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CRITICAL EVALUATION OF RESULTS OF TOTAL KNEE REPLACEMENT BY COMPUTER NAVIGATION TECHNOLOGY

Orthopaedics

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ABSTRACT

Objective: The procedure of TKR consists of joint articular surface replacement with a knee prosthesis whose positioning has been conventionally performed with the use of intramedullary or extramedullary alignment. More recently, computer assisted systems have been developed to improve the positioning of the prosthesis components with the goal of improving the postoperative prosthesis alignment, which in turn improves the overall survivorship of the prosthesis.

Methods: This study was a prospective type of interventional clinical study. The study was conducted in the department of orthopaedics of Santokba durlabhji memorial hospital cum medical research institute jaipur. 20 consecutive patients of osteoarticular disease of knee with proven diagnosis of severe arthritis, diagnosed radiographically and clinically were selected and computer Assisted total knee arthroplasty performed. All the patients were evaluated for clinical, functional and radiological status according to knee society scores.

Results: There were total 20 patients out of them 5 were male and 15 were female. Overall the mean age of total knee arthroplasty was 62.85 years. 28 knees out of the 34 were replaced bilaterally and 06 replaced unilaterally. Average follow-up was 12 months. Main indication of total knee arthroplasty was severe pain. After total knee arthroplasty 16 knees had no pain and 15 knees had mild pain. The mean preoperative knee society pain score was 11.76 and postoperative pain score was 42.50. The mean preoperative range of movement before TKA was 96.32 degree and after total knee arthroplasty mean ROM was 116.47 degree. There was statically significant improvement present in functional score after total knee arthroplasty.

Conclusion: With the better understanding of biomechanics of knee, availability of newer prosthesis, newer technique like computer navigation system has led to good clinical and functional outcome. There is accurate restoration of mechanical limb axis by the computer navigated total knee arthroplasty.

KEYWORDS

Total knee replacement, Computer assisted navigation, Knee society score.

INTRODUCTION:

Osteoarthritis of the knee is common, affecting almost a tenth of the population aged over 55 years. Severe osteoarthritis of knee joint is a common problem in older people and a major concern for pain and disability. Apart from osteoarthritis, conditions like rheumatoid arthritis, seronegative arthritis, posttraumatic arthritis and malignant tumour conditions of the knee joint also cause significant morbidity to patients[1].Most patients with early osteoarthritis of the knee are able to manage their symptoms with medical treatment and conservative methods, but a large number of patients referred to the specialist surgeon for further management have debilitating disease.

Currently, approximately 2% of the population of 55 years age and above are so disabled that they need TKR, and this rate increases with age. The estimated prevalence in women is nearly twice as high as in men[2]. The goals of TKR surgery include adequate alignment of the prosthesis components and the limb, stability of the knee, and attainment of sufficient range of motion, which permits adequate movement to attain improved quality of life[3].

TKR usually presents excellent results, although serious complications occur in around 5% of cases because of loosening, infection, instability, dislocation or fracture. The surgeon's experience in patient's selection, soft tissue balancing, the alignment of the leg, the restoration of the joint line and also the prosthetic design are all possible factors influencing the success of TKR.

In orthopaedic surgery, there is a well-recognised relationship between accuracy and outcome. A well-aligned hip or knee replacement is less likely to dislocate and will last longer. In joint replacement, freehand techniques have been augmented by the introduction of mechanical alignment jigs and cutting blocks. Despite the continuing improvement in mechanical alignment systems, it has been estimated that the error in tibial and femoral alignment of over 3^0 occurs in about 10% of total knee replacements. This is due to drawbacks of the conventional alignment systems. The conventional alignment tools assume a standard bone geometry which may not apply to specific patients. Finally, all mechanical alignment tools rely on direct visual inspection to confirm the accuracy of implant positioning at the end of the procedure[6].

More recently, computer assisted surgery (CAS) have been developed to improve the positioning of the prosthesis components. CAS has shown to improve the positioning of implant placement and more properly align the lower limb mechanical axis according to the desired plan[7]. Improved prosthesis alignment improves the overall survivorship of the prosthesis.

History of CAS

Navigation was first introduced experimentally in the 1980s and clinically in the 1990s, but has only entered mainstream orthopaedics in the last 7 years.

Intraoperative navigation in total joint replacement began in 1992, when William Barger, in Sacramento, California, performed the first computer-assisted surgery in orthopaedics on a total hip replacement. Frederich Picard performed the first intraoperative computer-navigated knee replacement surgery in 1997, updating work that he conducted in a postdoctoral thesis in 1993.

Basics of CAS-how it works?

A digital image, which serves as a map for each procedure, is created. This image is provided to the operating surgeons for guidance during surgery. Surgical instruments can also be incorporated into the map for knowing their position, attitude and accuracy even in millimetres or fractions of degrees during operation. The technique utilized to achieve accurate imaging modalities intraoperatively can be divided into three types:

1. Preoperatively imaged technique-This type of modality requires information from CT/MRI scan of the knee about the anatomy of the knee.
2. Intraoperative imaging technique-In this type, modified fluoroscopy is used to help in anatomical mapping of the knee during surgery. The data collected are transferred to the computer via wired connection directly in the operating theatre.

3. Image-free technique-An anatomical model that is fixed in the software is upgraded by the process of a so called surface registration proc ess or bone morphing. This is recently the most used technique for navigated TKR. However, there has been no study yet showing a comparison of precision of this technique vs image-based modality techniques.

All the above techniques or systems require the process of registration. This is a predetermined sequence in which a surgeon identifies the key anatomical landmark for the computer. Registration in orthopaedic procedures tells the computer where the bone is in space. The prerequisite for registration is that there is a tracking marker on the bone that can be recognised by the computer's tracking systems.

The most fundamental aspect of registration is accuracy in doing this. Once registration is done, it is possible to proceed with operation. There are various methods of registration available, which include simple fluoroscopy, optical tracking and a newer technology like electromagnetic tracking.

Planning

After the initial process of registration, the computer gathers the information regarding joint anatomy and size and limb alignment and matches the anatomy with the size and type of implant. The computer then gives the information regarding the orientation of bony cuts, implant sizing and soft tissue tension. Recent technique includes so called kinematic-based workflows, where before bony cuts are made based on the optimized knee kinematics and optimized flexion/extension gaps, adequate cutting is suggested for optimal soft tissue balancing.

Implementation and verification

The essential components after registration are setting up of the cutting blocks and rechecking of the cuts. The alignment is confirmed on the computer screen. The hardware used is similar in most systems. The computer receives the information from an infrared camera. This in turn transfers signals from the beacons fixed to the patient. The computer screen provides the visual images required for the surgery.

The software provides a structural model which provides interactive images and allows storage of data that describe the surgery. The software used is of two types, namely, closed and open system. The closed system produces visual displays of the prosthesis, and the open system needs its own software, which is operation-specific and not prosthesis-specific.

The next step is to determine the component-to component position and soft tissue balance, which in turn help in analysing the radiological and clinical outcomes.

AIM AND OBJECTIVES:

- To describe the basic principles of total knee replacement.
- To evaluate the results of knee replacement basis on knee society scoring.
- Assessment of functional abilities of patients in follow up study.

INCLUSION & EXCLUSION CRITERIA:

This study was performed in Santokba Durlabhji Memorial Hospital, Jaipur during the period of March 2011 to may 2011. 20 consecutive patients knees of osteoarticular disease of knee with proven diagnosis of severe arthritis, diagnosed radiographically and clinically were candidates of total knee arthroplasty.

INCLUSION CRITERIA:

- Primary OA patients above age of 55 years.

EXCLUSION CRITERIA :

- Non consented patients
- Post-traumatic arthritis
- Post-infective
- Complex deformities

METHODS:

- All patients were evaluated clinically and radiologically at the time of admission. History, General Examination and local examination was recorded on the proforma. Patient were investigated completely for operative and anesthesia purpose.
- All the patients were evaluated for clinical, functional and radiological status according to **knee society score.**This includes:-

1. Pain
2. ROM
3. Stability
4. Flexon contracture
5. Extension Lags
6. Alignment
7. Walking ability
8. Stair climbing
9. Use of support

- Each of these criteria was allotted points according to the knee society score and functional score.
- For the radiology assessment of affected knees, AP and lateral views were taken. The AP view was taken in the standing position.
- Pre operative counseling of the patients and his relatives regarding the treatment option and prognosis was done and consent for surgery obtained.
- Surgery was performed under epidural/GA/SA depending upon the patient condition.

SURGICAL TECHNIQUE:

The patient is positioned supine on the operating table under tourniquet. Area to be operated upon is washed with savlon and painted with betadine and a sterile draping to be done. A mini medial parapatellar approach combined with an imageless computer navigation system (Ci total knee replacement version 1.0; DePuy/Brainlab, Munich, Germany) is used to perform the procedure. An imageless computer navigation system (Ci-CAS; DePuy International) is set up opposite to the involved limb.

A midline skin incision measuring <10 cm is made. An abbreviated quadriceps tendon-splitting approach as described by Scuderi et al. is used to enter the joint. This incision do not extend >2 cm into the tendon proximal to the patella. The patella is subluxated laterally, and the medial facet is osteotomized to provide improved vision of the operative field.

Dual 3-mm unicortical pins are drilled into the tibia and femur through separate stab incisions, and the respective passive infrared reflectors are attached to the pins. Registration for bone morphing is performed with use of a pointer with attached passive reflectors. During rotation of the femur, kinematic analysis is used to obtain the position of the center of the femoral head. The orientation and position of a slotted cutting block are guided by the computer (with use of a plane verifier), and then the block is pinned in place.

Bone cuts are then made under computer guidance, with the tibial cuts being completed first, followed by the femoral cuts, without violation of the medullary canals. The resulting bone cuts are verified with the computer. A medial or lateral release with a so-called pie-crusting technique is performed, depending on the knee deformity. So-called gap balancing is performed with spacer blocks. Limb alignment, joint stability, and patellar tracking throughout the full range of movement are checked and recorded.

The definitive implants are cemented with finger pressurization. The tibial implant is cemented first, and excess cement is removed circumferentially around the plate. The coronal, sagittal, and rotational positions of the implant are recorded. The wound is closed over suction drain in layers with sutures.

POST OPERATIVE CARE:

After surgery vitals, severity of pain, amount of blood loss in drain, soakage, neuro vascular deficit were noted. Intravenous antibiotics including inj. Tazobactam +piperacillin 4.5gm after sensitivity test I.V tds, inj. Amikacin 500 mg i.v. bd were given for 5 days. Oral anticoagulant rivaroxaban 10 mg once a day for 3 days was given antero-posterior and lateral radiographs of operated knee were taken. On day 2nd drain was removed and active quadriceps exercises, knee movements, standing, walking with help of walker were started if patient is comfortable.

First dressing was on 3rd post op day and compression bandage was replaced by crepe bandage. Status of the dressing was noted. IV antibiotics were continued. Any signs of complication like fever, swelling knees, chest discomfort were noted. Knee bending exercises

were started and rests of exercises were continued. On day 6th oral antibiotic were given and patient discharged. Staple suture were removed on the 18th day if they are healthy. Then patient were followed up post operatively at 3 month, 6 month, 12 month.

OBSERVATIONS :

Table No. 1: Age Distribution

S. No.	Age Group (yrs.)	No. of knees	Percentage
1.	50-55	9	26.48%
2.	56-60	3	08.82%
3.	61-65	10	29.41%
4.	66-70	7	20.59%
5.	71-75	4	11.77%
6.	>75	1	02.94%

Table No. 2: Sex Distribution

S. No.	Sex	No. of patients	Percentage
1	Male	5	25%
2	Female	15	75%

Table No. 3: Bilateral and Unilateral Surgery

S.No	Procedure	No. of patients	%	No. of knees	%
1	Simultaneous bilateral	14	70%	28	82.35%
2	Unilateral	6	30%	6	17.65%

Table No. 4: Pain score (knee society pain score)

S. No.	Pain score (mean)	Score
1.	Preoperative	11.76
2.	Postoperative	42.50

Table No. 5: Range of Motion

S. No.		ROM Score (mean)	Range of motion (mean)
1.	Preoperative	19.26	96.32^0
2.	Postoperative	23.20	116.47^0

Table No. 6: Flexion contracture

S.No.	Flexion contracture	Preoperative (no. of knees)	%	Postoperative (no. of knees)	%
1.	5-10	17	50	4	11.76
2.	11-15	2	5.89	0	0
3.	16-20	5	14.71	0	0
4.	>20	3	08.82	0	0

Table No. 7: Extension Lag

S. No.	Extension lag	Preoperative (no. of knees)	Postoperative (no. of knees)
1	<10º	9	3
2	10-20º	7	1
3	>20º	1	0

Table No. 8: Alignment

S. No.	Alignment	Preoperative (no. of knees)	Postoperative (no. of knees)
1	0-4º	9	17
2	5-10º	17	0
3	11-15º	6	0
4	Other	2	0

Table No. 9: Walking Score

S. No.	Walking	Preoperative (no. of knees)	Postoperative (no. of knees)
1	Unlimited	0	6
2	>10 blocks	0	28
3	5-10 blocks	16	0
4	<5 blocks	11	0
5	Housebond	7	0
6	Unable	0	0

Table No. 10: Stair Climbing

S. No.	Stairs	Preoperative (no. of knees)	Postoperative (no. of knees)
1	Normal up and down	0	6
2	Normal up, down with rail	0	18
3	Up and down with rail	10	10
4	Up with rail, unable down	7	0
5	Unable	17	0

Table No. 11: Knee Society Knee Score

S. No.		Score
1.	Preoperative	30
2.	Postoperative	94

Table No. 12: Knee Society Function Score

S. No.		Functional Score(Mean)
1	Preoperative	33.38
2	Postoperative	80.44

DISSCUSSION: Thirty-four knees with primary osteoarthritis were replaced in twenty patients who were operated in Santokba Durlabhji Memorial Hospital, Jaipur during the period of March 2011 to may 2011. All the cases were operated by single chief surgeon with computer navigation system. Pneumatic tourniquet was used in all the cases. Anterior midline incision was used in all cases. Medical parapatellar retinacular approach was used in all the cases. All the prosthesis were fixed with polymethylmethaacrylate(PMMA) cement. The design of the prosthesis was cruciate sacrificing posterior stablilised press fit total condylar type (PFC). All the patients were subjected to the similar post operative rehabilitation schedule and patients were followed after 3, 6, and 12 months. Average follow-up was 12 months.

Evaluation of clinical results were done on the basis of knee society score. The KS score is a versatile scoring system designed for the evaluation of the results of total knee arthroplasty. In 1989, the knee society published its revised knee rating system (attached with proforma). Before this, the most commonly used rating system was the knee rating system of the hospital for special surgery. The main reason for the knee society revision was to separate patient's overall functional ability from knee functional alone.

There were total 20 patients out of them 5 (25%) were male and 15 (75 %) were female. Mean age for the male was 69.2 years and mean age for the female was 61.13. Minimum age was 50 years and maximum age was 79 years. Overall the mean age of total knee arthroplasty was 62.85 years. Below the age 60 year primary osteoarthritis is not so common hence the bulk of the patients are from age group 60-70.

We found that female patients outnumbered the male patients. Which is also supported by the study of the CH Yan, K Y Chiyu, FY Ng et al.(2011) who performed 1157 TKAs in QMH, Hong Kong. In their study there were 78% female and 22% male patients. In other study conducted by bistolfi A Massazza G, Rosso F et al. (2011) they found 78.9% women had TKA and 21.15% of male patients had TKA.[9]

The mean age of knee in total knee arthroplasty in our study is 62.85 years. Which is also supported by the international study of Martin SD et al. and Bistolfi A.[10] in which they had mean age of total knee artroplasty 67 and 68.4 years respectively.

28 (82.35%) knees out of the 34 were replaced bilaterally and 6 (17.65%) replaced unilaterally. We found that there is no increase incidence of complication and functional outcome was similar to unilateral replacement. In 1978, Hardaker et al published the first study on simultaneous bilateral total knee arthroplasty. They concluded that functional results were comparable and the incidences of complications were similar.[11] Ernest L. Gradillas et al have reported that postoperative relief of pain was greater among the patients undergoing bilateral replacement.[12] Mc Laughlin TP et al have documented that the functional result of a simultaneous bilateral procedure compares favorably with the result of a single procedure.[13]

Main indication of total knee arthroplasty is severe pain. Before total knee arthroplasty in our study 10 knees had severe pain, 14 knees had moderate continual pain and 4 knees had moderate occasional pain and remaining 6 knees had pain on walking. After total knee arthroplasty 16 knees had no pain and 15 knees had mild pain, none of the knees had moderate or severe pain after total knee arthroplasty. The mean preoperative knee society pain score was 11.76 and postoperative pain score was 42.50. This shows significant improvement in pain after TKA .Our results are comparable with the study conducted by Young-Hoo Kim et al. In which preoperative knee society pain score was 19 (0 to 25) which improved to 41 (42 to 50) at mean 10.8- year postoperative followup.[14]

The mean preoperative range of movement before TKA was 96.32

degree and after total knee arthroplasty mean ROM was 116.47 degree. The preoperative ROM score was 19.26 while after TKA it was 23.2 which shows good improvement. Our postoperative mean range of movement is higher than the recent study of Callaghan et al.[15] (mean 102^0) and the study of Ranawat et al.[16] (mean 111^0) .

There was statically significant improvement present in functional score after total knee arthroplasty before total knee arthroplasty functional score was 33.38 and improved to 84.44. This improvement was largely due to decrease in pain, deformity and disability. Our results are also comparable with the study conducted by Young-Hoo Kim et al. In which preoperative knee function score was 17 (13 to 28) which improved to 81(61 to 100) at mean 10.8- year postoperative followup.[14]

The male patients had better functional score as compared to the female patients. Our results are also comparable with a study conducted by department of orthopaedics, mayo clinic showing that sex has been consistently shown to impact both function and pain relief both before and after TKA. Although women achieve at least the same degree of functional improvement as men, women have worse preoperative physical function and do not reach the final level of physical function as men.[17]

In our study there is significant improvement in alignment after total knee arthroplasty. Preoperatively all patients had varus deformity ranging from 1to 25 degree but after TKA no patient had more than 3 degree malalignment. A prospective randomised study comparing the positioning of total knee arthroplasty with and without navigation support by Sparmann et al. reported a highly significant difference between the two groups in favour of navigation with regard to the mechanical axis, frontal and sagittal femoral axis and frontal tibial axis. There was no difference in axis of alignment of the tibial component in the sagittal plane between the two groups.[18]

Conclusion:

With the better understanding of biomechanics of knee, availability of newer prosthesis, newer technique like computer navigation system has led to good clinical and functional outcome. There is accurate restoration of mechanical limb axis by the computer navigated total knee arthroplasty.

By the computer navigation technique calculation of soft tissue tension can be done to give a perfectly balanced knee and there is reduced blood loss as there is no intramedullary instrumentation. Patients with bony deformity or hardware above or below the knee are ideal candidates for utilizing computer navigation guidance system.
There are several advantages of the CAS:

1. Dynamic assessment of deformity at any angle of flexion with patella in situ as opposed to conventional TKR where tensioning devices can be used in zero and 90° only.
2. Calculation of soft tissue tension to give a perfectly balanced knee.[19]
3. Accurate restoration of mechanical limb axis.[19]
4. Reduced blood loss.[20]
5. Decrease in incidence of fat embolism due to extra medullary instrumentation.
6. Accuracy of data on soft tissue tensions even in 1 mm and 1°. Surgeon is given control, feedback, ability to correct errors and documentation needed by CAS.

But there are some disadvantages:
1. Prolonged operative time
2. Certain learning curves
3. Significant cost implication for purchase and maintenance of the system
4. Lack of adequate evidence of the long-term benefits of CAS over conventional surgery in terms of implant survivorship and patient benefits for TKA.

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