Cementless Total Knee Arthroplasty

Bradley A. King and Arthur L. Malkani

Contents

E. Hansen, K.-D. Kühn (eds.), *Essentials of Cemented Knee Arthroplasty*,
https://doi.org/10.1007/978-3-662-63113-3_32

32

32.1 Introduction

Cemented fixation for total knee arthroplasty (TKA) remains the gold standard for primary TKA worldwide with a record of excellent clinical outcomes and implant survivorship for up to 20 years (Scuderi and Insall 1992; Attar et al. 2008; Falatyn et al. 1995). Cementless TKA designs have been present since the 1980s with variable outcomes (Meneghini and Hanssen 2008). Early cementless implants contained flaws and never gained traction due to multiple factors such as patch porous coating, poor polyethylene locking mechanisms, tibial screw augmentation leading to screw track osteolysis, femoral component fracture, and patella failures. Corrections of these design flaws, together with advances in biomaterials, have led to a new generation of cementless TKA implants. As demonstrated in total hip arthroplasty (THA), cementless fixation is advantageous because of intimate biologic fixation, leading to long-term durable survivorship.

Joint arthroplasty, previously performed in a more sedentary and elderly population with end-stage osteoarthritis, continues to experience a changing demographic to include younger, more active, and obese patients (Kurtz et al. 2007, 2009; Dalury 2016). The proportion of younger patients undergoing TKA increased between 1993 and 2006. The demand for primary TKA in patients ages 45–54 years is projected to increase by 17 times from 2006 to 2030. Patients younger than 65 years are expected to make up the majority of demand for primary or revision TKA by 2030 (Kurtz et al. 2009). The prevalence of TKA has increased across all age groups in the past two decades. In 2015, the estimated prevalence of patients living with a TKA in the United States was 0.68% at 50 years, 2.92% at 60 years, 7.29% at 70 years, 10.38% at 80 years, and 8.48% at 90 years (Maradit Kremers et al. 2015). Increased life expectancy, together with this increasing prevalence of TKA, means more patients are living longer with knee implants, therefore placing increased stress at the bone–cement–implant interface.

Obesity continues to be a major problem in the United States. The combined number of patients undergoing TKA categorized as obese or morbidly obese (BMI $\geq$30) increased significantly from 1990 to 2005 from 42% to 60%. Obese patients make up a disproportionately large proportion of TKA patients, as the nationwide prevalence of obesity in 2005 was 32% (compared to 60% of TKA population) (Fehring et al. 2007). By 2030, it is estimated that 87% of adults in the United States will be either overweight or obese (Wang et al. 2008).

Aseptic loosening is the one of the most common reasons for revision TKA. The cement–bone interface has been shown to attenuate over time (Miller et al. 2014). Studying a series of postmortem retrieved knee implants, it was found that implants with greater time in service had less interlock at the cement–bone interface, demonstrated by resorption of the trabeculae in the cement interlock region (Miller et al. 2014; Sharkey et al. 2014).

> Younger patients with active lifestyles and obese patients pose a challenge to cemented TKA due to greater amounts of stress on the cement–bone interface.

Cement has poor resistance to shear and tension forces that are present in greater amounts at this interface in larger or active patients (Lewis 1997; Harrysson et al. 2004). Abdel et al. (2015) demonstrated that patients with a BMI > 35 experienced a two times greater risk of revision with cemented implants due to aseptic tibial loosening compared to patients with a BMI < 35, regardless of age or coronal alignment. Patients experiencing aseptic loosening of the tibia in their study were statistically younger. Meehan et al. (2014) demonstrated that the risk of revision surgery due to aseptic loosening in cemented primary TKA at 1 year postoperatively in patients <50 years old was 4.7 times greater than that of a >65-year-old cohort.

> Long-term component fixation remains a concern in the obese and younger population.

32.2 Cementless TKA Designs

Given the current and anticipated demand for TKA by younger and heavier patients, there is an emphasis on improving the reliability and survivorship of joint replacements. With the past success of cementless THA, there has been an increased interest in the use of cementless TKA to provide biologic fixation over mechanical cement fixation for long-term durability. However, given the failure rates of first-generation cementless TKA, a cautious approach is needed in proceeding with newer- or second-generation cementless TKA designs.

32.2.1 Early Cementless TKA Designs

> The first generation of cementless TKA designs in the 1980s had limited acceptance due to fixation and design flaws leading to high failure and poor clinical outcomes.

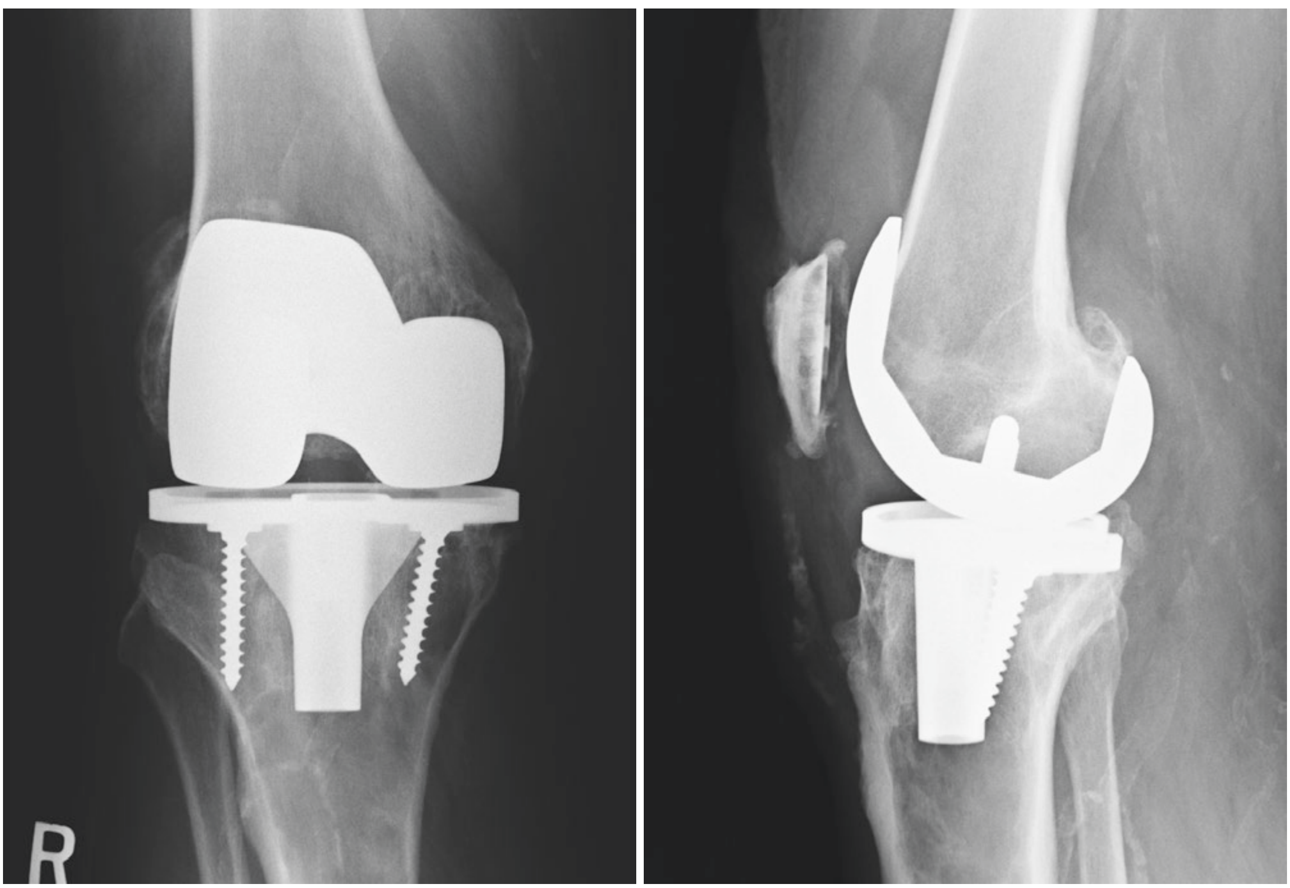
Early cementless implants had multiple design flaws including the following

- Patch porous coating
- Poor polyethylene locking mechanisms
- Tibial screw augmentation leading to screw track osteolysis
- Femoral component fracture
- Patella failures

Additionally, these first-generation design implants did not provide adequate mechanical fixation for immediate implant stability (Meneghini and Hanssen 2008; Cherian et al. 2014; Berger et al. 2001).

Tibial component fixation in early designs was inconsistent and had issues with initial fixation. Dunbar et al. (2009) used radiostereometric analysis to demonstrate that immediate rigid implant stability is essential for long-term biological fixation in cementless TKA. Early designs did not attain adequate initial mechanical fixation to allow for bony ingrowth due to multiple reasons, in addition to issues with liftoff and subsidence (Matassi et al. 2014). These first-generation designs had an increased incidence of progressive radiolucent lines at the implant–bone interface leading to aseptic loosening (Rand 1991; Rosenberg et al. 1990). Stems or screws were added to enhance initial fixation to allow for osseointegration. These screw tracks created an access channel into the tibial metaphysis for debris. Together with first-generation polyethylene and a poor polyethylene liner locking mechanism, particulate debris caused osteolysis along the screw track (◘ Fig. 32.1). The incidence of screw track osteolysis was reported to be greater than 30% in some cementless tibial component designs (Lewis et al. 1995; Peters Jr et al. 1992). Holloway et al. (2010) showed reliable fixation with screwless cementless tibial baseplates at an average of 7.6 years follow-up. Other studies have also demonstrated no advantage to using tibial baseplate with or without screws (Ferguson et al. 2008; Schepers et al. 2012; Ritter and Meneghini 2010). Another cause of metaphyseal osteolysis and loosening was baseplates with a patch porous coating, which created access channels that allowed particulate debris to spread into the metaphysis (Whiteside 1995). Subsequent designs had a circumferential and fully porous-coated surface to prevent this problem.

Early patellar failures were due to both flawed design and surgical technique. Femoral components had a non-anatomic trochlea (Varadarajan et al. 2011). Less atten-



◘ **Fig. 32.1** AP and lateral radiographs of first-generation cementless TKA with polyethylene wear and osteolysis along the screw track in the tibial metaphysis tion was given to femoral component rotation leading to malalignment and wear (Ritter and Meneghini 2010). The use of first-generation polyethylene along with a metal-backed patella also accelerated polyethylene wear leading to metal-on-metal articulation with the femoral component and eventual metallosis (Berger et al. 2001; Ritter and Meneghini 2010). Failure of the metal-backed patella was the most common mode of failure of early cementless TKA designs due to polyethylene wear, failure of ingrowth, and dissociation of the metal and polyethylene components (Rosenberg et al. 1988; Lombardi Jr et al. 1988).

While early designs of cementless tibial and patellar implants had concerns, early design cementless femoral components fared well. The femoral implant attains its initial mechanical stability through the multiplanar bone cut providing initial stability for bony ingrowth. Some early design cementless femoral components did fail due to fatigue fracture at weak points along the implant (Whiteside et al. 1993). Early femoral components, both cemented and cementless, were not designed to optimize patellar tracking, which contributed to patella polyethylene wear and metal-backed patellar component failure.

Despite design flaws and problems with the metal-backed patella, there were successes with femoral and tibial fixation. In a review of primary cementless TKA with the Miller-Galante 1 system (Zimmer, Warsaw, IN) at an average of 11 years follow-up, Berger et al. (2001) reported mixed results: cementless femoral fixation was excellent, whereas 48% of metal-backed patellar components were revised. These patellar component failures led to a 12% femoral revision rate due to femoral component damage. None of the femoral components were loose and none had radiolucency. Cementless tibial fixation had a 9% aseptic loosening rate and 12% of the well-fixed tibial components had small osteolytic lesions develop. Using aseptic loosening as the end point, the 10-year survivorship was 90.7% for the patellar component, 100% for the femoral component, and 94.3% for the tibial component.

Ritter and Meneghini (2010) reviewed 73 cementless knees from 1984 to 1986 and demonstrated that many of the early cases of cementless TKA failures were due to the metal-backed patella. Twelve of the 15 failures leading to revision in their series were due to patellar component failure with an overall 76.4% survivorship at 20 years. The survivorship of the cementless tibial and femoral components was 96.8%.

Bassett (1998) reviewed 1000 consecutive primary TKA using the Performance prosthesis (Biomet/Kirschner, Warsaw, IN) from 1988–1993. Of these, 584 cases had cementless femoral and tibial components. All had a cemented all-polyethylene patella. At an average of 5.2-year follow-up, the implant survival rate in the cementless group was 99%, with slightly higher subjective and functional knee scores for cementless knees compared to knees with cemented components. There were a number of early cementless TKA designs that were able to achieve successful long-term results similar to cemented TKA with 10-year survival rates greater than 94% (Table 32.1) (Ritter and Meneghini 2010; Whiteside 1994; Hofmann et al. 2001; Schroder et al. 2001; Khaw et al. 2002; Hardeman et al. 2006; Watanabe et al. 2004; Tarkin et al. 2005; Buechel Sr et al. 2001).

Table 32.1 First-generation cementless TKA survivorship studies

Research group	Length of follow-up (years)	Survivorship (%)	Design
Whiteside (1994)	10	94.1	Ortholoc
Hofmann et al. (2001)	10	95.1	Natural
Schroder et al. (2001)	10	97.1	AGC-2000
Khaw et al. (2002)	10	95.6	PFC
Hardeman et al. (2006)	10	97.1	Profix
Watanabe et al. (2004)	13	96.7	Osteonics
Tarkin et al. (2005)	17	97.9	LCS-RP
Buechel Sr et al. (2001)	18	98.3	LCS-RP
Ritter and Meneghini (2010)	20	98.6	AGC

32.2.2 Second-Generation Cementless TKA Designs

> Lessons learned from early cementless TKA design flaws, together with advances in biomaterials and manufacturing processes, have led to the creation of a second generation of cementless TKA implants.

The emergence of new biomaterials, such as hydroxyapatite (Soballe et al. 1991a, b, 1992), porous tantalum (Bobyn et al. 1999; Cohen 2002; Zhang et al. 1999), and highly porous titanium (Frenkel et al. 2004), and advanced manufacturing techniques have led to implants with improved ability to achieve early mechanical stability to allow for long-term biologic ingrowth. The initial fixation strength can be achieved without screw fixation eliminating the risk of screw track osteolysis. Improved wear characteristics of highly cross-linked polyethylene along with improved polyethylene tibial baseplate locking mechanisms have minimized the risk of polyethylene wear and osteolysis.

Modern-design cementless TKA implants are composed of highly porous metals, such as tantalum or titanium with increased porosity leading to improved capacity for osseointegration compared to first-generation implants (Levine et al. 2006). The greatest potential for biologic fixation exists with a pore size range of 100–700 μm, an average pore size of 400–500 μm, and 55–65% overall porosity (Bobyn et al. 1999; Levine et al. 2006). In the absence of screw fixation, the initial fixation and immediate stability comes from interference fit and frictional resistance to motion. A high-friction surface is desirable in order to improve initial fixation (Dimaano et al. 2010). Highly porous tantalum has been used in the manufacturing of cementless TKA (Trabecular Metal™, Zimmer-Biomet, Warsaw, IN) (◘ Fig. 32.2). Porous tantalum has improved material elasticity and increased surface friction compared to first-generation designs. The coefficient of friction of porous tantalum (0.88–0.98) is greater than prior cementless designs that included porous coating or sintered beads (0.66). The modulus of elasticity of tantalum is between cortical and cancellous bone, creating a more physiologic stress transfer to the periprosthetic bone interface (Lombardi Jr et al. 2007; Karageorgiou and Kaplan 2005).

Highly porous titanium, formed using laser sintering technology through an additive manufacturing process, has also been used in modern-design cementless TKA (Tritanium®, Stryker, Mahwah, NJ) (◘ Fig. 32.3). This porous titanium tibial baseplate has a porosity of 65–70%, which is greater than that of traditional titanium or cobalt–chrome beads. Highly porous titanium has a coefficient of friction of 1.01 ± 0.18 (Dimaano et al. 2010). The manufacturing process consists of laser rapid manufacturing wherein commercially pure titanium or a titanium alloy powder is deposited layer by layer using computer-based designs and laser sintering technology. Advantages of additive manufacturing include the creation of either solid, porous, or fenestrated features on an implant of any form that cannot be attained through conventional manufacturing. This technology can optimize porosity for ingrowth and has the ability to manufacture complex geometries including the solid keel with porous tibial fixation at the baseplate or porous pegs designed at specific locations.

Initial implant stability is crucial to allow for osseointegration, which had been an issue with first-generation cementless tibial component designs. Bhimji and Meneghini (2014) studied two cementless baseplate designs:

- One with two hexagonal pegs made of porous tantalum without a keel.
- The other with four cruciform pegs of porous titanium which also included a keel.

Their findings demonstrated that a baseplate with dual-hex peg fixation without a keel experienced more rocking motions, making it susceptible to larger amounts of liftoff than the baseplate with a keel and four surrounding pegs.

Hydroxyapatite (HA) coatings are osteoconductive, facilitating the formation of bone structure and potentially contributing to more stable fixation over the years. HA coatings can enhance the stability of implants by promoting early bone ingrowth even in the presence of small gaps or initial instability (Dumbleton and Manley 2004). In a review of HA-coated cementless tibia components, Voigt and Mosier (2011) found that longer term durability may be enhanced with HA-coated implants, particularly in patients who are younger than 70 years of age.

32.3 Surgical Technique

Adequate bone quality is needed for mechanical stability and osseointegration. When compared to normal controls, cementless tibial components show decreased mechanical stability in osteoporotic bone (Meneghini et al. 2011).

> However, at present, definite objective preoperative studies from which to base a selection criteria for cementless TKA are lacking. The author's indications include young, active patients, and morbidly obese patients with good bone quality.

Preoperative radiographs can be used initially as a tool to determine bone quality, but intraoperative evaluation of the patient's bone quality is needed.

> Contraindications may include patients with osteoporotic bone, the elderly, posttraumatic arthritis where the bone vascularity is compromised, and in cases with bone loss requiring grafts or augments.

Whereas cemented fixation allows for slightly imperfect bony cuts, bony defects, and variable bone porosity, cementless TKA requires a rim fit with maximum coverage of the available host proximal tibia bone surface for coverage with the tibial implant. The preparation

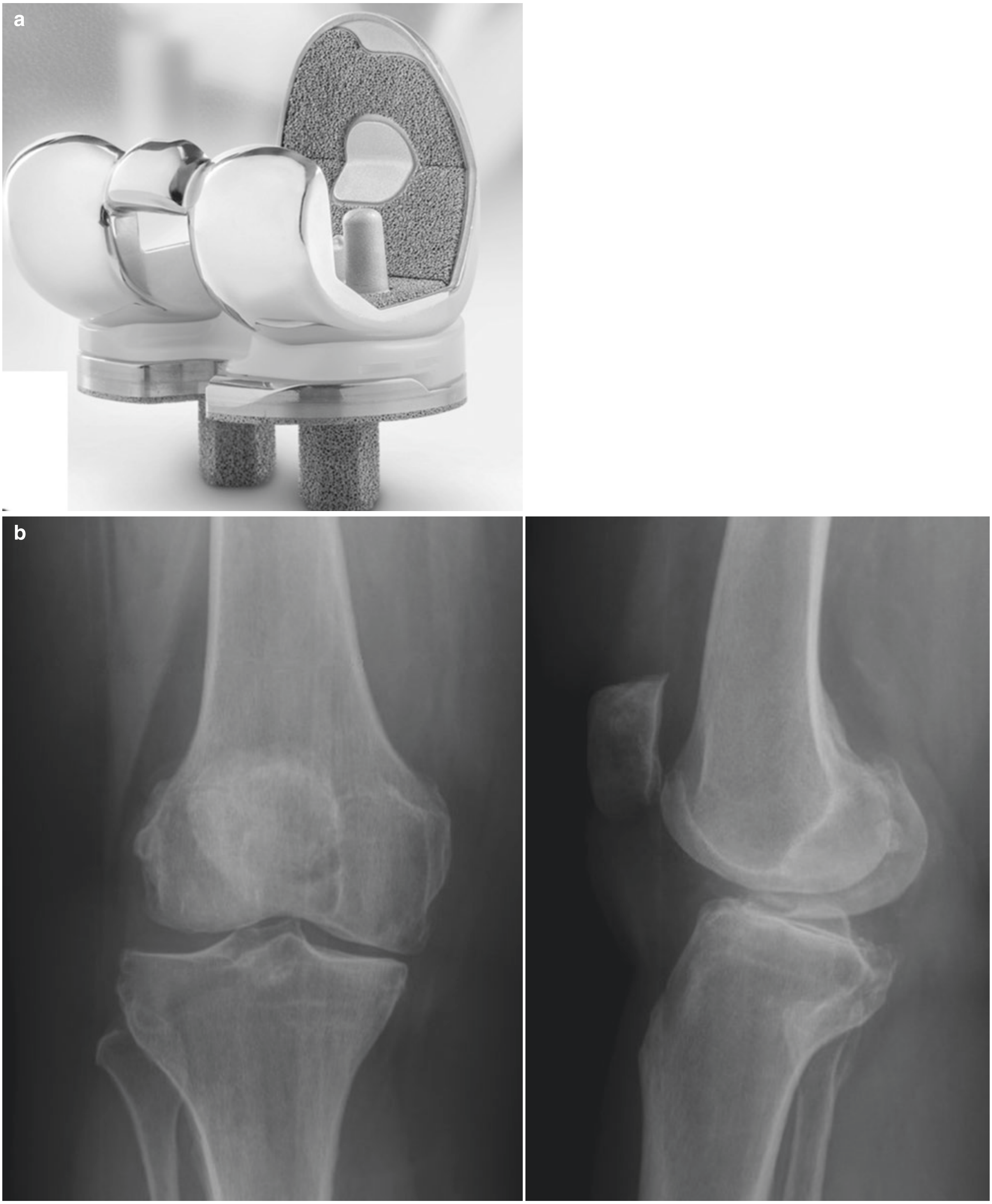


Fig. 32.2 **a** Zimmer Persona® cementless TKA design. **b** Preoperative AP and lateral radiographs of a 67-year-old female with right knee osteoarthritis. **c** Postoperative AP and lateral knee radiographs using the Persona® design

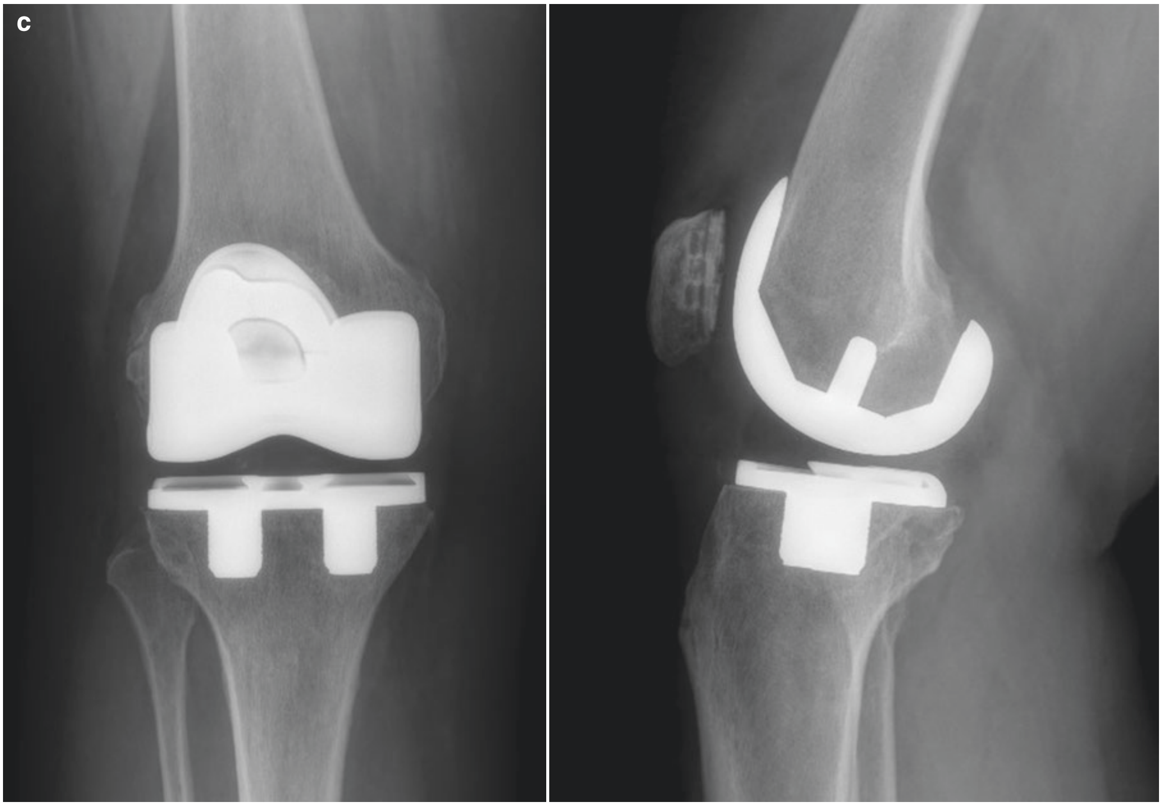


Fig. 32.2 (continued)

of the tibial plateau can result in an uneven surface in cases of very sclerotic bone as the saw blade can skive off the dense sclerotic bone. Togsvig-Larsen and Ryd (1991) reported the potential of a 1–2 mm gap between the uppermost and lowermost points of a cut tibial surface. An uneven cut may contribute to implant instability with weight-bearing and possible subsequent loss of fixation. The tibial cut can be evaluated intraoperatively with the "four corners" technique described by Whiteside, that being digital impaction of each corner of a flat tibial baseplate trial to ensure no liftoff. Cementless posteriorly stabilized (PS) TKA carried additional concerns about micromotion at the tibial fixation interface caused by cam–post engagement potentially leading to aseptic loosening (Mikulak et al. 2001). These early concerns have not endured. Harwin et al. (2018) reviewed cementless PS TKA at minimum 7-year follow-up, and at a mean of approximately 8 years excellent survivorship of 98% was maintained.

32.4 Results

Several recent studies have compared the survivorship of cemented versus cementless TKA with promising results for modern cementless TKA designs.

Fig. 32.3 **a** Stryker Triathlon® cementless TKA design. **b** Preoperative AP and lateral radiographs of a 63-year old female with left knee osteoarthritis. **c** Postoperative AP and lateral knee radiographs using the cementless Triathlon®

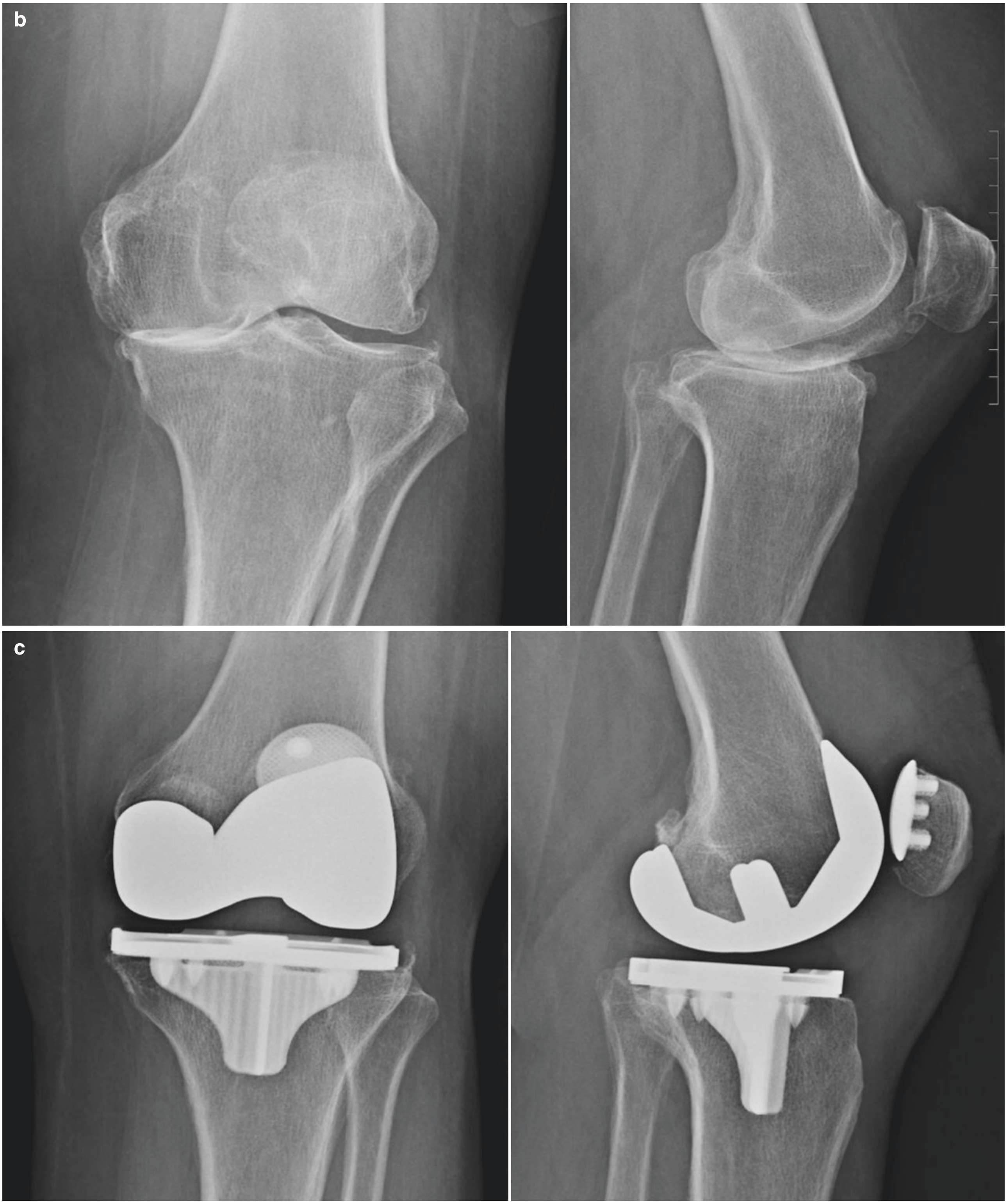


Fig. 32.3 (continued)

In a retrospective study comparing cemented versus cementless fixation for primary TKA using the same implant design, Miller et al. (2018) demonstrated a failure rate due to aseptic loosening of 0.5% at an average follow-up of 2.4 years following TKA using a cementless highly porous tibial baseplate. The matched cemented cohort with the same implant design had an aseptic failure rate of 2.5%. Boyle et al. (2018) performed a similar retrospective review using a single CR system in cemented versus cementless TKA in patients with BMI > 30 with a mean follow-up of 5.7 years. In their study, 154 uncemented patients and 171 cemented patients were found to have a 99.3% and 99.4% survivorship for tibial aseptic loosening, respectively.

In a retrospective study of cemented versus cementless PS TKA in morbidly obese patients with a mean BMI of 45 and 5-year follow-up, there was an overall revision rate of 5.4% with a revision rate of 0.9% for aseptic loosening in the cementless group versus a 25.9% overall revision rate and 11.8% aseptic loosening failure in the cemented cohort. Survivorship with aseptic loosening as the end point was 92.9% at 5 years for the cementless group and 88.2% at 8 years for the cemented group (Sinicrope et al. 2019). In a similar earlier study at the same institution, Bagsby et al. (2016) demonstrated improved survivorship of the cementless TKA prosthesis over the cemented TKA for all causes of revision and for aseptic loosening. Their study demonstrated that morbidly obese patients undergoing cementless TKA had a lower rate of aseptic revision, greater improvement in functional scores, and comparable postoperative range-of-motion to patients who underwent cemented TKA.

> They concluded that cementless fixation may provide biologic bony ingrowth leading to a more durable implant–bone interface, which may better tolerate the added mechanical stress generated in this challenging patient population.

Cementless TKA has also been effective in a younger population. In a review of 29 young patients (mean age 45 years) undergoing cementless TKA, at average of 4-year follow-up, the overall implant survivorship was 100%. There were no failures or revision surgeries performed and no evidence of radiographic loosening (Mont et al. 2017). In a separate study, a Kaplan–Meier survivorship analysis showed primary cemented TKA patients <55 years old had significantly higher rates of revision due to aseptic loosening at both 5 and 10 years postoperatively compared with cementless TKA (McCalden et al. 2013).

There are multiple studies demonstrating excellent survivorship for modern cementless TKA designs

Table 32.2 Modern design cementless TKA survivorship studies

Research group	Length of follow-up (years)	Survivorship (%)	Design
Harwin et al. (2015)	4	99.5	Triathlon®
Boyle et al. (2018)	5	99.3	Triathlon®
Kwong et al. (2014)	7	95.7	NexGen®
Cross and Parish (2005)	10	99.6	Active
Tai and Cross (2006)	12	97.5	Active
Kim et al. (2014)	17	98.9	NexGen®

(Table 32.2) (Boyle et al. 2018; Harwin et al. 2015; Kwong et al. 2014; Cross and Parish 2005; Tai and Cross 2006; Kim et al. 2014).

Cementless components experience a period of initial migration before osseointegration. In a study investigating the press-fit fixation of Stryker Triathlon® cementless tibial baseplate and metal-backed patella to the underlying bone, most component migration was observed over the first 6 postoperative weeks, after which no significant migration between the 12- and 24-month timepoints was observed. This demonstrates the biphasic migration pattern in cementless components, characterized by a high initial migration followed by stabilization. This suggests osseointegration of the components at about 6 weeks (Nevelos et al. 2019). The micromotion experienced by cementless tibial components may indicate a lower initial mechanical stability than cemented components. However, this difference in initial stability may be subclinical, as the differences between average cemented and cementless micromotion were <150 μm in one study (Crook et al. 2017). In a study by Dunbar et al. (2009), 70 patients were randomized to a cemented or cementless tantalum tibial baseplate (NexGen®, Zimmer-Biomet, Warsaw, IN). A radiostereometric analysis was performed at 6, 12, and 24 months. Cementless components experienced migration, with 9/28 components migrating >1 mm at 1 year. These components then stabilized and none were considered be at risk for early aseptic loosening, whereas 4/21 cemented components were at risk for early aseptic loosening.

Radiolucent lines (RLL) following TKA are concerning for osteolysis and loosening. In a study by

Aebli et al. (2004), the radiographic results from 91 cementless TKA over a 7.5-year follow-up showed that RLL appeared most frequently near the tibial plateau and that most RLL were present immediately postoperatively or appeared within the first year (96%). RLL were largely non-progressive (99%). In a review of a primary cementless TKA using a CR RP TKA system, there were femoral and/or tibial radiolucencies at almost all time points including 6 weeks, 1 year, and final follow-up with an average final follow-up of 9.6 years. These were found to be non-progressive partial and stable lines at final follow-up. In addition, the presence of these stable RLLs did not seem to affect the functional outcome of these patients at final follow-up (Costales et al. 2020). These results suggest that if RLLs are visible within the first year postoperatively, but do not increase further, observation or conservative treatment can be pursued.

Nam et al. (2017) compared cementless versus cemented total knee implants and demonstrated no difference in blood loss or change in hemoglobin but did show decreased operative time in the cementless group. There have been concerns of increased bleeding due to lack of tamponade by cement that have not been substantiated. Given the ongoing transition to alternative payment models by insurance providers, the value of healthcare continues to be evaluated. Cementless components are more expensive than their cemented counterparts. However, savings in the non-implant costs of decreased surgical time and not using cement negate these higher implant costs (Yayac et al. 2020). There are several modern design implants available for cementless TKA fixation at present (Table 32.3).

Table 32.3 Modern design cementless TKA implants available in the United States

Company	System
DePuy	Attune®
Donjoy	EMPOWR™
Exactech	Truliant®
Medacta	GMK
MicroPort	Evolution®
Stryker	Triathlon®
Zimmer	NexGen®
Zimmer	Persona®

Take-Home Messages

- Younger patients with active lifestyles and obese patients pose a challenge to cemented components due to greater amounts of stress on the cement–bone interface. Long-term component fixation remains a concern in this population.
- First-generation cementless knee components contained design flaws. Lessons learned from these flaws, together with advances in materials and manufacturing techniques, have given rise to the modern generation of cementless components with excellent mid-term results.
- Modern-design cementless TKA components have demonstrated equivalent and even improved survivorship in certain patient populations, including the young and the morbidly obese. Cementless fixation may provide biologic bony ingrowth leading to a more durable implant–bone interface, which may better tolerate the added mechanical stress generated inthesepatient populations.
- Objective preoperative studies from which to base a selection criteria for cementless TKA are lacking. The author's indications include young, active patients, and morbidly obese patients with good bone quality. Contraindications may include patients with osteoporotic bone, the elderly, posttraumatic arthritis where the bone vascularity is compromised, and in cases with bone loss requiring grafts or augments.

References

Abdel MP, Bonadurer GF, Jennings MT, Hanssen AD (2015) Increasedaseptic tibial failures in patients with a BMI ≥ 35 and well-aligned total knee arthroplasties. J Arthroplasty 30(12):2181–2184

Aebli N, Krebs J, Schwenke D, Hii T, Wehrli U (2004) Progression of radiolucent lines in cementless twin-bearing low-contact-stress knee prostheses: a retrospective study. J Arthroplasty 19(6): 783–789

Attar FG, Khaw FM, Kirk LM, Gregg PJ (2008) Survivorship analysis at 15 years of cemented press-fit condylar total knee arthroplasty. J Arthroplasty 23(3):344–349

Bagsby DT, Issa K, Smith LS, Elmallah RK, Mast LE, Harwin SF, Mont MA, Bhimani SJ, Malkani AL (2016) Cemented vs cementless total kneearthroplasty in morbidly obese patients. J Arthroplasty 31(8):1727–1731

Bassett RW (1998) Results of 1,000 performance knees: cementless versus cemented fixation. J Arthroplasty 13(4):409–413

Berger RA, Lyon JH, Jacobs JJ, Barden RM, Berkson EM, Sheinkop MB, Rosenberg AG, Galante JO (2001) Problems with cementless total knee arthroplasty at 11 years followup. Clin Orthop Relat Res 392(392):196–207

Bhimji S, Meneghini RM (2014) Micromotion of cementless tibial baseplates: keels with adjuvant pegs offer more stability than pegs alone. J Arthroplasty 29(7):1503–1506

Bobyn JD, Stackpool GJ, Hacking SA, Tanzer M, Krygier JJ (1999) Characteristics of boneingrowth and interface mechanics of a new poroustantalumbiomaterial. J Bone Joint Surg Br 81(5):907–914

Boyle KK, Nodzo SR, Ferraro JT, Augenblick DJ, Pavlesen S, Phillips MJ (2018) Uncemented vs cemented cruciate retaining total knee arthroplasty in patients with body mass index greater than 30. J Arthroplasty 33(4):1082–1088

Buechel FF Sr, Buechel FF Jr, Pappas MJ, D'Alessio J (2001) Twenty-year evaluation of meniscal bearing and rotating platform knee replacements. Clin Orthop Relat Res (388):41–50

Cherian JJ, Banerjee S, Kapadia BH, Jauregui JJ, Harwin SF, Mont MA (2014) Cementless total knee arthroplasty: a review. J Knee Surg 27(3):193–197

Cohen R (2002) A porous tantalum trabecular metal: basic science. Am J Orthop 31(4):216–217

Costales TG, Chapman DM, Dalury DF (2020) The natural history of radiolucencies following uncemented total knee arthroplasty at 9 years. J Arthroplasty 35(1):127–131

Crook PD, Owen JR, Hess SR, Al-Humadi S, Wayne JS, Jiranek WA (2017) Initial stability of cemented vs cementless tibial components under cyclicload. J Arthroplasty 32(8):2556–2562

Cross MJ, Parish EN (2005) A hydroxyapatite-coated total knee replacement: prospective analysis of 1000 patients. J Bone Joint Surg Br 87(8):1073–1076

Dalury DF (2016) Cementless total knee arthroplasty: current concepts review. Bone Joint J 98-B(7):867–873

Dimaano F, Hermida J, D'Lima D, Cowell CW, Kulesha G (2010) Comparison of the coefficient of friction of porous ingrowth surfaces. 56th annual meeting of the Orthopaedic Research Society

Dumbleton J, Manley MT (2004) Hydroxyapatite-coated prostheses in total hip and knee arthroplasty. J Bone Joint Surg Am 86(11):2526–2540

Dunbar MJ, Wilson DA, Hennigar AW, Amirault JD, Gross M, Reardon GP (2009) Fixation of a trabecular metal knee arthroplasty component. A prospective randomized study. J Bone Joint Surg Am 91(7):1578–1586

Falatyn S, Lachiewicz PF, Wilson FC (1995) Survivorship analysis of cemented total condylar knee arthroplasty. Clin Orthop Relat Res (317):178–184

Fehring TK, Odum SM, Griffin WL, Mason JB, McCoy TH (2007) The obesityepidemic: its effect on total joint arthroplasty. J Arthroplasty 22(6):71–76

Ferguson RP, Friederichs MG, Hofmann AA (2008) Comparison of screw and screwless fixation in cementless total knee arthroplasty. Orthopedics 31(2):127–110

Frenkel SR, Jaffe WL, Dimaano F, Iesaka K, Hua T (2004) Bone response to a novel highly porous surface in a canine implantable chamber. J Biomed Mater Res B Appl Biomater 71(2):387–391

Hardeman F, Vandenneucker H, Van Lauwe J, Bellemans J (2006) Cementless total knee arthroplasty with Profix: a 8- to 10-year follow-up study. Knee 13(6):419–421

Harrysson OLA, Robertsson O, Nayfeh JF (2004) Higher cumulative revision rate of knee arthroplasties in younger patients with osteoarthritis. Clin Orthop Relat Res 421:162–168

Harwin SF, Elmallah RK, Jauregui JJ, Cherian JJ, Mont MA (2015) Outcomes of a newer-generation cementless total knee arthroplasty design. Orthopedics 38(10):620–624

Harwin SF, Levin JM, Khlopas A, Ramkumar PN, Piuzzi NS, Roche M, Mont MA (2018) Cementless posteriorly stabilized total knee arthroplasty: seven-year minimum follow-up report. J Arthroplasty 33(5):1399–1403

Hofmann AA, Evanich JD, Ferguson RP, Camargo MP (2001) Ten- to 14-year clinical followup of the cementless natural knee system. Clin Orthop Relat Res 388:85–94

Holloway IP, Lusty PJ, Walter WL, Walter WK, Zicat BA (2010) Tibial fixation without screws in cementless knee arthroplasty. J Arthroplasty 25(1):46–51

Karageorgiou V, Kaplan D (2005) Porosity of 3D biomaterial scaffolds and osteogenesis. Biomaterials 26(27):5474–5491

Khaw FM, Kirk LM, Morris RW, Gregg PJ (2002) A randomised, controlled trial of cemented versus cementless press-fit condylar total knee replacement. Ten-year survival analysis. J Bone Joint Surg Br 84(5):658–666

Kim YH, Park JW, Lim HM, Park ES (2014) Cementless and cemented total knee arthroplasty in patients younger than fifty five years. Which is better? Int Orthop 38(2):297–303

Kurtz S, Ong K, Lau E, Mowat F, Halpern M (2007) Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. J Bone Joint Surg Am 89(4):780–785

Kurtz SM, Lau E, Ong K, Zhao K, Kelly M, Bozic KJ (2009) Future young patient demand for primary and revision joint replacement: national projections from 2010 to 2030. Clin Orthop Relat Res 467(10):2606–2612

Kwong LM, Nielsen ES, Ruiz DR, Hsu AH, Dines MD, Mellano CM (2014) Cementless total knee replacement fixation: a contemporary durable solution--affirms. Bone Joint J 96-B(11 Supple A):87–92

Levine BR, Sporer S, Poggie RA, Della Valle CJ, Jacobs JJ (2006) Experimental and clinical performance of porous tantalum in orthopedic surgery. Biomaterials 27(27):4671–4681

Lewis G (1997) Properties of acrylicbonecement: state of the art review. J Biomed Mater Res 38(2):155–182

Lewis PL, Rorabeck CH, Bourne RB (1995) Screw osteolysis after cementless total knee replacement. Clin Orthop Relat Res (321):173–177

Lombardi AV Jr, Engh GA, Volz RG, Albrigo JL, Brainard BJ (1988) Fracture/dissociation of the polyethylene in metal-backed patellar components in total knee arthroplasty. J Bone Joint Surg Am 70(5):675–679

Lombardi AV Jr, Berasi CC, Berend KR (2007) Evolution of tibial fixation in total kneearthroplasty. J Arthroplasty 22(4):25–29

Maradit Kremers H, Larson DR, Kremers WK, Crowson CS, Berry DJ, Washington RE, Steiner CA, Jiranek WA (2015) Prevalence of total hip and knee replacement in the United States. J Bone Joint Surg Am 97(17):1386–1397

Matassi F, Carulli C, Civinini R, Innocenti M (2014) Cemented versus cementless fixation in total knee arthroplasty. Joints 1(3):121–125

McCalden RW, Robert CE, Howard JL, Naudie DD, McAuley JP, MacDonald SJ (2013) Comparison of outcomes and survivorship between patients of different age groups following TKA. J Arthroplasty 28(8):83–86

Meehan JP, Danielsen B, Kim SH, Jamali AA, White RH (2014) Younger age is associated with a higher risk of early periprosthetic joint infection and aseptic mechanical failure after total knee arthroplasty. J Bone Joint Surg Am 96(7):529–535

Meneghini RM, Hanssen AD (2008) Cementless fixation in total kneearthroplasty: past, present, and future. J Knee Surg 21(4):307–314

Meneghini RM, Daluga A, Soliman M (2011) Mechanicalstability of cementless tibial components in normal and osteoporotic-bone. J Knee Surg 24(03):191–196
Mikulak SA, Mahoney OM, dela Rosa MA, Schmalzried TP (2001) Loosening and osteolysis with the press-fit condylar posterior-cruciate-substituting total knee replacement. J Bone Joint Surg Am 83(3):398
Miller M, Goodheart J, Izant T, Rimnac C, Cleary R, Mann K (2014) Loss of cement-bone interlock in retrieved tibial components from total knee arthroplasties. Clin Orthop Relat Res 472(1):304–313
Miller AJ, Stimac JD, Smith LS, Feher AW, Yakkanti MR, Malkani AL (2018) Results of cemented vs cementless primary total knee arthroplasty using the same implant design. J Arthroplasty 33(4):1089–1093
Mont MA, Gwam C, Newman JM, Chughtai M, Khlopas A, Ramkumar PN, Harwin SF (2017) Outcomes of a newer-generation cementless total knee arthroplasty design in patients less than 50 years of age. Ann Transl Med 5(Suppl 3):S24
Nam D, Kopinski JE, Meyer Z, Rames RD, Nunley RM, Barrack RL (2017) Perioperative and early postoperative comparison of a modern cemented and cementless total knee arthroplasty of the same design. J Arthroplasty 32(7):2151–2155
Nevelos J, Maclean L, Sporer S, Harwin S, Nam D, Nunley R, Malkani A (2019) Design, migration and earlyclinicalresults of the first mass produced 3D printedcementless total knee implants. Scientific Exhibit Presented at AAOS. Las Vegas, NV, 12–16 Mar 2019
Peters PC Jr, Engh GA, Dwyer KA, Vinh TN (1992) Osteolysis after total knee arthroplasty without cement. J Bone Joint Surg Am 74(6):864–876
Rand JA (1991) Cement or cementless fixation in total knee arthroplasty? Clin Orthop Relat Res (273):52–62
Ritter MA, Meneghini RM (2010) Twenty-year survivorship of cementless anatomic graduated component total knee arthroplasty. J Arthroplasty 25(4):507–513
Rosenberg AG, Andriacchi TP, Barden R, Galante JO (1988) Patellar component failure in cementless total knee arthroplasty. Clin Orthop Relat Res (236):106–114
Rosenberg AG, Barden RM, Galante JO (1990) Cemented and ingrowth fixation of the miller-galante prosthesis. clinical and roentgenographic comparison after three- to six-year follow-up studies. Clin Orthop Relat Res (260):71–79
Schepers A, Cullingworth L, van der Jagt DR (2012) A prospective randomized clinical trial comparing tibial baseplate fixation with or without screws in total knee arthroplasty: a radiographic evaluation. J Arthroplasty 27(3):454–460
Schroder HM, Berthelsen A, Hassani G, Hansen EB, Solgaard S (2001) Cementless porous-coated total knee arthroplasty: 10-year results in a consecutive series. J Arthroplasty 16(5):559–567
Scuderi GR, Insall JN (1992) Total knee arthroplasty. current clinical perspectives. Clin Orthop Relat Res (276):26–32
Sharkey PF, Lichstein PM, Shen C, Tokarski AT, Parvizi J (2014) Why are total knee arthroplasties failing today – has anything changed after 10 years? J Arthroplasty 29(9):1774–1778
Sinicrope BJ, Feher AW, Bhimani SJ, Smith LS, Harwin SF, Yakkanti MR, Malkani AL (2019) Increased survivorship of cementless versus cemented TKA in the morbidly obese. A minimum 5-year follow-up. J Arthroplasty 34(2):309–314
Soballe K, Hansen ES, Brockstedt-Rasmussen H, Hjortdal VE, Juhl GI, Pedersen CM, Hvid I, Bunger C (1991a) Fixation of titanium and hydroxyapatite-coated implants in arthriticosteopenic-bone. J Arthroplasty 6(4):307–316
Soballe K, Hansen ES, Brockstedt-Rasmussen H, Hjortdal VE, Juhl GI, Pedersen CM, Hvid I, Bunger C (1991b) Gap healing enhanced by hydroxyapatite coating in dogs. Clin Orthop Relat Res (272):300–307
Soballe K, Hansen ES, Brockstedt-Rasmussen H, Pedersen CM, Bunger C (1992) Bone graft incorporation around titanium-alloy- and hydroxyapatite-coated implants in dogs. Clin Orthop Relat Res (274):282–293
Tai CC, Cross MJ (2006) Five- to 12-year follow-up of a hydroxyapatite-coated, cementless total knee replacement in young, active patients. J Bone Joint Surg Br 88(9):1158–1163
Tarkin IS, Bridgeman JT, Jardon OM, Garvin KL (2005) Successful biologic fixation with mobile-bearing total knee arthroplasty. J Arthroplasty 20(4):481–486
Toksvig-Larsen S, Ryd L (1991) Surface flatness after bone cutting. A cadaver study of tibial condyles. Acta Orthop Scand 62(1):15–18
Varadarajan KM, Rubash HE, Li G (2011) Are current total knee arthroplasty implants designed to restore normal trochlear groove anatomy? J Arthroplasty 26(2):274–281
Voigt JD, Mosier M (2011) Hydroxyapatite (HA) coating appears to be of benefit for implant durability of tibial components in primary total knee arthroplasty. Acta Orthop 82(4):448–459
Wang Y, Beydoun MA, Liang L, Caballero B, Kumanyika SK (2008) Will all Americans become overweight or obese? Estimating the progression and cost of the US obesity epidemic. Obesity 16(10):2323–2330
Watanabe H, Akizuki S, Takizawa T (2004) Survival analysis of a cementless, cruciate-retaining total knee arthroplasty. Clinical and radiographic assessment 10 to 13 years after surgery. J Bone Joint Surg Br 86(6):824–829
Whiteside LA (1994) Cementless total knee replacement. nine- to 11-year results and 10-year survivorship analysis. Clin Orthop Relat Res (309):185–192
Whiteside LA (1995) Effect of porous-coating configuration on tibial osteolysis after total knee arthroplasty. Clin Orthop Relat Res (321):92–97
Whiteside LA, Fosco DR, Brooks JG Jr (1993) Fracture of the femoral component in cementless total knee arthroplasty. Clin Orthop Relat Res (286):71–77
Yayac M, Harrer S, Hozack WJ, Parvizi J, Courtney PM (2020) The use of cementless components does not significantly increase procedural costs in total knee arthroplasty. J Arthroplasty 35(2):407–412
Zhang Y, Ahn PB, Fitzpatrick DC, Heiner AD, Poggie RA, Brown TD (1999) Interfacial frictional behavior: cancellous bone, cortical bone, and a novel porous tantalum biomaterial. J Musculoskelet Res 03(04):245–251