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# Conventional, Specific, and Robotic Instrumentation in Total Knee Arthroplasty. How Are We Progressing in Functional Outcomes and Patient Satisfaction?

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## ABSTRACT

***Background:*** In recent years, technological advances in total knee arthroplasty (TKA) have made procedures more precise, reducing complications and accelerating recovery. Although the latest techniques offer several advantages, there are still doubts regarding their true functional efficacy and the level of patient satisfaction they provide.

***Methods:*** A retrospective study involving 1,076 patients, distributed as follows: 366 (34.0%) conventional instrumentation (CI), 591 (54.9%) Patient-Specific Instrumentation (PSI), and 119 (11.1%) robotics. All functional outcomes were assessed preoperatively and 90 days postoperatively. Bivariate analyses were performed using ANOVA and the Kruskal-Wallis test, with a significance level of $p < 0.05$.

***Results:*** At 90 days, the robotics maintained the greatest flexion range ($p = 0.001$) and outperformed the PSI and IC in the walking test (350.3 ± 102.1 vs. 312.5 ± 92.9 and 283.8 ± 84.8, respectively; $p < 0.001$). On the WOMAC test, PSI performed best (14.5 ± 10.6; $p = 0.001$), with IC and robotics showing similar results ($p = 0.974$). There was no difference between the groups in absolute gains. In terms of percentage gains, PSI was higher in WOMAC compared to IC ($p=0.041$) and robotics ($p<0.001$). Satisfaction was identical between the instrumentation methods ($p=0.199$).

***Conclusion:*** Absolute gains in functional evolution and satisfaction appear to be independent of the surgical technique, although PSI appears to offer improvements in functional activities.

Given the still-limited experience with robotic surgery, the functional benefits and long-term satisfaction remain inconclusive.

***Keywords:*** Computer-Assisted Navigation; Conventional Surgery; Customized Instrumentation; Functionality; Knee Arthroplasty; Robotic Surgery.

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## INTRODUCTION

Knee osteoarthritis is one of the most prevalent musculoskeletal disorders worldwide, with incidence increasing alongside population aging [1,2]. In advanced stages of the disease, conservative treatments often become ineffective, making total knee arthroplasty (TKA) the treatment of choice. This procedure has been shown to significantly alleviate pain, restore joint function, and improve patients' quality of life [3,4].

Over the past decade, technological advancements in orthopedic surgery - including three-dimensional imaging, computerized preoperative planning, surgical navigation systems, and the development of novel biomaterials - have aimed to enhance the precision and reproducibility of TKA [5]. These innovations seek to optimize implant positioning, minimize surgical trauma, reduce complication rates, and accelerate postoperative recovery.

Despite these advances, conventional instrumentation (CI) remains the most widely used technique. However, CI relies largely on the surgeon's experience and intraoperative visual landmarks, which may increase the risk of alignment errors, greater blood loss, and complications such as embolism [6]. To address these limitations, patient-specific instrumentation (PSI) has been developed, using preoperative three-dimensional imaging to manufacture customized cutting guides, thereby improving surgical accuracy and reducing operative time and blood loss [6,7]. More recently, robot-assisted surgery (RAS) has emerged as another alternative, allowing highly accurate bone resections and real-time assessment of ligament balance based on pre- or intraoperative imaging [5].

Although PSI and RAS offer theoretical and technical advantages over CI, their actual clinical benefits remain a matter of debate. The existing literature presents heterogeneous and sometimes conflicting results, particularly in comparative studies between CI and PSI [8], CI and RAS [9-11], and among all three techniques [12]. Functional outcomes, complication rates, and cost-effectiveness vary widely across studies, making it difficult to draw definitive conclusions.

Patient satisfaction, a critical outcome measure following TKA, also remains inconclusive in the current literature, particularly in comparisons between RAS and other instrumentation techniques [13]. Given these uncertainties, further comparative studies are warranted to clarify the short-term functional outcomes and patient-perceived benefits of these approaches.

Therefore, the objective of this study was to analyze and compare functional outcomes and patient satisfaction at 90 days following TKA performed with conventional instrumentation, patient-specific instrumentation, and robot-assisted surgery.

## METHODOLOGY

### Study Design

This was a prospective study in which patients were recruited sequentially from the hospital database where the authors work, created in 2011, and provided they met the inclusion criteria. The group of surgeons remained stable in terms of instrumentation. Patients were evaluated 15 days before and 90 days after surgery. The study was approved by the local Ethics Committee (Opinion No. 17/2024).

### Sample

A total of 1,076 patients participated, divided into CI (366 – 34%), PSI (591 – 54.9%), and RAS (119 – 11.1%), with a mean age of 70.8 ± 7.8 years. There were 708 (65.8%) women. Inclusion criteria were primary osteoarthritis (mainly grades 3 and 4 of the Kellgren–Lawrence classification), resistant to conservative treatment, voluntary participation, and complete data.

Patients with previous TKA or postoperative complications, such as joint infection, extensive hematoma, orthe need for a blood transfusion, were excluded.

### Surgical Protocols

Conventional instrumentation, considered the standard for TKA, uses intramedullary and/or extramedullary alignment systems that rely heavily on visual references. These devices can hinder surgical flow, prolong operative time, and increase blood loss and the risk of fat embolism due to their highly invasive nature.

In this study, the systems used were: Visionaire® from Smith & Nephew® for PSI, and the CORI® system from the same manufacturer for RAS. Both surgical approaches utilize the conventional internal parapatellar approach. The implant used is cemented, has an asymmetric tibia, does not include patellar replacement, and preserves the posterior cruciate ligament. When preservation is not possible, an ultra-congruent implant is used, avoiding the need for reaming of the femoral cage.

### Physical Therapy Protocol

The physical therapy protocol is organized as follows:

i) Between 7 and 15 days before surgery: assessment of all functional measures; teaching isometric contractions of the main muscle groups of the lower limb (LL), such as the knee extensors and flexors and the hip extensors and abductors; guidance on active LL mobilization; training the transition from sitting to standing; training the transition from lying to standing ("getting in/out of bed"); walking training with walkers on a firm surface and stairs. At the end of the session, a booklet is provided detailing the entire surgical process, postoperative period, and all phases of rehabilitation.

ii) On the first postoperative day: the program begins with active mobilization of the operated limb, isometric muscle strengthening, training in transferring from sitting to standing (including using the toilet), and gait training within the room. iii) On the following days, until discharge, the described session is continued, increasing the number of repetitions and sets of the exercises, including stair climbing training, widening the gait range, and functional standing exercises.

iv) When surgery is performed in the morning, the first day of treatment occurs in the afternoon. In the absence of clinical complications, discharge criteria include walking independently, walking at least 60 meters with a walker, and climbing ten steps twice. This "fast track" protocol has been adopted since May 2016.

**Assessment Instruments**

The following were assessed: type of instrumentation, age, sex, BMI, laterality, surgical time, and hospital length of stay.

Functionality was measured by: Range of Motion (ROM), Pain through Visual Analog Scale (VAS), Walking (6-Minute Walk Test), and WOMAC Index. Satisfaction was assessed using a numerical scale from 1 to 10.

**Data Collection and Analysis**

Data collection was performed preoperatively and on the 90th postoperative day, including functional capacity outcomes. Preoperatively, sample characterization variables were also collected, except for surgery and hospital stay times, which were recorded at hospital discharge. Satisfaction was assessed at a single time point, on the 90th postoperative day.

For ethical reasons, all data were anonymized.

Data analysis was performed using the Statistical Package for the Social Sciences (SPSS) software, version 29.

Statistical analysis used descriptive statistics and bivariate inferential statistics. To compare the three groups of interest on the studied variables, ANOVA was applied to numerical variables, and, when necessary, the Tukey HSD post-hoc test was used. For categorical variables, the Kruskal-Wallis test was used, with a p-value <0.05 considered statistically significant.

## RESULTS

Table 1 presents the sample characterization variables; the results showed similarities between the groups, except for BMI: the CI group had a higher BMI than the PSI group (30.3 vs. 29.0; p=0.002).

**Table 1: Sample Characterization**

| Variable | | p-value |
|---|---|---|
| **Age** | | |
| CI | 71,2 ± 8,1 [50-92] | 0,336 1) |
| PSI | 70,5 ± 7,5 [48-89] | |
| RAS | 71,4 ± 8,2 [47-87] | |
| **Sex** | | |
| CI | | 0,138 2) |
| Female | 253 (69,1%) | |
| Male | 113 (30,9%) | |
| PSI | | |
| Female | 384 (65,0%) | |
| Male | 207 (35,0%) | |
| RAS | | |
| Female | 71 (59,7%) | |
| Male | 48 (40,3%) | |
| **BMI** | | |
| CI | 30,3 ± 5,3 [14,2-56,8] | 0,002 1) |
| PSI | 29,0 ± 4,5 [17,6-44,4] | |
| RAS | 29,3 ± 4,3 [18,9-41,0] | |
| **Laterality** | | |
| CI | | 0,849 2) |
| Right | 187 (51,7%) | |
| Left | 175 (48,3%) | |
| PSI | | |
| Right | 315 (53,3%) | |
| Left | 276 (46,7%) | |
| RAS | | |
| Right | 61 (51,3%) | |
| Left | 58 (48,7%) | |

1) ANOVA; 2) Kruskal-Wallis

Table 2 presents descriptive statistics for surgery and hospital length of stay, as well as a comparison between the groups of interest. Regarding surgical time, the PSI group had the shortest duration among the groups (p<0.001), followed by CI, which was faster than RAS (58.2 vs. 78.5 min; p<0.001). Regarding hospital length of stay, the RAS group had better results (p < 0.001), with CI and PSI showing similar lengths of stay (p = 0.467).

**Table 2: Surgery time and hospital length of stay**

| Variable | | p-value ANOVA |
|---|---|---|
| **Surgery time** | | |
| CI | 58,2 ± 15,1 [29-125] | <0,001 |
| PSI | 49,8 ± 11,7 [30-125] | |
| RAS | 78,5 ± 15,2 [48-130] | |
| **Hospital length of stay** | | |
| CI | 2,7 ± 1,9 [1-22] | <0,001 |
| PSI | 2,5 ± 1,0 [1-12] | |
| RAS | 2,0 ± 0,7 [1-4] | |

The preoperative functional profile is presented in Table 3, showing significant differences in ROM and walking perimeter. Knee flexion showed higher values in the RAS compared to the other two instruments (p<0.001), and these values were similar (p=0.882). Regarding walking perimeter, the RAS group had superior performance (p=0.003) compared with PSI (287.0 m versus 262.8 m) and CI (287.0 m versus 238.8 m). PSI and CI performance in the 6-minute walk test showed no significant differences (p=0.080).

**Table 3: Preoperative functional status**

| Variable | CI | PSI | RAS | p-value ANOVA |
|---|---|---|---|---|
| ROM | 109,0 ± 20,9 [10-150] | 108,0 ± 21,2 [33-150] | 116,6 ± 15,2 [75-150] | <0,001 |
| Pain-VAS | 6,0 ± 2,2 [0-10] | 5,4 ± 2,5 [0-10] | 5,6 ± 2,5 [0-10] | 0,105 |
| 6-Minute Test | 238,8 ± 104,5 [0-488] | 262,8 ± 103,9 [0-522] | 287,0 ± 108,0 [0-540] | 0,003 |
| Score WOMAC | 49,7 ± 15,9 [11-93] | 48,7 ± 15,9 [8-96] | 51,7 ± 18,7 [0-85] | 0,281 |

At 90 days (Table 4), all techniques showed functional improvement, except pain (VAS), which showed no significant differences. The RAS maintained the greatest flexion range (p=0.001), and in the 6-minute walk test, it outperformed PSI and CI (350.3 m vs. 312.5 m and 283.8 m, respectively; p<0.001). In the WOMAC score, PSI performed best (14.5 points; p=0.001), with CI and RAS showing similar results (18.4 vs. 18.7 points; p=0.974).

**Table 4: Functional status on day 90**

| Variable | CI | PSI | RAS | p-value ANOVA |
|---|---|---|---|---|
| ROM | 106,1 ± 12,0 [75-134] | 106,9 ± 14,7 [62-53] | 112,9 ± 16,6 [10-139] | 0,001 |
| Pain-VAS | 1,8 ± 2,1 [0-8] | 1,4 ± 2,0 [0-8] | 1,9 ± 2,3 [0-9] | 0,090 |
| 6-Minute Test | 283,8 ± 84,8 [40-504] | 312,5 ± 92,9 [20-570] | 350,3 ± 102,1 [32-600] | <0,001 |
| Score WOMAC | 18,4 ± 12,6 [0-58] | 14,5 ± 10,6 [0-61] | 18,7 ± 13,6 [0-63] | 0,001 |

In absolute gains, there was no difference between the groups. However, in percentage gains, PSI was superior to CI on WOMAC (p=0.041) and RAS (p<0.001). CI also outperformed RAS on this variable (p < 0.001). Absolute and percentage gains are presented in Table 5.

**Table 5: Functional evolution in absolute and percentage gains on day 90**

| Variable | CI | PSI | RAS | p-value ANOVA |
|---|---|---|---|---|
| **Absolute gains** | | | | |
| ROM | -4,0 ± 22,2 [-55-65] | -0,1 ± 21,8 [-50-92] | -4,2 ± 22,5 [-100-45] | 0,155 |
| Pain-VAS | 4,1 ± 2,8 [-4-10] | 4,0 ± 2,9 [-6-10] | 3,6 ± 2,9 [-4-9] | 0,443 |
| 6-Minute Test | 46,3 ± 85,2 [-140-287] | 53,2 ± 92,6 [-206-371] | 57,6 ± 115,8 [-330-436] | 0,701 |
| Score WOMAC | 31,4 ± 17,5 [-1-73] | 34,0 ± 17,9 [-12-79] | 32,6 ± 19,1 [-14-71] | 0,428 |
| **Percentage gains** | | | | |
| ROM | 5,0 ± 66,6 [-35-650] | 4,4 ± 29,5 [-36-263] | -2,3 ± 21,4 [-100-53] | 0,351 |
| Pain-VAS | 65,1 ± 57,3 [-400-100] | 72,2 ± 42,6 [-167-100] | 64,8 ± 42,8 [-100-100] | 0,277 |
| 6-Minute Test | 34,5 ± 68,3 [-37-329] | 44,7 ± 120,3 [-67-1500] | 32,8 ± 85,0 [-100-675] | 0,536 |
| Score WOMAC | 60,2 ± 26,2 [-3-100] | 67,5 ± 25,4 [-55-100] | 41,0 ± 31,3 [-75-130] | <0,001 |

Regarding satisfaction, despite the trend favouring RAS, there was no statistically significant difference between the groups, as shown in Table 6.

**Tabela 6: Satisfaction difference between the groups**

| Variable | CI | PSI | RAS | p-value ANOVA |
|---|---|---|---|---|
| Satisfaction | 8,6 ± 1,9 [1-10] | 8,7 ± 1,7 [1-10] | 9,0 ± 1,1 [6-10] | 0,199 |

## DISCUSSION

The team has frequently observed improved surgical times with PSI compared to CI [14-16]. In addition to its high case volume and years of experience (being one of the first centres in the country to adopt this technique in 2015), the centre is also recognized as an international training centre.

On the other hand, the longer surgical time observed with RAS is explained by the team's limited practice and experience, as well as the time required to reach adequate proficiency on the learning curve. Although variable (the literature mentions between 6 and more than 20 cases), this finding has also been made by other authors [17, 18]. For example, in the study by Duan et al. (2023), which used CUSUM statistical analysis, the inflection point only occurred in the 20th case, with a significant reduction in surgical time (from 128 to 96 minutes). The shorter hospital length of stay observed in the RAS and PSI groups, compared to CI, may be related to the "fast track" protocol implemented in 2016, but this was adopted for all participants and techniques.

Regarding functional improvement at 90 days, all techniques showed significant improvements (with the exception of pain assessed by VAS), with the best gait perimeter result observed in the RAS and the best WOMAC score in the PSI. The first finding can be explained by the fact that these patients already had higher values preoperatively. The second may be related to the team's extensive experience with this technique, which enables faster functional recovery, a finding the team had previously observed compared with CI [15,16].

However, when the outcome was analysed in terms of absolute and percentage gains, the outcome profile changed. In absolute gains, neither technique demonstrated superiority, which is corroborated by several studies. For example, in the systematic review with meta-analysis by Rudran et al. (2022) [8], which included 2,277 TKAs, the WOMAC score showed a statistically significant difference only after 12 months, favouring the PSI group over the CI group. In the review by Alrajeb et al. (2024) [9], which included 1,942 knees, the conclusion was similar regarding CI and RAS. However, robotics showed superior postoperative anatomical and mechanical alignment, a result also observed in the meta-analysis by Kort et al. (2022) [19]. In contrast, in Daoub's review, the WOMAC score in RAS was more favourable, whereas the range of motion (ROM) was greater in the CI group.

Finally, in the only meta-analysis that compared the three instrumentation techniques (in addition to computerized navigation), it was concluded that navigation and RAS improved alignment accuracy compared to PSI and CI. Still, none of the four techniques showed clinically significant differences in postoperative functional outcomes.

Regarding satisfaction, the results also remain inconclusive. Comparisons between CI and PSI show both the absence of significant differences between them [8, 16, 20, 21] and an association between PSI's better functional results and higher levels of satisfaction [22].

In studies by Hoveidaei et al. (2024) [13] and Ghazal et al. (2023) [23], patients who underwent RAS reported higher satisfaction than those who underwent CI. However, in the meta-analysis by Lei et al. [12], the three instrumentation techniques presented similar levels of satisfaction.

The authors acknowledge the short follow-up period as a limitation of the study, which precludes conclusions about functioning and long-term satisfaction. Age and sex could have been explored as moderating variables in this type of study and population.

Future studies should take this into account and consider intermediate follow-ups.

## CONCLUSION

Although PSI appears to improve functional outcomes, in general, the absolute gains in functional evolution and satisfaction appear independent of the surgical technique used, provided that qualified teams perform the procedure.

Several reviews highlight other factors that influence the functional outcomes of instrumentation, such as the surgeon's experience, hospital surgical volume, rehabilitation protocols, and specific patient characteristics.

Most reviews also point out that the available studies have critically low methodological quality, which requires caution in interpreting the results. Given the still-limited experience with robot-assisted surgery, the long-term functional and satisfaction benefits remain inconclusive.

## REFERENCES


[1] Yang G, Wang J, Liu Y, et al. Burden of Knee Osteoarthritis in 204 Countries and Territories, 1990-2019: Results from the Global Burden of Disease Study 2019. Arthritis Care Res (Hoboken) 2023;75(12):2489-2500. doi:10.1002/acr.25158

[2] GBD 2021 Osteoarthritis Collaborators. Global, regional, and national burden of osteoarthritis, 1990-2020 and projections to 2050: a systematic analysis for the Global Burden of Disease Study 2021. Lancet Rheumatol. 2023;5(9):e508-e522. Published 2023 Aug 21. doi:10.1016/S2665-9913(23)00163-7

[3] Kahlenberg CA, Nwachukwu BU, McLawhorn AS, Cross MB, Cornell CN, Padgett DE. Patient Satisfaction after Total Knee Replacement: A Systematic Review. HSS Journal®. 2018;14(2):192-201. doi:10.1007/s11420-018-9614-8

[4] Wild L, Dimitriou D, Radzanowski S, Grabherr M, Fösel A, Helmy N. Surgical Outcomes and Analysis of Quality of Life Following Knee Arthroplasty in Very Elderly Patients. J Knee Surg. 2023;36(9):933-940. doi:10.1055/s-0042-1747946

[5] Sappey-Marinier E, Dutra Vieira T, Schmidt A, Aït Si Selmi T, Bonnin M. How New Technologies Will Transform Total Knee Arthroplasty from a Singular Surgical Procedure to a Holistic Standardized Process. *J Clini Med*. 2025; 14(9):3102. https://doi.org/10.3390/jcm14093102

[6] Predescu V, Prescura C, Olaru R, Savin L, Botez P, Deleanu B. Patient specific instrumentation versus conventional knee arthroplasty: comparative study. Int Orthop. 2017;41(7):1361-1367. doi:10.1007/s00264-016-3356-3

[7] Kizaki K, Shanmugaraj A, Yamashita F, et al. Total knee arthroplasty using patient-specific instrumentation for osteoarthritis of the knee: a meta-analysis. BMC Musculoskelet Disord. 2019;20(1):561. doi:10.1186/s12891-019-2940-2

[8] Rudran B, Magill H, Ponugoti N, Williams A, Ball S. Functional outcomes in patient specific instrumentation vs. conventional instrumentation for total knee arthroplasty; a systematic review and meta-analysis of prospective studies. BMC Musculoskelet Disord. 2022;23(1):702. doi:10.1186/s12891-022-05620-2

[9] Alrajeb R, Zarti M, Shuia Z, Alzobi O, Ahmed G, Elmhiregh A. Robotic-assisted versus conventional total knee arthroplasty: a systematic review and meta-analysis of randomized controlled trials. Eur J Orthop Surg Traumatol. 2024;34(3):1333-1343. doi:10.1007/s00590-023-03798-2

[10] Daoub A, Qayum K, Patel R, Selim A, Banerjee R. Robotic assisted versus conventional total knee arthroplasty: a systematic review and meta-analysis of randomised controlled trials. J Robot Surg. 2024;18(1):364. doi:10.1007/s11701-024-02048-9

[11] Mert Ü, Khasawneh MY, Ghandour M, Al Zuabi A, Horst K, Hildebrand F, Bouillon B, Mahmoud MA, Kabir K. Comparative Efficacy and Precision of Robot-Assisted vs. Conventional Total Knee Arthroplasty: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *J Clini Med*. 2025; 14(9):3249. https://doi.org/10.3390/jcm14093249

[12] Lei K, Liu L, Chen X, Feng Q, Yang L, Guo L. Navigation and robotics improved alignment compared with PSI and conventional instrument, while clinical outcomes were similar in TKA: a network meta-analysis. Knee Surg Sports Traumatol Arthrosc. 2022;30(2):721-733. doi:10.1007/s00167-021-06436-8

[13] Hoveidaei AH, Esmaeili S, Ghaseminejad-Raeini A, et al. Robotic assisted Total Knee Arthroplasty (TKA) is not associated with increased patient satisfaction: a systematic review and meta-analysis. Int Orthop. 2024;48(7):1771-1784. doi:10.1007/s00264-024-06206-4

[14] Vide J, Freitas TP, Ramos A, Cruz H, Sousa JP. Patient-specific instrumentation in total knee arthroplasty: simpler, faster and more accurate than standard instrumentation-a randomized controlled trial. Knee Surg Sports Traumatol Arthrosc. 2017;25(8):2616-2621. doi:10.1007/s00167-015-3869-0

[15] Fontes AP, Cintra RM, Gomes LF, Sousa JP. Feel, move, or walk? Which has a greater contribution to functioning in total knee arthroplasty? A comparative study between two instrumentations based on a classification and regression tree. Curr Orthop Pract. 2024; 35(2):71-78. doi: 10.1097/BCO.0000000000001245

[16] Vaz Pinto G, Dantas SCD, Bessa Magalhães T, Fontes AP, Marreiros A, Ribeiro De Sousa, JP. Comparing conventional and patient specific instrumentation in total knee arthroplasty: an early analysis of function

and satisfaction. Int J Res Orthop. 2023; 9(6):1108-1111. https://doi.org/10.18203/issn.24554510.IntJResOrthop20233254

[17] Zhang H, Bai X, Wang H, Zhu Z, Li X. Learning curve analysis of robotic-assisted total knee arthroplasty with a Chinese surgical system. J Orthop Surg Res. 2023;18(1):900. doi:10.1186/s13018-023-04382-4

[18] Duan X, Zhao Y, Zhang J, et al. Learning curve and short-term clinical outcomes of a new seven-axis robot-assisted total knee arthroplasty system: a propensity score-matched retrospective cohort study. J Orthop Surg Res. 2023;18(1):425. doi:10.1186/s13018-023-03899-y

[19] 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(8):2639-2653. doi:10.1007/s00167-021-06472-4

[20] Benignus C, Buschner P, Meier MK, Wilken F, Rieger J, Beckmann J. Patient Specific Instruments and Patient Individual Implants—A Narrative Review. J. Pers. Med. 2023; 13(3):426. https://doi.org/10.3390/jpm13030426

[21] Wang H, Zhang L, Teng X. The efficacy and safety of patient-specific instrumentation versus conventional instrumentation for unicompartmental knee arthroplasty: Evidence from a meta-analysis. *Medicine (Baltimore)*. 2024;103(3):e36484. doi:10.1097/MD.0000000000036484

[22] Reimann P, Brucker M, Arbab D, Lüring C. Patient satisfaction - A comparison between patient-specific implants and conventional total knee arthroplasty. J Orthop. 2019;16(3):273-277. doi:10.1016/j.jor.2019.03.020

[23] Ghazal AH, Fozo ZA, Matar SG, Kamal I, Gamal MH, Ragab KM. Robotic Versus Conventional Unicompartmental Knee Surgery: A Comprehensive Systematic Review and Meta-Analysis. *Cureus*. 2023;15(10):e46681. doi:10.7759/cureus.46681