EPiC Series in Health Sciences
Volume 6, 2024, Pages 94–105
Proceedings of The 22nd Annual Meeting of the International Society for Computer Assisted Orthopaedic Surgery

# Short-term clinical & radiologic outcomes of Imageless - robotic assisted total knee arthroplasty versus conventional total knee arthroplasty in Thabo Crown Prince Hospital: Retrospective cohort study

Pornpavit Sriphirom[1,*], Pitee Wongyongsilp[2,†] and Woraphot Wicharn[2,‡]
[1]Rajavithi Hospital, Bangkok, Thailand
[2]Ministry of Public Health Thabo Crown Prince Hospital Nongkhai province, Thailand
Pornpavit@yahoo.com, five_2_jive@hotmail.com,
Woraphott2516@gmail.com

**Abstract**

**Introduction:** Robotic assisted total knee arthroplasty (RATKA) was proven that improved component position, ligament balanced and decreased outlier leading to improved clinical results and implant survivorship. Aiming of this study is comparison of short-term clinical and radiologic outcomes between RATKA versus conventional TKA (CMTKA) in Thabo Crown Prince Hospital, Thailand.

**Methods:** Retrospective cohort study by single surgeon, from July 2020 to August 2022 compared 51 RATKA and 49 CMTKA. Baseline data and short-term clinical outcomes including knee society score (KSS), operative time, estimated blood loss (EBL), length of stay (LOS), complications and radiologic outcomes were collected at postoperatively 3 months follow up.

**Results:** There was no statistically significant difference in KSS, EBL, LOS and complications between RATKA and CMTKA ($P < 0.05$). Operative time was significant greater in RATKA (138 vs. 162 min, $P < 0.05$). Radiologic outcomes in CMTKA, posterior condylar Offset, posterior condylar deviation, tibial slope was significant higher ($P < 0.05$). In subgroup analysis, patients with post operative tibial slope $\geq 7°$ (poor clinical outcomes) in CMTKA significantly higher than in RATKA ($P = 0.021$).

[*] Supervision and validation
[†] Conceptualization, writing – review and editing
[‡] Supervision and validation

**Conclusions:** Imageless - robotic assisted total knee arthroplasty demonstrated that more benefit in posterior condylar offset and posterior tibial slope restoration and seem to be better in short-term clinical outcomes.

# 1 Introduction

Total knee arthroplasty (TKA) is the main standard treatment for patients with severe osteoarthritis (OA) of knee [1,2,29]. Positioning of implant and lower limb alignment are the important predicting factor that leads to better clinical outcome and long-term survivorship [3,18]. Main implant position that needs to be restored is mechanical axis and joint line level. Mechanical axis deviation of more than 3° significantly increases the risk of prosthesis loosening [4-9]. Deviation in anatomical joint line can leading to anterior knee pain, mid-flexion instability, reduced range of motion, and patellar mal-tracking [30]. In the same way, alteration in posterior condylar offset and posterior tibial slope angle relate to decrease post operative range of motion after TKA [10,25], leading to poor clinical outcome [26]. Recently few years, Robotic assisted TKA(RATKA) is a new technology and available in Thailand. RATKA was proved that improving implant position by precise bone cutting, reduce radiographic outliers and good ligament balanced [11,12,13,14]. Unfortunately, lack of many studies in Thailand to comparison clinical and radiologic outcome between RATKA versus conventional TKA (CMTKA). So, we decide to study retrospective comparison of short term clinical and radiologic outcome between RATKA versus CMTKA in Thabo Crown Prince Hospital.

# 2 Materials and methods

After the institutional review board approved, we retrospectively cohort reviewed the patients was diagnosed primary OA of knee who underwent TKA performed in Thabo Crown Prince Hospital by single board-certified arthroplasty surgeon from July 2020 to August 2022. Two groups of patients were identified: 1) 49 patients with CMTKA 2) 51 patients with RATKA that met Inclusion criteria as follows: unilateral primary OA of knee, age 50 – 85 years. The patients who diagnosed with secondary OA, had previous problem around hip and spine, previous hip-knee surgery, body mass index >35 kg/m$^2$ and those who were unable to contact follow-up at 3 month after surgery were excluded from the study.

## 2.1 Surgical technique

All of patients were performed TKA procedure in the same preoperative and perioperative protocol with a single implant design (Anthem, Smith & Nephew). Surgical approach was done by mid vastus technique under tourniquet application. Then generalize osteophyte was removed and patella non-resurfacing was done by circumferential electrocautery.

## 2.2 Conventional TKA

All CMTKAs were performed by using standard Instrumentation device with measure resection technique. The tibial cutting was performed extramedullary guide perpendicular to tibial axis with 3-degree posterior slope. Femoral bone cutting was performed by intramedullary guide with fixed 5-degree valgus cutting angle and 3 - 5-degree external rotation. After balanced flexion and extension gap, tibial rotation was set by anatomical reference as Akagi's line and final prosthesis implantation was done with polyethylene insert.

## 2.3 Robotic Assisted TKA

The handheld using the NAVIO® Surgical System (Smith & Nephew, Inc., Memphis, TN, USA), which is an imageless semi-active system [15], with the same single implant design (Anthem). After two percutaneous femoral and tibial pining tracker array, anatomical surface of tibia and femur, mechanical axis, preoperative motion were registered to robotic system. Implant sizing was planned, medial and lateral gapping were evaluated. The accuracy of femur and tibial resection were confirmed by using the robotic alignment tool after adjusted to fine-tune the soft tissue and ligament balance. Finally, both femoral and tibial components were cemented, and closure was carried out as normal.

All patients were performed in the same postoperative protocol which included post operative care, analgesic drug, post operative rehabilitation program until discharge from the hospital.

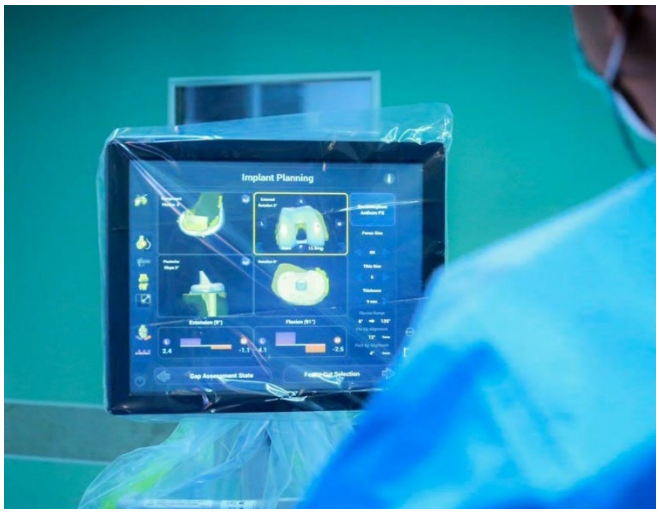


**Figure 1** Robotic assisted TKA gap balanced adjustment

## 2.4 Retrospective chart & Radiographic review

From the medical record, basic demographic information was collected from patient medical records including age, gender, body weight, height, body mass index, underlying disease, ASA classification, side of surgery.

Clinical evaluations were conducted preoperative and postoperative at 3-month, including knee score, functional score and knee society score (KSS). Clinical scores before the operation and at the 3-months follow-up were compared between two groups. Perioperative information was collected including operative time, estimated blood loss and length of hospital stay. Complications data such as periprosthetic fracture, postoperative hematoma, surgical site infection, joint stiffness and periprosthetic joint infection were collected until 3-month follow-up postoperative visit.

Radiographic review was collected: preoperative deformity(varus/valgus), degree of OA (Kellgren and Lawrence classification). Joint line height, posterior condylar offset and tibial slope angle on weight bearing radiograph anteroposterior & lateral standing view were collected preoperative and postoperative at 3 months follow-up and calculated the deviation value in each parameter.

Joint line height was measured by IJLCM technique **(**Imperial Joint Line Congruency Measurement**)** [16,31]. The difference in joint line height was calculated by postoperative joint line height (mm.) minus preoperative joint line height (mm.) Negative values indicate depression of the joint line height

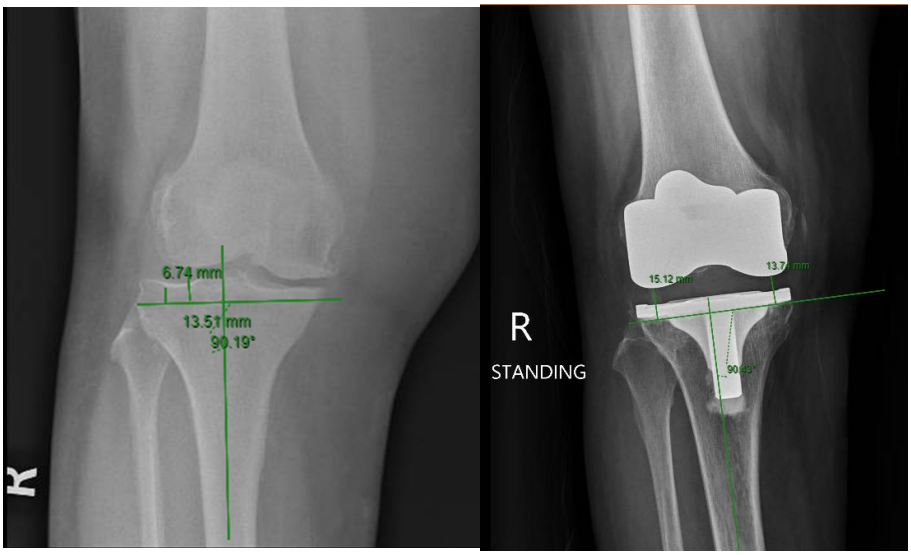


**Figure 2** Pre and postoperative joint line height measurement (mm.).

Posterior condylar offset was measured by Bellemans et al. technique [17,31]. The difference in posterior condylar offset was calculated by postoperative posterior condylar offset (mm) minus preoperative posterior condylar offset (mm.).

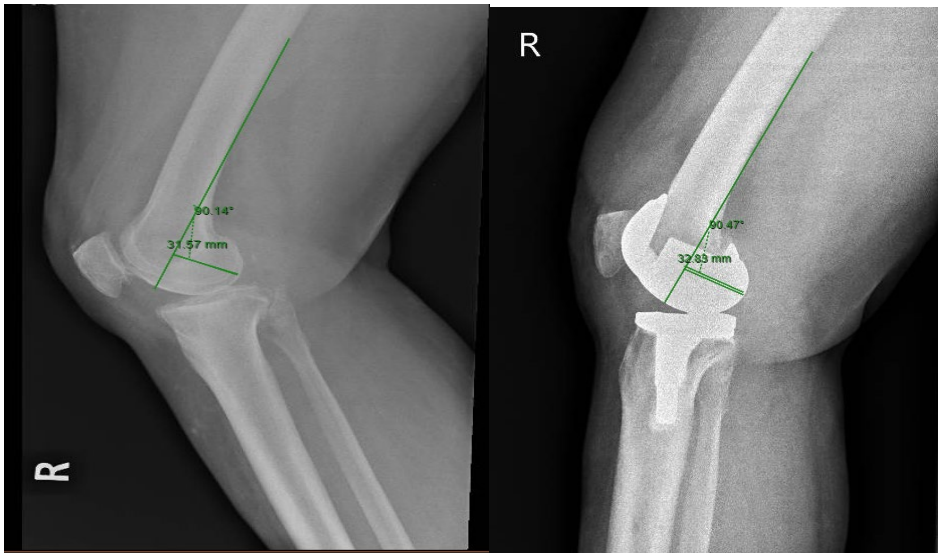


**Figure 3** Pre and postoperative posterior condylar offset measurement (mm.).

Posterior tibial slope (PTS) measured at preoperative and postoperative time were performed by using the posterior tibial cortex as a reference according to one of the six methods suggested by Braizier et al. [27].

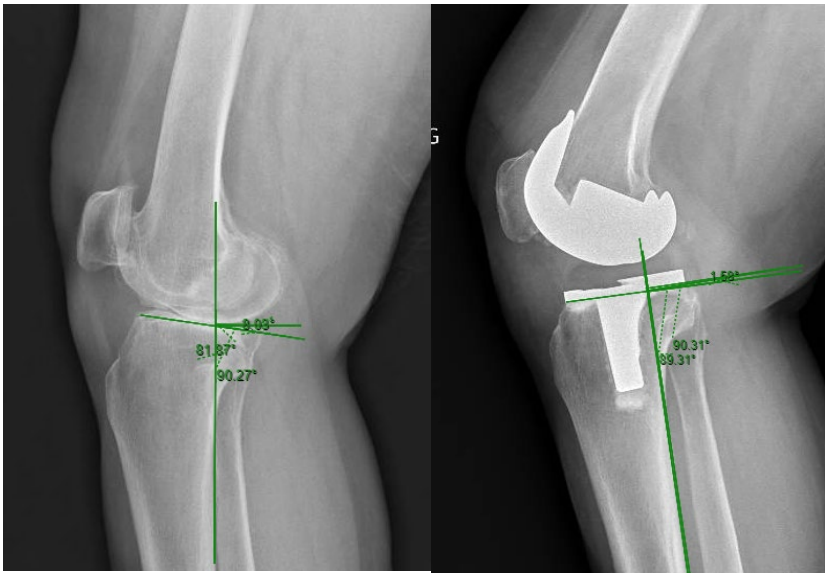


**Figure 4** Pre and postoperative posterior tibial slope (degrees).

## 2.5 Statistical analysis

The data were analyzed using the SPSS statistical software for Windows. Means, standard deviations, and percentages were used to describe the baseline patient data. T-tests, Chi-squared tests, and Mann–Whitney U test were used to compare variable factors between two groups, CMTKA and RATKA. A p-value of <0.05 was considered statistically significant.

# 3 Results

## 3.1 Demographic data

There was no difference in age, gender, body weight, height, BMI, comorbid disease, ASA classification, side of surgery, preoperative deformity(varus/valgus), degree of OA, preoperative joint line height, preoperative posterior condylar offset, preoperative tibial slope and knee society score between two groups. Only the preoperative knee score in RATKA group was significantly lower than CMTKA group ($p < 0.05$) (Table 1)

**Table 1** Comparison baseline data between CMTKA and TKA

| | Surgical technique | | P-value |
|---|---|---|---|
| | CMTKA (n=49) | RATKA (n=51) | |
| Gender | | | |
| Male (%) | 11(22%) | 8(16%) | 0.389 |
| Female (%) | 38(78%) | 43(84%) | |
| Age (years) | 62.16(±7.58) | 63.14(±7.56) | 0.522 |
| BW (kg) | 67.88(±15.25) | 65.94(±14.68) | 0.519 |
| Height (cm) | 155.63(±7.75) | 155.96(±7.75) | 0.810 |
| BMI (kg/m2) | 28.13(±5.75) | 27.01(±5.64) | 0.810 |
| Underlying | 44(90%) | 39(77%) | 0.076 |
| ASA classification | | | |
| 1 | 1(2%) | 4(8%) | 0.286 |
| 2 | 33(67%) | 36(71%) | |
| 3 | 15(31%) | 11(21%) | |
| Surgery side | | | |
| Right | 26(53%) | 31(61%) | 0.435 |
| Left | 23(47%) | 20(39%) | |
| Preoperative Deformity | | | |
| Varus | 10(20%) | 8(16%) | 0.669 |
| Valgus | 41(80%) | 41(84%) | |
| Degree of OA | | | |
| 2 | 0 | 3(6%) | |
| 3 | 13(26%) | 16(31%) | 0.173 |
| 4 | 36(74%) | 32(63%) | |
| Preoperative Knee score | 47.47(±12.09) | 41.10(±13.88) | 0.014* |
| Preoperative Functional score | 42.04(±19.03) | 44.02(±22.00) | 0.664 |
| Preoperative KSS | 89.51(±23.72) | 85.12(±26.15) | 0.382 |
| Preoperative Average Joint line height(mm.) | 13.27(±3.58) | 12.10(±3.46) | 0.099 |
| Preoperative posterior condylar Offset(mm.) | 36.27(±6.60) | 34.19(±4.62) | 0.070 |
| Preoperative Tibia slope (Degree) | 7.90(5.26) | 8.08(5.34) | 0.953 |

* Significant difference P – value < 0.05

**Table 2** Comparison of perioperative clinical outcomes and complication between CMTKA and TKA

| | Surgical technique | | P-value |
|---|---|---|---|
| | CMTKA (n=49) | RATKA (n=51) | |
| Operative Time(mins) | 138.61 ± 48.28 | 162.98 ± 31.30 | 0.004* |
| Estimate Blood Loss(ml) | 18.48 ± 29.73 | 17.94 ± 26.20 | 0.614 |
| Length of Hospital Stay(day) | 7.61(3.43) | 7.8(3.04) | 0.676 |
| Complication | 18(37) | 17(33) | 0.721 |

* Significant difference P – value < 0.05

**Table 3** Comparison of postoperative Knee society score between CMTKA and RATKA

| | Surgical technique | | P-value |
|---|---|---|---|
| | CMTKA (n=49) | RATKA (n=51) | |
| Knee Score | 90.51 ± 6.92 | 90.55 ± 7.49 | 0.854 |
| Functional Score | 75.31 ± 16.21 | 80.98 ± 14.11 | 0.106 |
| KSS | 165.81 ± 18.51 | 171.53 ± 16.91 | 0.192 |
| KSS improvement | 76.31 ± 25.14 | 86.41 ± 31.96 | 0.160 |

* Significant difference P – value < 0.05

**Table 4** Comparison of postoperative radiologic outcomes between CMTKA and RATKA

| | Surgical technique | | P-value |
|---|---|---|---|
| | CMTKA (n=49) | RATKA (n=51) | |
| Joint line heigh (mm.) | 13.63(3.63) | 14.86(3.60) | 0.074 |
| Joint line deviation (mm.) | 3.09(2.41) | 3.01(2.44) | 0.828 |
| Posterior condylar Offset (mm.) | 38.28(5.81) | 35.00(4.49) | 0.002* |
| Posterior condylar Offset deviation (mm.) | 5.52(3.32) | 2.33(1.93) | 0.000* |
| Tibial slope (degree) | 4.58(2.65) | 2.16(1.80) | 0.008* |

* Significant difference P – value < 0.05

**Table 5** Subgroup analysis of postoperative radiologic outcome between CMTKA and RATKA

| Radiologic parameter | Surgical Technique | | P - value |
|---|---|---|---|
| | CMTKA (n=49) | RATKA (n=51) | |
| Tibia slope category (Degree) | | | |
| < 7 | 40(81.6) | 49(96.1) | 0.021* |
| ≥ 7 | 9(18.4) | 2(3.9) | |
| Tibial slope change category (mm.) | | | |
| ≤ 4 | 24(49) | 22(43.1) | 0.558 |
| > 4 | 25(51) | 29(56.9) | |
| Joint deviation category (mm.) | | | |
| ≤ 4 | 15(30.6) | 14(27.5) | |
| > 4 | 34(69.4) | 37(72.5) | 0.728 |

* Significant difference P – value < 0.05

## 3.2 Short-term Clinical outcomes

In perioperative period**,** there was no statistically significant difference in estimate blood loss, length of hospital stays and complications between the two group but operative time in RATKA group was statistical significantly higher than CMTKA group (P = 0.004), average difference was 24.37 mins. (Table2).

At follow up 3 months postoperatively, knee society score was improved in both study groups (CMTKA 76.31 vs RATKA 86.41). Otherwise, there were no statistically significant differences between two groups (Table3).

## 3.3 Radiologic outcome

Postoperative joint line height and joint line deviation were no significantly difference between two groups. In contrast to postoperative posterior condylar offset, posterior condylar offset deviation and postoperative tibial slope were significantly difference, higher in CMTKA group (38.28, 5.52, 4.58 respectively) (P <0.005) (Table 4).

In subgroup analysis, there was significantly difference of postoperative tibial slope (group1 < 7-degree, group 2 ≥ 7 degree) (P = 0.021*) but no statistically significant difference in tibial slope deviation and joint line deviation subgroup (group 1 ≤ 4 mm., group 2 > 4 mm.) between two surgical technique (Table 3).

# 4 Discussion

This study did not find a significant difference in knee society score between two groups at 3-months follow up. Similar to Michael B. Held et al. [18] retrospective study report that no significant difference in KSS-FS, SF-12 P, SF-12 M, WOMAC F, WOMAC S scores in short term follow up at 3-, 12-, 24 months between CMTKA and RATKA by Imageless-robotic system. In their suggestion, the study does not account for preoperative alignment and severity of osteoarthritis, that may effect on post operative outcomes. In our retrospective study collected and compared preoperative knee score between both groups. We found that preoperative knee score in RATKA group significantly lower than CMTKA group. Although preoperative knee score in RATKA significantly lower but seem to be greater improvement and higher in postoperative knee society score than"CMTKA. Muzaffar Ali et al. [19], retrospectively report that 36 RATKA have early superior short term clinical outcome (WOMAC score, KOOS) compared with 36 CMTKA at 3-, 6-, and 12-months follow-up. In further study, we suggest that long term, adequately powered randomized controlled trials are necessary to explored clinically significant between RATKA than CMTKA.

The operative time in our study was significantly longer in RATKA group. Similarly, to previous study, Michael B. Held [18] and Sang-Woo Jeon et al. [20] study, they shown the average difference operative time was 16 minutes and 45 minutes respectively. The added time in RATKA group is associated with process of bone registry and milling process with unfamiliar robotic equipment of surgical teamwork. However, the perioperative complication in each group was no difference.

In current study, estimate blood loss in RATKA group and CMTKA group was no significant difference, similar to S. J. Bhimani et al. [28], reports that no significant difference between two groups (RATKA = 70.3 ml. vs CMTKA = 74.1 ml.). The reason may be from tourniquet application in all TKAs. In contrast, Michael B. Held study [18] reports that estimate blood loss in RATKA significantly greater than CMTKA (240 ml vs 190 ml). The reasons may be from non-tourniquet technique in all TKAs with longer operative time due to bone registry process and milling procedure in RATKA group.

Similar to Michael B. Held [18] study, length of hospital stays in our study was no significant difference between RATKA vs CMTKA. even in contrast, Muzaffar Ali et al. [18] and Rawan Masarwa et al. [21], report RATKA have shorter length of hospital stay than CMTKA. Greater sample size may need to explored significant outcome. The complications that we concern in new technology robotic assisted TKA is pin tract infection & pin tract fracture, previous study report pin tract site infection 0.47% and pin site fracture 0.16% but not found in our study [22].

Deviation in joint line correlated to poor clinical outcome such as anterior knee pain, mid-flexion instability, reduced range of motion, and patellar mal-tracking [10]. Nikhil Gupta et al., report Joint line elevation more than 4 mm effect to Inferior functional outcomes [23]. In our study, even though joint line deviation was not shown significant difference between CMTKA and RATKA group but the average of joint line deviation in both groups were 3 mm., that means both surgical techniques have good effect in functional outcome.

Posterior condylar offset is associate with postoperative range of motion and clinical outcome [24]. In our study, shown significant posterior condylar offset deviation in CMTKA higher than RATKA group but no significant difference in clinical outcome. Correlated to previous study, Ravi Popat et al. [16], report that deviation of posterior condylar offset in RATKA was significantl lower than CMTKA (2.19 mm. vs 4.24 mm.). In further study ,we suggest that specific clinical outcome such as postoperative range of motion, patellar score with long term follow-up should be collected to confirm correlation with posterior condylar offset.

Postoperative tibia slope and tibia slope deviation effect on postoperative knee flexion and clinical outcome. In Weipeng Shi et al. [25] study, post operative tibia slope is greater than or equal 7-degree lead to poor clinical outcome. In our study, tibial slope was significantly difference, higher degree was seen in CMTKA group (4.58, P = 0.008) (Table 4). In addition, subgroup analysis demonstrated that the number of patients with postoperative tibia slope greater than or equal 7 degree in CMTKA group, was statistically significantly higher than RATKA group (9 vs 2, P = 0.021) (Table 5). However, adequately powered randomized control trial are needed to demonstrated the clinical correlation.

# 5 Limitations

First, due to the situation of Coronavirus outbreak (COVID-19) and infection control policy in Thailand 2019 – 2022, that may affect to number of populations in this study and impact to outcomes. Second, this study is retrospective review, make it more susceptible to selection bias and confounding factor, the patients were not randomly assigned in each group, so we found Knee score in CMTKA higher than RATKA group, greatly affect to the result. Third, the follow up period was too short and may be not enough to determine clinical outcome and survivorship of implant. In additional, all TKA in this study were performed by single surgeon, the generalizability of this study is limited.

# 6 Conclusions

Imageless - robotic assisted total knee arthroplasty demonstrated that more benefit in posterior condylar offset and posterior tibial slope restoration and seem to be better in short term clinical outcome when compare with convention total knee arthroplasty. Although RATKA used longer operative time but not created more complication and blood loss.

# Reference

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

2. Carr AJ, Robertsson O, Graves S, Price AJ, Arden NK, Judge A et al (2012) Knee replacement. Lancet 379:1331–1340

3. Lombardi A Jr, Berend K, Adams J (2014) Why knee replacements fail in 2013: patient, surgeon, or implant? Bone Joint J 96:101–104

4. Berend ME, Ritter MA, Meding JB, Faris PM, Keating EM, Redelman R et al (2004) Tibial component failure mechanisms in total knee arthroplasty. Clin Orthop Relat Res.
https://doi.org/10.1097/01.blo.0000148578.22729.0e26-34

5. Goodfellow JW, O'Connor J (1986) Clinical results of the Oxford knee. Surface arthroplasty of the tibiofemoral joint with a meniscal bearing prosthesis. Clin Orthop Relat Res 205:21–42

6. Insall JN, Binazzi R, Soudry M, Mestriner LA (1985) Total knee arthroplasty. Clin Orthop Relat Res 192:13–22

7. Insall JN, Ranawat CS, Aglietti P, Shine J (1976) A comparison of four models of total knee-replacement prostheses. J Bone Joint Surg Am 58:754–765

8. Liu HX, Shang P, Ying XZ, Zhang Y (2016) Shorter survival rate in varus-aligned knees after total knee arthroplasty. Knee Surg Sports Traumatol Arthrosc 24:2663–2671

9. Ranawat CS, Boachie-Adjei O (1988) Survivorship analysis and results of total condylar knee arthroplasty. Eight- to 11-year follow-up period. Clin Orthop Relat Res 226:6–13

10. Goutham GDV, Jain VK, Sinha S, Arya RK. Effect of posterior condylar offset in post operative range of motion in cruciate retaining and sacrificing TKR: A comparative analysis. J Orthop. 2020; 20. https://doi. org/10.1016/j.jor.2020.06.012 PMID: 32684670

11. Bollars P, Boeckxstaens A, Mievis J, Kalaai S, Schotanus M, Janssen D (2020) Preliminary experience with an image-free handheld robot for total knee arthroplasty: 77 cases compared with a matched control group. Eur J Orthopaedic Surg Traumatol 30:723–729

12. Cho K-J, Seon J-K, Jang W-Y, Park C-G, Song E-K (2019) Robotic versus conventional primary total knee arthroplasty: clinical and radiological long-term results with a minimum follow-up of ten years. Int Orthop 43:1345–1354

13. Liow MHL, Xia Z, Wong MK, Tay KJ, Yeo SJ, Chin PL (2014) Robot-assisted total knee arthroplasty accurately restores the joint line and mechanical axis. A prospective randomised study. J Arthroplasty 29:2373–2377

14. Song E-K, Seon J-K, Park S-J, Jung WB, Park H-W, Lee GW (2011) Simultaneous bilateral total knee arthroplasty with robotic and conventional techniques: a prospective, randomized study. Knee Surg Sports Traumatol Arthrosc 19:1069–1076

15.Casper M, Mitra R, Khare R, Jaramaz B, Hamlin B, McGinley B, et al. Accuracy assessment of a novel image-free handheld robot for total knee arthroplasty in a cadaveric study. Computer Assist Surg (Abingdon) 2018; 23:14–20. https://doi.org/ 10.1080/24699322.2018.1519038.

16. Popat R, Dhillon K, Mahapatra P, Khan H, Nathwani D. The Imperial Joint Line Congruency Measurement is a valuable tool in total knee arthroplasty. PLoS One. 2021; 16(9): e0257325. https://doi.org/10. 1371/journal.pone.0257325 PMID: 34506586

17. Bellemans J, Banks S, Victor J, Vandenneucker H, Moemans A. Fluoroscopic analysis of the kinematics of deep flexion in total knee arthroplasty. Influence of posterior condylar offset. J Bone Joint Surg Br. 2002; https://doi.org/10.1302/0301-620x.84b1.12432 PMID: 11837832

18. Michael B. Held1 · Anastasia Gazgalis1 · Alexander L. Neuwirth1 · Roshan P. Shah1 · H. John Cooper1 · Jefrey A. : Imageless robotic-assisted total knee arthroplasty leads to similar 24-month WOMAC scores as compared to conventional total knee arthroplasty: a retrospective cohort study Geller1 Received: 8 March 2021 / Accepted: 27 April 2021 © European Society of Sports Traumatology, Knee Surgery, Arthroscopy (ESSKA) 2021

19.Muzaffar Ali et al.Anthony Kamson ,Charlie Yoo, Inderpreet Singh, Christopher Ferguson,Raymond Dahl : Early Superior Clinical Outcomes in Robotic-Assisted TKA Compared to Conventional TKA in the Same Patient: A Comparative Analysis Thieme Medical Publishers, Inc.333 Seventh Avenue, 18th Floor, New York, NY 10001, USA

20. Sang-Woo Jeon, MD, Kang-Il Kim, MD, PhD, Sang Jun Song, MD, PhD: Robot-Assisted Total Knee Arthroplasty Does Not Improve Long-Term Clinical and Radiologic Outcomes.The Journal of

Arthroplastyhttps ://doi.org/10.1016/j.arth.2019.04.007 0883-5403/© 2019 Elsevier Inc. All rights reserved

21. Rawan Masarwa a, Yaniv Yonai a, Merav Ben Natan b: Short-term outcomes of an imageless robot-assisted total knee arthroplasty compared with a conventional method: A retrospective cohort study: International Journal of Surgery Open 47 (2022) 100557

22.Brown MJ, Matthews JR, Bayers-Thering MT, Phillips MJ, Krackow KA (2017) Low incidence of postoperative complications with navigated total knee arthroplasty. J Arthroplasty 32:2120–2126

23. Nikhil Gupta*, Rajesh Singh, Akash Saxena, The influence of joint line position on functional outcome in primary total knee arthroplasty: International Journal of Research in Orthopaedics Gupta N et al. Int J Res Orthop. 2021 May;7(3):526-530 http://www.ijoro.org

24. Alessandro Panciera 1, Vitantonio Digennaro 1: The role of posterior condylar offset ratio on clinical and functional outcome of posterior stabilized total knee arthroplasty: a retrospective cohort study: Eur J Orthop Surg Traumatology. 2022 Dec 19. doi: 10.1007/s00590-022-03459-w. Online ahead of print.

25. Weipeng Shi1,2†, Yaping Jiang3†, Xuan Zhao4 , Haining Zhang1 , Yingzhen Wang1* and Tao Li1* : The influence of posterior tibial slope on the mid-term clinical effect of medial-pivot knee prosthesis Shi et al. Journal of Orthopaedic Surgery and Research (2021) 16:563 https://doi.org/10.1186/s13018-021-02704-y

26.James L. Howard, MD, FRCSC, Mina W. Morcos, MD et al.: Reproducing the Native Posterior Tibial Slope in Cruciate-Retaining Total Knee Arthroplasty: Technique and Clinical Implications November 22, 2019https://doi.org/10.3928/01477447-20191122-06: Orthopedics. 2020; 43(1): e21–e26.

27. Brazier J, Migaud H, Gougeon F, Cotten A, Fontaine C, Duquennoy A. Evaluation of methods for radiographic measurement of the tibial slope: a study of 83 healthy knees. Rev Chir Orthop Reparatrice Appar Mot. 1996; 82:195-200.

28. S. J. Bhimani, R. Bhimani, A. Smith, C. Eccles, L. Smith, A. Malkani: Robotic-assisted total knee arthroplasty demonstrates decreased postoperative pain and opioid usage compared to conventional total knee arthroplasty Bone Joint Open 2020;1:8–12.: VOL. 1, NO. 2, February 2020

29. Kyu-Jin Cho1 & Jong-Keun Seon1 & Won-Young Jang1 & Chun-Gon Park1 & Eun-Kyoo Song1,2 Robotic versus conventional primary total knee arthroplasty: clinical and radiological long-term results with a minimum follow-up of ten years. International Orthopaedics https://doi.org/10.1007/s00264-018-4231-1.

30. Varun O. Agrawal1,2* , Anup P. Gadekar2 and Narendra Vaidya1,2: Does robotic technology successfully restore the joint line after total knee arthroplasty? A retrospective analysis: Agrawal et al. Arthroplasty (2022) 4:6 https://doi.org/10.1186/s42836-021-00103-6

31. Ravi PopatID1 *, Ali Albelooshi2 , Piyush Mahapatra3 , Peter Bollars4 , Max Ettinger5 , Simon Jennings3 , Jan-Louis Van den Berg6 , Dinesh Nathwani1: Improved joint line and posterior offset restoration in primary total knee replacement using a robotic-assisted surgical technique: An international multi-centre retrospective analysis of matched cohorts: PLOS ONE | https://doi.org/10.1371/journal.pone.0272722 August 25, 2022