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Implementation of Modern Technologies in Total Knee Replacement

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Abstract:- Severe osteoarthritis can be effectively treated with a total knee replacement (TKR), often referred to as an arthroplasty. Even though TKR patients have good survival rates, up to 20% of them are nevertheless unhappy. Current improvements in knee arthroplasty technology exhibit promise & may boost functional results. This study sought to present some unique TKR technologies, their current ideas, merits, & limitations. Whilst implant placement & limb positioning may be improved with patient-specific equipment, functional results are unchanged. The sensors must attempt to offer accurate data on equilibrium of ligaments during TKR. The accelerometers are sophisticated instruments created to enhance TKA positioning. However, their benefits remain still debatable. The robotic-assisted (RA) systems provide an exact & repeatable bone preparation owing to a robotic interface having a 3D surgical planning, based on preoperative 3D imaging or not. The new technologies in TKA are highly appealing & have continually progressed. Future orthopaedic technology will increasingly serve as a beneficial tool for surgeons performing patient-specific arthroplasty with patient-specific positioning goals.

Keywords:- *Knee Arthroplasty; New Technologies; Patient-Specific Instrumentation; Sensors; Accelerometers; RA Surgery.*

I. INTRODUCTION

Orthopaedic surgery, an active medical specialty, has experienced swift & creative improvements in both surgery & treatment. Recent developments in knee replacement technology show promise. TKR, sometimes referred to as arthroplasty, is an extremely efficient treatment for serious osteoarthritis (Naresh, 2022). Benefits of TKR include a high rate of survival, a prompt resumption to daily activities, & a general increase in function, all of which help to meet patients' functional expectations. A significant surgical objetive is still arthroplasty. Despite advancements in surgical procedures & after care, up to 20% of TKR patients still dislike their outcomes (Noble et al., 2016). Just 64% of patients in a multicenter cohort of 547 non-selected TKR patients reported pain-free gait, 35% reported pain-free stair climbing or descending, & 40% experienced discomfort when jogging (Bonnin et al.,2020).

Since TKR is already a successful procedure, focus is now on raising patient contentment & enhancing functional results. The development of several novel technologies to increase surgical accuracy has raised hopes for an improvement in patient contentment following TKR.

Aiming to personalise procedure & consider each patient's unique anatomy & ligament balancing, technologies like PSI, CAS, navigation, computer, smart tools, & positioning accuracy & reliability enhancement, all work to enhance implant positioning. But because novel technologies frequently have drawbacks & limits, understanding how to effectively use them to enhance surgical results is crucial. The objective of this work is to introduce some recent developments in TKR technology.

II. MATERIAL & METHOD

The study is conducted using a descriptive methodology that relied on secondary data collected through case studies & observational studies. The information was gathered on cutting-edge technology utilised in field of TKR, including RA arthroplasty, sensors utilised in TKR, accelerometer smart tools & PSI. The following is a discussion of these advance technologies utilised for TKRs.

➢ *Patient Specific Instrumentation (PSI):*

Several orthopaedic implant manufacturers currently provide PSI systems (Smith & Nephew, Wright Medical Technology, DePuy, Biomet, Medacta, & Zimmer). Both complete & single-compartment knee arthroplasty procedures can be performed using these systems. To simulate anatomy of knee & create a custom surgical plan regarding bone resection, component location, & positioning, preoperative 3D imaging (CT scan or MRI) is performed. Cutting blocks or pin guides are produced & transported to hospital once surgeon has given his or her approval, typically in sterile packaging suitable for OR. To position implantation of pins into femur & tibia, pin guides are positioned on front surfaces of distal femur & proximal tibia. With help of these unique cutting guides, bone resections can be precisely sliced in accordance with preoperative 3D planning.

➢ *Sensors in TKR:*

Sensors are utilised to provide unbiased data on soft tissue balance throughout TKR. These disposable gadgets transmit wireless data to an intra-operative monitor to assist in making well-informed decisions about implant placement & soft tissue releases to enhance balance & stability throughout a wide range of motion. When tibial & femoral cuts are finished during surgery, system—a wireless, disposable articular loading measurement device—is inserted in tibial component tray. A few sutures are utilised to close capsule. In order to monitor pressures exerted medially and laterally from a fully extended to a fully flexed position, surgeon maintains limb in a neutral posture. A medial & lateral compartment load differential of less than 15 pounds is deemed to be sufficiently "balanced". Further soft tissue releases or bone resection can be done if joint exhibits imbalance following initial ligament balance assessment.

- *Accelerometer:*

Accelerometers are high-tech instruments designed to facilitate better femoral & tibial component positioning during TKR. The chance of functional rehabilitation, patient contentment, & TKR survival may all be increased with careful component positioning. There is still some debate over what best positioning is for TKR. The precision of tibial & femoral cuts is still crucial, regardless of positioning technique (mechanical, kinematic, limited kinematic). Having a goal positioning that is presently in varus or valgus makes an inaccuracy of 3 degrees in element positioning very detrimental. Because of need for precise positioning of each component during surgery, these aids are invaluable.

- *Robotic-Assisted Knee Arthroplasty:*

RA surgery’s widespread use is a logical development from almost 20-year-old practise of computer-assisted surgery in knee arthroplasties. Whatever technology is employed, major advantage of robotics is precise & repeatable bone preparation made possible by a robotic interface. This RA technology also enables an evaluation of ligament balancing in accordance with surgically performed bone cuts & implant placement. The surgeon's valgus or varus stress is typically a factor in this ligament balance. Robotic devices are not intended to take position of surgeons, but rather to enhance their effectiveness. The robotic arm helps surgeon carry out extremely precise bone cuts in accordance with surgical plan. Preoperative imaging study costs, inconvenience to patient in having examination done at accredited facilities, & radiation exposure are some drawbacks. Image-free RA devices need a manual bone surface mapping performed intraoperatively. The planning is then carried out during surgery using a 3D virtual model. No specific preoperative mapping is done, & 3D imaging is not required. Because human mistake is possible, intraoperative registration depends on surgeon's accuracy in entering relevant data points. Robotic systems for knee arthroplasty fall into three categories: passive, semiautonomous, & autonomous. A 3D virtual model provided by a passive system enables precise preoperative planning. The bone preparation system, however, does not exist. Safeguards are built into autonomous & semiautonomous systems to prevent bone from being removed outside of 3D plan.

III. RESULT & DISCUSSION

This section will discuss comparison of advanced technologies being utilised for TKR to highlight findings gathered from earlier studies.

There are studies that have been published that claim that PSI increases implant location accuracy, although effects of PSI on radiologic outcomes remain unclear according to various meta-analyses (Bonnin et al., 2020). De et al., (2017) studied postoperative long-leg radiographs from 155 conventionally conducted TKAs & 569 PSI-performed TKAs. With PSI, they found 9% & 22% fewer HKA angle outliers than they did with conventional instrumentation.

Two meta-analyses comparing positioning accuracy found no notable variation in outlier numbers for mechanical axis, coronal, sagittal, and axial positioning. (Ng et al., 2015). Nevertheless, a meta-analysis of 6 trials with 444 knees by Mannan et al., (2016) found positive femoral rotational outcomes. In a randomised controlled experiment involving 69 patients, Randelli et al.,(2019) found PSI didn’t increase of femoral component rotation’s precision during TKA compared to standard instrumentation. No research has found any differences in clinical or functional results between PSI & traditional techniques.

The preoperative planning of PSI, which includes implant sizing, rotation, & femoral & tibial excision, should theoretically shorten surgery time. However, a newly published meta-analysis by Mannan et al.,(2016) that examined 957 patients discovered a pattern without statistical significance of shorter operating times, with 5-minute average per patient. Comparing length of a surgical procedure using various modern technologies, such as PSI & CAS, would be intriguing & more pertinent.

The outcomes & effects of sensors on TKR’s ligament balancing have been described & evaluated in a number of studies. In TKA (for measured resection TKA or modified gap balancing TKA), Lustig et al., (2016) discovered that an objective measurement employing real-time orthosensor enhanced soft tissue balance. So, in a potential cohort of 50 sensor-assisted (SA) TKAs (without substantial deformity), Scholes et al., (2016) reported that 74% of knees needed further rebalancing with sensor following traditional gap balancing using tensiometer. Evaluation with sensor revealed coronal and sagittal load imbalances even when a proper gap balance was attained using a tensiometer. However, few studies have indicated that functional outcomes following sensor assisted TKA are better than those following conventional TKA, & there are frequently several limitations. Without a prior radiographic evaluation, Lustig et al.,(2016) found that clinical ratings & ROM were notably greater following SA TKA in comparison with post manually balanced TKA. In a comparison investigation of 50 SA TKAs, Scholes et al., (2016) found no clinical or radiological differences between two types of TKAs. To evaluate clinical value of this gadget, clinical follow-up is still insufficient.

Accelerometer-based navigation was preferred by Jiang et al., (2015) for restoration of Hip-Knee-Ankle (HKA), although other research reported no differences between study groups (Ng et al., 2012). At short-term follow-up, there was no discernible difference between functional knee score of iASSIST group (To aid in the placement of orthopaedic implants, iASSIST Knee System is utilised, which is a computer-assisted stereotaxic surgical tool system.) & traditional group (Abdel et al., 2018). According to Scholes et al., (2016) study, using accelerometer-based navigation did not result in longer operating times when compared to traditional methods. There hasn't been any analysis of learning curve in literature, as it is merely a tool, but not a full navigation system. The rate of complications with each surgery was found to be equivalent.

RA systems with image-based & image-free capabilities have dramatically improved outcomes, particularly about implant location. The level of joint line was extremely successfully regulated utilising a robotic system (RS), as demonstrated by (Randelli et al.,2019). According to research, RA Unicompartmental Knee Arthroplasty (UKA) does not necessarily result in a significant improvement in mean implant location. Yet, decrease in outliers is notable (Naresh, 2022) & hence pertinent to decline in failure. Similar findings were found by several meta-analyses & systematic reviews. Moreover, studies have revealed that a RA system results in superior functional ratings, lower post-operative discomfort, quicker return to work & activity, & improved ligament balancing (Noble et al.,2016).

Research on RA have found that short- & medium-term survival rates are satisfactory. Yet, no comparative study has shown that RA Unicompartmental Knee Arthroplasty (UKA) has a higher survival rate than traditional UKA. At midterm, published revision rates following RA UKA range from 3% to 10%. (Vundelinckx et al., 2016). According to (Noble et al., 2016), image-based RS increased, in comparison to a conventional technique, precision of femoral sagittal & coronal positioning, tibial sagittal & coronal positioning, tibial slope & limb positioning, & joint line restoration. RA TKA & traditional TKA did not significantly differ in rate of early complications (Vundelinckx et al., 2016).

According to Ajay et al. (2015), image-based RA TKA results in less damage to periarticular soft tissues & bone than traditional TKA. For semiautonomous RA system, additional research over long & medium terms is required. The cutting-edge medical innovations, particularly robotic surgery, are also highly intriguing instruments for contentious issue of limb positioning. As a consequence, this study summarizes discussed technologies, which include patient-specific instrumentation that improves implant placement & limb positioning but not functional outcomes, TKA sensors that must provide objective ligament balance data, smart accelerometers that improve TKA positioning, & RA systems that, due to a robotic interface, provide accurate & reproducible bone preparation & 3D surgical planning on the basis of preoperative 3D imaging. As an outcome, incorporation of these technologies into TKR has shown to be a promising aspect of equipment in future.

IV. CONCLUSION

In conclusion promising novel technologies that potentially enhance functional outcomes of TKR have recently been discovered. Therefore, while technologies like as patient-specific instrumentation can improve implant location & limb positioning, functional outcomes are unaffected. The customised knee implants aim to function similarly to natural knee. The sensors should make every effort to provide reliable information on ligament stability during TKA. Accelerometers - ingenious tools utilised to enhance TKA positioning. Their aids haven't been settled upon. Accurate & reproducible bone preparation is made possible by RA systems thanks to a robotic interface & 3D surgical planning, which may or may not be based on preoperative 3D imaging. The latest innovations in TKA are incredibly alluring & are always changing. All technologies, however, need to be critically examined over a long period. Predictive modelling & artificial intelligence have ability to lessen downsides of emerging technologies.

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