Review
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Specifics of rotational planning and intraoperative alignment of the femoral component in the knee implant with navigation devices (systematic review)

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Abstract

Introduction The optimal rotational alignment of the femoral component in a knee implant with navigation devices is important for total knee arthroplasty. Measured resection and gap technique are available intraoperative methods to determine the rotation of femur with navigation devices, but each of these methods has its advantages and disadvantages. These aspects have contributed to the development and clinical validation of navigation tools for large joint arthroplasty.

The **objective** of this study was to evaluate the efficacy of determining the rotational alignment of the femoral component in a knee implant with mechanical and robotic navigation devices as a basis for processing intraoperative decision making by surgeons.

Material and methods The planning, execution and reporting of this systematic review were conducted in accordance with the established Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines. Initially we identified 366 studies that corresponded to the main focus of this research, and 158 studies were selected for analysis after the duplicates had been excluded. Ultimately, only 11 studies fully met the selection criteria. The evaluation included the article data, the type of mechanical or robotic navigation device, the number of cases, the complication rate, and the specifics of the preoperative, intraoperative, and postoperative methods used for determining the rotation of the femoral component in a knee implant in the cohorts reviewed. A total of 1,198 total knee arthroplasties reported in those studies were analyzed.

Results and discussion It should be noted that in most of the scientific papers on the postoperative complications of surgeries that involved various navigation devices, the information about them was incomplete or the patients with complications were excluded from the study. In general, the incidence of complications averaged 2 %.

Conclusions When the navigation devices are used, the preoperative planning of the femoral component alignment frequently remains unperformed, and techniques and reference points used in surgeries are the same as in the traditional technique. The postoperative monitoring of rotational alignment of the knee implant is performed exclusively when complications are detected.

Keywords: total knee arthroplasty, mechanical and robotic navigation devices, femoral component malrotation, patellofemoral pain, knee endoprosthesis rotation, preoperative planning, intraoperative techniques, postoperative rotation assessment

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INTRODUCTION

Total knee arthroplasty is one of the most effective methods of treating progressive osteoarthritis of the knee joint (terminal stages) that ensures restoration of the lower limb weight-bearing. Over the past two decades, this technique has undergone significant improvements including surgical tactics, development of accompanying instruments and materials used to manufacture endoprosthesis components. Despite this, 20 % of patients show poor results after surgery [1, 2].

According to the findings of analysts, precise rotational positioning of the endoprosthesis components and alignment of the limb axis are key issues that determine patient's satisfaction and necessary functional results after total knee arthroplasty [3–5]. However, it should be noted that the task of achieving the correct positioning of the endoprosthesis components is quite difficult for surgeons, since visual and tactile assessment of anatomical structures is often difficult, especially in the presence of severe deformations and post-traumatic changes.

It is known that malrotation of the femoral component of the knee implant significantly affects the kinematics of the joint and results in tracking disorders, subluxation and dislocation of the patella, instability during flexion, development of arthrofibrosis and accelerated wear of the knee implant components [6, 7]. Therefore, these issues lead to active development of navigation tools for large joint arthroplasty and its clinical testing.

Many authors opine that the use of mechanical and robotic navigation in total knee arthroplasty allows for more precise bone resection and optimal implant placement, and also provides balanced extension and flexion gaps (femoral component rotation) that best match the anatomy of the human skeleton and help maintain the natural balance of ligaments [3, 8, 9]. This reduces the likelihood of excessive stress and wear of the endoprosthesis components, as well as the development of pain in the anterior knee joint, which is largely associated with improper rotation of the implant. The use of mechanical and robotic navigation tools initiates preoperative planning with an examination of the affected joint and the entire lower limb of the patient using computed tomography (CT), which is performed along with standard radiography. The use of this methodology in combination with full length X-rays in the direct, lateral and axial projections allows to determine the size and quality of the bone, the anatomical and mechanical axis of the lower limb, and rotation of the femur and to identify any possible deformities. Intraoperatively, surgeons use mechanical devices (tensioners) to install the femoral component in primary and revision knee arthroplasty, based on the gap balancing technique.

In the case of robotic computer navigation systems, rotational positioning of the femoral component of the knee implant is based on the measured resection, including the one oriented by the level of antetorsion of the proximal femur (neck) [10, 11]. The presented methodological approaches have significant theoretical potential to improve clinical outcomes. However, there is an ongoing debate regarding the effectiveness of mechanical and robotic navigation systems compared to visual-manual techniques. Researchers have not reported statistically significant differences in postoperative outcomes, despite favorable radiographic studies [7]. Therefore, we attempted to identify relevant studied and conduct a meta-analysis of the capabilities of navigation devices in the context of correct rotational positioning of the endoprosthesis in total knee arthroplasty.

The **purpose** of this study was to evaluate the efficacy of determining the rotational alignment of the femoral component of a knee implant with mechanical and robotic navigation devices as a basis for processing intraoperative decision making by surgeons.

The main hypothesis of this study is to substantiate the evidence base of anatomically and clinically superior results of mechanical and robotic navigation devices compared to visual-manual techniques used in surgical orthopedics.

MATERIALS AND METHODS

A systematic review of the available literature was performed using several combinations of synonymous or related terms: femoral component rotation, robotic arthroplasty systems, mechanical navigation devices in total arthroplasty, knee endoprosthesis component positioning, total knee arthroplasty, patellofemoral pain after arthroplasty. The search was conducted in the PubMed, Google Scholar, Web of Science, CyberLeninka and eLibrary databases from March 10 to March 31, 2025, with no time limit. Peer-reviewed journals were considered: the results presented in randomized controlled trials, prospective trials and retrospective studies. The search was limited to Russian-language and English-language sources.

One of the authors studied the titles and abstracts of the sources presented in the listed abstract databases with subsequent full-text selection of materials in the areas of the search. References in the literature sources were subsequently also studied in detail as potentially informative in the field of interest. In the event of detecting contradictory data in the available literature, consensus was reached with the involvement of senior authors.

Studies were considered to be relevant to the goals and objectives of the study if they had the following mandatory formal characteristics:

— The source included a detailed description of mechanical and/or robotic navigation devices used in primary or revision total knee arthroplasty;

— The source reflected the possibilities of either pre-, intra-, or postoperative assessment of the rotation of the femoral component of the endoprosthesis using navigation devices;

— The sources provided evaluation of complications after the use of navigation devices.

In addition to language restrictions, this review excluded review studies without an exploratory component, technical notes that did not contain descriptions of patients, results of experimental studies performed on animals, or in vitro tests.

Planning, execution, and reporting of this systematic review were carried out in accordance with the established PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines recommended for the correct conduct of systematic reviews and meta-analyses of data.

Figure 1 shows a flow chart of the literature source selection process. Initially, 366 publications relevant to the main vector of this study were identified. After removing duplicate publications, 158 sources were accepted for consideration. From that set of literature sources, 85 full-text works were extracted according to the title and abstract. After a detailed review of the texts, 74 articles were excluded from the analytical review based on non-compliance with the stated inclusion and exclusion criteria. This systematic review includes 11 studies that met the selection criteria.

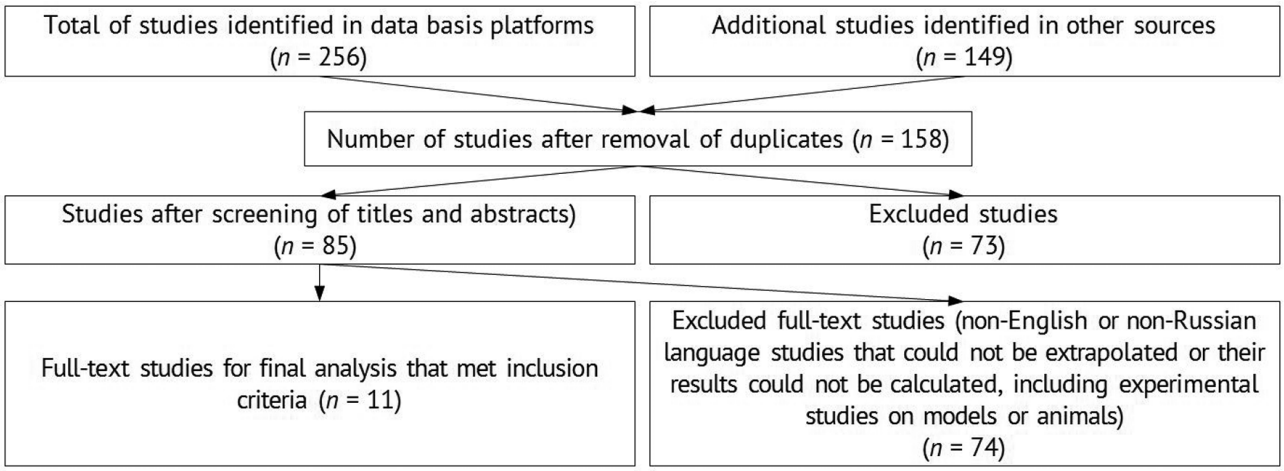

Fig. 1 Method of literature sources selection according to PRISMA

RESULTS AND DISCUSSION

The results of 1,198 total knee arthroplasty operations presented in the literature sources were analyzed. It should be emphasized that in most scientific papers, information on postoperative complications was insufficient, or patients with complications were excluded from the studies. The average incidence of complications was 2 %.

According to the literature, revision knee arthroplasty is frequently performed dueto pain in the anterior region. It should be noted that it is the rotational alignment of the femoral component of the endoprosthesis that has a direct impact on the patellofemoral joint and, as a consequence, on the final clinical results [12, 13]. The rotation of the femoral component must be carefully adjusted with the same precision as the alignment of the component in the frontal and sagittal planes. It also seems natural to strive for correct patellar centration in arthroplasty. The introduction of new mechanical and robotic navigation devices makes this a fundamental principle, since the centration process determines the rotation imparted to the femoral component [14, 15].

In order to ensure gap balance and determine the amount of rotation of the femoral component of the endoprosthesis in robotic surgery, two main methods are used: measured resection and gap technique. Preoperative planning using mechanical devices such as FUZION is not performed since the assessment of rotational positioning of the femoral component is based on the gap technique [16]. Bensa et al. conducted a randomized control study comparing the measured resection and gap technique methods in total knee arthroplasty using a force sensor immediately before implant placement. The results showed that the use of the gap technique resulted in a greater dispersion of rotation of the femoral component due to an increase in the thickness of the posterior resection of the femur (which expands the space for flexion) [17].

As a rule, preoperative planning for knee arthroplasty using robotic navigation devices is based on computed tomography (CT) data, which in some cases requires the use of specialized software that is not always available. In contrast to these methods, in mechanical navigation devices and visual-manual techniques, preoperative assessment of the topography of joint components is based on the analysis of radiographs in direct, lateral and sometimes axial projections, which is not always sufficiently informative.

Despite the fact that traditional knee arthroplasty has proven its effectiveness and availability, as well as constant innovations in the field of implants and surgical instruments, a significant number of patients

remain dissatisfied with the results of this type of surgery. The reasons for this phenomenon can be both well known and uncertain and difficult to identify. Striving to achieve the ultimate goal of a reliable, painless and durable joint, the orthopedic surgeon increasingly relies on robotic navigation systems that allow him to measure the parameters of the knee joint, select a endoprosthesis and implement a surgical plan using standardized approaches [18–20]. Active development of robotic arthroplasty is due to good results based on strict standards for positioning the implant components, correct restoration of the axis of the lower limb and long-term postoperative stability of the joint [21–24]. This approach is designed to eliminate potential inaccuracies in implant positioning and alignment, thereby reduce the number of patients dissatisfied with the result and improve their quality of life.

It has been established that navigation systems assist in reduction of errors in component positioning, especially in the sagittal plane. However, the question remains open as to whether new technologies, which have been discussed in numerous studies above, will be able to predict and reproduce intraoperative rotation of implant components, improve postoperative functional recovery, and increase the clinical effectiveness of the surgical approaches used [21, 22, 25].

Assessing the overall results of the effectiveness of mechanical and robotic navigation systems in large joint arthroplasty, it is possible to determine the special significance of aligning the axes of the lower limbs with their use, which ensures the accuracy of implant positioning. Today, there is no doubt that maintaining the mechanical axis in a safe range limited to ±3° can contribute to a significant increase in implant survival. This parameter is a determining factor affecting the survival of the implant. In case of the mechanical axis deviation from the permissible values, the risk of implant dislocation and instability increases significantly and can lead to a disorder in functional recovery and an increase in the rate of revisions [26].

External rotation of 3° from the posterior femoral condyles is considered acceptable and is generally accepted in the measured resection method. However, the relationship between precise implant positioning and clinical outcomes remains controversial [26]. Many systematic reviews show that visual-tactile techniques and navigation systems do not show a significant difference in achieving the planned clinical outcomes, which is consistent with our own results [27]. Thus, the question arises whether 180° mechanical alignment and 3° external rotation of the femoral component are universal “normal” parameters and whether this should be the routine goal of total arthroplasty for all patients. Based on a study of 250 healthy patients, a varus angle of 1° in women and 2° in men was found to be normal [28]. Furthermore, these studies demonstrate significant variability in natural knee anatomy among the 4,884 patients who underwent CT scanning, with only 5 % of the overall population demonstrating natural neutral alignment [29]. In the majority of patients undergoing total knee arthroplasty, the knee may be forced into an unnatural position, potentially leading to negative clinical outcomes despite achieving neutral alignment. Given the variability in coronal knee alignment in patients without osteoarthritic disease and the wide variability in all alignment parameters, the need for a more precise and individualized approach to knee arthroplasty is evident [30].

As follows from the presented literature data, the setup and registration of a robotic or mechanical navigation systems in total arthroplasty are unique, require detailed development and lead to an increase in the overall time of the operation [31]. This study showed that when using mechanical or robotic navigation, a longer period of time is spent on completing the integration of the endoprosthesis than in the visual-tactile technique group, which may be due to the complexity of performing individual stages, the inexperience of the operator and a longer training period for this methodology. Significant time during the operation is devoted to performing such tasks as adjustment, fixation of the femur and tibia, as well as their alignment [32].

It should be noted that an increase in the duration of surgical intervention may lead to an increased likelihood of infectious complications, which, in turn, can cause irreversible changes in both the soft tissues and bone structures of the joint [33].

The data on the studies, types of mechanical or robotic navigation devices used, number of observations, number of complications (%), and features of the pre-, intra- and postoperative methods for determining the rotation of the femoral component of the knee joint endoprosthesis of the patients' samples are reflected in Table 1.

Table 1

Number of patients, navigation device, methods of pre-, intra- and postoperative determination of the rotational position of the femoral component of the knee endoprosthesis

Authors (s), ref. number	Mechanical or robotic navigation devise used	Number of cases, *n*	Complications, %	Preoperative planning of component rotation	Intraoperative method of implant rotation determination	Postoperatuve control of implant rotation
Petukhov et al. [34]	Medtronic, Stryker *и* Brain LAB	120	2.5 %	Not performed	Measured resection	Not performed
Blyth et al. [35]	Electromagnetic navigation systems	101	Not available	CT	Measured resection	CT
Matassi et al. [36]	i-ASSIST accelerometer-based navigation system	18	Not available	CT or MRI	Combined technique	CT
Nam et al. [37]	MAKO (Stryker, Mahwah, NJ)	154	Not available	CT	Measured resection	Not performed
Lychagin et al. [38]	T-Solution One® (THINK Surgical Inc.)	29	Not available	CT	Measured resection	Not performed
Airapetov et al. [39]	Robotic assistent	20	Not available	CT	Measured resection	Not performed
Lychagin et al. [40]	T-Solution One® (THINK Surgical, Inc.)	47	Not available	KT	Measured resection	Not performed
Chandrashekar et al. [41]	CUVIS Joint™	500	Not available	CT, preoperative J planner™	Measured resection	CT
Blum et al. [42]	OMNIBotics and ultracongruent system OMNI Apex (Corin USA, Raynham, MA)	32	1.9 %	CT	Measured resection	CT
Vanlommel et al. [43]	ROSA Total Knee System	90	Not available	CT	Measured resection	CT
Maciąg et al. [44]	Dynamic tensioner FUZION	87	Not available	Not performed	Gap technique	CT

Given the key aspects, the results should be interpreted with caution and cannot be extrapolated to all systems. Due to the progress in mechanical and robotic navigation systems, there is a need for new studies to evaluate the latest advances in this area, including long-term follow-up, to draw more accurate conclusions regarding the results and benefits.

Thus, total knee arthroplasty performed using mechanical and robotic navigation devices demonstrated more effective restoration of the mechanical axis of the lower limb compared to the group of patients operated using visual-tactile technology. However, the rotational position of the implant components in the pre- and postoperative periods was not alwaysassessed, and the operation time using the standard technique was shorter by 30-40 minutes.

CONCLUSION

Preoperative planning of the femoral component rotation is often not performed when mechanical and robotic navigation devices are used, and the same techniques are utilized during the surgical intervention as in the traditional technique of total knee arthroplasty.

Postoperative monitoring of the rotational positioning of the knee endoprosthesis is carried out only if complications are detected. The studies of this review mainly assess mechanical alignment and clinical results evaluated with the WOMAC score.

Total arthroplasty performed according to the traditional technique involves a longer observation period and shows comparable results in terms of range of motion. Further research is needed to fully analyze the long-term benefits and economic feasibility of using mechanical and robotic navigation systems.

Conflict of interest *None.*

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REFERENCE

1. Maciąg BM, Wilk B, Nawrocki M, et al. Establishing femoral component rotation using a dynamic tensioner does not improve patellar position after total knee replacement with use of anatomic implants: A case-control study. Knee. 2024;48:217-225. doi: 10.1016/j.knee.2024.04.001.
2. Cidambi KR, Robertson N, Borges C, et al. Intraoperative Comparison of Measured Resection and Gap Balancing Using a Force Sensor: A Prospective, Randomized Controlled Trial. J Arthroplasty. 2018;33(7S):S126-S130. doi: 10.1016/j.arth.2018.02.044.
3. Berger RA, Crossett LS, Jacobs JJ, Rubash HE. Malrotation causing patellofemoral complications after total knee arthroplasty. Clin Orthop Relat Res. 1998;(356):144-153. doi: 10.1097/00003086-199811000-00021.
4. Matsuda S, Miura H, Nagamine R, et al. Effect of femoral and tibial component position on patellar tracking following total knee arthroplasty: 10-year follow-up of Miller-Galante I knees. Am J Knee Surg. 2001;14(3):152-156.
5. Akagi M, Matsusue Y, Mata T, et al. Effect of rotational alignment on patellar tracking in total knee arthroplasty. Clin Orthop Relat Res. 1999;(366):155-163. doi: 10.1097/00003086-199909000-00019.
6. Anouchi YS, Whiteside LA, Kaiser AD, Milliano MT. The effects of axial rotational alignment of the femoral component on knee stability and patellar tracking in total knee arthroplasty demonstrated on autopsy specimens. Clin Orthop Relat Res. 1993;(287):170-177.
7. Onggo JR, Onggo JD, De Steiger R, Hau R. Robotic-assisted total knee arthroplasty is comparable to conventional total knee arthroplasty: a meta-analysis and systematic review. Arch Orthop Trauma Surg. 2020;140(10):1533-1549. doi: 10.1007/s00402-020-03512-5.
8. Kaneko T, Igarashi T, Takada K, et al. Robotic-assisted total knee arthroplasty improves the outlier of rotational alignment of the tibial prosthesis using 3DCT measurements. Knee. 2021;31:64-76. doi: 10.1016/j.knee.2021.05.009.
9. Thilak J, Babu BC, Thadi M, et a;. Accuracy in the Execution of Pre-operative Plan for Limb Alignment and Implant Positioning in Robotic-arm Assisted Total Knee Arthroplasty and Manual Total Knee Arthroplasty: A Prospective Observational Study. Indian J Orthop. 2021;55(4):953-960. doi: 10.1007/s43465-020-00324-y.
10. Ueyama H, Kanemoto N, Minoda Y, et al. Comparison of postoperative knee flexion and patient satisfaction between newly and conventionally designed medial pivot total knee arthroplasty: a 5-year follow-up matched cohort study. Arch Orthop Trauma Surg. 2022;142(8):2057-2064. doi: 10.1007/s00402-021-04121-6.
11. Fil AS, Tarakanov VN, Kulyaba TA, Kornilov NN. Primary knee joint arthroplasty trends at the Vreden National Medical Research Centre for Traumatology and Orthopedics compared with other national joint replacement registries. Is our way similar? Genij Ortopedii. 2020;26(4):476-483. doi: 10.18019/1028-4427-2020-26-4-476-483.
12. Gerasimenko MA, Zhuk YV, Loznuho PI, et al. The use of computer navigation system in total knee arthroplasty. Military Medicine. 2018;(2):135-139. (In Russ.)
13. Lychagin AV, Gritsyuk AA, Rukin YA, Elizarov MP. The history of the development of robotics in surgery and orthopedics (literature review). Department of Traumatology and Orthopedics. 2020;(1):13-19. (In Russ.) doi: 10.17238/issn2226-2016.2020.1.13-19.
14. Lychagin AV, Rukin YA, Gritsyuk AA, Elizarov MP. First experience of using an active robotic surgical system in total knee arthroplasty. Department of Traumatology and Orthopedics. 2019;(4):27-33. (In Russ.) doi: 10.17238/issn2226-2016.2019.4.27-33.
15. Bellemans J, Colyn W, Vandenneucker H, Victor J. The Chitranjan Ranawat award: is neutral mechanical alignment normal for all patients? The concept of constitutional varus. Clin Orthop Relat Res. 2012;470(1):45-53. doi: 10.1007/s11999-011-1936-5.

16. Ritter MA, Faris PM, Keating EM, Meding JB. Postoperative alignment of total knee replacement. Its effect on survival. Clin Orthop Relat Res. 1994 Feb;(299):153-156.
17. Bensa A, Sangiorgio A, Deabate L, et al. Robotic-assisted mechanically aligned total knee arthroplasty does not lead to better clinical and radiological outcomes when compared to conventional TKA: a systematic review and meta-analysis of randomized controlled trials. Knee Surg Sports Traumatol Arthrosc. 2023;31(11):4680-4691. doi: 10.1007/s00167-023-07458-0.
18. Almaawi AM, Hutt JRB, Masse V, et al. The Impact of Mechanical and Restricted Kinematic Alignment on Knee Anatomy in Total Knee Arthroplasty. J Arthroplasty. 2017;32(7):2133-2140. doi: 10.1016/j.arth.2017.02.028.
19. Moser LB, Hess S, Amsler F, et al. Native non-osteoarthritic knees have a highly variable coronal alignment: a systematic review. Knee Surg Sports Traumatol Arthrosc. 2019;27(5):1359-1367. doi: 10.1007/s00167-019-05417-2.
20. Naranje S, Lendway L, Mehle S, Gioe TJ. Does operative time affect infection rate in primary total knee arthroplasty? Clin Orthop Relat Res. 2015;473(1):64-69. doi: 10.1007/s11999-014-3628-4.
21. Nogalo C, Meena A, Abermann E, Fink C. Complications and downsides of the robotic total knee arthroplasty: a systematic review. Knee Surg Sports Traumatol Arthrosc. 2023;31(3):736-750. doi: 10.1007/s00167-022-07031-1.
22. Xu J, Li L, Fu J, et al. Early Clinical and Radiographic Outcomes of Robot-Assisted Versus Conventional Manual Total Knee Arthroplasty: A Randomized Controlled Study. Orthop Surg. 2022;14(9):1972-1980. doi: 10.1111/os.13323.
23. Evans JT, Walker RW, Evans JP, et al. How long does a knee replacement last? A systematic review and meta-analysis of case series and national registry reports with more than 15 years of follow-up. Lancet. 2019;393(10172):655-663. doi: 10.1016/S0140-6736(18)32531-5.
24. Ren Y, Cao S, Wu J, et al. Efficacy and reliability of active robotic-assisted total knee arthroplasty compared with conventional total knee arthroplasty: a systematic review and meta-analysis. Postgrad Med J. 2019;95(1121):125-133. doi: 10.1136/postgradmedj-2018-136190.
25. Singh JA, Yu S, Chen L, Cleveland JD. Rates of Total Joint Replacement in the United States: Future Projections to 2020-2040 Using the National Inpatient Sample. J Rheumatol. 2019;46(9):1134-1140. doi: 10.3899/jrheum.170990.
26. Saber AY, Marappa-Ganeshan R, Mabrouk A. Robotic-Assisted Total Knee Arthroplasty. 2023. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025.
27. Song IS, Sun DH, Chon JG, et al. Results of revision surgery and causes of unstable total knee arthroplasty. Clin Orthop Surg. 2014;6(2):165-172. doi: 10.4055/cios.2014.6.2.165.
28. Von Keudell A, Sodha S, Collins J, et al. Patient satisfaction after primary total and unicompartmental knee arthroplasty: an age-dependent analysis. Knee. 2014;21(1):180-184. doi: 10.1016/j.knee.2013.08.004.
29. Marchand RC, Sodhi N, Bhowmik-Stoker M, et al. Does the Robotic Arm and Preoperative CT Planning Help with 3D Intraoperative Total Knee Arthroplasty Planning? J Knee Surg. 2019;32(8):742-749. doi: 10.1055/s-0038-1668122.
30. Vaidya NV, Deshpande AN, Panjwani T, et al. Robotic-assisted TKA leads to a better prosthesis alignment and a better joint line restoration as compared to conventional TKA: a prospective randomized controlled trial. Knee Surg Sports Traumatol Arthrosc. 2022;30(2):621-626. doi: 10.1007/s00167-020-06353-2.
31. 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(2):266-275. doi: 10.1097/CORR.0000000000000916.
32. Vagapova VSh. Functional morphology of the knee joint. Medical Bulletin of Bashkortostan. 2007;2(5):69-74. (In Russ.)
33. Khominets VV, Gaivoronsky IV, Kudyashev AL, et al. Experimental substantiation of the optimal technique for choosing the rotation of the femoral component of the knee endoprosthesis. Bulletin of the Russian Military Medical Academy. 2021;23(1):129-134. (In Russ.) doi: 10.17816/brmma63630.
34. Petukhov AV, Kornilov NN, Kulyaba TA, et ak. Complications in the use of computer navigation during total knee arthroplasty. Traumatology and Orthopedics of Russia. 2009;(3):161-163. (In Russ.) doi: 10.17816/2311-2905-1969.
35. Blyth MJ, Smith JR, Anthony IC, et al. Electromagnetic navigation in total knee arthroplasty-a single center, randomized, single-blind study comparing the results with conventional techniques. J Arthroplasty. 2015;30(2):199-205. doi: 10.1016/j.arth.2014.09.008.
36. Matassi F, Cozzi Lepri A, Innocenti M, et al. Total Knee Arthroplasty in Patients With Extra-Articular Deformity: Restoration of Mechanical Alignment Using Accelerometer-Based Navigation System. J Arthroplasty. 2019;34(4):676-681. doi: 10.1016/j.arth.2018.12.042.
37. Nam CH, Lee SC, Kim JH, et al. Robot-assisted total knee arthroplasty improves mechanical alignment and accuracy of component positioning compared to the conventional technique. J Exp Orthop. 2022;9(1):108. doi: 10.1186/s40634-022-00546-z.
38. Lychagin AV, Gritsyuk AA, Rukin YaA, et al. Clinical evaluation and accuracy of mechanical axis alignment in robotic total knee arthroplasty. Genij Ortopedii. 2023;29(5):487-494. doi: 10.18019/1028-4427-2023-29-5-487-494.
39. Airapetov GA, Yablonskiy PK, Serdobintsev MS, et al. Robot-assisted knee arthroplasty: first experience (a prospective randomized study). Genij Ortopedii. 2023;29(5):475-480. doi: 10.18019/1028-4427-2023-29-5-475-480.
40. Lychagin AV, Gritsyuk AA, Kalinsky EB, et al. Kinematic alignment in robotic total knee arthroplasty. Genij Ortopedii. 2024;30(6):845-854. doi: 10.18019/1028-4427-2024-30-6-845-854.
41. Chandrashekar P, Babu KA, Nagaraja HS, et al. Intra-operative Safety of an Autonomous Robotic System for Total Knee Replacement: A Review of 500 Cases in India. Indian J Orthop. 2023;57(11):1800-1808. doi: 10.1007/s43465-023-00970-y.
42. Blum CL, Lepkowsky E, Hussein A, et al. Patient expectations and satisfaction in robotic-assisted total knee arthroplasty: a prospective two-year outcome study. Arch Orthop Trauma Surg. 2021;141(12):2155-2164. doi: 10.1007/s00402-021-04067-9.

43. Vanlommel L, Neven E, Anderson MB, et al. The initial learning curve for the ROSA® Knee System can be achieved in 6-11 cases for operative time and has similar 90-day complication rates with improved implant alignment compared to manual instrumentation in total knee arthroplasty. J Exp Orthop. 2021;8(1):119. doi: 10.1186/s40634-021-00438-8.
44. Maciąg BM, Wilk B, Nawrocki M, et al. Establishing femoral component rotation using a dynamic tensioner does not improve patellar position after total knee replacement with use of anatomic implants: A case-control study. Knee. 2024;48:217-225. doi: 10.1016/j.knee.2024.04.001.

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