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Cementless knee arthroplasty: a review of recent performance

**A. Asokan,
R. Plastow,
B. Kayani,
G. T. Radhakrishnan,
A. A. Magan,
F. S. Haddad**

*From University College
Hospital, London,
United Kingdom*

Cementless knee arthroplasty has seen a recent resurgence in popularity due to conceptual advantages, including improved osseointegration providing biological fixation, increased surgical efficiency, and reduced systemic complications associated with cement impaction and wear from cement debris. Increasingly younger and higher demand patients are requiring knee arthroplasty, and as such, there is optimism cementless fixation may improve implant survivorship and functional outcomes.

Compared to cemented implants, the National Joint Registry (NJR) currently reports higher revision rates in cementless total knee arthroplasty (TKA), but lower in unicompartmental knee arthroplasty (UKA). However, recent studies are beginning to show excellent outcomes with cementless implants, particularly with UKA which has shown superior performance to cemented varieties. Cementless TKA has yet to show long-term benefit, and currently performs equivalently to cemented in short- to medium-term cohort studies. However, with novel concepts including 3D-printed coatings, robotic-assisted surgery, radiostereometric analysis, and kinematic or functional knee alignment principles, it is hoped they may help improve the outcomes of cementless TKA in the long-term. In addition, though cementless implant costs remain higher due to novel implant coatings, it is speculated cost-effectiveness can be achieved through greater surgical efficiency and potential reduction in revision costs. There is paucity of level one data on long-term outcomes between fixation methods and the cost-effectiveness of modern cementless knee arthroplasty.

This review explores recent literature on cementless knee arthroplasty, with regards to clinical outcomes, implant survivorship, complications, and cost-effectiveness; providing a concise update to assist clinicians on implant choice.

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Introduction

Knee arthroplasty is the preferred treatment of end-stage osteoarthritis (OA) with over 99,000 performed annually in the UK.¹ This includes approximately 90,000 total knee arthroplasties (TKAs) and 9,000 unicompartmental knee arthroplasties (UKAs) per year. The fixation method can vary between cemented, cementless, and hybrid implant systems. Cemented implants remain the most commonly used components for TKA, making up 86% of all primary knee arthroplasties in the UK.¹ Cemented TKAs have well-established long-term functional outcomes and excellent survivorship, with greater than 95% implant survivorship at minimum ten years follow-up.¹⁻³ However, multiple registries report higher rates of revision in younger patients secondary to aseptic

loosening, which has led to surgeons seeking better osseointegration and biological fixation to improve implant survivorship.^{4,5}

Cementless implant fixation in knee arthroplasty offers a number of conceptual benefits including: improved component fixation through direct osseointegration with the implant coatings, better preservation of the native bone stock, improved surgical efficiency and reduced systemic complications associated with cement impaction and debris wear.^{4,6} Cementless implants have also been shown to reduce the prevalence of radiological radiolucent lines (RLL), which may help to improve implant survivorship and reduce revision rates compared to cemented implants for UKA and TKA.⁷ These advantages have led to a number of high-volume centres selecting cementless over cemented

Correspondence should be sent to
Mr Ajay Asokan; email:
ajay.asokan@nhs.net

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UKA,^{1,8} with excellent patient-reported outcomes and implant survivorship of over 97% at minimum ten years follow-up.^{9,10} Over the last decade, evolution of implant design and materials have enabled TKA to follow a similar trend to UKA.

Critics of cementless implants for TKA and UKA cite potentially increased periprosthetic fracture rates,¹¹ femoral component fracture rates,¹² increased risk of aseptic loosening in the tibial component,¹³ and reduced long-term implant survival rates compared to their cemented counterparts.^{14,15} However, these studies were based on early implant designs, with rudimentary implant materials and limited contouring of implants to match the native osseous architecture. Recent advances in implant design, component materials and operative techniques, have improved implant survivorship compared to their predecessors, achieving ten- to 15-year survivorship of 96% to 100%.¹⁶⁻¹⁸

This comprehensive review provides an update on recent outcomes following cementless knee arthroplasty, primarily evaluating functional outcomes and implant survivorship; with additional evaluation of complications, novel technologies and alignment principles, and overall cost-effectiveness of cementless knee arthroplasty.

Methods

A comprehensive literature search was performed between the years 2000 and 2020 across three electronic databases – PubMed, Embase, and MEDLINE. Included search terms were: (total knee arthroplasty OR arthroplasty) AND (unicompartmental knee arthroplasty OR arthroplasty) AND (cementless OR uncemented). Bibliographies of relevant articles were searched for additional studies. Eligibility criteria included: 1) patients undergoing primary total or unicompartmental knee arthroplasty; 2) cementless implants; 3) reported outcomes including functional outcomes, and/or implant survivorship, and/or complications, and/or cost analysis. Studies not in the English language or without full text availability were excluded, as were studies before 2000 as they reported on previous generation cementless implants. All studies were divided between UKA and TKA, and outlined in Tables I and II, respectively.

UKA outcomes

Functional outcomes. UKA has proven to be an excellent procedure in both cemented and cementless variants, with superior functional outcomes to TKA.²⁶⁻²⁸ Advantages include shorter surgical time, reduced blood loss, retention of soft tissue structures, preservation of bone stock, and retention of native knee kinematics.²⁸⁻³³

A large body of the literature on UKA surrounds a mobile bearing unicompartmental implant, reported to have consistently excellent functional outcomes with cementless fixation.^{8-10,28,29,34-36} Recently, Mohammad

et al³⁷ reported their prospective results at ten-year follow-up of 1,000 cementless mobile bearing UKA. They used Oxford Knee Scores (OKS), Tegner Activity Scores, and American Knee Society Scores (Objective (KSS-O) and Functional (KSS-F)) to measure functional outcomes. At ten years, their mean OKS was 41.2, Tegner 2.8, KSS-O 89.1, and KSS-F 80.4, which were all significantly better to mean preoperative scores ($p < 0.0001$). Similar results were shown by Campi et al,¹⁰ who report seven-year results, on their prospective study analyzing functional outcomes of 1,000 consecutive cementless UKAs performed at two high-volume centres. They used the same mobile bearing unicompartmental implant as above. Their mean OKS improved from 23.2 preoperatively to 42.7 at seven years ($p < 0.001$). Similar excellent mid- to long-term results are shown in a number of other recent studies on cementless UKA.^{9,38,39}

There are limited studies comparing outcomes directly between cemented and cementless UKA. However, Pandit et al⁴⁰ performed a prospective study of 1,000 cemented UKA at ten-year follow-up, in a similar study to Mohammad et al,³⁷ with both studies performed at the same centre. They used the cemented version of the same mobile bearing unicompartmental implant, through a minimally invasive approach, and measured the same functional outcomes. At ten years, their mean OKS was 40, Tegner 2.7, KSS-O 80, KSS-F 76, and mean flexion angle 127°. They report 55% of patients having excellent outcomes (OKS > 41), and 10% having poor outcomes (OKS < 27). Both studies were very similar, and although lower functional outcome scores were found in the cemented UKA study, there is no statistical analysis between these two.

Cementless UKA may also be associated with faster return to activities. Panzram et al⁴¹ recently studied return to sports and level of activity following cementless UKA in a retrospective series of 228 UKA, with follow-up at two years in their independent, high-volume centre. In this series, 92.9% of all patients returned to sport, and of these, 64% within the first three months postoperatively.

Several National Joint Registries (NJR) have shown UKA to have higher revision rates to TKA in both cemented and cementless forms.¹⁻³ The same registries, however, have shown some cementless UKA to perform significantly better than cemented with regards to implant survivorship, citing progression of OA as the leading cause for revision in both fixation systems. Some studies have suggested cementless fixation is better suited for UKA,^{35,42} specifically through restoration of normal ligament tension with minimal implant constraint, which restores native kinematics producing compressive forces across components. These minimize the shear forces at the implant-bone interface, thus reducing aseptic loosening and failure.³⁵

Table 1. Summarised characteristics of UKA studies.

Study	Year	Implant	Study design	Mean age, yrs	Number of knees, cementless cemented		Outcomes	Main findings	Survivorship	Mean follow-up, yrs
Horvath et al ¹⁹	2020	HA-cementless vs cementless vs cemented	Meta-analysis	55.7 to 72.6	N/R	N/R	MTPM, KSS	HA significantly lower MPTM than cementless, but greater than cemented. No difference in KSS.	N/R	N/A
Toksvig-Larsen et al ²⁰	2020	3D-printed cementless vs cemented	Prospective cohort	Cementless 65, cemented 66	35	34	MTPM, KSS	Greater migration in Cementless in first three months. No difference in migration between groups after three months.	N/R	2
Chen et al ²¹	2019	Cementless vs cemented	Meta-analysis	51 to 61	229	255	KSS, ROM, pain score, RLL, aseptic loosening	KSS: N/S ROM: N/S Pain: improved in cementless. RLL: Improved in cementless. Aseptic loosening: N/S.	N/R	2 to 13.6
Fricka et al ²²	2019	Cementless vs cemented	RCT	Cemented 58.4, cementless 59.8	41	44	KSS, OKS, VAS, RLL,	KSS cemented 92.7. KSS cementless 89.3. OKS cemented 44.8 OKS Cementless 44.0	95.9% cemented, 95.3% cementless.	5
Dunbar et al ²³	2019	Cementless and cemented	Prospective Cohort	62	21	58	MTPM	Significant correlation between one and two years migration with long-term migration. No difference in long-term migration between cementless and cemented. Inducible displacement significantly higher in Cemented components.	N/R	2 and 12
Moric et al ²⁴	2019	Cementless - 3D-printed coating	Prospective Cohort	64	29		MTPM, KSS, KOOS, EQ-5D	Rate of migration largest over first six weeks postoperatively. No migration after six months. All PROM measurements showed significant improvement at final F/U.	N/R	2
Zhou et al ¹⁶	2018	Cementless vs cemented	Meta-Analysis	54.3 to 73	409	403	KSS, MTPM, WOMAC, ROM, RLL	No statistically significant difference across all outcomes	No statistically significant difference.	7.1
Kim et al ²⁵	2013	Cementless vs cemented	Prospective cohort	4	80	80	KSS, WOMAC, ROM, RLL	No significant difference across all outcome measures.	98.7% in cementless tibial component. 100% in all other components.	16.6

EQ-5D, Euro-Qol five-dimension index; F/U, follow-up; HA, hydroxyapatite; KOOS, Knee Injury and Osteoarthritis Outcome Score; KSS, Knee Society Score (Objective, Functional); MTPM, maximum total point motion; N/A, not applicable; N/R, not reported; N/S, not significant; OKS, Oxford Knee Score; PROM, patient-reported outcome measure; RCT, randomized controlled trial; RLL, radiolucent lines; ROM, range of movement; RTS, return to sport; UCLA, University of California, Los Angeles Activity Score; VAS, visual analogue scale; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

The aforementioned study by Campi et al¹⁰ prospectively reviewed 1,000 cementless UKA performed in two high-volume centres, and reported ten-year survivorship. When defining failure as revision for any cause, they report ten-year survivorship at 96.8% (95% confidence interval (CI) 93.1 to 100). Whereas using component failure (loosening, wear, component fracture) as the end-point, only one patient required revision producing a ten-year survivorship of 99.9%. Of the 25 (2.5%) patients who required revision, the most common cause was progression of lateral OA, in line with registry data. This is currently the largest published prospective study on cementless UKA, with extremely low incidence of failure from loosening, suggesting cementless UKA may have excellent osseointegration.

Mohammad et al⁹ undertook a pooled analysis of 8,760 cemented and 1,946 cementless UKAs, and reported ten-year survivorship was 92.7% and 95.5%, respectively ($p < 0.001$). The authors reported improved revision rates in cementless mobile-bearing UKAs relative to cemented,

but consistent revision rates among fixed-bearing UKAs regardless of cementation group. Similarly, Parratte et al⁴³ reviewed outcomes in 5,325 UKA (mobile- and fixed-bearing) for medial compartment OA and found overall component survivorship was 95% at ten-year follow-up.

Van der List et al⁴² reviewed outcomes from a series of prospective cohort studies, including 2,218 cementless UKA and reported extrapolated component survivorship at five, ten, and 15 years was 96.4%, 92.9%, and 89.3%, respectively. In 10,309 cementless TKAs, these values were 97.7%, 95.4%, and 93%, respectively.

Although a similar trend to registry data is reported, there are clear discrepancies between them and the higher reported survivorship in large cohort studies. This effect has been noted by several studies^{10,37,40,42}, and is hypothesized to be attributed to cohort studies often being performed at high-volume centres, which has a known positive influence on outcomes.⁴⁴⁻⁴⁶ Registry data does not differentiate between high- and low-volume surgeons. Nevertheless, there is an overall positive trend

Table II. Summarized characteristics of total knee arthroplasty studies.

Study	Year	Implant	Study design	Number of knees,			Outcomes	Main findings	Survivorship up, yrs	Mean follow-up, yrs
				Mean age, yrs	cementless	cemented				
Horvath et al ¹⁹	2020	HA-cementless vs cementless vs cemented	Meta-analysis	55.7 to 72.6	N/R	N/R	MTPM, KSS	HA significantly lower MPTM than cementless, but greater than cemented. No difference in KSS.	N/R	N/A
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of improved implant survivorship in cementless UKA relative to their cemented counterparts.

TKA outcomes

Functional outcomes. Unlike UKA, there is great paucity of prospective studies evaluating recent cementless TKA outcomes. Chen and Li²¹ performed a meta-analysis of six randomized controlled trials (RCTs)^{25,47-51} comparing cemented and cementless TKA in younger patients (aged ≤ 60 years), focusing on functional outcomes. There were 255 cemented, and 229 cementless prostheses with mean follow-up between two to ten years. They concluded cementless TKA to be vastly superior in pain scores and radiological outcomes (defined by the presence of RLLs), but performed equally to cemented TKA in functional outcome, range of movement, and aseptic loosening. Specifically, a significant improvement in pain with weighted mean difference (WMD) in pain score (visual analogue scale) of 3.029 (95% CI 5.119 to 0.939, $p = 0.005$). Additionally, cementless fixation was found to have KSS of equivalent or better (WMD -0.239; 95% CI -2.154 to -1.676; $p = 0.807$), and less incidence of

aseptic loosening (RD -0.001; 95% CI -0.030 to 0.028; $p = 0.946$), relative to cemented.

Fricka et al²² performed an RCT with five-year follow-up between 50 cementless (cementless femur CR flex design with a fibre metal mesh ingrowth surface and a cementless modular trabecular metal pegged tibia tray) and 50 cemented TKA (cemented precoat CR flex femur and a cemented precoat keeled tibia tray), both groups receiving the same polyethylene liner, resurfaced patella, surgical approach, and rehabilitation protocol. They found equivalent results between the two groups at five years when measuring KSS, OKS, and pain scores. The scores were: KSS 92.7 ± 12.5 in cemented, and 89.3 ± 14.2 in cementless ($p = 0.14$); OKS 44.8 ± 3.5 cemented, 44.0 ± 3.8 cementless ($p = 0.33$); and visual analogue scale (VAS) pain score at four months 1.6 ± 2.0 cemented, 2.1 ± 1.8 cementless ($p = 0.06$).

Horvath et al¹⁹ performed a meta-analysis of RCTs comparing specifically hydroxyapatite (HA) coated TKAs against other cementless and cemented implants. They concluded HA-coating provides better stability as measured by the maximum total point motion (MTPM)

of the tibial stem, assessed by radiostereometric analysis (RSA), in comparison to non-HA coated cementless implants (WMD = 0.28 mm, 95% CI 0.01 to 0.56, $p = 0.045$), but has worse stability than cemented fixation (WMD = -0.29, 95% CI -0.41 to 0.16, $p < 0.001$). Their secondary outcome measures were functional outcome assessed through KSS. They found the KSS of HA-coated cementless prostheses were not significantly different to other cementless implants (WMD = -0.64, 95% CI -3.02–1.73, $p = 0.596$), and similarly, there was no statistically significant difference between KSS of HA-coated and cemented implants (WMD = -0.29, 95% CI -2.27 to 1.69, $p = 0.775$).

The functional outcome data of cementless over cemented UKA is firmly established, with data in cementless TKA improving. Mid-term results show equivalent outcomes between cemented and cementless TKA, however there is a paucity of high-quality RCT data assessing long-term functional outcomes.

Implant survivorship. Traditionally, cementless TKA have exhibited worse implant survivorship than cemented equivalents; however, newer prostheses in the last decade have set to improve upon this. At present, both the UK and Australian NJRs report higher revision rates in cementless TKA over cemented.^{1,3} However, in the Australian NJR, they do note if a posterior stabilized implant is used, cemented implants have lower revision rates in the first 2.5 years, but after 4.5 years cementless implants display lower revision rates. As previously discussed in UKA, there continues to be discrepancies in outcomes between registry data and cohort studies, attributed to the amalgamation of high- and low-volume centre outcomes for cementless TKA.^{44,46}

At present, recent literature suggests cementless TKA performs equivalently to cemented TKA. Zhou et al¹⁶ performed a meta-analysis, which analyzed the survivorship between 409 cementless TKAs and 403 cemented TKAs with a range of follow-up between two and 17 years. The RCTs were published between 1998 and 2014. They found no significant difference in survivorship between cemented and cementless TKA at a mean follow-up of 7.1 years ($p = 0.25$).

Fundamentally, cemented TKA remains the preferred choice of implant with a long history of good results.^{15,52} However, increasing interest in cementless TKA surrounds the higher rates of failure in cemented TKA found in younger, obese and active patients.^{48,53–56} The UK NJR shows the ten-year survivorship across all types of knee arthroplasty is worse with younger age: 89% in age < 55 years, 94% in age 55 to 64 years, 96% in age 65 to 74 years, and 98% in age ≥ 75 years.⁵⁷ The mechanism in these patients is said to arise from increased sheer forces and stress at the bone-cement interface, thus leading to micromotion and aseptic loosening or osteolysis. The principle of cementless fixation relies on biological

fixation through excellent ingrowth of bone into the surface of the implant.⁵⁸ Salem et al¹⁷ concluded through their analysis of a number of cohort studies, cementless TKA is a viable treatment option in a variety of patient demographics including those: < 60 or > 75 years of age, were obese, had rheumatoid arthritis, or had osteonecrosis of the knee.

Kim et al²⁵ performed a prospective, randomized trial comparing cemented and cementless TKA in patients aged under 55 year. They performed simultaneous bilateral TKA in 80 patients (160 knees), with cemented fixation in one limb, and cementless in the other. Their mean age at operation was 54.3 years, and mean follow-up was 16.6 years. All procedures were performed by their senior author, with the same technique, anaesthetic, and rehab. They reported a 100% survival of both cemented and cementless femoral components, with one cementless tibial component requiring revision at one year post-operative due to aseptic loosening, meaning a 98.7% survival of the cementless tibial components. This study showed equivalent survivorship of cementless TKA with cemented in young patients.

With a lack of long-term high quality evidence in the literature, radiostereometric analysis represents an excellent surrogate for long-term migration and thus survivorship. Dunbar et al²³ studied the level of tibial component migration between 58 cemented, and 21 cementless TKAs, using RSA. They compared RSA results at one to two years, to those ten years later with mean follow-up of 12 years (10 to 14). Their measurement variable was MTPM, used to record both static and inducible tibial component migration (loaded single-leg stance). They report significant correlation between one to two year RSA findings with \geq ten-year follow-up findings ($p < 0.001$), with strongest correlation at two years for cementless components. Median overall migration at long-term follow-up was the same in both groups (0.6 mm, $p = 0.99$). However, inducible displacement at ten years was significantly higher for cemented components ($p < 0.001$), which leads to their conclusion of cementless fixation in TKA to offer equal if not superior long-term results to cemented. In addition, they outline two different migration patterns; cemented showing progressive migration over the long-term, whereas cementless fixation migrates the most in the first two years, but then stabilizes.

More recently, Toksvig-Larsen's group²⁰ performed a similar RCT using RSA between 36 cemented TKA and 36 novel 3D-printed cementless TKA. They compared mean MTPM at three, 12, and 24 months with results of 0.33 mm, 0.42 mm, and 0.47 mm, respectively in the cemented group, versus 0.52 mm, 0.62 mm, and 0.64 mm, respectively in the cementless group ($p = 0.003$). However, if three month results were used as baseline, they found no difference in mean migration between the

two groups ($p = 0.497$). Their conclusion parallels that of Dunbar et al,²³ in which cementless TKA show increased migration in the initial three months, which then stabilises. Other novel 3D-printed implants have shown similar results; Moric et al²⁴ in their prospective cohort study of 29 cementless TKAs with highly porous tibial baseplates, report largest tibial migration in the first six weeks post-operatively, but nil after six months. Parallel results have been shown in cemented implants with RSA studies reporting cemented TKA migrate less in the initial three months, but continue up to and beyond one year, which may be the reason for failure in younger patients.^{48,59} The literature shows good evidence that cementless implants exhibit increased rates of migration in the short-term (up to one year), but stabilize thereafter.^{47,60,61}

Fundamentally, although a number of encouraging recent studies suggest conceptual improvements in performance through reduced migration, and some cohort studies suggest equivalent survivorship; cementless TKA has yet to be proven to have better survivorship relative to cemented TKA in the long-term through level 1 studies or indeed the NJR. Unlike cementless UKA, there are insufficient high-quality prospective cohort studies comparing outcomes between fixation methods, and this would be a primary area of further research.

Complications

In UKA, aseptic loosening and progression of OA are the two most common forms of complications, quoted at 36% and 20%, respectively.⁶² However, specifically in cementless UKA, progression of lateral OA followed by dislocation are reported to be the most common complications, with notably reduced incidence of aseptic loosening.¹⁰ Similar results are shown by Blaney et al who report no incidence of aseptic loosening in their series of 238 cementless mobile-bearing UKA at five-year follow-up.⁶³

A risk of intraoperative fracture is a worry in all cementless arthroplasty, but is noted to be a rare complication, with a low incidence of 0.003% reported by Liddle et al¹¹ in their multicentre series of 1,000 cementless UKA. They note two risk factors: extended sagittal saw cuts, or breach of the posterior cortex upon tibial preparation, both of which would be reduced by higher volumes.

The positive effect of high volume centres is well noted, Mohammad et al's⁶⁴ analysis of the UK NJR reports low-volume surgeons had a higher revision rate in both cemented and cementless UKA ($p < 0.001$), with higher volumes showing ten-year survivorship of 97.5%, comparable to the best-performing TKAs. Additionally, they show cementless fixation decreases revision rate by 25%, regardless of volume ($p = 0.002$). Robotic-assisted surgery may be an avenue to increase reproducibility to allow low-volume UKA centres to achieve similar results to high-volume centres.⁶⁵

Cementless TKA exhibit a slightly different failure-mode profile to cementless UKA. In a series of 244 cementless TKA, Van Der List et al⁴² report 25% of failures due to aseptic loosening, with infection (16%) and instability (9%) the second and third most common. Cemented TKA show a similar failure profile, but with higher incidence of aseptic loosening at 31%.⁶⁶

Interest in cementless TKA has increased due to higher demand patients suffering increased failure rates from aseptic loosening in cemented TKA. Bagsby et al⁵⁵ demonstrate in their multicentre series of 292 morbidly obese patients (143 cementless vs 149 cemented), cementless TKAs have significantly lower revision rates compared to cemented TKA (0.7% vs 13%, $p < 0.001$), with the most common cause in cemented (5.8%, nine knees) secondary to aseptic loosening, and no incidence of this in the cementless group ($p = 0.005$). Whiteside and Vigano⁶⁷ concur in their study comparing 122 young, overweight patients with 122 older but normal weight patients. They report equivalent KSS and survivorship at a minimum of 5 years follow-up ($p < 0.03$), between cementless and cemented TKA, concluding cementless TKA is safe in young, overweight patients.

Prosthetic joint infection (PJI) is a major complication, and has been investigated to see if cementless arthroplasty can reduce the rates due to less operating time, as increased operating time is a known risk factor for infection. Anis et al⁶⁸ in their case-control study of 3,180 TKA which underwent matched (age, sex, body mass index, Charlson comorbidity index) analysis of 133 cementless TKA and 132 cemented TKA, found cementless TKA to take 17 minutes less (98 ± 26 vs 115 ± 37 minutes, $p < 0.001$), and no significant difference in infection rate (PJI and superficial surgical infection) between cemented and cementless TKA at two years follow-up.⁶⁸ Equally, Onggo et al found largely equivalent results between cemented, cementless and hybrid fixation in their meta-analysis of 12 RCTs (1,573 knees) looking solely at infection rates. They report on 926 knees from studies evaluating cemented versus cementless, and 646 knees from studies evaluating cemented vs hybrid. The mean follow-up was 10.25 years across all 12 RCTs. They conclude the infection rate was lowest among cemented TKA relative to cementless TKA (odds ratio (OR) 0.90, 95% CI 0.35 to 2.28). However, the rate of PJI requiring revision surgery was lowest in cementless TKA as compared to cemented (OR 0.89, 95% CI 0.30 to 2.41).

With aseptic loosening being the most common cause of failure in TKA, research moving forward should focus on minimizing this. In part, cementless techniques seek to solve this, but novel technologies with implant coatings and robotics will look to improve this further.

Alignment and robotics

Both functional alignment and robotic-assisted surgery are evolving concepts in knee arthroplasty, which have potential to improve clinical outcomes.

Functional alignment aims to reproduce a patient's natural kinematics to theoretically improve functional outcomes and survivorship.⁶⁹⁻⁷¹ Within cementless knee arthroplasty, functional alignment may improve corticocancellous contact of the tibial component, thus reducing subsidence of the tibial component. This subsidence into varus or valgus has been reported by a number of studies.^{22,72,73} Moran et al⁷⁴ reported a 19% failure rate at mean 64-month follow-up in a series of cementless total knee arthroplasties. They concluded that surgeons needed to maximize the tibial corticocancellous contact with the tibial component to reduce micromotion, subsidence and increase the area for ingrowth.

Arguably a principle cause for poor outcomes in cementless knee arthroplasty is poor surgical technique, due to the finer margins involved relative to cemented knee arthroplasty.^{37,64} This in part has allowed robotic-assisted arthroplasty to evolve and aim to equalize the gap between high- and low-volume surgeons. Studies have shown benefits in the short- to medium-term, of the efficacy of robotic-assisted TKA in improving both functional outcomes and survivorship,⁷⁵ in addition to causing less periarticular soft tissue trauma,⁷⁶ reduced postoperative pain, decreased analgesia requirements, and increased knee flexion at discharge.⁷⁷ The reduced soft tissue trauma may lead to faster recovery thus improving surgical efficiency. In addition, the Australian NJR reports robotic-assisted UKA have lower revision rates compared to manual UKA, and has been shown to reduce loosening, progression of disease and pain, but does increase revisions for infection³

Both concepts display promising results to date, and conceptually are well suited to cemented knee arthroplasty, although the lack of high-quality prospective trials does not allow for direct recommendation at present. However, this is an exciting area for future research, which should focus on RCT data comparing functional alignment and robotic-assisted surgery with their counterparts.

Cost-effectiveness

Traditionally, cementless implant design has proved more costly due to manufacturing costs of novel coatings applied to ensure osseointegration. However, recent studies have analyzed the overall costs including operating time, implant costs, cement and cement accessory costs to assess the true cost difference.

Lawrie et al's⁷⁸ recent RCT reviewed the cost differences between cemented and cementless TKA. They compared 67 cemented and 80 cementless TKAs, analyzing operative time (cost of \$36/minute), implant costs, cement,

and cement accessories. They report although cementless implants cost on average \$366 more than cemented, the total costs of cementation in addition to implant costs were \$588 to \$1,043, which outweighs the additional cementless implant costs. A similar outcome was reported by Yayac et al, who retrospectively analyzed itemised costs in 2307 cemented TKA and 119 cementless TKA. They report although cementless implant costs were higher (\$3,047 vs \$2,808); cementless TKA was associated with lower total costs (\$5,921 vs \$6,111). This was due to shorter operative time, lower supply costs, and no cement costs.⁷⁹ It is worth noting that the incremental time savings through not cementing over the course of an arthroplasty list may provide enough time to perform extra procedures.

A large retrospective analysis of the National Inpatient Sample database by Gwam et al⁸⁰ have found opposing results to the above. They reviewed 167,930 TKA (4,870 cementless vs 163,060 cemented), with primary outcomes of complications, length of stay, and inpatient costs. They report cementless TKA to have higher inpatient costs (\$17,357 vs \$16,888) and charges (\$67,366 vs \$64,190), but shorter inpatient stay with higher odds of being discharged to home. The authors concluded the higher charges may be secondary to patient selection, as they were used in younger, more active patients, predominantly under private insurance over public funding.

Overall, a holistic approach to costings must be taken. Although implant costs are greater in cementless, particularly with the advent of novel technologies, the overall procedural costs are lower. With greater uptake of the technology, inevitable economies of scale will follow, allowing further cost-savings. The benefits of surgical efficiency with cementless knee arthroplasty is clear; however, there is a lack of research evaluating the potential outpatient savings and reduced revision costs associated with cementless arthroplasty in appropriate patients, which would be an area for further research. Fundamentally, one must not use cost alone as a barrier to cementless TKA, as confirmed by studies in other healthcare economies.^{78,79,81,82}

Conclusion

Recent studies of cementless knee arthroplasty are beginning to encourage surgeons back to this technique. This article shows that cementless TKA performs as well as cemented in functional outcomes and survivorship, particularly when used in high-demand groups, with emerging evidence of superior performance. In cementless UKA, both functional outcomes and survivorship are strongly outperforming cemented UKA.

Complication rates of cementless knee implants are much improved upon their predecessors. New coatings and surgical techniques are improving osseointegration, thus reducing aseptic loosening risk. In addition, with

novel technologies such as 3D-printing and robotic-assisted arthroplasty, we will hopefully see these outcomes improve further.

At present, the cost of cementless implants remains higher than cemented. Some studies have shown greater overall cost effectiveness with cementless implants through greater surgical efficiency, and reduced peripheral costs. However, there is a lack of high-quality data which evaluates long-term cost analysis, including potentially reduced revision rates and better functional outcomes.

There are a number of areas for further research, with the literature primarily lacking in high-quality evidence for long-term outcomes to clearly answer whether cementless knee implants improve functional outcomes and implant survivorship. There is greater paucity surrounding outcomes in cementless TKA than UKA. Greater long-term RCT evidence comparing both fixation methods is required to justify the use of cementless knee arthroplasty. Additionally, analysis of the true cost-effectiveness of cementless knee arthroplasty can only occur once a holistic overview including survivorship and revision rates are taken into account.



Take home message

- Cementless knee arthroplasty has shown promising results in total knee arthroplasty (TKA) and unicompartmental knee arthroplasty (UKA). However, long-term randomized controlled trial evidence of cementless TKA is yet awaited.
- Cementless knee implants remain of higher cost, though cost-effectiveness may be gained through potentially lower revision rates and improved functional outcomes in the longer-term.
- Cementless knee implants are a viable choice in younger and high-demand patient groups.

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Author information:

- A. Asokan, MBBS, BSc (Hons), MRCS, Clinical Research Fellow
- R. Plastow, FRCS (Orth), Senior Clinical Fellow
- B. Kayani, MBBS, BSc (Hons), MRCS, Specialty Trauma & Orthopaedics Registrar
- G. T. Radhakrishnan, MBBS, BSc (Hons), MRCS, Clinical Research Fellow
- A. A. Magan, FRCS (Orth), Senior Clinical Fellow
- F. S. Haddad, BSc, MD (Res), FRCS, Professor of Orthopaedic Surgery
Department of Trauma and Orthopaedic Surgery, University College Hospital, London, UK; Department of Orthopaedic Surgery, The Princess Grace Hospital, London, UK.

Author contributions:

- A Asokan: Devised, researched, wrote and edited the manuscript
- R Plastow: Wrote and edited the manuscript
- B Kayani: Prepared the manuscript.
- G.T Radhakrishnan: Prepared the manuscript.
- A.A Magan: Edited the manuscript.
- F.S Haddad: Hypothesis generation, prepared manuscript.

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