Arthroplasty Today 27 (2024) 101360

Contents lists available at ScienceDirect

Arthroplasty Today

journal homepage: http://www.arthroplastytoday.org/

Original Research

Cemented vs Cementless Robotic-Assisted Total Knee Arthroplasty Yield Similar Short-Term Clinical Outcomes

David Molho, MD[a], Swaroopa Vaidya, MS[b,*], David O'Sullivan, PhD[c], Dianne Vye, MSN, RN, ONC[a], Stephen Nelson, MD[a], Jenna Bernstein, MD[b]

[a] Connecticut Orthopaedic Institute, MidState Medical Center, Hartford Healthcare, Bridgeport, CT, USA
[b] Connecticut Orthopaedic Institute, St. Vincent's Medical Center, Hartford Healthcare, Bridgeport, CT, USA
[c] Hartford HealthCare Research Program, Hartford Healthcare, Hartford, CT, USA

A R T I C L E I N F O

Article history:
Received 24 October 2023
Received in revised form
4 January 2024
Accepted 27 February 2024
Available online xxx

A B S T R A C T

Background: In primary total knee arthroplasty (TKA), there is ongoing controversy about optimal fixation (cemented vs cementless). Cemented TKA remains the gold standard, with the largest body of long-term evidence available to support it. However, cementless TKA implants are gaining popularity due to potential biomechanical advantages and a growing body of literature supporting survivorship. Due to paucity of literature investigating fixation methods in robotic-assisted TKA (Ra-TKA), we aim to compare clinical outcomes of cementless Ra-TKA with those of cemented Ra-TKA.
Methods: This is a retrospective cohort study of patients who underwent Ra-TKA by 19 surgeons comparing results of cases using cementless vs cemented fixation. We observed short-term complications, emergency room visits, and readmissions. We collected patient-reported outcomes measurement information system and knee injury and osteoarthritis outcome scores preoperatively and 12 weeks after surgery.
Results: A total of 582 TKA cases were included: 335 cementless and 247 cemented. The patients in the cementless group were younger and had a higher body mass index. The cemented group had a higher rate of return to the operating room, with manipulation under anesthesia for stiffness being the most common indication in both groups. There were no statistically significant differences in 30-day readmissions, 90-day emergency room visits, or patient-reported outcomes.
Conclusions: Our retrospective study demonstrated higher return to operating room in the cemented group vs the cementless group. We reported no differences in any other short-term outcomes between the cementless and cemented Ra-TKA. Our data support efficacy and safety of cementless Ra-TKA at 3-month follow-up.

Introduction

Aseptic loosening remains the most common indication for revision surgery in the United States [1] and according to worldwide registry data [2]. According to worldwide registry data pooled in a study in 2016, the 10-year risk of revision after total knee arthroplasty (TKA) is 5%, with aseptic loosening accounting for 30% of revisions [2]. Obesity and younger age are known risk factors for aseptic loosening [3].

Cementation is considered the current gold standard for fixation [4,5], supported by the largest body of long-term evidence [6]. However, the optimal fixation for TKA remains controversial [7]. The theoretical advantage of cementless fixation in TKA is that it relies on osseointegration; once this occurs, the only mechanisms for loosening are osteolysis or sepsis [6]. In cemented TKA, the tibial bone-cement interface is vulnerable to failure with cyclical loading, especially in obese, young patients [7,8]. Abdel et al. showed increased risk for tibial aseptic loosening in cemented TKA patients with a body mass index $\geq$35 kg/m^2 even with well-aligned components [9]. Many studies have shown equivalent survivorship between cemented and cementless TKA [7,8,10,11]. Smaller, shorter-term studies have shown improved survivorship of cementless TKA in morbidly obese patients [12,13].

* Corresponding author. 2800 Main Street, Bridgeport, CT 06606, USA. Tel.: +1 475 210 4287.
E-mail address: swaroopa.vaidya@hhchealth.org

https://doi.org/10.1016/j.artd.2024.101360

The computerized tomography−based robotic-assisted system MAKO system (Stryker, Mahwah NJ) became available in 2016. Robotic-assisted TKA (Ra-TKA) has gathered momentum as a method to improve surgical accuracy and patient outcomes [14]. The data comparing Ra-TKA to conventional TKA have mixed results; many of these studies have small sample sizes and short-term follow-up intervals [14]. Several studies have demonstrated improved postoperative pain scores, functional outcomes, and diminished inpatient opioid requirements with Ra-TKA compared to conventional TKA [15-19]. A PRISMA systematic review on MAKO system demonstrated reduced analgesia requirements during the hospitalization and lower 90-day episode of care costs compared to conventional TKA [20]. However, larger studies have not consistently replicated these differences; a randomized controlled trial with 10-year follow-up showed no differences in outcomes between conventional TKA and Ra-TKA [21]. According to the American Academy of Orthopedic Surgeons clinical practice guideline from 2022 commenting on robotic vs conventional TKA, strong evidence shows “no difference in function, outcomes, complications in the short term.” [22]

To date, only one study has compared cementless Ra-TKA to cemented Ra-TKA [23] and they found no differences in survivorship or complication. This study was a single-surgeon series comparing 72 cemented cases to 380 cementless Ra-TKA. The aim of our study was to replicate this study with multiple surgeons and a larger cohort, comparing clinical results, survivorship, and complications in Ra-TKA cementless vs Ra-TKA cemented. Our hypothesis was that our study would have results similar to those of McCormick et al. [23], showing no significant differences in short-term outcomes.

Material and methods

Our design was a retrospective cohort study of patients who underwent Ra-TKA by 19 arthroplasty surgeons at either of 2 hospitals within the Hartford HealthCare System in Connecticut, United States. These hospitals are part of the Connecticut Orthopaedic Institute in which protocolization is replicated between the sites. Cases were performed from January 2022 to March 2023. Institutional review board approval was obtained. The case list was extracted retrospectively from monthly reports that were issued as a part of clinical practice. Inclusion criteria were patients of any gender, race/ethnicity, and at least 18 years of age who underwent primary Ra-TKA. Exclusion criteria were body mass index >50 kg/m^2 or concurrent surgical procedure at the time of TKA. Data were extracted from medical records and included patient demographics, fixation method during Ra-TKA (cementless vs cemented), in-hospital complications, 30-day readmissions, 90-day emergency room visits, and reoperation. We also recorded patient-reported outcomes preoperatively and 12 weeks after surgery via the patient engagement platform used at Connecticut Orthopaedic Institute.

Patient-reported outcomes

Patient-reported outcomes were collected as a part of routine practice. The Knee injury and Osteoarthritis Outcome Score for joint replacement is a validated, widely used, patient-reported outcome created using 7 items from the original, longer Knee injury and Osteoarthritis Outcome Score survey. Raw responses are summed and converted to a score from 0-100 using a table; a score of 0 denotes “total knee disability,” whereas a score of 100 denotes “perfect knee health.” [24]

The patient-reported outcome measurement information system is a widely available, validated assessment that observes physical health, general mental health, and generalized satisfaction with quality of life. It consists of 10 items and yields a score up to 20, with higher values indicating a better positive quality of life [25].

Robotic-assisted TKA

All cases were performed using the MAKO robotic arm and used the Stryker Triathlon Knee components which has cementless (as shown in Fig. 1) and cemented implant options (Stryker, Mahwah NJ). MAKO robotics requires a preoperative computerized tomography scan and 4 pins to be placed to support the arrays (2 tibial, 2 femoral pins). There are either 4.0-mm or 3.2-mm pins available from the manufacturer; selection is based on surgeon preference. The tibial pins are typically placed distal to the TKA incision through 2 small incisions, although per surgeon preference they may be placed intraincisionally. The femoral pins may be placed proximal to the TKA incision through 2 anterior thigh small incisions or may be placed in the medial metaphyseal femoral bone through the standard TKA incision. After exposure is performed, the tibia and femur are registered and matched to the computerized tomography scan using probes. Prior to making bone cuts, the ligaments are tensioned. The planned position of the femoral and tibial components may be modified precisely in any plane using the computer software operated by a Stryker technician, with the goal of creating balanced gaps, selecting appropriate sizing, and position. The robotic arm is attached to the saw which guides the planned cuts without any cutting blocks. Care must be taken to protect soft-tissue structures. The robotic arm is pulled away from the field and trialing proceeds. If desired, the robotic arm may be reintroduced, and adjustments may be made to any cut by changing the planned position of components on the computer system. If the patella is resurfaced, it is performed manually without the robotic arm. The femoral and tibial cuts for both cementless and cemented components are identical, so the surgeon may decide to use cementless vs cemented components at any point during the case. The decision to use cementless vs cemented was at the discretion of the surgeon and the reason was not documented. Due to the retrospective nature of the study, there were no predetermined criteria to make the decision between cementless and cemented implants.

Postoperative care

Both hospitals included in the study are of high volume, certified total joint centers with standardized protocols and order sets. The majority of patients received preoperative nerve blocks, local anesthesia intraoperatively, and multimodal pain control postoperatively. Spinal anesthesia is used when possible. There is emphasis on early physical therapy and home discharge when appropriate.

Statistical analysis

Power analysis was performed prior to data collection and a sample of 582 was found to be necessary for 80% power. Continuous variables were analyzed using independent sample *t*-test (normal distribution was confirmed). Categorical variables were analyzed using Pearson *Chi*-square test. Significance level was set at a *P* value of .05. All analyses were generated with SPSS v. 26 (IBM; Armonk, NY 2019).

Results

Demographics

The demographics of our study sample are described in Table 1. A total of 582 TKAs performed; 335 cementless and 247 cemented.

Table 1
Demographics.

Variable (unit)	Total cases (n = 582)		P value
	Cementless cases (n = 335)	Cemented cases (n = 247)	
Age, y (mean ± SD)	67.3 ± 8.7	72.0 ± 8.7	<.001[a]
BMI, kg/m^2 (mean ± SD)	32.2 ± 5.2	30.6 ± 5.4	<.001[a]
Gender %			
Female	50.7	70	<.001[a]
Male	49.3	30	
Other	0	0	
ASA class %			
I	1.2	0.8	.551
II	46.9	44.9	
III	50.4	51.8	
IV	0.3	1.2	
Insurance type %			
Commercial	35.8	25.9	.012[a]
Managed Medicare	35.2	36	
Medicaid	5.7	4.5	
Medicare	22.4	33.2	
Race %			
Black/African-American	11.6	5.3	.045[a]
Hawaiian/Pacific Islander	0.9	0.8	
White	75.8	78.9	
Asian	0.6	1.6	

ASA, American Society of Anesthesiologists; BMI, body mass index; SD, standard deviation.
Age and BMI reported with *t*-test; gender, ASA class, Insurance type, Race reported with *Chi*-squared test.
[a] Denotes statistical significance at $P < .05$.

Table 2
Patient-reported outcomes.

Variable	Cementless	Cement	P value
PROMIS Global preop	121, 35.3 ± 5.9	141, 34.3 ± 6.6	.087
PROMIS Global 3 month	116, 37.1 ± 5.5	143, 37.9 ± 5.9	.183
KOOS preoperatively	123, 51.9 ± 11.4	139, 53.5 ± 13.3	.161
KOOS 3 mo	117, 67.9 ± 11.0	140, 69.5 ± 12.5	.149
Pain score preoperatively	250, 5.9 ± 2.1	201, 5.7 ± 2.1	.114
Pain score 3 mo	228, 2.9 ± 2.1	196, 2.6 ± 1.8	.151
PROMIS difference	112, 2.0 ± 6.3	127, 3.3 ± 5.5	.088
KOOS difference[a]	112, 16.3 ± 14.1	124, 16.2 ± 15.2	.976
Pain score difference[a]	219, 3.1 ± 2.5	180, 3.0 ± 2.3	.996

KOOS, knee injury and osteoarthritis outcome score; PROMIS, patient-reported outcome measurement information system.
All values n, mean ± SD.
[a] Differences were calculated based on 3-month score minus preoperative score; negative values mean the 3 month score was lower than that preoperatively.

The cementless group was significantly younger than the cemented group (mean age 67.3 ± 8.7 years vs 72.0 ± 8.7 years; $P < .001$). The cementless group had a higher body mass index than the cemented group (32.2 ± 5.2 kg/m^2 vs 30.6 ± 5.4 kg/m^2, $P < .001$). The overall sample was 58.9% women. Sixty-nine percent of men received cementless implants, whereas 49.6% of women received cementless implants (χ^2 (1,N = 582) = 21.9, $P < .001$). The distribution of insurance coverage is shown in Table 1. The percent of patients with commercial insurance that received cementless implants was the highest (65.2%), followed by Medicaid (63.3%), managed Medicare (57.0%), and standard Medicare (47.8%) (χ^2 (3,N = 582) = 11.0, P = .012). The frequency of White/Caucasian patients in our sample was highest (87.7%), followed by Black/African American (10.2%), Asian (1.3%), and Hawaiian/Pacific Islander (1.0%). There were differences in frequency of cementless TKA by race: 75% of Black/African American patients received cementless implants, followed by 60% of Hawaiian/Pacific Islander, 56.6% of White/Caucasian patients, and 33.3% of Asian patients (χ^2 (3,N = 582) = 8.0, P = .045).

Patient-reported outcomes

There were no differences between cementless and cemented groups in preoperative patient-reported outcomes and 3-month patient-reported outcomes. There were also no differences in the change between preoperative and 3-month patient-reported outcomes (see Table 2).

Complications, readmissions, discharge disposition

There were no differences between cementless and cemented groups in 30-day readmissions, 90-day return to the emergency room, nor discharge disposition (see Table 3). There were 9 cases with a 30-day readmission: 5 (1.5%) in the cementless group and 4 (1.6%) in the cemented group (P = .880). The 90-day return to ED rate was 6.6% in the cementless group and 6.9% in the cemented group (P = .496). The majority of patients in both groups were discharged home with or without home health services. In the cementless group, 3.6% of cases resulted in discharge to a skilled nursing facility, and in the cemented group 4.9% of cases resulted discharge to a skilled nursing facility (P = .438).

Return to the operating room

There were 13 reoperations performed on the cemented group and 6 reoperations performed on the cementless group. The cemented group had a significantly higher rate of return to the operating room compared to the cementless group (χ^2 (1,N = 582) = 5.4, P = .020). Stiffness treated with manipulation under anesthesia (MUA) was the most common indication for return to the operating room in both groups – the MUA rate in the cementless and cemented groups was 0.9% and 2.8%, respectively (see Table 4). Four superficial irrigation and debridements were performed for superficial wound complications, none of which involved opening the fascial layer and exchanging hardware. There was a 2-week postoperative periprosthetic femur fracture in the cemented group which was treated with a retrograde nail. There was one medial epicondyle femur fracture in the cemented group that was fixed acutely and required a removal of hardware 6 weeks postoperatively due to prominent screws. In the cementless group, there was one revision for patellar maltracking. One patient in the cementless group suffered an acute popliteal vein deep vein thrombosis 1 week postoperatively, which was treated with an inferior vena cava filter.

Discussion

In our retrospective cohort, we found that the cemented group had a higher rate of return to the operating room than the cementless group (1.8% vs 3.3%). This differs from the single surgeon study by McCormick et al., which found no differences [23]. The most common indication for return to the operating room in both groups was MUA for stiffness. The MUA rate in the cementless vs cemented group was 0.9% vs 2.8%, respectively. There were 3 superficial wound complications in the cemented group and 1 in the cementless group. Other indications for return to OR in the cemented group included a periprosthetic femur fracture and a medial epicondyle fracture fixation that required removal of hardware. The cementless group had 1 revision for patellar maltracking and 1 patient who required an inferior vena cava filter for an acute deep vein thrombosis. These results are challenging to interpret because the characteristics of each group differ: the cementless group had a higher proportion of young patients, male

Table 3
Complications, readmissions, discharge disposition.

Variable	Number of patients		P value (χ^2)
	Cementless	Cemented	
30-d readmission			
No	330	243	.880
Yes	5	4	
90-d return to ER			
No	313	230	.496
Yes	22	17	
Discharge disposition			
Home/Home health	323	234	.438
Skilled nursing facility	12	12	

ER, emergency room.

patients, and obese patients. It is not appropriate to attribute these differences to the implant choices.

We found no differences in patient-reported outcomes between cementless and cemented Ra-TKA. Surprisingly, we found that the majority of the cases at our institution that were being done using robotic technology also were using press fit technology. Our study's results are similar to the results of the only other study comparing cementless vs cemented Ra-TKA, which was a single surgeon series [23]. Our series included 19 surgeons between 2 hospitals within a single healthcare system and had a larger patient population.

Cementation remains the "gold standard" for TKA implant fixation due to its reliable track record and large body of long-term evidence supporting its use [5,7,26]. However, the debate on the optimal fixation method for TKA remains ongoing. Many large studies show no differences in outcomes between cementless and cemented TKA [7,8,10,11,27,28]. A systematic review and meta-analysis with 7 studies and a mean follow-up of 7 years found no differences between cemented and cementless TKA [29]. Cementation in TKA is advantageous in patients with poor bone quality; it offers immediate fixation and allows the ability to add antibiotics in complex cases [30]. Aseptic loosening, one of the most common causes of TKA revision [1,2], may occur at the bone cement interface or the metal implant may debond from the cement [30].

Cementless TKA has been of interest due to the theoretic ability to achieve bony ingrowth and a more durable biologic fixation [23,30]. The 1980s and 1990s saw the emergence of cementless TKA implants which had early failures with ingrowth, and were susceptible to osteolysis, [23,26,30] particularly at the tibial implant [30]. TKA patients are getting younger, more obese, and more active, [7,30] which increases our need for durable, long- term fixation. Despite the studies listed previously showing equal survivorship between cementless and cemented TKA, some studies have shown increased survivorship of cementless TKA in morbidly obese patients [12,13]. As cementless TKA use increases, the body of evidence describing its long-term outcomes will continue to grow.

Table 4
Return to OR.

Reason for return to OR	Number cases with return to OR	
	Cementless (n = 6)	Cemented (n = 13)
MUA for stiffness	3	7
Superficial irrigation and debridement	1	3
Periprosthetic fracture	-	1
Removal of hardware	-	1
Revision for patellar maltracking	1	-
IVC filter insertion for DVT	1	-

DVT, deep vein thrombosis; IVC, inferior vena cava; MUA, manipulation under anesthesia.

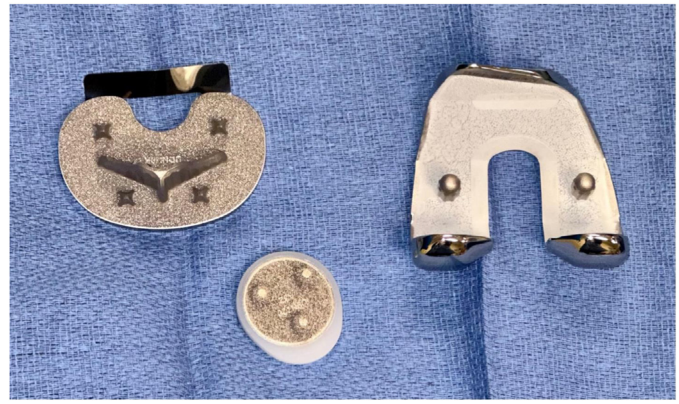

Figure 1. Photograph demonstrating the porous titanium coating on the undersurface of the cementless femoral, tibial, patellar components. The porous titanium surface is added layer by layer to the baseplate using focused laser. The mean porosity of the tibial baseplate is 68%.

The benefits of robotic-assisted TKA vs conventional TKA are mixed in the literature. The American Academy of Orthopedic Surgeons clinical practice guideline updated in 2022 affirms using "strong evidence" that there is no difference in function, outcomes, complications in the short term between Ra-TKA and conventional TKA [22]. Ra-TKA improves the accuracy of implant position [31] and has been shown to improve radiologic outcomes [32], but this has not consistently shown better functional or clinical outcomes in larger studies [21,31-34]. Despite these findings, there are studies showing less postoperative pain, better functional outcomes, and diminished opioid requirements with Ra-TKA vs conventional TKA [15-19]. Our study did not compare Ra-TKA to conventional TKA, which is an important direction for future research.

Limitations of this study include the retrospective design; patients are not randomized which introduces selection bias into the data. There were no consistent criteria to determine whether cementless implants were used – the decision-making by each of the 19 surgeons in the study group varied. Certain surgeons made decisions preoperatively based on characteristics such as patient age, gender, or deformities; others decided based on bone quality during surgery. This created inconsistency, variability and bias within our data set which is a significant limitation. Our data did not include data on pain scores or medication usage within the first several weeks after surgery which would have been valuable.

Additionally, we did not include data on cruciate-retaining vs posterior stabilized implants, which may be an undetected confounding variable. We also did not include data on tourniquet usage. Our follow-up was short term, so we are not able to make any inferences about long-term survivability. It will be important to follow these patients in the long term to see whether cementless robotic TKA provides an optimal construct.

There are surgeons who believe that performing cementless TKA using robotics may optimize the accuracy of cuts and may result in longer survivorship compared to cemented robotic TKA or manual cementless TKA, but longer follow-up will be needed.

Conclusions

Our retrospective review with short-term follow-up at 3 months showed a higher rate of return to the operating room in the cemented group vs the cementless group. This likely reflects the differences in the characteristics of the groups. There were no patient-reported outcome differences between cementless Ra-TKA and cemented Ra-TKA. Further research is needed to observe the long-term differences between these fixation methods and how they are affected by robotic-assisted techniques. Longer term results are needed to see if there is any difference in survivorship.

Conflicts of interest

Jenna Bernstein reports being a paid consultant for and a part of speakers bureau/paid presentations for Smith & Nephew and Depuy Synthes; received research support from Stryker; and a part of board member for AAKHS, AAOS, EOA, and CT Ortho Society. All other authors declare no potential conflicts of interest.

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2024.101360.

CRediT authorship contribution statement

David Molho: Writing – original draft, Investigation. **Swaroopa Vaidya:** Writing – review & editing, Validation, Methodology, Data curation. **David O'Sullivan:** Writing – review & editing, Software, Formal analysis. **Dianne Vye:** Writing – review & editing, Validation, Data curation. **Stephen Nelson:** Supervision, Conceptualization. **Jenna Bernstein:** Writing – review & editing, Supervision, Conceptualization.

References

[1] Vasarhelyi EM, Petis SM. Use of national joint registries to evaluate a new knee arthroplasty design. J Arthroplasty 2020;35:413–6.
[2] Khan M, Osman K, Green G, Haddad FS. The epidemiology of failure in total knee arthroplasty: avoiding your next revision. Bone Joint J 2016;98-B:105–12.
[3] Carr AJ, Robertsson O, Graves S, Price AJ, Arden NK, Judge A, et al. Knee replacement. Lancet 2012;379:1331–40.
[4] Ranawat CS, Meftah M, Windsor EN, Ranawat AS. Cementless fixation in total knee arthroplasty: down the boulevard of broken dreams - affirms. J Bone Joint Surg Br 2012;94(11 Suppl A):82–4.
[5] Nugent M, Wyatt MC, Frampton CM, Hooper GJ. Despite improved survivorship of uncemented fixation in total knee arthroplasty for osteoarthritis, cemented fixation remains the gold standard: an analysis of a national joint registry. J Arthroplasty 2019;34:1626–33.
[6] Dalury DF. Cementless total knee arthroplasty: current concepts review. Bone Joint J 2016;98-b:867–73.
[7] Chen C, Li R. Cementless versus cemented total knee arthroplasty in young patients: a meta-analysis of randomized controlled trials. J Orthop Surg Res 2019;14:262–75.
[8] Nam D, Lawrie CM, Salih R, Nahhas CR, Barrack RL, Nunley RM. Cemented versus cementless total knee arthroplasty of the same modern design: a prospective, randomized trial. J Bone Joint Surg Am 2019;101:1185–92.
[9] Abdel MP, Bonadurer GF, Jennings MT, Hanssen AD. Increased aseptic tibial failures in patients with a BMI ≥35 and well-aligned total knee arthroplasties. J Arthroplasty 2015;30:2181–4.
[10] Goh GS, Fillingham YA, Sutton RM, Small I, Courtney PM, Hozack WJ. Cemented versus cementless total knee arthroplasty in obese patients with body mass index ≥35 kg/m(2): a contemporary analysis of 812 patients. J Arthroplasty 2022;37:688–693.e1.
[11] Yazdi H, Choo KJ, Restrepo C, Hammad M, Sherman M, Parvizi J. Short-term results of triathlon cementless versus cemented primary total knee arthroplasty. Knee 2020;27:1248–55.
[12] Sinicrope BJ, Feher AW, Bhimani SJ, Smith LS, Harwin SF, Yakkanti MR, et al. Increased survivorship of cementless versus cemented TKA in the morbidly obese. A minimum 5-year follow-up. J Arthroplasty 2019;34:309–14.
[13] Bagsby DT, Issa K, Smith LS, Elmallah RK, Mast LE, Harwin SF, et al. Cemented vs cementless total knee arthroplasty in morbidly obese patients. J Arthroplasty 2016;31:1727–31.
[14] Khlopas A, Sodhi N, Sultan AA, Chughtai M, Molloy RM, Mont MA. Robotic arm-assisted total knee arthroplasty. J Arthroplasty 2018;33:2002–6.
[15] Kayani B, Konan S, Tahmassebi J, Pietrzak JRT, Haddad FS. Robotic-arm assisted total knee arthroplasty is associated with improved early functional recovery and reduced time to hospital discharge compared with conventional jig-based total knee arthroplasty: a prospective cohort study. Bone Joint J 2018;100-b:930–7.
[16] Khlopas A, Sodhi N, Hozack WJ, Chen AF, Mahoney OM, Kinsey T, et al. Patient-reported functional and satisfaction outcomes after robotic-arm-assisted total knee arthroplasty: early results of a prospective multicenter investigation. J Knee Surg 2020;33:685–90.
[17] Marchand RC, Sodhi N, Anis HK, Ehiorobo J, Newman JM, Taylor K, et al. One-year patient outcomes for robotic-arm-assisted versus manual total knee arthroplasty. J Knee Surg 2019;32:1063–8.
[18] Marchand RC, Sodhi N, Khlopas A, Sultan AA, Harwin SF, Malkani AL, et al. Patient satisfaction outcomes after robotic arm-assisted total knee arthroplasty: a short-term evaluation. J Knee Surg 2017;30:849–53.
[19] Petursson G, Fenstad AM, Gøthesen Ø, Dyrhovden GS, Hallan G, Röhrl SM, et al. Computer-assisted compared with conventional total knee replacement: a multicenter parallel-group randomized controlled trial. J Bone Joint Surg Am 2018;100:1265–74.
[20] Batailler C, Fernandez A, Swan J, Servien E, Haddad FS, Catani F, et al. MAKO CT-based robotic arm-assisted system is a reliable procedure for total knee arthroplasty: a systematic review. Knee Surg Sports Traumatol Arthrosc 2021;29:3585–98.
[21] Kim YH, Yoon SH, Park JW. Does robotic-assisted TKA result in better outcome scores or long-term survivorship than conventional TKA? A randomized, controlled trial. Clin Orthop Relat Res 2020;478:266–75.
[22] AAOS. AAOS Clinical practice guideline 2023. https://www.aaos.org/globalassets/quality-and-practice-resources/surgical-management-knee/smoak2cpg.pdf; 2022. [Accessed 2 December 2022].
[23] McCormick BP, Rigor P, Trent SM, Lee JW, Tefera E, Mistretta KL, et al. Short-term outcomes following cemented versus cementless robotic-assisted total knee arthroplasty. Cureus 2022;14:e30667.
[24] Website, H.f.S.S. KOOS Jr. Scoring instructions. https://www.hss.edu/files/KOOS-JR-Scoring-Instructions-2017.pdf; 2022. [Accessed 2 December 2022].
[25] Technology, C. PROMIS global 10 questionnaire. https://www.codetechnology.com/blog/promis-global-10/; 2015. [Accessed 16 September 2015].
[26] Gold PA, Garbarino L, Sodhi N, Barrack R, Springer BD, Mont MA. The case for cementless total knee arthroplasty. Surg Technol Int 2020;36:388–96.
[27] Haeberle HS, Salem HS, Ehiorobo JO, Sodhi N, Mont MA. Newer generation of cementless total knee arthroplasty: a systematic review. Surg Technol Int 2020;36:351–9.
[28] Mont MA, Pivec R, Issa K, Kapadia BH, Maheshwari A, Harwin SF. Long-term implant survivorship of cementless total knee arthroplasty: a systematic review of the literature and meta-analysis. J Knee Surg 2014;27:369–76.
[29] Zhou K, Yu H, Li J, Wang H, Zhou Z, Pei F. No difference in implant survivorship and clinical outcomes between full-cementless and full-cemented fixation in primary total knee arthroplasty: a systematic review and meta-analysis. Int J Surg 2018;53:312–9.
[30] Schwabe MT, Hannon CP. The evolution, current indications and outcomes of cementless total knee arthroplasty. J Clin Med 2022;11:6608.
[31] Deckey DG, et al. Robotic-assisted total knee arthroplasty improves accuracy and precision compared to conventional techniques. Bone Joint J 2021;103-B:74–80.
[32] Chin BZ, Tan SSH, Chua KCX, Budiono GR, Syn NL, O'Neill GK. Robot-assisted versus conventional total and unicompartmental knee arthroplasty: a meta-analysis of radiological and functional outcomes. J Knee Surg 2021;34:1064–75.
[33] Kort N, Stirling P, Pilot P, Müller JH. Robot-assisted knee arthroplasty improves component positioning and alignment, but results are inconclusive on whether it improves clinical scores or reduces complications and revisions: a systematic overview of meta-analyses. Knee Surg Sports Traumatol Arthrosc 2022;30:2639–53.
[34] Lee DY, Park YJ, Hwang SC, Park JS, Kang DG. No differences in mid- to long-term outcomes of computer-assisted navigation versus conventional total knee arthroplasty. Knee Surg Sports Traumatol Arthrosc 2020;28:3183–92.