Section: Research Paper
ISSN 2063-5346

Technologies and Techniques in Total Knee Replacement Surgery: A Comprehensive Review"

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ABSTRACT:

Background: In severe osteoarthritis, trauma, diseased knee joint and others conditions, total knee arthroplasty or total knee replacement is assigned as most favorable surgical procedure when others conservative managements become fails. It corrects the associated knee joint deformities, restore alignment, enhance balance, get free from pain and improve and recover functionality. Now a day's different advanced surgical techniques and technologies are executed more compared to conventional or manual TKA/TKR surgeries such as; robotic assisted, computer assisted, computer navigated. In these surgeries, surgeon use to prefer some of the latest technologies to enhance the standard of the surgical procedure and getting maximum patient satisfaction following surgery. The aim of this review is to find out most favorable techniques and technologies performed in terms of TKA surgeries.

Methods: Appropriate subjected data has been collected from PubMed and Google Scholar electronic databases. We screened TKA records from 2021 to 2023. Relevant articles are selected by using medical subject heading (MesH) terms, total knee replacement and techniques (phrase) and following PRISMA concept. Duplicates and paid articles have been removed from the gathered data set.

Discussion: After being searched databases in connection with TKA surgical techniques and technologies, estimation was made concerned with more advanced or new surgical techniques. These were compared with old and contemporary techniques and technologies to get which is superior and most common technique/method. For this a narrative review was underwent to achieve optimal facts.

Conclusion: This current review suggest that new robot assisted and computer assisted surgical techniques along with latest technologies such as artificial intelligence based, smart sensors, MARS CT imaging, VISIONAIRE guides, circular external fixators, skywalker, point-light

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display observation, deep convolution neural network (CNN) through transfer learning, deep learning (DL) have been favored against conventional and others.

Key words: TKA/TKR, techniques, technology, robotic assisted system (RAS), computer assisted system (CAS)

INTRODUCTION:

Progression of knee joint osteoarthritis does occur if Knee becomes misaligned due to change in biomechanical factors. [1] Total knee arthroplasty (TKA) is a technique with reliable results that is both safe and efficient to manage the patients with severe osteoarthritis. [2] TKR, usually executed surgery has various interventional methods such as one, two or three-compartment prostheses. Patellar replacement in TKR has contradictory statement if it will be done. [3] New implantable smart biosensors are found highly relevant to collect data regarding decisions, complex-trauma-treatment, and performance of osseo-integrated prostheses. [14, 5] patient-specific instrumentation (PSI), computer-assisted surgery (CAS) included with robotic assisted system (RAS), are techniques with surgical perfection. [6, 7, 24] Load sensors are used to balancing soft tissue and calculating loads of medial and lateral compartments of knee along with information about knee kinematics. [8] CAS began to gain popularity from the beginning of 2000 while RAS is the newest assistive technology with huge popularity. [9] AI is a broad concept, involving virtual (computing) and physical (robotic) elements. [10] It improves accuracy in terms of diagnosis, decision making, to improving conditions, identifying resources, along with early intervention. [11, 12] Joint surgery using artificial intelligence (AI) is set to advance quickly in China. [13]

Giving coating, pattern, design, performance, high flexion, stability, except incapability in osseo-integration and aseptic loosening of implants, the single radius (SR) ultracongruent, (UC), Endoprosthesis design, Physica KR's tibial insert, mega prostheses, Uncemented knee implants, Circular external fixators have greater value in TKR surgeries. [14, 15, 16, 17, 18, 19].While arthrodesis or knee fusion is a primary or last resort for many complicated issues, such as tubercular joint and poliomyelitis. offer the advantages of gradual length or alignment correction and improved mechanics. [20] The long-term success of distal femur implants continues to be jeopardized by wear and severe deterioration to polyethylene components. [19] Metals like cobalt chromium molybdenum, titanium, ceramic, and, more recently, poly-ether-ether-ketone (PEEK) which is preferred now have different ways in which biomaterials can interact with the body exist. These metals have been around for a while because of their durability and inertness.[21, 22]

Two surgical procedures; high tibial osteotomy (HTO) in young and active patients and unilateral knee arthroplasty (UKA) for older patients in case of moderate or severe osteoarthritis have been found crucial. [1] Nevertheless, strict patient screening and technological advancements have allowed for 10-year survival rates for prosthesis to surpass 90% for patients

receiving lateral UKA that is more difficult and less repeatable than medial unicompartmental replacement.[23] CAS can be divided into three categories: passive systems, hybrid systems, and active systems. In this bone cuts are still made manually and decided by surgeon in passive systems, however, saw jig orientation is checked through computer system. With hybrid systems, the surgeon still performs the actual bone cut while using robotic arms to follow a predetermined and intraoperatively determined cut orientation. In case of active systems, the computer system uses robotic arms to conduct both the cut orientation and the actual bone cut. [24] To improve surgical perfection, radiological images using computed tomography (CT), magnetic resonance imaging (MRI), x-ray, and fluoroscopic x-ray sequences are some of the current 3D reconstruction techniques. Reconstruction methods such two-stage optimization method and Statistical shape modeling are carried out for patient knee anatomy during kinematic motion and bone shape successively. [25]

In order that uncertainty regarding ideal prosthetic alignment in the sagittal plane, femoral component be placed slightly off-center. Flexed femoral-component with a posterior reference are supposed to show in a computer simulation research to improve kinematics and biomechanical effects in TKA.[26] Another popular PSI is the VISIONAIRETM Cutting Guides from Smith + Nephew Inc. in Memphis, Tennessee, USA. [27] The fixation technique in the case of stemmed implantation may not be enough with merely conventional lateral. [28] Using item response theory and computerized adaptive testing, the widely-used full-length (42-item) HOOS and KOOS instruments were transformed into the HOOS-12 and KOOS-12 to produce three domain scores and an overall summary score in a condensed style. [29] The recently created multi-energy spectral photon-counting computed tomography (MARS) allows for high efficiency detection within the human diagnostic energy range (30-120 keV). A "colour" image of the object of interest with high resolution structural data and some compositional data can be created from this multi-energy data. [30]

Good implant position, mechanical alignment and balancing may cause implant-survivorship of 82.3% at 25 years. [31] If proprioceptive instability and incorrect alignment are found leading to patients' dissatisfaction. Thus, biomechanical corrections can be achieved through the Bicruciate-retaining (BCR) TKA process. [32] The use of RAS and PSI that provide incredibly precise alignment is growing now [33] However, CAS is not perfect since the implant positioning objective is not met is 5% of cases. For this we need 3D printing, patient-specific cutting guides. Nevertheless, 30% of procedures cannot be completed with navigation due to intraoperative hurdles. [34, 35] To prevent early failure of TKR surgeries, disruptions in the extensor mechanism of the knee and improper axial alignment will be considered. [36] For this, correct augmentation of damaged host tissue is made possible by the allograft that should be tightly tensioned in full extension for optimal outcomes. [37]

The polyethylene inlay of FB and MB implants provide a wider range of motion. Out of these, no one is given preference over another. [38] Enhanced recovery after surgery (ERAS) has attained huge popularity. [39] However, RAS uses dynamic referencing and precision

instrumentation for patient-specific bone cuts and implant placement. [40] Therefore, accurate implant location, implant sizing, restoring the joint line, and balancing soft tissue are all being taken into consideration during TKR. RAS reduce the margin of error connected to component and osteotomy placements. [41]whereas wearable sensors, including Inertial Measurement Units (IMUs), offer a low-cost, portable option for gathering functional metrics, such as spatiotemporal gait characteristics, that are recorded using three-dimensional gait analysis. [42]

Periprosthetic loosening is the chief cause for TKR failure. In revision TKR the gap between the bone and each of the two components is the defect that needs to be addressed to prevent loosening. [43, 44] Machine learning is the answer not only for this but also for implant size, placement, and ligament balancing. Variables influencing revision rates are patient characteristics, surgical technique, surgeon expertise, and the number of instances is examples of non-device-related problems. The variance in revision rates between different prostheses may be also caused by device-related factors. [45, 44] Plain radiography, scintigraphy, arthrograms, fluodeoxyglucose-positron emission tomography (FDG-PET), and magnetic resonance imaging are only a few of the imaging techniques utilized for diagnosis like implant loosening.[45]

An efficient physical preventative technique for deep vein thrombosis is intermittent pneumatic compression.[46] Tourniquet was linked to a higher risk of major adverse events, higher pain thresholds, and longer hospital stays. The safe execution of this in TKA has been made possible by procedures such anemia screening, controlled hypotension, knee flexion via surgery, implantation of a bone plug in the femoral canal, pulse lavage, swab packing, CO2 gas application, and computer navigation. [47] Following computer-assisted navigation (CAN) and robotic-assisted (RA) knee arthroplasty, pin-related problems are rather rare. [48, 49] Effective hemo-stasis, such as tissue adhesives and sealants, is extremely important in clinical therapies and has the potential to save lives in the pre-hospital scenario. [50] Mid-level inserts had a low incidence of post-TKA instability or aseptic loosening at mid-term follow-up and are helpful for patients with severe deformity and ligamentous laxity. [51] To control increased intraoperative coronal plane laxity that cannot be resolved with conventional ligament balancing procedures and a posterior-stabilized (PS) insert. [41] Large osseous deficiencies in the tibia and the detrimental effects they have on fixation are a frequent and difficult issue that arises during rTKA. When there are significant osseous abnormalities present, trabecular metal (TM) tantalum cones (Zimmer, Warsaw, IN, USA) are one method for establishing metaphyseal (zone 2) fixation. Long stems have historically been utilized to offload the insufficient metaphyseal bone and enhance implant. [52] This study aims to review that which one of the surgical techniques is preferred and executing most currently.

METHODS:

SEARCH STRATEGY:

PUBMED DATABASE SEARCH:

A literature search for scientific articles on the Technologies and Techniques in Total Knee Replacement Surgery: A Comprehensive Review “was performed using PubMed and Google

scholar from 2021 to 2023 (for 3 years). The applied search strategies of the databases can be found in Table1. A total of 4719 PubMed-results were found without time frame. And with filer (2021-23) it was 706 results. Of these studies, 198 were subsequently excluded after title and abstract screening and duplicate removal. Thus 84 results out of 282 articles were selected for the study.

GOOGLE SCHOLAR DATABASE SEARCH:

The following keywords or their combinations were used for Google scholar search: With topic-[emerging techniques and technologies in total knee replacement surgeries] and time filters: {2021-23]; Results were 17400 articles. And with phrases "total knee replacement surgery" AND "techniques" and time limit 2021-23, 1100 articles were identified (any type). In which, 896 were detected as free full text (any type). Out of 896 articles, 238 results were considered as review articles. And after screening 67 review articles out of 238 articles were selected for the current study. Search filters of the databases were used to identify RCTs if applicable. No language restrictions were applied. The reference lists of the relevant articles were manually reviewed for additional studies. Screening for relevance was performed based on title and abstract initially, and then by reviewing the full text.

TABLE.1 PubMed and Google scholar databases search;

Strategies on PubMed	Google scholar	Key words on PubMed	Total article	Final selected article
1. ("Artificial Intelligence/classification"[Mesh] OR "Artificial Intelligence/history"[Mesh] OR "Artificial Intelligence/standards"[Mesh] OR "Artificial Intelligence/statistics and numerical data"[Mesh] OR "Artificial Intelligence/trends"[Mesh]) OR new OR bleeding edge OR deep OR derivative OR eventual.	Topic:[emerging techniques and technologies in total knee replacement surgeries]	new, bleeding edge, deep, derivative, eventual	4719 on PubMed and 17400 on Google scholar	84 on PubMed and 67 on Google scholar
2. ("Technology/classification"[Mesh] OR "Technology/history"[Mesh] OR "Technology/methods"[Mesh] OR "Technology/statistics and numerical data"[Mesh] OR	Phrases:"total knee replacement surgery" AND "techniques"	innovation, machine, apparatus, instrument, device		

"Technology/trends"[Mesh]) OR innovation OR machine OR apparatus OR instrument OR device.				
3. ("Arthroplasty, Replacement, Knee/adverse effects"[Mesh] OR "Arthroplasty, Replacement, Knee/classification"[Mesh] OR "Arthroplasty, Replacement, Knee/instrumentation"[Mesh] OR "Arthroplasty, Replacement, Knee/methods"[Mesh] OR "Arthroplasty, Replacement, Knee/mortality"[Mesh] OR "Arthroplasty, Replacement, Knee/rehabilitation"[Mesh] OR "Arthroplasty, Replacement, Knee/standards"[Mesh] OR "Arthroplasty, Replacement, Knee/statistics and numerical data"[Mesh] OR "Arthroplasty, Replacement, Knee/trends"[Mesh]) OR total knee arthroplasty OR total knee reconstruction.		total knee arthroplasty, total knee reconstruction		

TABLE.2 summary of various techniques and technologies used in TKR surgeries

Authors	Study-year	Article-type	Topic	Methods/techniques	Conclusion
D. Alesi,	2021	review	Total knee arthroplasty in valgus knee deformity: is it still a challenge in 2021?	Several soft tissue release techniques for knee valgus correction	All STR techniques give satisfactory results
Cécile Batailler	2021	review	Concepts and techniques of a new robotically assisted	the ROSA knee system	Good reproducibility and productivity in TKR

			technique for total knee arthroplasty: the ROSA knee system		
Junren Zhang	2022	review	Robotic-arm assisted total knee arthroplasty is associated with improved accuracy and patient reported outcomes: a systematic review and meta-analysis	robotic-arm assisted total knee arthroplasty (RATKA)	RATKA demonstrated improved accuracy of component positioning and early patient-reported outcomes, though it may not be clinically significant.
Prakash Jayakumar, MBBS, DPhil	2021	RCT	Comparison of an Artificial Intelligence–Enabled Patient Decision Aid vs Educational Material on Decision Quality, Shared Decision-Making, Patient Experience, and Functional Outcomes in Adults	Cohort study with 3 modules; education, preferences and personalized outcomes	AI-enabled decision aid significantly improved decision quality, level of SDM, satisfaction, and physical limitations without significantly impacting consultation times, TKR rates, or treatment concordance in patients with knee OA considering TKR

			With Knee Osteoarthritis		
Jiazheng Xu	2022	RCT	Early Clinical and Radiographic Outcomes of Robot-Assisted Versus Conventional Manual Total Knee Arthroplasty: A Randomized Controlled Study	Comparison between robot-assisted total knee arthroplasty (RA-TKA) with conventional manual total knee arthroplasty (CM-TKA)	RA-TKA requires more time than CM-TKA, however, RA-TKA improved the accuracy of tibial component alignment.
Simon W Young	2022	RCT	A prospective randomized controlled trial of mechanical axis with soft tissue release balancing vs functional alignment with bony resection balancing in total knee replacement-a study using Stryker Mako robotic arm-assisted technology	compare the patient and surgical outcomes of FA to the current gold standard surgical technique, mechanical alignment (MA),	FA delivers superior outcomes for patients than MA
Cheol Hee Park	2021	review	Sensor-Assisted Total Knee Arthroplasty: A Narrative Review	2 sensors available, VERASENSE[mostly used] and eLIBRA	No apparent consensus that loads sensors technology will result in improved functional results.
Régis Pailhé	2021	review	Total knee arthroplasty: Latest robotics implantation	Assessing the types of robot, implantation techniques and steps in	TKA implantation is more accurate when using robotic systems than when using conventional instruments, the

			techniques	surgical procedure	functional outcomes appear better with newer synergistic systems, favor of using robotic systems
Bogdan Uivaraseanu	2022	review	Highlighting the advantages and benefits of cementless total knee arthroplasty (Review)	Comparative study for cemented and non cemented surgeries	Modern cement less TKA has similar survival rates and functional results as cemented prostheses. Non cemented is preferred in young people
Prasoon Kumar	2021	Review	Application of 3D Printing in Hip and Knee Arthroplasty: A Narrative	PubMed search with 30 relevant articles	3D printing in arthroplasty is an evolving field with promising results
E Carlos Rodríguez-Merchán	2022	review	The current role of the virtual elements of artificial intelligence in total knee arthroplasty	Compare the ML and DL of the AI	Deep learning (DL) is more advantageous than machine learning (ML)
Karthikeyan. P. Iyengar [a]	2021	review	Smart sensor implant technology in total knee arthroplasty	Compared the sensor and smart sensor technology	Smart Sensor implant technology in total knee arthroplasty appears to provide superior patient satisfaction rates and improved functional outcomes
Vikas Kulshrestha,	2022	Cohort	Early Outcomes of	prospective cohort study for DP AND	DP knee design had similar knee function to the UC

			Dual-Pivot Total Knee Replacement Compared to an Ultracongruent Design	UC	knee. The DP knee design had significantly better stair climbing ability
Man-Soo Kim	2023	review	Machine Learning for Detecting Total Knee Arthroplasty Implant Loosening on Plain Radiographs	Comparison study through survey for CNN and implant loosening	Deep convolution neural network (CNN) through transfer learning, shows high accuracy for detecting the loosening of TKA implants on plain radiographs.
Zhonghua Xu & Yuan Zhang	2022	review	What's new in artificially intelligent joint surgery in China? The minutes of the 2021 IEEE ICRA and literature review	robotic AND arthroplasty OR replacement	The safety and efficacy of domestic robot-assisted arthroplasty in China are well documented, and its accuracy and short-term clinical efficacy have been reported
Michael B Held	2021	Retrospective cohort	Improved Compartment Balancing Using a Robot-Assisted Total Knee Arthroplasty	Difference between RA-TKA and CM-TKA	RA-TKA resulted in improved intraoperative compartment balancing in flexion with no observed difference in mid-flexion and extension compared with CM-TKA
Rajesh Malhotra	2021	review	Navigated Unicompartmental Knee Arthroplasty: A Different Perspective	computer navigated UKA [unicompartmental arthroplasty]	validates the role of computer navigation in desirable implant positioning and limb alignment

David C. Birkhoff, BSc, Anne Sophie H.M. van Dalen, MD	2021	review	A Review on the Current Applications of Artificial Intelligence in the Operating Room	applications of AI in the OR [operating room]	Currently described applications of AI in the OR are limited to date. They may, however, have a promising future in improving surgical precision, reduce manpower, support intraoperative decision-making, and increase surgical safety
Tao Wen	2023	review	A standardized technique for lateral unicompartmental knee arthroplasty	UKA and its clinical score	lateral UKA protocol was reproducible and the patients had a good postoperative outcomes
Stefano Marco Paolo Rossi[1]	2023	CT	High accuracy of a new robotically assisted technique for total knee arthroplasty: an in vivo study	robotic system (ROSA® Knee System; Zimmer Biomet, Warsaw, IN) with a Posterior Stabilized Total Knee Arthroplasty (Persona® Knee System)	New surgical robot in total knee arthroplasty it is possible to perform accurate bone cuts and to achieve the planned angles and resections.
Christel Bidet-Ildei	2022	RCT	The Added Value of Point-Light Display Observation in Total Knee Arthroplasty Rehabilitation Program: A Prospective Randomized Controlled Pilot	Difference between point light and conventional 3 week rehab. programme	Favoring point-light display observation to improve functional recovery in patients with total knee arthroplasty.

			Study		
Ian A Harris	2022	RCT	Increased early mortality after total knee arthroplasty using conventional instrumentation compared with technology-assisted surgery: an analysis of linked national registry data	Conventional versus technology assisted	The use of conventional instrumentation during TKA is associated with higher odds of early postoperative death than when technology-assisted instrumentation is used.
Runzhi Xia	2021	Clinical trial	Verification and clinical translation of a newly designed "Skywalker" robot for total knee arthroplasty: A prospective clinical study	difference between the actual and the expected resection thickness, and the preoperative and postoperative lower limb alignments	The "Skywalker" system has good osteotomy accuracy, can achieve the planned angles well, and is expected to assist surgeons in performing accurate bone cuts and reconstructing planned lower limb alignments in the relevant clinical applications in future
Brett K Jones	2023	CT	Better flexion and early recovery with medial-stabilized vs single-radius total knee arthroplasty with kinematic alignment: Two-	retrospective cohort single center study for comparison between single-radius (SR) versus medial-stabilized	The MS group had better clinical outcomes than the SR group, with significantly greater knee flexion from six months through two years, better Knee Society Pain scores at six weeks

			year clinical results	(MS) knee devices	through one year, and higher Knee Society Pain/Motion scores at six weeks and one year postoperatively.
Yousef Marwan	2023	Retrospective review	Circular external fixation for knee fusion in complex indication	knee fusion with circular external fixator	Knee fusion using circular external fixation is a reliable surgical option for complex knee problems especially in infected failed revision total knee replacements. circular external fixators provide the advantages of gradual correction of length or alignment and superior mechanical stability
Tizian Heinz	2023	review	Trends in Computer-Assisted Surgery for Total Knee Arthroplasty in Germany: An Analysis Based on the Operative Procedure Classification System between 2010 to 2021	Difference between conventional, navigated and robotic surgery	Computer-assisted surgery, and particularly robotics for TKA, is seeing growing popularity and stepwise translation into routine clinical use in Germany, with a steep increase rate of more than 80% per year since 2018.
Carsten O Tibesku	2023	Systemic review	Comparison of clinical outcomes of VISIONAIRE patient-specific instrumentation with conventional instrumentation in total knee arthroplasty: a	VISIONAIRE, were conducted to assess TKA accuracy, intraoperative outcomes, and postoperative outcomes, compared	VISIONAIRE guides can lead to improved alignment accuracy and surgical efficiency compared with CI,

			systematic literature review and meta-analysis	with conventional instrumentation (CI).	
Lawrence Chun Man Lau	2021	Case report	Multi-energy spectral photon-counting computed tomography (MARS) for detection of arthroplasty implant failure	MARS Versus standard current imaging techniques	MARS CT imaging can detect orthopedic implant failure not detected by standard current imaging techniques
Olga Vl Bitkina, Jaehyun Park	2023	review	Application of artificial intelligence in medical technologies: A systematic review of main trends	AI in healthcare	Useful in medicine and other streams
Bin Zhang	2023	review	Unicompartmental knee arthroplasty versus high tibial osteotomy for medial knee osteoarthritis: A systematic review and meta-analysis	Compared UKA[unicompartmental knee arthroplasty] and HTO[high tibial osteotomy]	UKA produced less postoperative pain, less complications and superior WOMAC score, whereas HTO offered extended range of motion (ROM) and less revision rate
Terence L. Thomas BS [a]	2022	review	Pin-Related Complications in Computer Navigated and Robotic-Assisted Knee Arthroplasty: A Systematic Review	Studied pin-related complication in computer-assisted navigation (CAN) and robotic-assisted (RA) knee arthroplasty	Rare findings

Cheol Hee Park, MD	2021	review	Sensor-Assisted Total Knee Arthroplasty: A Narrative Review	Advantages of sensor based technology	An orthopedic surgeon's experience, adaptability, and technical knowledge of the sensor are crucial to the success of sensor-assisted TKA
Cécile Batailler	2022	review	Artificial intelligence in knee arthroplasty: current concept of the available clinical applications	Advantage of Before surgery, machine learning and During surgery, the robotic-assisted systems	AI-based tools improve the decision-making process, surgical planning, accuracy, and repeatability of surgical procedures

DISCUSSION:

Since its initial use in orthopaedic surgery in the 1980s, robotics has been embraced more frequently to increase the precision of implant location, prosthesis alignment, and to lower the rate of problems compared to manual procedures. Robotic total knee arthroplasty improves the surgeon's preoperative planning skills and real-time intraoperative dynamic referencing to enable ongoing range of motion and ligamentous tensioning assessments. However, robotic TKA is linked to longer operating times and iatrogenic injuries, so this surgical technique has both benefits and drawbacks. [53, 54] The effects of robotic surgery (RAS), kinematic alignment (KA), and computer-assisted surgery (CAS), as well as mechanical alignment (MA), alone or in combination, are unknown. R-TKA showed equal MCID accomplishment to M-TK, according to [55]. [56] To balance the knee and achieve functional alignment (FA) of the components, robotic surgery generates quantitative soft tissue information. Increased pre-resection balancing efficiency, fewer soft tissue releases than with a mechanical alignment technique, and precise bone cuts with robotic help are all advantages of FA. [57] However, the best aim for each patient is still up for dispute. Regarding the placement of a total knee arthroplasty (TKA), there are various schools of thought. The mechanical axis (MA) of the lower limb is used by the most widely accepted school for all patients. In some other research, kinematic axis alignment (KA) is used preferably. [58] Robotic-assisted TKAs may result in better health outcomes due to their decreased annualized revision rates and enhanced postoperative quality of life. [59] The additional surgical trays needed for the techniques and the longer operating times they required had a minimal impact on total expenses, however comparison data are lacking. [60]

With traditional TKA surgery, it is impossible to prevent significant errors of 10% and 30% patient dissatisfaction. It has been discovered that computer navigation systems have improved mechanical axis rotation and component placements compared to conventional TKA, gaining advantages from clinical and imaging procedures. It does not, however, improve functional outcomes. Although CAS was anticipated to improve clinical outcomes, TKA's short-term functional performance, and survivorship, as well as reduce revisions and associated health care costs, along with accuracy and reproducibility in prosthetic orientation with 3°, it is debatable whether CAS has any effect on long-term functional outcomes and implant survivorship. **Table_2.** [61, 54]

One study shown that; by minimizing angular deviation from the preoperatively planned target and by lowering the proportion of outliers from the target zone, both CAS and PSI can enhance the precision of rotational alignment of the tibial base plate. [62] Using jig-based manual procedures, total knee arthroplasty (TKA) exhibits good durability, yet considerable rates of dissatisfaction persist. There are few studies evaluating the relative effectiveness of mTKA and raTKA. When compared to mTKA, raTKA showed significant early clinical advantages, such as lower opioid needs, a shorter length of stay, and fewer PT sessions. [63] All around the United States, RA-TKA and CAN-TKA are increasingly being used. The odds of readmission within 90 days of surgery are reduced when these technologies are used. [64] A small number of studies showed PROM differences that reach clinical relevance, despite the majority of studies comparing RA-TKA and N-TKA with C-TKA demonstrating superior radiographic alignment outcomes. [65]

In the past 70 years, artificial intelligence (AI) has advanced quickly, with computer models and algorithms created to mimic human intelligence and carry out specialized jobs in a variety of sectors. The decision-making process, surgical planning, accuracy, and repeatability of surgical procedures are all improved by AI-based technologies. [66] Given that many issues related to TKA can be resolved quickly and effectively, AI's utility for knee joint replacement procedures cannot be overlooked. Artificial intelligence (AI) applications have typically been used to forecast risk, cost, and results rather than surgical problems. [67] Where conventional pre-operative imaging techniques fall short, multi-energy spectrum photon-counting computed tomography (MARS) can detect knee arthroplasty implant failure. MARS allows for the creation of material-specific pictures while minimizing the beam-hardening artifact frequently present in conventional CT imaging. [68]

Patient-specific instrumentation (PSI) is suggested as a solution to the major issues associated with malalignment and the ensuing consequences in total knee arthroplasty (TKA). The relevance of previous PSI studies on TKA outcomes is restricted since they often do not distinguish between PSI systems and only evaluates a small number of outcomes. A PSI system based on X-ray and preoperative magnetic resonance imaging is called VISIONAIRETM cutting guides. Compared to CI (conventional imaging), VISIONAIRE guides can increase alignment

precision and surgical efficiency without compromising postoperative safety and return-to-function outcomes. [69]

Findings from one study offer fresh insights in favour of systematically observing point-light displays to enhance functional restoration in TKA cases. [70] In order to achieve the required kinematic aims after TKA, smart sensor assisted technology can be used intraoperatively to offer an objective assessment of ligament and soft tissue balancing while maintaining the sagittal and coronal alignment. Additionally, it can offer post-implantation data to track the effectiveness of the implant under real-world situations and the clinical progress of the patient during rehabilitation. In TKA, the introduction of Smart Sensor implant technology appears to result in higher patient satisfaction scores and better functional outcomes. [71] A subset of machine learning (ML) and artificial intelligence (AI), deep learning (DL) is increasingly seen as a key technology of the current Fourth Industrial Revolution. A deep convolution neural network (CNN) could be used to precisely identify implants used in total knee arthroplasty on plain radiographs. The CNN algorithm has great accuracy for detecting the loosening of TKA implants on plain radiographs through transfer learning. [72]

Circular external fixators offer the advantages of gradual length or alignment correction and improved mechanical stability in complex circumstances. Additionally, because contact between the implant and the diseased location is avoided, the danger of biofilm formation and infection persistence is reduced. [73]

When opposed to traditional total knee arthroplasty (COTKA), robotic arm-assisted total knee arthroplasty (RATKA) has the advantage of restoring femoral rotational alignment. Although RATKA reduces intraoperative blood loss and postoperative LOS, the short-term clinical efficacy comparison has not yet proven the benefits of robotic technology. The accuracy of femoral rotational alignment reconstructed by RATKA is significantly better than that of COTKA and is more conducive to the recovery of knee flexion function after surgery. [74]

LIMITATIONS:

1. Fast development in robotic technologies made a shift from active to semi-active to passive systems of TKA surgery

2. Availability of short term data reflects that modern techniques and technologies have early positive results rather than long term results.

3. Lack of RCT studies

4. Comparison between robotic and conventional system of TKA surgery is limited and difficult due to use of different implants.

5. Comparison between different implants and same robotic system is also limited since usually one robotic system uses same type of implants.

6. Procedures are carried out in close environment.

7. Lack of homogeneity in collected data set

CONCLUSION:

Numerous studies have advocated the use of various surgical technologies, including robotic assistance and artificial intelligence. The current study reveals that robotic assisted surgery, computer assisted surgery, and guided surgery with intraoperative utilization of sensor technologies are the most frequently employed surgical approaches. Additional classifications for robotic surgery assistance include passive, semi-passive, and active. Robotic aided surgery has been proven to be the most applicable in terms of alignment, balancing, gap management, and bone cutting techniques among these surgical approaches. Orthopaedic surgeons typically favour semi-passive robotic aided surgery since, with this method, the decision to cut the bone stays with the surgeon. As a result, orthopaedic surgeons are in charge of planning and making decisions regarding the surgical operation. However, the practical value of passive robotic aided surgery in relation to total knee arthroplasty cannot be ignored.

The most frequently used technologies in contemporary TKA surgeries include AI-based tools, MARS CT imaging, VISIONAIRE guides, circular external fixators, skywalker, point-light display observation, deep convolution neural network (CNN) through transfer learning, Smart Sensor implant technology, deep learning (DL) and machine learning, DP [dual pivot], etc. Some of these technologies have been shown to be superior than others, but because there is a dearth of comparison data in the literature, it is very difficult to categorize them as being of higher or lower value. Every technology, including imaging, arthrodesis, and fusion surgeries, bone cutting, knowledge of internal changes in ligament tension, implant position, and gap management, unquestionably plays a crucial role in procedures related to TKA surgeries. Some of these technologies are essential for helping with decision-making, diagnostics, and surgical technique. A few of them assist with alignment concerns prior to and following TKA procedures, while others can handle balancing problems and are utilized to handle axis rotation, bone cutting, fusion, etc. However, its equivalent technologies favour MARS, VISIONAIRE guidance, deep leaning, point light display observation, CNN, and smart sensor technologies. These technologies' capacity to focus their goals in the context of total knee replacement surgery has been linked to a high degree of diversity in their usefulness and effectiveness.

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