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Optimal Implant Fixation in Knee Arthroplasty: Cemented Versus Cementless Knee Arthroplasty

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Keynotes

1. Cement fixation provides immediate primary stability, is useful to fill small defects, delivers local antibiotics, and acts as barrier to wear debris from the joint. Cement fixation is performed in the majority of knee arthroplasties although geographical differences exist.
2. Newer implant geometries with keels and better surface properties for osteointegration have led to better outcomes with cementless TKA. Modern cementless implants have comparable clinical outcomes and survival rates with cemented designs.
3. Cementless implants are ideally indicated for younger patients with osteoarthritis and good bone stock. However, good results have also been reported with older patients and inflammatory arthritis. Fixation in unicondylar knee arthroplasty has followed the same trends; with cemented fixation being the most popular and a growing interest in cementless fixation.
4. Cemented TKA shows superior survival rate compared to cementless TKA and is predominantly performed worldwide.

39.1 Introduction

The long-term functional outcome of knee arthroplasty depends on optimal and durable fixation of implants to the bone. Cement fixation has been used extensively for total knee arthroplasty (TKA) and unicondylar knee arthroplasty (UKA). It is still the most widely used form of fixation. Cement fixation provides excellent primary stability for decades; however, it carries the risk of failure at the bone cement interface in time. The success of cementless designs in the hip have led to cementless implants in TKA. However, the results have been mixed, with worse outcomes in earlier designs. Newer generation of cementless TKA with improved surface coatings and better designs showed promising short-term results; however, long-term durability of these implants has not been published. This chapter reviews the current knowledge and future trends on fixation methods in knee arthroplasty.

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39.2 Cemented Fixation

Bone cement (polymethyl methacrylate, PMMA) is widely used to fix orthopedic implants to the bone. PMMA is made up of a liquid MMA monomer and a powdered MMA-styrene copolymer [1]. Zirconium dioxide (ZrO_2) or barium sulfate ($BaSO_4$) is added to the compound to make it radio-opaque. Bone cement is not adhesive but interdigitates with the cancellous bone to form a micro-interlock. Once polymerization is complete, the primary stability of fixation is excellent and immediate weight bearing and range of motion exercises are possible.

The polymerization of cement occurs with an exothermic reaction and temperatures up to 82–86 °C. However, due to the thin layer of cement, large surface area, and the cooling effects of blood circulation, this value is lower in the body and has been reported to be less than 48 °C in total hip arthroplasty [2]. This is well below the level of protein denaturation of 56 °C. PMMA may cause transient hypotension during the curing phase; this side effect may be accentuated in patients with hypovolemia and may lead to cardiac arrhythmias and myocardial ischemia.

Cement fixation of TKA is much more common compared to cementless fixation. Excellent clinical outcomes and survival rates of over 95% have been reported with different implant designs [3]. Cement fixation provides immediate primary stability and is useful to fill small defects and cover imperfect bone cuts. Cement acts as barrier to wear debris from the joint and prevents the particles from reaching the bone-cement interface. Cement can also be used to deliver local antibiotics.

The use of cement has several disadvantages. One is prolonged operative time (and tourniquet time if used) needed to prepare bone surfaces, waiting for cement polymerization and clearing the excess cement. Third body wear from retained cement particles and extraarticular impingement on the tibial liner might also be a problem. Bone-cement interface carries a risk of failure in time resulting in aseptic loosening. Other proposed disadvantages are an increased risk of deep vein thrombosis (DVT), fat embolism, thermal necrosis during polymerization and an additional interface for wear particles [4].

39.2.1 Surface Preparation

The cementation technique is of great importance to achieve a good clinical outcome (Video 39.1).

A deep penetration of the cement into the trabecular bone helps to avoid micromotion and increases longevity of the implant. Precise bone cuts are important to achieve a flat surface and avoid toggling of the implant under load. The quality of cancellous bone decreases when the tibial cut is moved more distally. Therefore, the minimum amount of bone should be removed to achieve adequate flexion and extension gaps. The surface should be cleaned of any debris and blood and dried thoroughly. Majkowski has shown in a cancellous bone model that active bleeding reduces the shear strength of bone-cement interface by 50% although cement penetration is not affected [5]. Therefore, even if the penetration depth of the cement into bone is not affected, the presence of blood in the bone-cement interface carries the risk of inferior fixation and possibly early failure of the implant.

Pneumatic tourniquets are commonly used to improve visualization and achieve a bloodless field during TKA. The use of pneumatic tourniquet might affect cement penetration. Pfitzner et al. found an increased cement mantle thickness (13 vs. 14.2 mm) when a tourniquet was used, but this difference did not reach statistical significance in 90 cases [6]. However, the use of a tourniquet was associated with a significantly higher postoperative pain. Liu et al. also compared cement mantle thickness in patients with & without tourniquet and could demonstrate no significant difference [105].

In contrast, Vertullo and Nagarajan performed a single blinded randomized study comparing cement penetration in TKA with and without tourniquet and could not find any significant difference [7]. If surgery is performed without a tourniquet, hypotensive anesthesia with or with-

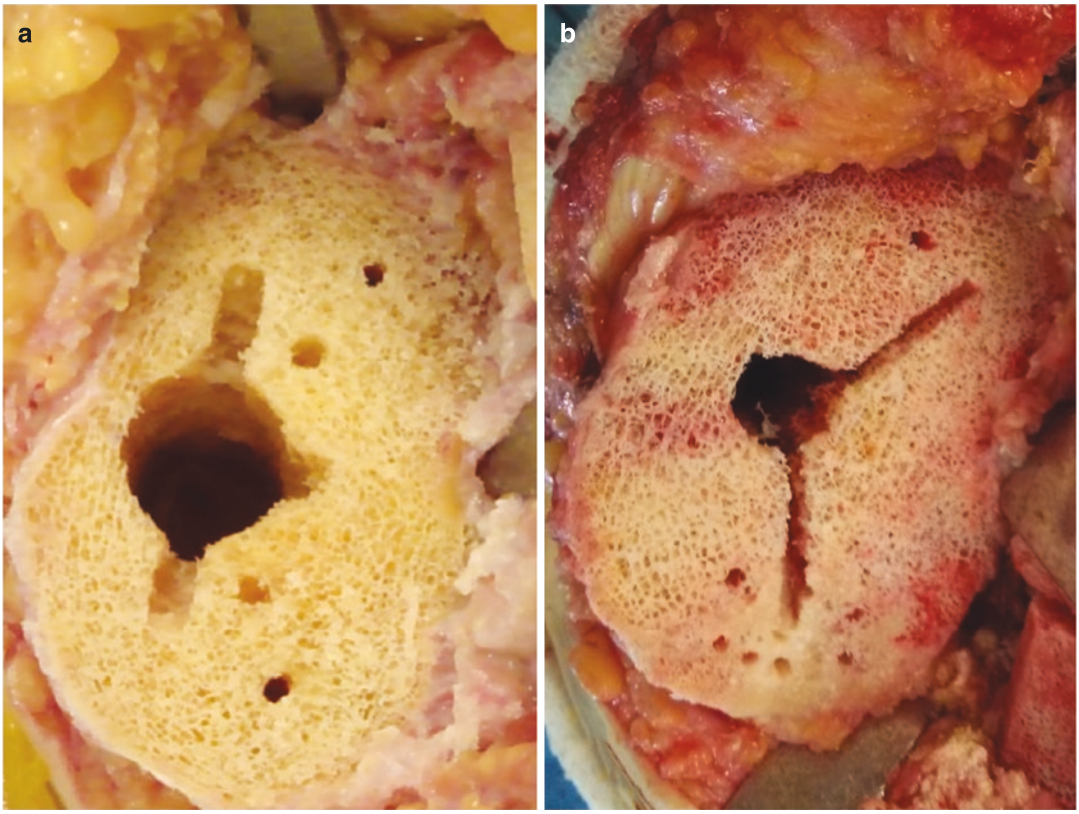

Fig. 39.1 (**a**, **b**) Application of a thigh tourniquet is not essential for good cement penetration. Final tibial surface after pulsed lavage and drying. (**a**) Patient under tourniquet. (**b**) Patient under hypotensive anesthesia and no tourniquet, note similar surface preparation

out adrenalin-soaked sponges are helpful to achieve a bloodless field (Fig. 39.1). This is important both for improved visualization and cement penetration.

Clean and dry cancellous bone surfaces free of debris, blood, and marrow elements are important to achieve good cement penetration. Cleaning of the cancellous surface can be done manually using a syringe or more commonly with a disposable pulsed high pressure lavage system (Fig. 39.2). Pulsed lavage has been shown to increase the cement mantle thickness and penetration into the cancellous bone compared to lavage with a syringe in both TKA and UKA [8, 9]. Pressurized filtered carbon dioxide jets have also been used to prepare bone surfaces in TKA. The proposed advantages are a better and drier surface cleaning compared to pulsatile lavage. A few studies presented as abstracts only have reported good clinical outcomes with adequate cement penetration.

Sclerotic bone impedes cement interdigitation to trabecular bone. Multiple drill holes have been used to induce cement interdigitation in sclerotic bone (Fig. 39.3). 4.5 mm holes have shown less radiolucent lines at 2 years and improved cement penetration compared to 2 mm drill holes [97]. However, larger holes increase the risk of a stress riser, and should be used judiciously.

Side Summary

A clean and dry cancellous bone surface is mandatory before cementation. This can be achieved without a tourniquet providing hypotensive anesthesia is performed.

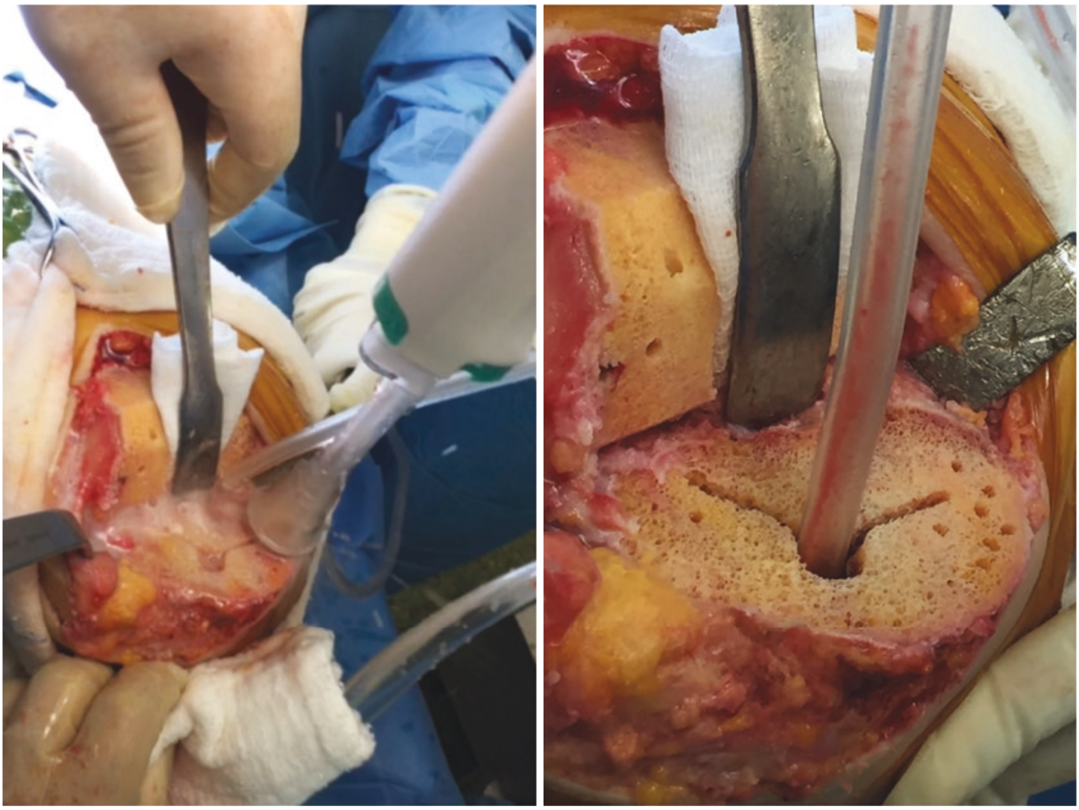

Fig. 39.2 Tibial surface after pulsed lavage cleaning. The surface is cleaned of all debris, blood, and fat and is ready for cement intrusion

39.2.2 Cementing Technique

Cement intrusion in cancellous bone is affected by the viscosity of the cement, the porosity of the bone, and the pressure gradient during application. The minimum amount of cement penetration needed for a stable fixation is unclear; however, one study pointed out 1.5 mm as a cut-off point for failure during pull-out testing [9]. Other studies have shown that at least 2 mm penetration is necessary to achieve micro-interlock with transverse trabeculae [10]. The ideal cement penetration during TKA is thought to be 3–4 mm [11, 12]; more than 5 mm penetration may cause thermal injury to cancellous bone [13].

Side Summary
The ideal cement penetration into the bone at TKA should be between 2 and 4 mm.

Various combinations of tibial cementing have been analyzed by Vanlommel et al. using a sawbone model [14]. The best cementing was achieved when cement was applied to both the undersurface of the components and to the bone with finger packing. When a cement gun was used, cement penetration was excessive.

Side Summary
The best cementing is achieved with a double cementing technique, in which cement is put on the bone and on the prosthesis.

Few studies have analyzed cementing techniques on the femoral side. Radiolucent lines are frequently seen in well-fixed femoral components on posterior condyles, as cement penetration in that region is difficult to achieve. A study on open-pore sawbones found the best cementation

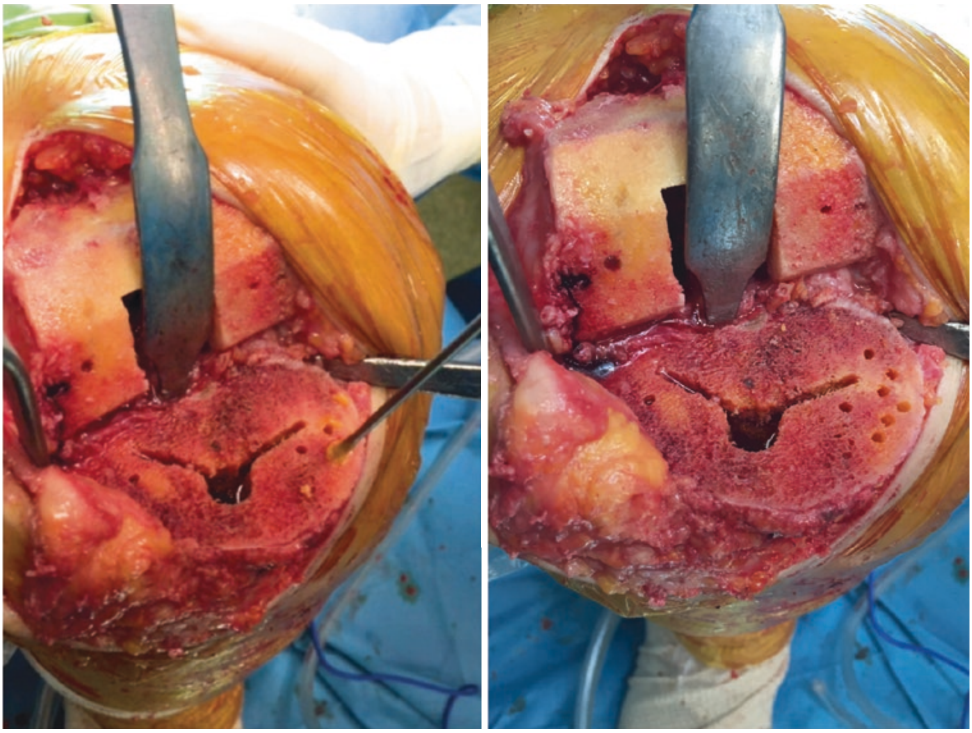

Fig. 39.3 Multiple drill holes are placed in sclerotic bone to improve cement penetration

when the cement was placed on the anterior and distal femur and the posterior condyles of the femoral implant [15]. No cement should be placed on the posterior femoral condyles, since this may lead to retained cement in the posterior compartment and cause limitation of flexion and polyethylene wear.

Cement may be applied with a spatula/finger packing or with a cement gun (Fig. 39.4). Finger packing typically results in 2–3 mm while cement gun usage results in 4–7 mm cement penetration.

Side Summary
Cement may be applied with a spatula/finger packing or with a cement gun. Finger packing typically results in 2–3 mm while cement gun usage results in 4–7 mm cement penetration.

Fig. 39.4 Cement application with a spatula achieves a more uniform penetration pressure

Unlike total hip arthroplasty, the use of cement pressurization guns in TKA is controversial. The clinical consequences of cementing technique have been analyzed in several studies. Ritter found less radiolucent lines under the tibial component in 363 knees at 1–3 years follow-up when a pulsed lavage and cement gun had been used compared to syringe lavage and finger packing of cement [16]. Lutz has shown a twofold increase in penetration of the cement when a cement gun was used, resulting in less radiolucent lines [17]. However, the authors compared a low viscosity cement to standard viscosity cement.

Kopec et al. compared vacuum mixing and gun pressurization versus hand mixing and packing in the proximal tibia in 82 patients undergoing TKA [18]. Cement penetration was marginally better in some but not all zones around the tibial component, and the difference was too small to be of clinical importance. No difference in outcomes was observed at short-term follow-up. It can be concluded that finger packing is adequate for most patients to achieve adequate cement penetration. Some authors have advocated the use of a cement gun in dense sclerotic bone [11].

In a comparative study, cement penetration with pressurization alone was worse compared to pulsed lavage and manual packing of the cement [19]. This study showed that pulsed lavage combined with finger packing improves bone cement penetration by a factor of 4 and interface strength by a factor of almost 12 when compared with syringe lavage combined with pressurizing-gun cementing. The authors concluded that the effect of high pressure lavage was more important than that of cement pressurization with a gun.

Another method used to increase cement penetration is applying negative pressure in the proximal tibia by using a cannula through the holes created during tibial jig fixation [20, 21]. Depending on surgeon preference and dexterity, the components can be cemented separately or in one setting using a single packet (40 g) cement. Cooling the cement increases the working time but also delays curing.

Side Summary

Pulsed lavage is helpful to increase cement penetration into cancellous surfaces. The use of a cement gun with pressurization is not necessary.

39.2.3 Cement Type

High viscosity cements have been associated with lower cement penetration and early failures and should be avoided [22, 23]. Standard and low viscosity cements are routinely used in TKA. If a cement gun is used, two 40 g packets of low-viscosity cement are needed and vacuum mixing if possible. Different types of cements may have different penetration depths even when using the same technique. Walden has shown penetration depths between 2.8 and 3.7 mm using finger packing for three cement types [24]. The brand of cement does not seem to influence the outcome and survival of TKA. Birkeland et al. have analyzed over 26,000 patients in the Norwegian registry, comparing different types of cement. No clinical difference between different types of cement used in this large cohort was found [25].

39.2.4 Surface Versus Full Cementation

Fully cementing the tibial baseplate versus surface cementation is controversial. The proponents of fully cementing the tibial component cite better stability in biomechanical studies, less micromotion, and effective seal for intraarticular debris. Advocates of surface cementing claim adequate stability of the component, and greater loading of the proximal tibial bone avoiding loss of bone stock in case of revision [11]. Some biomechanical studies have shown increased stability and less micromotion and strain in patients with fully cemented baseplates [26]. Other biomechanical studies showed no difference between surface cementation versus full cementation of the tibial tray as long as adequate cement penetration is achieved on the cancellous surface [27]. Fully cementing the baseplate may result in difficulties in removal and possible bone loss if revision surgery is required. Fully cementing the tibia may also cause proximal bone resorption under the tibial tray. A finite element analysis has shown that surface cementation without cementing the tibial stem would produce the least amount of bone resorption [28].

The effect of bearing type on tibial cementation is controversial. Luring et al. found increased micromotion and lift-off in surface-cemented tibias using a conforming mobile bearing design. The author cited increased rotatory forces on the tibial cement bone interface in mobile bearing articulations and advocated fully cementing the stem [29]. In contrast, Rossi has shown excellent early outcomes and no radiological loosening in 70 patients using a mobile bearing TKA and surface cementation [30].

The surgeon should also be aware of the tibial implant design and instrumentation. Some tibial instrumentations are designed for a press fit-keel preparation, while others leave a space around the keel for a cement mantle (Fig. 39.5). It would be a mistake to use surface cementation in keels prepared for a cement mantle, as this would leave a void around the keel (Fig. 39.6).

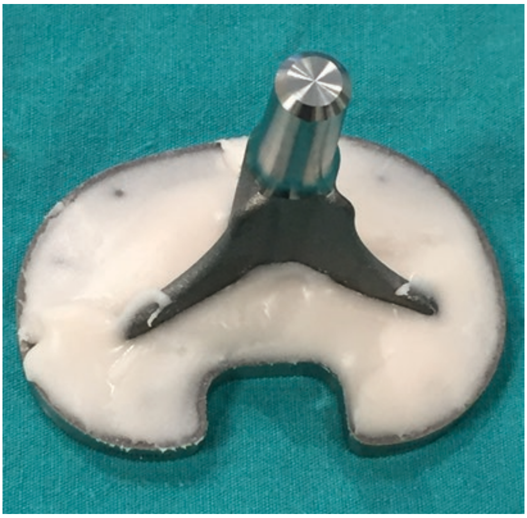

Fig. 39.5 This implant achieves a press fit implantation around the keel; therefore, surface cementing is performed, avoiding cement around the keel

No significant clinical differences in functional outcome or survival have been reported in surface cemented implants compared to full cementation. Galasso et al. compared 232 patients who underwent TKA using full or surface cementation of the tibial baseplate [31]. The cumulative survival rate at 8 years was 97.1% with no difference in clinical outcomes and aseptic loosening. Similar conclusions were reached by Schlegel in a matched pair analysis of patients at 10–12 years follow-up [32]. Aseptic loosening rates were similar even in rheumatoid patients.

In conclusion, it can be stated that surface or fully cementing the tibia result in the same clinical outcomes, provided a 3 mm cement mantle is created under the baseplate and the keel design is appropriate for the chosen technique.

Side Summary

There is no difference in aseptic loosening rates between surface and complete cementing of the tibia component.

39.2.5 Implant Surface and Design Properties

Bone cement must also provide a strong interlock with the implant. Increasing the surface roughness of the cement-implant interface is beneficial for primary stability. Pittman et al. have shown that common surface treatments such as grit-blasting produce interface strengths similar to plasma-spray, porous-coated implants [33]. The authors advocate avoidance of macro surface textures due to concerns for failure during rotational loads.

The addition of a peripheral lip or cement pocket under the tibial baseplate increases cement penetration by decreasing escape of the cement under the metal during implantation. Vertullo et al. have shown that a peripheral lip significantly increases cement penetration in the periph-

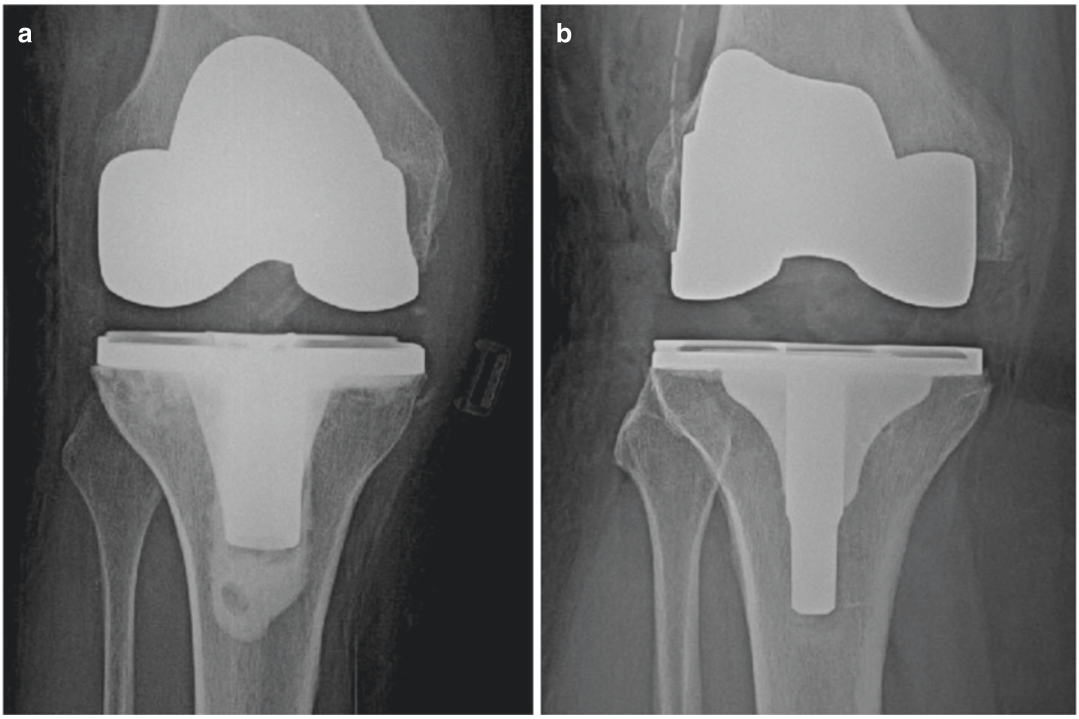

Fig. 39.6 (**a**, **b**) Surface versus full cementation on the tibia. (**a**) The keel of this implant (Zimmer Next-Gen) allows for a cement mantle and is fully cemented. (**b**) The keel of this tibia (Smith & Nephew Genesis 2) is designed for press-fit implantation, only surface cementing is performed

eral part of the cement mantle compared to implants without a lip [34]. However, this effect is true only for the peripheral 5mm of the cement mantle, which equalizes in the central part of the mantle.

High flexion designs have been reported to have a higher early failure rate of the femoral component due to high stresses on the bone cement interface. The addition of drill holes under the anterior flange of the femoral implant to increase cement penetration has been shown to decrease the risk of loosening in biomechanical studies [35].

39.2.6 Antibiotic-Loaded Cement

The addition of antibiotics to bone cement in primary TKA is controversial. Antibiotic elution from the cement is similar regardless of antibiotic type, with high elution in the first week, followed by a dramatic decrease thereafter. This chronic low-dose elution may not be enough to kill pathogen bacteria and may result in antibiotic resistance. Antibiotics up to 2 g per standard packet of cement can be mixed with the powder without compromising its mechanical properties [36]. However, antibiotics must be thermostable to withstand high temperatures. Gentamycin, Tobramycin, Erythromycin, Clindamycin, Oxacillin, Cefuroxime, Vancomycin, Lincomycin, Colistin and Teicoplanin can be mixed with cement for antimicrobial effect [1, 36, 37]. Doses higher than 2 g may be used to manufacture spacers in infected knees where mechanical strength is not an issue.

Proponents of antibiotic use cite decreased deep infection rates as the main advantage. Opponents of antibiotic usage in primary TKA cite the risk of systemic toxicity, hypersensitivity, loss of mechanical strength, expense, and emergence of resistant bacterial strains as disadvantages. Hypersensitivity to the antibiotics in the cement is rare but has been reported [38]. Nephrotoxicity has been reported with high dose antibiotics in spacers but is very rare in the doses used for primary TKA [37]. Randelli has shown that a 1.2% decrease in deep infection rates would be necessary to justify its routine use in primary TKA [36].

The use of antibiotic-loaded cement is guided more by practice patterns than scientific evidence. Registry data and prospective randomized studies also show conflicting results. Outcomes from the Finnish registry have shown decreased deep infections in antibiotic-loaded cements in primary TKA [39]. In contrast, data from the Australian and Canadian registries have shown no difference compared to cement without antibiotics [40, 41]. A recent meta-analysis of seven randomized controlled trials on hip and knee arthroplasty showed decreased deep infection rated when antibiotic-loaded cement was used [113]. Gentamycin was found to be superior to Cefuroxime in this study. The cost-effectiveness of antibiotic-loaded cement has also been discussed.

The limited evidence on the effect of antibiotic-loaded cement on deep infection rates has led some surgeons to advocate a selective use of antibiotic in high risk patients [13]. These include diabetics, immunocompromised patients, morbidly obese, and patients with previous history of fracture or infection around the knee. The effectiveness of antibiotic-loaded cement in revision TKA and established infection is undisputed. The dosage of antibiotic depends on the formulation but should not exceed 2 g per standard packet of cement to prevent mechanical failure.

Side Summary
Routine use of antibiotic-loaded cement in primary TKA is controversial and should be preferred in selected patients with risk factors.

39.3 Cementless Fixation

The concept of direct osteointegration of the host bone to the implant is attractive. However, the higher rates of earlier failure in cementless TKA designs led to an initial unpopularity. Early cementless tibial component designs using screw or pin fixation, with poor osteoconductive surface properties, had increased rates of failure and loosening [43]. The screw holes were also a conduit for debris material and a risk for osteolysis. Osteolysis is an inflammatory reaction to particulate debris and may sometimes lead to catastrophic cystic formation. Although osteolysis is multifactorial and is seen in both cemented and cementless TKAs, it occurred more frequently in earlier cementless designs of the nineties [44]. Newer cementless designs with fully porous coatings have decreased rates of osteolysis compared to older designs. Metal-backed patellae led to catastrophic failures and were discontinued [45]. This led to an initial abandonment of cementless fixation. Higher failure rates of the tibial component led to the utilization of hybrid fixation, in which the femur was uncemented and the tibial tray was fixed with cement. Better results of hybrid techniques led to a resurgence of interest on cementless implants.

Newer implant geometries with keels and better surface properties for osteointegration have led to better outcomes with cementless TKA. The use of mobile bearings has been cited as an advantage to decrease stress on the implant-bone interface [4]; however, similar results have also been achieved with fixed bearings in modern TKA designs. Modern cementless implants have comparable clinical outcomes and survival rates with cemented designs. Cementless implants are ideally indicated for younger patients with osteoarthritis and good bone stock. However, good results have been reported with older patients and inflammatory arthritis.

The proposed advantages of cementless fixation in TKA are preservation of the bone stock in younger patients and ease of revision. Other cited advantages are shorter operative time, decreased risk of DVT [46], and avoidance of complications associated with cement such as third body wear and retained cement. Unless osteolysis occurs, uncemented components are expected to stay fixed for a long period of time once initial osteointegration is established. This is not the case for cemented components where there is excellent initial stability; however, loosening is a definite risk with longer term follow-up. This has been shown in many studies including a Cochrane Database review of 5 randomized controlled trials including 297 patients [47]. This review concluded that although cemented implants demonstrated less migration in the first 2 years, they presented with more risk of aseptic loosening at longer term follow-up. Cementless implants exhibit early migration in RSA studies during the first year, then stabilize and show no further migration if osteointegration is achieved.

Cementless implants are more expensive and require precise bone cuts and perfect ligament balance as cement is not available to fill minor defects to provide primary stability. Given the similar clinical outcomes of cemented implants, the increased cost of cementless designs seems hard to justify in older patients.

Side Summary
Cementless fixation may provide durable fixation in younger patients with good bone stock; however, the added expense is prohibitive.

39.3.1 Initial Stability and Osteointegration

The initial stability of cemented and uncemented tibial baseplates under cyclic loading was measured by Crook [48]. Although uncemented baseplates exhibited more micro-movement, this was less than 150 μm at all the locations tested, and the authors concluded that this difference was not clinically significant. Bone mineral density has been found to correlate with migration of cementless TKA. In a 2 years study of 92 patients with uncemented tibial components, Andersen found a significant correlation with low preoperative bone mineral density of the tibia and migration of the implant measured with radiostereometric analysis (RSA) [49].

Side Summary
Due to increased micromotion of the cementless implants, the initial stability of cemented implants is better in the first year after implantation. Micromotion equalizes after the first year and may be less in cementless implants at longer term follow-up.

39.3.2 Bearing Type

Most of the reported series on uncemented TKAs have utilized either a mobile bearing or cruciate retaining design. This is due to concern about high stresses being transferred to the bone-implant interface in a fixed bearing PS design with a tibial post. However, good outcomes have been reported recently with an HA-coated fixed bearing PS design without osteolysis or loosening [50]. In contrast, National Joint Registry data for England and Wales show an increased risk of revision for fixed bearing posterior stabilized implants after 4 years [51]. An unconstrained mobile bearing or a cruciate retaining fixed bearing implant should be preferred if uncemented fixation is chosen.

39.3.3 Patient Age

Given the possibility of durable fixation, cementless implants are ideally suited for younger patients. A recent review of studies in patients younger than 60 years with mostly osteoarthritis, Franceschetti could not find a significant difference between cemented and cementless implants in terms of clinical outcomes and loosening [52]. Radiolucent lines of <2 mm were seen with both fixation methods. A survival rate of over 90% was reported in the majority of the studies at a mean follow-up of 8.6 years (range 5–18 years).

Kim et al. compared cemented and cementless implants of the same design (Zimmer Next-Gen CR) in simultaneous bilateral TKAs in patients younger than 55 years [53]. Clinical outcomes were similar at minimum 16 years follow-up. There was no femoral loosening in either group, tibial component survival was 100% for cemented and 98.7% for uncemented tibias.

Although cementless implants are advocated for younger patients with good bone stock, good results have been obtained in elderly patients as well. In a group of 134 patients with cementless TKAs, Newman has reported excellent outcomes with 98.6% survivorship at 4 years, as well as no progressive radiolucencies or subsidence in patients older than 75 years [54].

39.3.4 Obesity

Obesity does not seem to be contraindication to cementless TKA. In a comparative multicenter review of 298 TKAs in morbidly obese patients, a higher revision rate (13% vs. 0.7%) and aseptic loosening rate (6% vs. 0) were found in cemented implants when compared to cementless TKA [55]. The authors actually advocated the use of cementless implants for morbidly obese patients. Another study by Lizaur-Utrilla found similar clinical outcomes and implant survivorship at 7 years in 171 uncemented TKAs in obese and nonobese (BMI < 30) patients [56]. Conversely, in a comparative study of 100 matched knees followed for 9.2 years, Jackson et al. found inferior outcomes in obese patients undergoing cementless TKA, although implant survival was similar in both groups [57].

Side Summary
Patient age and obesity does not adversely affect the outcome of cementless TKA at mid-term follow-up.

39.3.5 Cementless Patellar Implants

Cementless fixation of the patella is controversial. Earlier studies have shown increased complication rates and catastrophic failures with metallosis using metal-backed patellae [58]. This has been attributed to poor locking mechanisms, thin polyethylene, poor tracking, and minimal femur contact in earlier designs [59]. Newer generation implants with hydroxyapatite coatings and thicker polyethylene have shown better results at short-term follow-up [58, 60]. However, the problems still persist as one study reported 20% fracture rate of tantalum-backed patellar components in 30 patients at 5.5 years follow-up [61].

Due to these concerns, cementless TKA is usually performed without patellar resurfacing or with a cemented all poly patellar button.

Side Summary
Cementless patellar resurfacing is not recommended.

39.3.6 Inflammatory Arthritis

Cementless fixation is not usually advocated for patients with inflammatory arthritis due to concerns about bone quality and risk of failure of osteointegration. However, many authors have reported good results with an acceptable survival rates in patients with inflammatory arthritis. Sizing is important as the tibial tray should cover the resected surface as much as possible to prevent subsidence in osteoporotic bone [62]. Buchheit et al. have reported a 97% survival rate at 6 years in 55 patients with RA [63]. There was only one loosening of the tibial tray in this series. Sharma, using low contact stress mobile bearing implants, reported 94% survival at 16 years in patients with rheumatoid arthritis [64]. Woo et al. reported 10 years outcomes of cementless TKA in rheumatoid patients [65]. Only one case of loosening was found in 179 knees, although radiolucent lines less than 2 mm were seen in 12% of the femoral and 24 % of the tibial components.

Although functional outcomes in RA patients are inferior to OA patients due to poor soft tissues, contractures, and multijoint involvement, survival of cementless systems seems to be unaffected.

39.3.7 Hybrid Fixation

The higher rate of tibial component failures in cementless TKA led to the introduction of hybrid fixation, where the femur is fixed without cement while the tibia is cemented. The results of hybrid TKA have been mixed, with some older studies reporting higher failure rates and newer studies with better results. Duffy reported a 27% revision rate at 15 years, mostly for the femoral component, for hybrid TKA and advised against its usage [66]. In contrast, good clinical outcomes have been reported with hybrid fixation in other studies. McLaughlin reviewed the 16 years results of 148 hybrid TKA and reported only one aseptic loosening with 99% implant survival [67]. Pelt et al. compared 111 cemented CR TKA to 174 hybrid TKA using either a Maxim or Vanguard system (Biomet) [68]. Knee Society Scores and implant survival was similar in both groups at 7 years, with 99.2% survival of the femoral component in hybrid knees. Interestingly, radiolucent lines were more frequent in cemented femurs. Yang reported on 235 hybrid TKA of 5 different designs [69]. Implant survival rates were 92% for the femur and 95% for the tibia at 10–15 years follow-up, and the authors concluded that their results were no different than cemented implants. Lass et al. compared 60 hybrid TKAs with 60 uncemented TKA [70]. Survivorship of the tibial component was 96% in both groups at 5 years follow-up, with similar clinical outcomes. Radiolucent lines were much less frequent in uncemented tibias, suggesting that once osteointegration was achieved, fixation was durable.

Side Summary

High aseptic loosening rates of the tibial component of earlier cementless designs led to the concept of hybrid fixation; an uncemented femur combined with a cemented tibia.

39.3.8 Surface Coating

39.3.8.1 Hydroxyapatite

Hydroxyapatite is an osteoconductive material that has been extensively used for fixation in cementless total hip arthroplasty. The addition of HA coatings has improved fixation of total knee implants [71]. In a meta-analysis of 14 trials including 926 TKA, Voigt and Mosier have shown that the addition of hydroxyapatite coating to metal-backed tibial trays improves fixation and durability [72]. This is especially helpful in patients over 65 years. However, no difference in functional outcome could be demonstrated comparing trays with or without HA coating.

Several studies have shown excellent long-term survivorship and outcomes of hydroxyapatite coated TKA (Table 39.1). Comparative studies using the same implant with cemented fixation have shown that uncemented implants perform equally well, and sometimes better than cemented implants.

39.3.8.2 Porous Tantalum

Another method of improving tibial fixation is the use of highly porous tantalum implants. Also named trabecular metal (Zimmer-Biomet, Warsaw, IN, USA), this newly developed metal has a similar elastic modulus with native bone and is highly osteoconductive. In a meta-analysis of six studies involving 977 patients, porous tantalum monoblock tibial components were associated with higher functional scores, fewer radiolucent lines, and shorter operation times compared to cemented implants [73]. However, no significant differences were seen in range of motion, functional scores, complications, reoperation, and loosening rates between the two groups. The durability of trabecular metal implants has been shown in long-term studies. After an initial migration up to 2 years, these implants have shown excellent fixation without loosening at 10 years [74], making them an attractive choice in younger patients. Several studies using monoblock tantalum tibial components have shown over 95% survivorship at 5–11 years with very few revisions for loosening (Table 39.2). Early failures have been reported in tall, heavy male patients with sub-

Table 39.1 Survivorship of hydroxyapatite-coated cementless TKA

Author	Year	Implant type	No. of patients	Follow-up (years)	Survival	Notes
Hydroxyapatite						
Cross [99]	2005	Fixed bearing CR	1000	10	99%	
Tai [111]	2006	Fixed bearing CR	118	5-12	97.5%	2 tibial tray revisions
Beaupré [98]	2007	Fixed bearing CR	75	5	100%	More pain in the cementless group compared to cemented at 6 months, equalized at 5 years
Epinette [101]	2014	Mobile bearing PS	270	15-22	97.1%	
Prudhon [109]	2017	Mobile bearing PS	100	11	95.4%	Similar outcome and survivorship compared to cemented implant
Melton [106]	2012	Fixed bearing CR	325	10	96%	2.3% aseptic loosening

CR Cruciate retaining, *PS* Posterior stabilized

Table 39.2 Survivorship of monoblock tantalum tibial components

Author	Year	Implant type	No. of patients	Follow-up (years)	Survival	Notes
Monoblock tantalum tibia						
Henricson [74]	2016	Fixed bearing CR	21	10	95.5%	No revision for loosening, 1 infection
DeMartino [100]	2016	Fixed bearing CR	33	11.5	96.9%	No revision for loosening or osteolysis
Niemelainen [108]	2014	All tantalum monobloc implants	1143	7	97%	No revision for loosening
Pulido [110]	2015	Fixed bearing PS	132	5	96.7%	No revision for loosening
Gerscovich [102]	2017	Fixed bearing CR	58	10.2	96.5%	2 tibial revisions
Kwong [104]	2014	Fixed bearing PS	115	7	95.7%	No revision for loosening

CR Cruciate retaining, *PS* Posterior stabilized

sidence of the component, so patient selection criteria for these implants continue to evolve [75]. The cost of this newly developed implant is still prohibitive.

39.3.8.3 Other Surface Coatings

Other porous osteoconductive coatings have recently been introduced for cementless TKA implants. Regenerex (Regenerex Biopharmaceuticals, USA) is a novel porous titanium construct with a three-dimensional porous structure and biomechanical characteristics close to that of normal trabecular bone. Biofoam (MicroPort Orthopedics Inc., Arlington, TN, USA) is a porous reticulated titanium material with a compressive modulus similar to that of native bone. Tritanium (Stryker Orthopedics, Kalamazoo, MI, USA) is a highly porous titanium surface coating manufactured using a 3D printing technology. Encouraging early results have been achieved with these coatings; however, longer follow-up is needed to define their value and justify the expense (Table 39.3).

Side Summary

Modern cementless designs with improved surface coatings have comparable outcomes to cemented implants.

Table 39.3 Outcomes of new porous coatings

Author	Surface coating	Year	Implant type	No. of patients	Follow-up (years)	Survival	Notes
Winther [114]	Regenerex	2016	Fixed bearing CR	61	2	n.a.	Similar clinical results with plasma sprayed implants
Waddell [112]	Biofoam	2016	Medial pivot CR	104	2	n.a.	One tibial radiolucency, no revision for loosening
Harwin [103]	Highly porous titanium	2017	Fixed bearing CR	219	4.4	99.5%	Outcomes and survival similar to periapatite coated implants
Nam [107]	Highly porous titanium	2017	Fixed bearing CR	38	1.4	n.a.	Early results similar to cemented implant of the same design

CR Cruciate retaining

39.3.9 Clinical Outcomes and Survivorship of Cementless TKA

The outcomes of large series and registry data for uncemented compared to cemented TKAs have reported conflicting results. Earlier registry data favor cemented implants with lower revision rates and higher implant survival. However, recent data with modern implants have shown similar results in systematic reviews and registry studies. The 13th Report of the National Joint Registry for UK and Wales including 737,759 patients showed a decline in the use of uncemented or hybrid knees compared to cemented implants [51]. In this dataset, the usage of uncemented/hybrid knees declined from 9.5% in 2003 to 2.7% in 2016. Cumulative revision rates of uncemented designs were still higher at 12 years for uncemented implants compared to cemented fixation (4.74% vs. 3.82%). The Swedish Knee Arthroplasty Register's 2016 Annual Report demonstrates no significant change in the use of cementless implants over the years [76]. However, cemented implants comprise more than 90% of arthroplasties. The cumulative rate of revision for uncemented tibias implanted before 1995 show a high rate of revision compared to cemented ones. However, this may be due to the failure of older cementless designs and may not reflect the performance of current implants.

In a meta-analysis of 3568 TKAs, Mont et al. found comparable survivorship for both types of fixation [77]. Survivorship at 10 years for cementless TKA was 95.6% compared with 95.3% for cemented TKA. At 20-years follow-up, implant survivorship had decreased to 76 and 71%, respectively. No difference was observed between fixation with or without screws. Petursson et al. compared 4585 hybrid TKAs to 20,095 cemented TKAs with risk of revision for any cause as the primary endpoint for the patients in the Norwegian Arthroplasty Register [78]. Survival at 11 years was 94.3% in the cemented TKR group and 96.3% in the hybrid TKR group. Depending on implant type, hybrid TKA performed equal to or better than cemented TKA. The National Joint Replacement Registry of the Australian Orthopedic Association's 2016 Annual Report finds lower cumulative rates of revision in hybrid TKA, compared to cemented and cementless implants (6.6%, 7.3% and 8.1%) at 15 years follow-up [79]. Constraint is another factor that should be taken into consideration as fixed bearing PS implants have lower rates of revision in cemented implants compared to uncemented ones. Wang et al. performed a comparative meta-analysis of registry data on cemented and uncemented fixation in TKA [42]. The method of fixation had no effect on the rate of infection. Pooled data of the registries showed a higher rate of revision for uncemented knees, although rates of aseptic loosening were similar.

Regional differences also play a role in the use of uncemented implants. An analysis in Nordic countries reveals that uncemented components are more frequent in Denmark (22%) than in Norway (14%) and Sweden (2%) [80]. This difference may be due to a variety of factors including training, surgical philosophy, availability of implants, and reimbursement.

Several conclusions can be drawn from registry data. Despite good results from specialized centers using newer generation uncemented implants, cemented fixation is still more frequently performed throughout the world for TKA. Hybrid fixation has been shown to be superior to either cemented or cementless fixation in two registry studies. Uncemented and hybrid implants perform better with mobile bearing and cruciate retaining designs, while cemented fixation is more durable for fixed bearing posterior stabilized implants. Newer implants with better geometry and coating may improve the results of uncemented fixation, but this has not been reflected in registry data that usually report the results of older designs.

Side Summary

Cemented fixation is still the most frequently performed type of fixation in TKA. Uncemented and hybrid implants perform better with mobile bearing and cruciate retaining designs, while cemented fixation is more durable for fixed bearing posterior stabilized implants.

39.4 Cemented Unicondylar Knee Arthroplasty

Cement fixation results in a more predictable fixation and survival in unicondylar arthroplasty. Excellent clinical outcomes have been reported at 10 years follow-up for both mobile and fixed bearing UKA [81, 82]. However, if designer series are excluded, registry-based studies indicate that the survival of UKAs are inferior to those of TKA. Niinimäki et al. reported on 4713 UKAs from the Finnish registry [83]. The survivorship of UKAs was 89.4% at 5 years, 80.6% at 10 years, and 69.6% at 15 years; the corresponding rates for TKAs were 96.3%, 93.3%, and 88.7%, respectively. The National Joint Registry of England reports similar results; the revision rate for unicondylar (medial or lateral UKR) is 2.9 times higher than the observed rate for all types of knee at 12 years [51].

Epinette et al. analyzed the modes of failure in a retrospective review of 418 revision UKAs in a multicenter French Society for the Hip and Knee study [84]. Eighty percent of the implants were fixed bearing UKAs and 85% of the implants had been cemented. The most common reason was aseptic loosening and 48% of them occurred during the first 5 years. Loosening of the tibial component was more frequent than the femoral implant. This highlights the importance of appropriate surgical technique, including precise bone cuts, good alignment/sizing, and cementation especially on the tibial side during surgery. Surgeon experience and volume are important factors for success in UKA. Registry studies have shown increased survival and lower revision rates with increased surgeon volume [85].

The limited exposure and working window increase the risk of retained cement in the posterior compartment in UKA. Excess cement should be avoided when placing the tibial component; most surgeons would apply a thin mantle of cement on the tibia but place cement only under the anterior half of the tibial component to prevent retained cement in the posterior compartment. The same is true for the posterior condyle of the femoral implant; only a thin layer of cement should be placed in the pocket of the implant to avoid retained cement in the difficult to reach posterior compartment (Figs. 39.7 and 39.8). Current instrumentation systems usually include curved hooks and dental pick like instruments to clean excess cement from the posterior compartment and adjacent to the medial collateral ligament (Video 39.2).

Biomechanical studies have shown a significantly higher wear rate of cement particles compared to bone debris [86]. Therefore, every effort should be made to avoid retained cement particles in UKA (Fig. 39.9).

Adding multiple drill holes to dense bone increases cement penetration and implant stabil-

Fig. 39.7 Very thin cement is placed on the posterior third of the tibial implant and posterior femoral condyles to avoid retained cement in the posterior compartment

ity in UKA [87]. Cementing to a flat surface without a possibility for cement interdigitation should be avoided. Pulsed lavage is also important in unicondylar arthroplasty to ensure adequate cement penetration. High pressure lavage is superior to syringe lavage for cement penetration. Jaeger et al. have shown that although cement mantle was adequate with both techniques, pulsed lavage led to an increased cement penetration distance and volume [8]. The same authors have shown less subsidence in biomechanical testing in cadavers when pulsed lavage was used in unicondylar arthroplasty [88]. Pulsed lavage is also helpful to decrease interface temperature between cement and bone. Cadaver studies have shown significantly lower interface temperatures in pulsed lavage specimens compared to syringe lavage (21 °C vs. 24 °C). However, both levels were far lower than thresholds for thermal damage [89].

In conclusion, cement fixation is still the gold standard for UKA. Meticulous surgical technique, focusing on precise sizing, bone cuts, ligament balance, and cementing technique is necessary to ensure a successful outcome.

Side Summary

Cement fixation is still the gold standard for UKA.

39.5 Cementless Unicondylar Knee Arthroplasty

Cementless fixation has also been used for UKA and offers the same advantages and drawbacks seen in cementless fixation of TKA. Cementless designs require a metal tibial tray, and this has

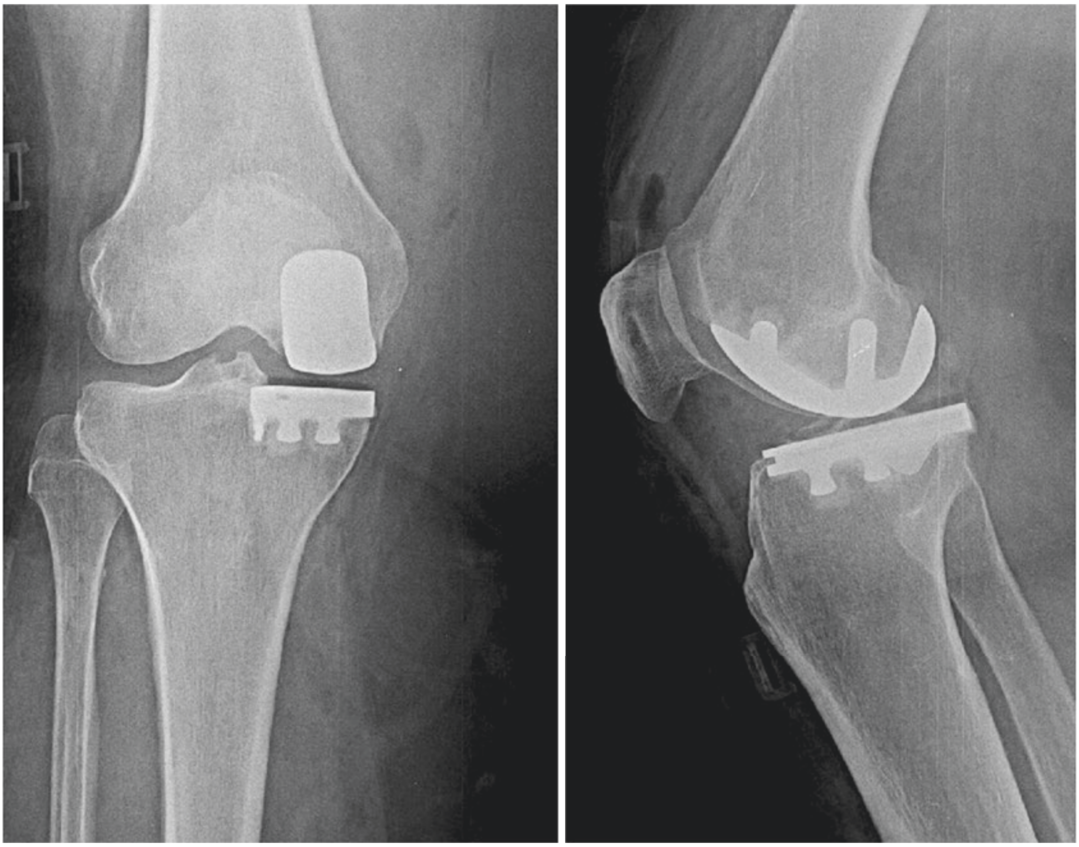

Fig. 39.8 Cemented fixed bearing medial unicondylar arthroplasty (ZUK, Zimmer). Cement is placed both on the bone and under the implants. Note minimal cement under the posterior femoral condyle

been criticized for requiring a more generous tibial cut and potentially sacrificing dense subchondral bone supporting the implant. However, Walker has shown that metal tibial trays show superior load distribution when using metal-backed implants compared to all-poly tibial components [90]. Metal-backed implants are also necessary if a mobile bearing design is used. Early cementless designs had an increased rate of revision at 10 years and fell out of favor [91]. Improvements in design and surface coatings have led to a resurgence of cementless fixation. Primary stability was improved with press-fit implantation followed by secondary stability with bone ingrowth/ongrowth into porous surfaces (Fig. 39.10).

Several studies have shown good outcomes of cementless UKAs at mid-term follow-up. Blaney reported on 238 cementless medial mobile bearing Oxford UKA [92]. No patient had progressive radiolucent lines or loosening at 5 years follow-up, and the cumulative survival rate was 98.8 % with only seven patients requiring revision. Six years follow-up results of 1000 mobile bearing cementless UKA were reported by Liddle et al. in a multicenter study [93]. 1.9% of the knees required revision; however, none were for tibial or femoral loosening. Implant survival at 6 years was 97.2%, and there was a partial radiolucency at the bone-implant interface in 72 knees (8.9%), with no complete radiolucencies. The authors could not find a specific contraindication to cementless unicondylar arthroplasty and found better radiological evidence of fixation in cementless implants compared to cemented ones.

RSA analysis of migration is an important tool to predict loosening. All cementless implants exhibit migration during the first 3 months until

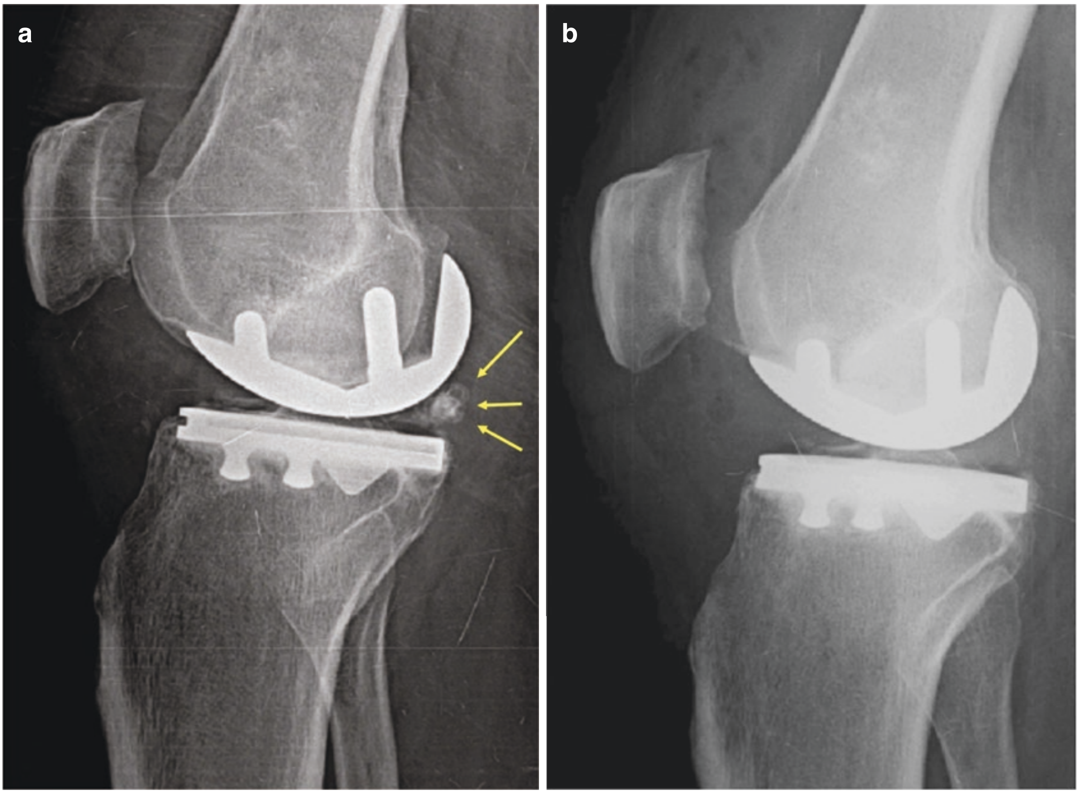

Fig. 39.9 (**a**) Retained cement in the posterior compartment after unicondylar arthroplasty causing mechanical symptoms. (**b**) Symptoms resolved after removal of the free cement particle

they stabilize at 1 year. Migration after 2 years is predictive for failure. In a comparative study of the same Oxford mobile bearing UKA, Kendrick et al. compared the migration of 43 cemented and cementless implants using RSA [94]. Femoral radiolucencies and tibial radiolucencies were significantly less in uncemented implants.

A recent meta-analysis evaluated the outcome of uncemented UKAs analyzing 10 studies including 1199 knees [95]. The 5-year survival ranged from 90 to 99% and the 10-year survival from 92 to 97%. The most common cause of revision was progression of OA in the unresurfaced compartment. The complication and revision rates were found to be similar with cemented implants. In a comparative systematic review of the survivorship of cementless 10,309 TKAs versus 2218 cementless UKAs, Van der List et al. showed better outcomes for UKA [96]. Aseptic loosening was more common in cementless TKA (25%) when compared to UKA (13%). The 5-, 10-, and 15-year survivorship of cementless UKA in this study were 96.4%, 92.9%, and 89.3%, respectively.

In conclusion, cementless fixation with modern designs have shown good mid-term results in UKA. Once durable fixation is achieved with cementless implants, aseptic loosening is not expected and other failure modes such as progression of OA in the contra-lateral compartment, dislocation (mobile bearings), and poly wear (fixed bearings) become an issue. Long-term follow-up studies are necessary to confirm the durability of cementless fixation.

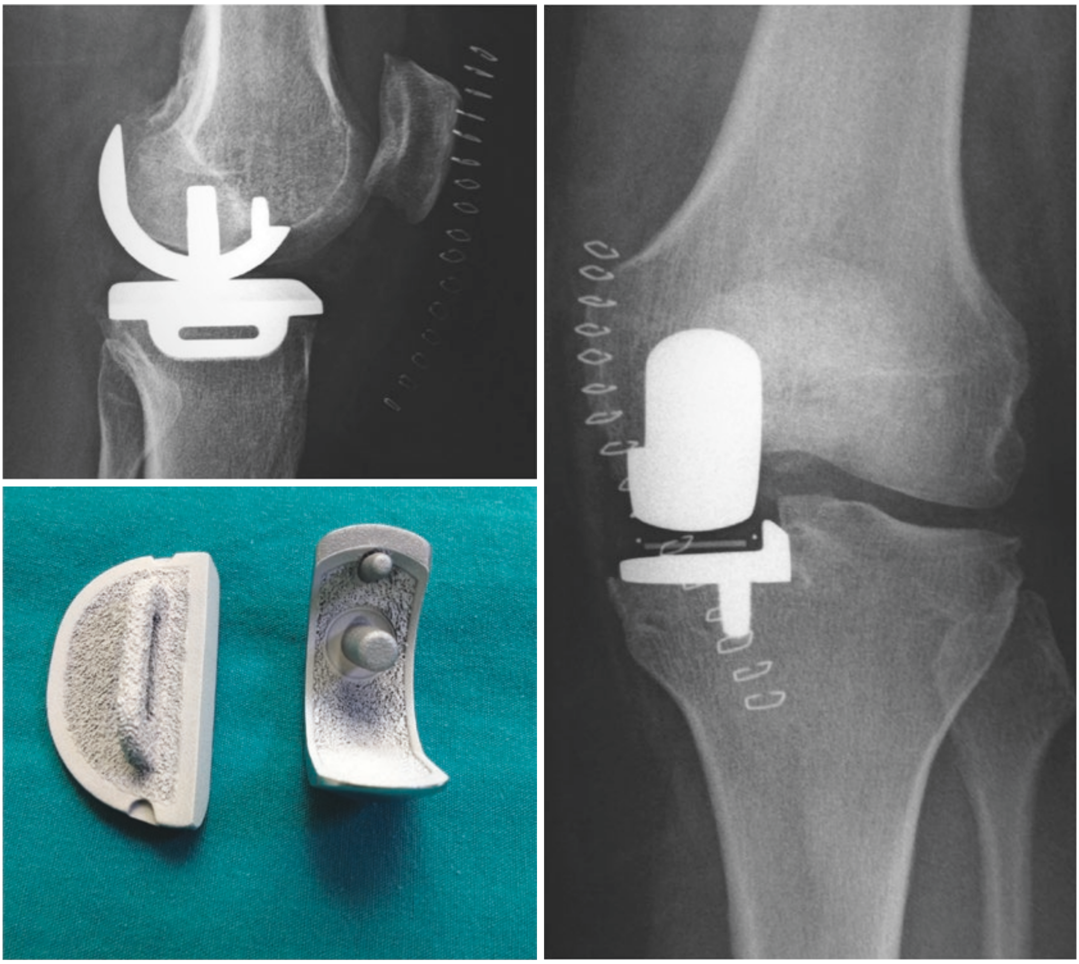

Fig. 39.10 Uncemented mobile bearing unicondylar arthroplasty. Note the porous-coated surface with keels and pegs for primary stability (Oxford Partial Knee with Porous Plasma Spray & HA coating, Zimmer-Biomet). (Figure Courtesy of Assoc. Prof. Burak Akan, Ufuk University, Ankara)

Side Summary

Cementless fixation with modern designs have shown good mid-term results in UKA. Once durable fixation is achieved with cementless implants, other failure modes such as progression of OA in the contralateral compartment, dislocation (mobile bearings), and poly wear (fixed bearings) are the determinants for revision.

Take Home Message

Cemented fixation is still the most widely used technique in knee arthroplasty. Meticulous surgical technique, including precise bone cuts, pulsed lavage, and avoidance of blood in the interface during implantation, is important to achieve adequate cement penetration. Early cementless designs had unacceptable failure rates, especially for the tibial and patellar components. Comparable short- to mid-term outcomes with cemented fixation have been reported with newer cementless implants with improved surface coatings and increased porosity. Cementless implants may be an attractive option in younger patients with good bone stock. However, cementless implants are more expensive, and superiority to cemented fixation in survival and outcomes have not been demonstrated at this time.

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