritis and obesity. *Int J Obes Relat Metab Disord*. 2001;25:622–627.
11. Dalury DF, Pomeroy DL, Gonzales RA, Gruen TA, Adams MJ, Empson JA. Midterm results of all-polyethylene tibial components in primary total knee arthroplasty. *J Arthroplasty*. 2009; 24:620–624.
12. Dewan A, Bertolusso R, Karastinos A, Conditt M, Noble PC, Parsley BS. Implant durability and knee function after total knee arthroplasty in the morbidly obese patient. *J Arthroplasty*. 2009;24(6 Suppl):89–94, 94.e1–3.
13. Ethgen O, Bruyere O, Richy F, Dardennes C, Reginster JY. Health-related quality of life in total hip and total knee arthroplasty: a qualitative and systematic review of the literature. *J Bone Joint Surg Am*. 2004;86:963–974.
14. Ewald FC. The Knee Society total knee arthroplasty roentgenographic evaluation and scoring system. *Clin Orthop Relat Res*. 1989;248:9–12.
15. Expert Panel on the Identification, Evaluation, and Treatment of Overweight in Adults. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: executive summary. *Am J Clin Nutr*. 1998;68:899–917.
16. Fisher DA, Trimble SM, Breedlove K. The medial trivector approach in total knee arthroplasty. *Orthopedics*. 1998;21:53–56.
17. Flegal KM, Carroll MD, Ogden CL, Curtin LR. Prevalence and trends in obesity among US adults, 1999–2008. *JAMA*. 2010; 303:235–241.
18. Foran JR, Mont MA, Etienne G, Jones LC, Hungerford DS. The outcome of total knee arthroplasty in obese patients. *J Bone Joint Surg Am*. 2004;86:1609–1615.
19. Foran JR, Mont MA, Rajadhyaksha AD, Jones LC, Etienne G, Hungerford DS. Total knee arthroplasty in obese patients: a comparison with a matched control group. *J Arthroplasty*. 2004;19:817–824.
20. Gioe TJ, Bowman KR. A randomized comparison of all-polyethylene and metal-backed tibial components. *Clin Orthop Relat Res*. 2000;380:108–115.
21. Gioe TJ, Glynn J, Sembrano J, Suthers K, Santos ER, Singh J. Mobile and fixed-bearing (all-polyethylene tibial component) total knee arthroplasty designs: a prospective randomized trial. *J Bone Joint Surg Am*. 2009;91:2104–2112.
22. Gioe TJ, Sinner P, Mehle S, Ma W, Killeen KK. Excellent survival of all-polyethylene tibial components in a community joint registry. *Clin Orthop Relat Res*. 2007;464:88–92.
23. Gioe TJ, Stroemer ES, Santos ER. All-polyethylene and metal-backed tibias have similar outcomes at 10 years: a randomized level I evidence study. *Clin Orthop Relat Res*. 2007;455:212–218.
24. Griffin FM, Scuderi GR, Insall JN, Colizza W. Total knee arthroplasty in patients who were obese with 10 years followup. *Clin Orthop Relat Res*. 1998;356:28–33.
25. Insall JN, Dorr LD, Scott RD, Scott WN. Rationale of the Knee Society clinical rating system. *Clin Orthop Relat Res*. 1989; 248:13–14.
26. Jackson MP, Sexton SA, Walter WL, Walter WK, Zicat BA. The impact of obesity on the mid-term outcome of cementless total knee replacement. *J Bone Joint Surg Br*. 2009;91:1044–1048.
27. L'Insalata JL, Stern SH, Insall JN. Total knee arthroplasty in elderly patients: comparison of tibial component designs. *J Arthroplasty*. 1992;7:261–266.
28. Ma HM, Lu YC, Ho FY, Huang CH. Long-term results of total condylar knee arthroplasty. *J Arthroplasty*. 2005;20:580–584.
29. Messier SP. Diet and exercise for obese adults with knee osteoarthritis. *Clin Geriatr Med*. 2010;26:461–477.
30. Mont MA, Mathur SK, Krackow KA, Loewy JW, Hungerford DS. Cementless total knee arthroplasty in obese patients: a comparison with a matched control group. *J Arthroplasty*. 1996;11:153–156.
31. Najibi S, Iorio R, Surdam JW, Whang W, Appleby D, Healy WL. All-polyethylene and metal-backed tibial components in total knee arthroplasty: a matched pair analysis of functional outcome. *J Arthroplasty*. 2003;18:9–15.
32. Niu J, Zhang YQ, Torner J, Nevitt M, Lewis CE, Aliabadi P, Sack B, Clancy M, Sharma L, Felson DT. Is obesity a risk factor for progressive radiographic knee osteoarthritis? *Arthritis Rheum*. 2009;61:329–335.
33. Nunez M, Lozano L, Nunez E, Sastre S, Luis Del Val J, Suso S. Good quality of life in severely obese total knee replacement patients: a case-control study. *Obes Surg*. 2010 June 6 [Epub ahead of print].
34. Ogden CL, Carroll MD, Curtin LR, McDowell MA, Tabak CJ, Flegal KM. Prevalence of overweight and obesity in the United States, 1999–2004. *JAMA*. 2006;295:1549–1555.
35. Pagnano MW, Levy BA, Berry DJ. Cemented all polyethylene tibial components in patients age 75 years and older. *Clin Orthop Relat Res*. 1999;367:73–80.
36. Pomeroy DL, Schaper LA, Badenhausen WE, Suthers KE, Smith MW, Empson JA, Curry JI. Results of all-polyethylene tibial components as a cost-saving technique. *Clin Orthop Relat Res*. 2000;380:140–143.
37. Rajgopal V, Bourne RB, Chesworth BM, MacDonald SJ, McCalden RW, Rorabeck CH. The impact of morbid obesity on patient outcomes after total knee arthroplasty. *J Arthroplasty*. 2008;23:795–800.
38. Ranawat AS, Mohanty SS, Goldsmith SE, Rasquinha VJ, Rodriguez JA, Ranawat CS. Experience with an all-polyethylene total knee arthroplasty in younger, active patients with follow-up from 2 to 11 years. *J Arthroplasty*. 2005;20:7–11.
39. Rand JA. Comparison of metal-backed and all-polyethylene tibial components in cruciate condylar total knee arthroplasty. *J Arthroplasty*. 1993;8:307–313.
40. Rodriguez JA, Baez N, Rasquinha V, Ranawat CS. Metal-backed and all-polyethylene tibial components in total knee replacement. *Clin Orthop Relat Res*. 2001;392:174–183.
41. Shen B, Yang J, Zhou Z, Kang P, Wang L, Pei F. Survivorship comparison of all-polyethylene and metal-backed tibial components in cruciate-substituting total knee arthroplasty—Chinese experience. *Int Orthop*. 2009;33:1243–1247.
42. Sowers MR, Karvonen-Gutierrez CA. The evolving role of obesity in knee osteoarthritis. *Curr Opin Rheumatol*. 2010;22:533–537.
43. Spicer DDM, Pomeroy DL, Badenhausen WE Jr, Schaper LA, Curry JI, Suthers KE, Smith MW. Body mass index as a predictor of outcome in total knee replacement. *Int Orthop*. 2001;25:246–249.
44. Stickles B, Phillips L, Brox WT, Owens B, Lanzer WL. Defining the relationship between obesity and total joint arthroplasty. *Obes Res*. 2001;9:219–223.
45. Toivanen AT, Heliovaara M, Impivaara O, Arokoski JP, Knekt P, Lauren H, Kroger H. Obesity, physically demanding work and traumatic knee injury are major risk factors for knee osteoarthritis—a population-based study with a follow-up of 22 years. *Rheumatology (Oxford)*. 2010;49:308–314.

46. Tsao AK, Jones LC, Lewallen DG. What patient and surgical factors contribute to implant wear and osteolysis in total joint arthroplasty? *J Am Acad Orthop Surg*. 2008;16(Suppl 1):S7–S13.
47. Udomkiat P, Dorr LD, Long W. Matched-pair analysis of all-polyethylene versus metal-backed tibial components. *J Arthroplasty*. 2001;16:689–696.
48. Winiarsky R, Barth P, Lotke P. Total knee arthroplasty in morbidly obese patients. *J Bone Joint Surg Am*. 1998;80:1770–1774.
49. Yeung E, Jackson M, Sexton S, Walter W, Zicat B. The effect of obesity on the outcome of hip and knee arthroplasty. *Int Orthop*. 2011;35:929–934.