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Current adoption trends and future perspectives on Robotic-assisted Total Knee Arthroplasty among Flemish knee surgeons

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ABSTRACT

Robotic-assisted Total Knee Arthroplasty (RA-TKA) is increasingly adopted to improve component position, limb alignment and soft tissue balance, potentially enhancing functional outcomes and patient satisfaction. However, long-term clinical benefits over conventional procedures remain unproven and emersion in daily practice remains limited. This study aims to investigate the adaptation rationale, workflow modifications and expectations of Flemish knee surgeons who adopted RA-TKA in their arthroplasty practice.

A 28-item Web survey was sent on January 21st, 2025 to 64 Flemish knee surgeons, all members of the Belgian Knee Society. 51 surgeons completed the survey, representing a response rate of 80.0%. The questionnaire addressed demographics, RA-TKA usage, alignment and balancing strategies, and opinions on cost-effectiveness and future trends. Data were analyzed descriptively.

Flemish surgeons adopted RA-TKA primarily to enhance operative assessment, component positioning and balance. Only 45% of surgeons expected improved clinical outcomes. Surgical techniques shifted significantly, with 73.0% altering alignment techniques, predominantly from mechanical to (inverse) kinematic alignment (59.0%). The type of constraint changed in 76.0% of surgeons, most commonly toward medial-stabilized (25.0%) and cruciate-retaining (22.0%) inserts. 98.0% support the continued inclusion of manual TKA training for residents. While 69.0% of surgeons considered RA-TKA too expensive, 76.0% expected to achieve cost savings due to reduced revisions.

RA-TKA is increasingly integrated into clinical practice by Flemish knee surgeons, influencing alignment philosophy and implant constraint. Despite the high satisfaction rate among RA-TKA users, cost remains a major concern. Furthermore, less than half of the surgeons expected to achieve improved clinical outcomes with the use of RA-TKA.

INTRODUCTION

Total knee arthroplasty (TKA) is a well-established treatment for end-stage knee osteoarthritis[1]. The evolution of TKA has progressed from conventional manual techniques to computer-assisted navigation in the late 1990s, and more recently to robotic-assisted TKA (RA-TKA). Computer-assisted navigation enabled intraoperative tracking of anatomical landmarks, improving surgical precision by enhancing the accuracy of bone resection and component placement. Their reliance on manual bone cuts resulted in variable accuracy and limited consistency, contributing to its partial abandonment[2,3].

The development of RA-TKA has enhanced the precision and accuracy of component placement, offering potential advantages over conventional TKA[1,4,5]. By integrating advanced imaging, patient-specific planning, and guided or automated bone cutting, RA-TKA allows consistent execution of the surgical plan with minimal deviation from the intended resection and alignment. RA-TKA has demonstrated potential advantages in terms of prosthetic accuracy, ligament balancing and soft-tissue preservation, supporting its increased adoption by knee arthroplasty surgeons[2,6,7]. Despite its transformative potential, widespread implementation of RA-TKA remains limited by high costs, inconsistent evidence of superior clinical outcomes and concerns regarding longer operative times compared to conventional TKA[3,8].

The adoption varies globally and to date, only a paucity of literature exists regarding the trends and grounds to introduce RA-TKA in a daily TKA practice. Therefore, we investigated the adaptation rationale, workflow alterations and expectations among Flemish knee surgeons who adopted RA-TKA, providing regional insight into its role in contemporary arthroplasty.

MATERIALS AND METHODS

An online questionnaire (Web Survey) was sent on January 21th, 2025 to 64 Flemish knee surgeons. All invitees were members of the Belgian Knee Society and actively practicing as knee surgeons at the time of the survey. 51 surgeons agreed to participate, representing a response rate of 80.0%.

The questionnaire (see Supplement) consisted of 28 questions covering surgeon demographics, annual TKA caseload, proportion of RA-TKA procedures, system preferences, surgical techniques, training background, and opinions on cost and future trends. Most questions were closed-ended with predefined response options (e.g. yes/no), whereas four items permitted multiple selections to capture a broader range of responses.

All results were retrieved anonymously from the online questionnaire provider and processed in Microsoft Excel. Data were analyzed descriptively using frequencies and percentages.

RESULTS

Demographics

Email invitations were sent to 64 Flemish knee surgeons, members of the Belgian Knee Society and known to use RA-TKA, on January 21st 2025. A total of 51 (80.0%) surgeons completed the questionnaire. Most respondents (33.3%) had 5 to 10 years of experience and reported a high annual TKA case volume, with the majority performing over 100 TKA procedures per year. Questioning possible conflicts of interest, two-thirds (66.7%) reported no consultancy affiliation with any RA-TKA company (Table I).

RA-TKA utilization

RA-TKA was widely adopted, with 82.4% of surgeons performing almost all TKAs robotically. The distribution of semi-active systems was balanced across saw-, cutting guide-, and milling-based platforms, with Rosa, Cori and Mako being most frequently used (Table I). Most surgeons (86.0%) reported no intention to switch systems, though 10.0% expressed interest in exploring alternatives, mainly saw-based devices.

Table I. — Overview of respondent demographics.

	n (%)
Consultant for knee surgery without fellowship (years)	
<5	13 (25.5%)
5-10	17 (33.3%)
11-20	13 (25.5%)
>20	8 (15.7%)
Case load (TKA/year)	
<50	5 (10.0%)
50-100	10 (20.0%)
101-200	16 (32.0%)
>200	19 (38.0%)
Percent RA-TKA /year	
(almost) 100%	42 (82.4%)
75-100%	5 (9.8%)
50-75%	1 (1.9%)
25-50%	3 (5.9%)
0-25%	0 (0.0%)
Robotic device	
Mako (Stryker)	10 (16.9%)
Rosa (Zimmer Biomet)	17 (28,8%)
Omnibot (OMNIlife Science)	3 (5,1%)
Cori (Smith & Nephew)	15 (25,4%)
Velys (Johnson & Johnson)	8 (13,6%)
NextAR (Medacta)	4 (6,8%)
Skywalker (MicroPort Orthopedics)	2 (3,4%)
Other	0 (0.0%)

Supplement

Q1. How long are you a consultant for knee surgery (fellowship not included)?
- A1.1. 0-5 years
- A1.2. 5-10 years
- A1.3. 10-20 years
- A1.4. 20+ years

Q2. Were you trained (during residency or fellowship) with Robotic assisted TKA (RA-TKA)?
- A2.1. Yes
- A2.2. No

Q3. How many TKA's do you perform a year?
- A3.1. 0-50
- A3.2. 50-100
- A3.3. 100-200
- A3.4. 200+

Q4. How many (approximately) TKA do you perform with a robot?
- A4.1. (almost) 100%: 42
- A4.2. 75-100%
- A4.3. 50-75%
- A4.4. 25-50%
- A4.5. 0-25%
- A5.6. I've never used a robot

Q5. What kind of Robotic device do you use?
- A5.1. Mako
- A5.2. Rosa
- A5.3. Omnibot
- A5.4. Cori
- A5.5. Velys
- A5.6. NextAR
- A5.7. Skywalker
- A5.8. Other

Q6. Are you happy with your Robotic System?
- A6.1. Yes, I won't switch:
- A6.2. Yes, but I'd switch to:
  - A6.2.1. Mako
  - A6.2.2. Velys
  - A6.2.3. Saw-specific one (Mako, Skywalker)
  - A6.2.4. Always looking for improvement
  - A6.2.5. No comment
- A6.3. No

Q7. Do you believe a CT or MRI is absolutely necessary in your preop planning using Robotics?
- A7.1. Yes
- A7.2. No

Q8. What insert do you use in most of your cases?
- A8.1. CR
- A8.2. PS
- A8.3. CS
- A8.4. MS
- A8.5. MP

Q9. Has your type of insert changed since you've been using Robotics?
- A9.1. No
- A9.2. Yes, more PS
- A9.3. Yes, more CR
- A9.4. Yes, more CS
- A9.5. Yes, more MS
- A9.6. Yes, more MP

Q10. What technique do you apply for your Robotic cases?
- A10.1 Patient specific alignment (Tibia first)
- A10.2. Mechanical alignment (Tibia first)
- A10.3. Mechanical alignment (Femur first)
- A10.4. Restricted Kinematic alignment (Femur first)
- A10.5. Kinematic alignment (Femur first)
- A10.6. Inverse Kinematic alignment (Tibia first)
- A10.7. Functional alignment
- A10.8. Other

Q11. Did you change your alignment technique from Manual to Robotic TKA?
- A11.1. Yes
- A11.2. No

Supplement - *continued*

Q12. Did you change your alignment technique?
- A12.1. I've changed from mechanical to restricted (inverted) kinematic alignment
- A12.2. I've changed from kinematic to restricted (inverted) kinematic alignment
- A12.3. I've changed from restricted (inverted) kinematic alignment to unrestricted kinematic alignment
- A12.4. I remain doing mechanical alignment
- A12.5. I remain doing restricted (inverted) kinematic alignment
- A12.6. I remain doing unrestricted kinematic alignment

Q13. Did you change your starting approach?
- A13.1. I remain at tibia first
- A13.2. I remain at femur first (full femur or only distal femur)
- A13.3. I've changed from tibia first to femur first
- A13.4. I've changed from femur first to tibia first

Q14. Why do you use a robotic assisted device? (multiple responses possible)
- A14.1. Better objective data
- A14.2. Less outliers
- A14.3. Faster and better rehab
- A14.4. Shorter length of stay
- A14.5. Better positioning of the components
- A14.6. Better clinical outcome
- A14.7. Pressure from surrounding hospitals
- A14.8. Pressure from directional board

Q15. Are you happy using Robotic Surgery for TKA?
- A15.1. Yes, and I will continue using it for all of my cases
- A15.2. Yes, but definitely not in all of my cases
- A15.3. No

Q16. Is Robotic surgery here to stay?
- A16.1. Yes
- A16.2. Yes, but definitely not in all cases
- A16.3. No

Q17. Are you a consultant for a Robotic assisted TKA company?
- A17.1. Yes
- A17.2. No

Q18. Did Robotic surgery provide you better insights in TKA?
- A18.1. Yes
- A18.2. No

Q19. Would you perform a TKA differently now that you use Robotics?
- A19.1. Yes
- A19.2. No

Q20. Do/would you use a Robotic device for uni-condylar knee replacement?
- A20.1 Yes
- A20.2. No

Q21. If you answered "No" in the previous question: Is robotics an added value for UKA?
- A21.1. Yes
- A21.2. No

Q22. Is Robotic TKA too much driven by the industry?
- A22.1. Yes
- A22.2. No

Q23. Is Robotic TKA too expensive?
- A23.1. Yes
- A23.2. No

Q24. Who pays for the extra cost for the Robotic TKA (draping, disposables, …)
- A24.1. The hospital
- A24.2. The company
- A24.3. The patient
- A24.4. The orthopaedic department
- A24.5. We have no extra costs

Q25. Do you believe that Robotic TKA will eventually lead to a lower cost for society on the long term?
- A25.1. Yes
- A25.2. No

Supplement - *continued*

Q26. If you answer "Yes" in 25. If Robotics would lead to a lower cost, how would that be? (multiple answers possible)

A26.1. Less revisions for malalignment
A26.2. Less revisions for instability
A26.3. Less reoperations short-term (f.e. MUA, arhrolysis, poly-exchange,..)
A26.4. Shorter length of stay
A26.5. Faster return to work
A26.6. Longer survival (= less revisions mid and long term)
A26.7. Less use of pain medication
A26.8. Less use of physiotherapy

Q27. Should residents and fellows still be trained for Manual TKA if they will perform Robotic assisted TKA?

A27.1. Yes
A27.2. No

Q28. Did you follow a training programme prior to performing Robotic surgery? (multiple answers possible)

A28.1. Cadaver training
A28.2. Saw bone
A28.3. Live case observation
A28.4. Alignment training
A28.5. Balance graph training

The main motivations for adopting RA-TKA were improved intraoperative objective data (26.3%), followed by an enhanced component positioning (21.1%) and aiming to reduce outliers in implant positioning as well as the overall limb alignment (17.1%) (Figure 1). Less than half of the surgeons expected to achieve improved clinical outcomes.

Additionally, 96.0% of surgeons indicated that RA-TKA provided deeper insights into the TKA procedure and 90.0% reported that their order of bone preparation in manual TKA had changed as a result. On the other hand, 58.8% were hesitant to extend robotic use to unicompartmental knee arthroplasty (UKA), although 50.0% of respondents acknowledged its potential value.

Training

Only 18.0% of respondents had received RA-TKA training during residency or fellowship. All participants underwent specific training before clinical implementation, most commonly through sawbone workshops (35.0%) or live case observations (28.0%). Despite the widespread adoption of RA-TKA, 98.0% emphasized the importance of maintaining education in conventional TKA techniques for trainees.

Techniques and alignment

Regarding implant design, more specifically the form of constraint, posterior-stabilized (37.2%) and cruciate-retaining (27.5%) prostheses were most

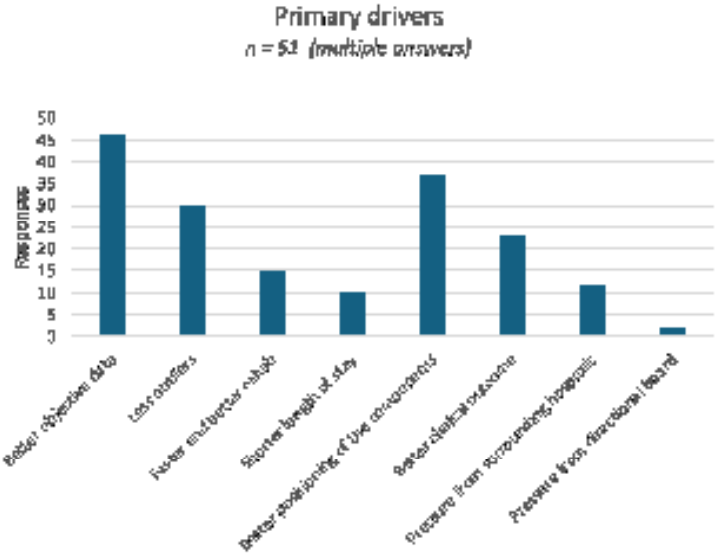

Fig. 1 — Primary drivers for switching to RA-TKA (n = 51, multiple answers).

common. 76.0% of surgeons reported a change in constraint preference after adopting RA-TKA, mostly toward medial-stabilized inserts (25.0%) and cruciate-retaining inserts (22.0%) (Figure 2).

In terms of alignment philosophy, the predominant technique was patient-specific alignment through a tibia-first technique (37.0%), followed by kinematic alignment, either being an inverse, tibia-first (25.0%) or femur-first (16.0% restricted, 6.0% unrestricted) technique (Figure 3).

Overall, 73.0% of surgeons had modified their alignment strategy after implementing RA-TKA. The most prominent shift was from a mechanical to a restricted or inverse kinematic alignment (59.0%). On the other hand, 37.0% reported no change in alignment strategy (Figure 4).

The sequence of bone preparation in RA-TKA remained unchanged for the majority of surgeons (45.0% tibia-first, 37.0% femur-first). 18.0% altered their sequence after adopting RA-TKA. A modified order of bone preparation was reported by 18.0% of respondents, with 10.0% shifting from a tibia-first to a femur-first technique (Figure 5).

Preoperative imaging was not routinely used by 78.0% of surgeons, who considered computed tomography (CT) or magnetic resonance imaging (MRI) unnecessary for RA-TKA.

Financial aspects

Approximately two-thirds of respondents perceived RA-TKA currently as too expensive, with hospitals bearing most of the additional costs. Nevertheless, 76.0% anticipated long-term societal cost savings, mainly through a reduction in revision surgeries necessary for malalignment (22.5%) or instability (26.5%). Other potential benefits included shorter hospital stays (7.1%), earlier return to work (7.1%), reduced consumption of pain medications (5.1%) and decreased need for physiotherapy (3.1%) (Figure 6).

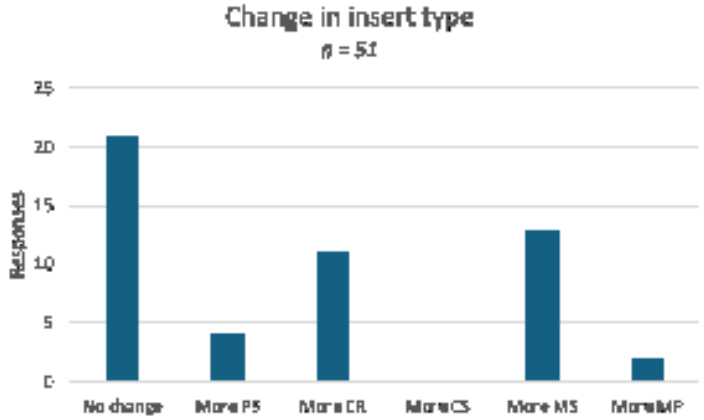

Fig. 2 — Changes in insert type preference with RA-TKA (n = 51, one answer).

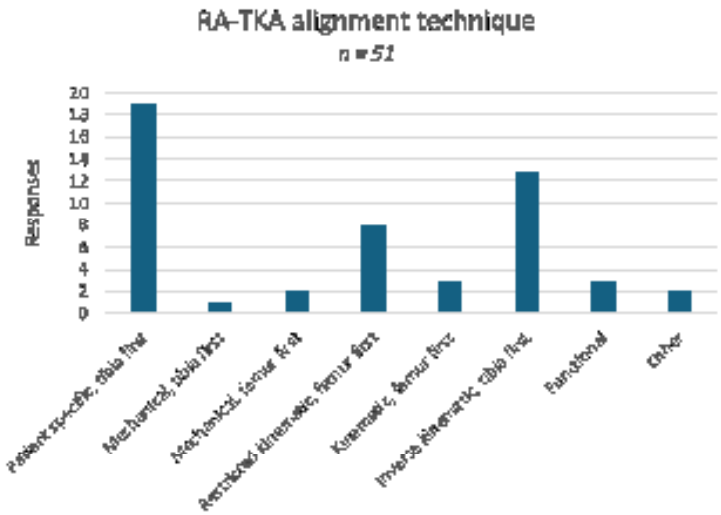

Fig. 3 — Alignment techniques among RA-TKA users (n = 51, one answer).

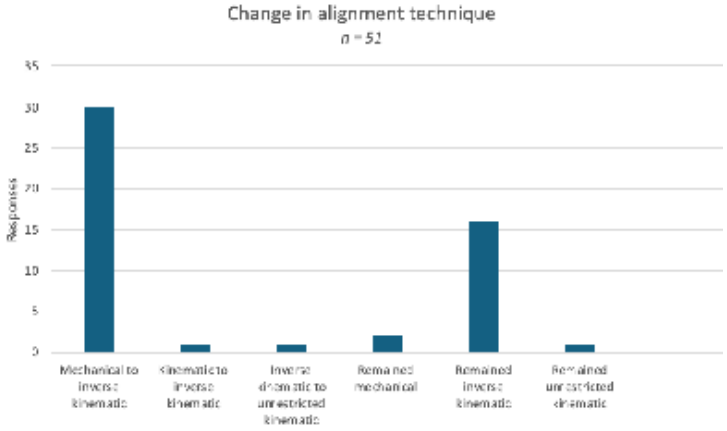

Fig. 4 — Change in alignment technique following the adoption of RA-TKA (n = 51, one answer).

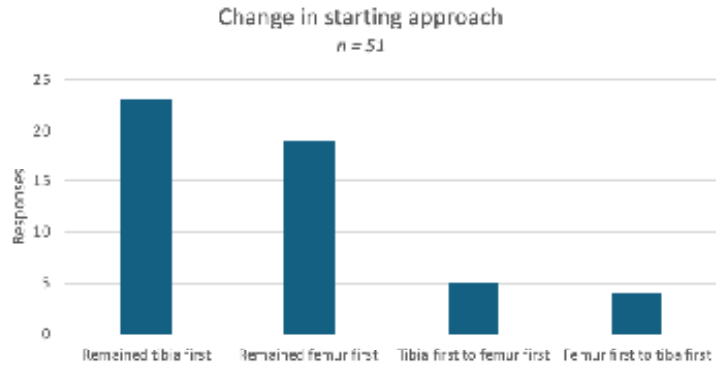

Fig. 5 — Change in starting technique with RA-TKA (n = 51, one answer).

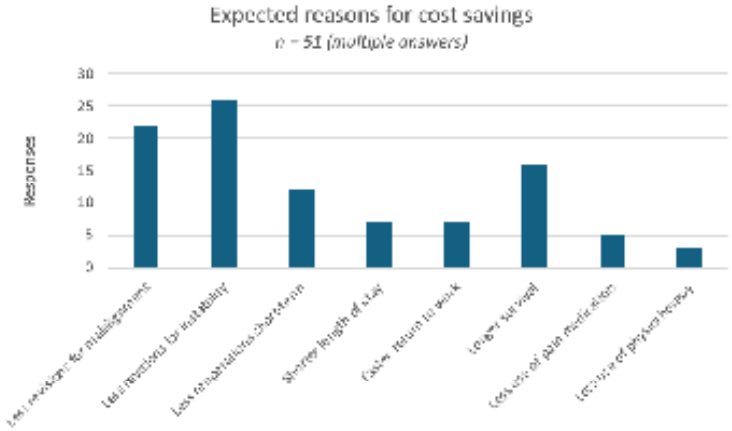

Fig. 6 — Surgeon perspectives on cost savings from RA-TKA.

Future Perspectives

Most surgeons (90.0%) reported high satisfaction with RA-TKA and intended to continue using it in future cases. An additional 8.0% planned selective application, while only one respondent reported dissatisfaction with their current RA-TKA practice.

DISCUSSION

This survey provides valuable insights into the adoption rationale, workflow modifications, and the expectations and perceptions of RA-TKA among Flemish knee surgeons. The present study is noteworthy in representing a region with exceptionally high robotic technology penetration. In Flanders, over four out of five participating surgeons reported performing

RA-TKA in nearly all TKA cases, representing one of the highest adoption rates reported in literature. This regional concentration of experienced RA-TKA users strengthens the relevance of the present findings.

A key observation is the generally positive attitude toward RA-TKA, with 90% of surgeons reporting satisfaction and continued use. Importantly, two-thirds were not affiliated with RA-TKA companies, underscoring that this attitude likely reflects clinical experience rather than commercial affiliations.

The main motivations for adopting RA-TKA, including improved intraoperative data, enhanced component positioning and reduced alignment outliers, are consistent with findings from EKS and AAHKS surveys[8,9]. These perceptions correspond with evidence showing that robotic systems improve the surgical precision and accuracy of bone cuts and implant positioning compared with conventional TKAs[1,7–11]. These motivations reflect the shift of early adapting surgeons toward data-driven and reproducible surgical techniques, enabling them to achieve more consistency in the accurate position of TKA components and soft tissue balancing. In addition, the use of robotic assistance was reported to enhance surgeons' understanding of knee kinematics, with 96.0% of respondents indicating that it provided deeper procedural insight. 90.0% of surgeons in this study also reported that robotics provided greater intraoperative feedback, prompting many to adjust their manual TKA techniques accordingly. These responses suggest that RA-TKA can serve as a valuable feedback-driven educational tool, encouraging continuous technical improvement even among experienced surgeons[11].

Importantly, while the pursuit of better clinical outcomes remains a consideration, it was not the dominant driver of RA-TKA adoption. Surgeons appear to value RA-TKA primarily as a means of personal and procedural optimization, rather than as a technology solely aimed at enhancing patient outcomes.

A notable finding in this survey is the shift toward more patient-specific alignment philosophies following RA-TKA adoption. The majority of surgeons (73.0%) modified their alignment philosophy, with a predominant shift from mechanical to restricted or inverse kinematic alignment (59.0%). This observation aligns with recent literature suggesting that RA-TKA facilitates individualized alignment strategies, which may enhance patient satisfaction and functional outcomes through improved replication of native knee kinematics[4,6,7]. The preference for patient-specific alignment with a tibia-first technique (37.0%) further highlights this trend.

Similarly, the observed tendency toward reduced constraint, with increased use of medial-stabilized and cruciate-retaining inserts, may reflect the enhanced soft-tissue balancing capabilities of RA-TKA. These allow for more precise ligament balancing and potentially favor inserts that allow for more natural knee kinematics[6,7.]

These adjustments in implant selection and alignment strategies reflect a broader evolution in the conceptualization of TKA from a standardized, one-size-fits-all method toward a patient-specific procedure. However, while the superiority of RA-TKA in achieving planned component positioning is well established, robust evidence demonstrating a corresponding improvement in functional outcomes, patient satisfaction, or implant survivorship remains limited. Long-term, high-quality comparative studies are warranted to determine whether the enhanced accuracy of RA-TKA translates into clinical benefit[8–11].

Preoperative imaging preferences varied in this study, with 78.0% of surgeons not considering CT or MRI essential for RA-TKA, likely due to the intraoperative mapping capabilities of imageless systems. This finding contrasts with previous studies advocating preoperative imaging to improve the accuracy of RA-TKA[3,6]. This preference is probably attributable to the advanced anatomical mapping capabilities, dynamic soft-tissue balancing, and intraoperative possibilities to adjust the surgical plan in imageless systems. This method offers advantages such as reduced radiation exposure and lower preoperative costs. However, image-based systems, which rely on preoperative CT or MRI, provide detailed three-dimensional patient-specific anatomy. Previous studies reported multiple benefits of image-based systems, including enhanced implant position accuracy, prediction of component sizes, reduced surgical time and improved postoperative limb alignment[14–17].

Robotic training remains a critical factor in RA-TKA adoption. Only 18.0% of the current RA-TKA users in this survey had prior exposure to robotic technology during residency or fellowship. This compels the reliance on training and learning modalities, provided by orthopedic companies, such as sawbone workshops and live case observations. Although useful, this limited hands-on training suggests a gap in formal education and the expected fast and efficient learning curve when adapting to RA-TKA. This observation aligns with previous reports advocating for standardized

RA-TKA training programs to ensure competency12. Despite widespread robotic use, 98.0% of respondents emphasized the continued importance of conventional TKA training, reducing potential over-reliance on robotic systems and ensuring preparedness in case of robotic malfunction[11].

Despite the high level of surgeon satisfaction and the progressive acceptance of robotic systems in TKA, cost remains a major limiting factor to broader adoption[5,8]. In this study, 69.0% of respondents indicated RA-TKA as too expensive, with hospitals bearing the additional financial burden. Nonetheless, 76.0% of surgeons expressed confidence in long-term societal cost savings, primarily through reduced revisions and faster recovery. These expectations are supported by studies showing that RA-TKA can decrease revision rates by improving alignment and stability[13,14]. Additionally, the reported benefit of shorter hospital stays and faster return to work align with existing evidence[1,4,13]. Nevertheless, further economic analyses are required to confirm their impact on overall healthcare costs.

The present study demonstrates a high adoption rate of RA-TKA among Flemish knee surgeons, with 82% of respondents using robotics in nearly all primary TKA procedures. This level of penetration substantially exceeds that reported in other regions. In the United States, Tamer et al[20] observed that only 36% of surgeons currently perform RA-TKA, despite an increase from 10% in 2018. Similarly, the European Knee Society (EKS) survey reported an adoption rate of 26.5%, while the American Association of Hip and Knee Surgeons (AAHKS) survey indicated that 33.8% of respondents used robotic assistance for either TKA or total hip arthroplasty. Furthermore, the response rate of the Flemish survey (80.0%) was higher than that of both the EKS (67%) and AAHKS (32.2%) surveys.

Several limitations should be acknowledged when interpreting the results of this study. First, the survey targeted only members of the Belgian Knee Society known to use RA-TKA, introducing selection bias and limiting generalizability to all Belgian knee arthroplasty surgeons. Furthermore, as only robotic users were invited, the findings are subject to selection bias and cannot be interpreted as a statement of the current TKA practice in Belgium.

CONCLUSION

This survey highlights a high satisfaction rate among Flemish RA-TKA users. Reported satisfaction relates primarily to improved intraoperative objective data, enhanced surgical precision and accuracy in component positioning, greater soft-tissue preservation and shorter hospital stays. These perceived advantages have influenced alignment philosophies and insights on implant constraint for the majority of surgeons, which has led to a more patient-specific perspective of TKA. Nevertheless, only a minority of surgeons employ RA-TKA based on the belief that it yields superior clinical outcomes. The lack of demonstrable clinical benefits in combination with financial concerns remain a significant barrier to broader adoption.

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