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A PROSPECTIVE STUDY INVOLVING COMPARISON OF FUNCTIONAL OUTCOME IN KNEES FOLLOWING TOTAL KNEE ARTHOPLASTY, PERFORMED USING SINGLE RADIUS(SR) AND MULTI RADIUS(MR) FEMORAL DESIGN COMPONENTS

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ABSTRACT

Introduction: This study includes prospective follow up of patients with severe osteoarthritis and resulting varus deformity of knee joint operated for total knee arthroplasty (TKA)Aim of study was to study and analyze the results following comparison of functional outcome in knees undergoing total knee arthroplasty performed using single radius (SR) and multi radius(MR) femoral design components. **Materials and Methods:** This study is a randomized comparative prospective study. It was conducted in Department of Orthopedics, Santokba Durlabhji Memorial Hospital and Medical Research Institute, Jaipur from January 2023 to December 2023 on 60 patients undergoing Total Knee Replacement. **Results:** The post-operative mean values for maximum knee flexion in groups 1(SR) and 2(MR) were 117.3 and 122 respectively. This data was statistically significant (P-value <0.05).In group 1(SR), the mean values for maximum knee flexion increased from 107.83 pre-operatively to 122 post-operatively. This data was statistically significant (P-value <0.05).In group 2(MR), the mean values for maximum knee flexion increased from 107.85 pre-operatively to 117.3 post-operatively. This data was statistically significant(P-value<0.05). The mean difference in KSS knee and function score, between pre-operative and post-operative values in group 1(SR), were 27.57 and 56.67 respectively while in group 2(MR) they were 29.21 and 60.71. This data was comparable between the two groups and was statistically not significant (P-value >0.05). **Conclusion:** The Single Radius TKA group showed significant increase in maximal knee flexion relative to the Multi Radius TKA group. There was no significant difference in terms of comparison of increase in KSS knee and function score between the two groups

KEYWORDS

Total Knee Arthroplasty, Single Radius Femoral design, Multi Radius Femoral design

INTRODUCTION

Osteoarthritis (OA) was previously thought to be a normal consequence of aging, leading to the term "degenerative joint disease." However, it is now realized that osteoarthritis results from the interplay of multiple factors, including joint integrity, genetics, local inflammation, mechanical forces, and cellular and biochemical processes. The process involves interactive degradation and repair processes of cartilage, bone, and synovium.

Osteoarthritis (OA) is one of the most prevalent conditions resulting in disability particularly in elderly population. OA is the most common articular disease of the developed world and a leading cause of chronic disability, mostly as a consequence of the knee OA and/or hip OA[1].

Chondrocytes are probably the most important cells responsible for the development of the osteoarthritic process. Human and animal studies indicate that chondrocytes exhibit numerous abnormal metabolic features as part of the osteoarthritis process. These include increased levels of proliferative[2,3], synthetic[4,5] and degradative activity[6,7].

The principal symptom associated with OA is pain, which is typically exacerbated by activity and relieved by rest. With more advanced disease, pain may be noted with progressively less activity, eventually occurring at rest and at night. Episodic increases in pain and inflammation suggest synovitis caused by crystalline disease or trauma.[8,9]

Treatment consists of the physical therapy and drug therapy. Many patients require weight reduction. Prolonged use of corticosteroids should be avoided. Most common operations performed for hip and knee are total joint replacements. Osteotomies to change the mechanical axis of weight bearing are useful for uni-compartmental arthritis.[10]

Total knee replacement in some form has been practiced for over 50 years, but the complexities of the knee joint only began to be understood 30 years ago. Significant advances have occurred in the type and quality of the metals, polyethylene, and, more recently, ceramics used in the prosthesis manufacturing process, leading to improved longevity. As with most techniques in modern medicine, more and more patients are receiving the benefits of total knee arthroplasty (TKA).[11,12]

INDICATIONS FOR TKA INCLUDE[13]:

Any arthritic disorder of knee that is unresponsive to usual non-operative treatment including appropriate non-steroidal anti-inflammatory drugs, or other arthritic medications, occasional bracing, limitation of activities and use of assistive devices such as cane or crutches.

CONTRAINDICATIONS TO TKA INCLUDE[13]:

Active infection in the knee or anywhere in the body
A nonfunctioning extensor mechanism
Poor extremity circulation/vascularity
Presence of a well-functioning knee arthrodesis
Recurvatum deformity secondary to muscular weakness

This study includes prospective follow up of patients with severe osteoarthritis and resulting varus deformity of knee joint operated for total knee arthroplasty (TKA).

AIM OF STUDY INCLUDES:

To study and analyze the results following comparison of functional outcome in knees undergoing total knee arthroplasty performed using single radius(SR) and multi radius(MR) femoral design components.

MATERIALS AND METHODS

STUDY AREA

This study is a randomized comparative prospective study. It was conducted in Department of Orthopedics, Santokba Durlabhji Memorial Hospital and Medical Research Institute, Jaipur from January 2023 to December 2023.

Cases were selected from patients visiting the outdoor department. Patients suffering from grade 4 osteoarthritis of the knee joint with varus deformity who were willing to undergo total knee arthroplasty were admitted for surgery and included in the study. Primary TKA was

carried out in 60 consecutive knees under spinal / epidural anesthesia. All patients were operated by a single surgeon. Patients were divided into two groups.

Group-1: Single radius femoral design implant (SR)
Group-2: Multi radius femoral design implant (SR)

CRITERIA OF SELECTION OF PATIENTS
INCLUSION CRITERIA
All elderly age group patients with grade 4 osteoarthritis and varus deformity of knee were selected for this study who were willing to undergo TKA.

EXCLUSION CRITERIA
1. Pre-existing neuromuscular disorder, infection.
2. Post traumatic knee contracture/deformity.
3. Psychiatric or non compliant patient.
4. Revision Total knee arthroplasty
5. Well functioning knee arthrodesis
6. Compromised limb vascularity.
7. Valgus deformity knees.
8. Neuropathic joint
9. Obesity

Clinical evaluation of the patient was based on the Knee Society Scoring system.

The patients were divided into two groups on a chit-based system. They were evaluated preoperatively using the knee society scoring system and points scored were added up to give a net pain and functional score. A goniometer was used for this purpose.

Out of 58 knees, a total of 14 male knees and 44 female knees were replaced. All cases were operated by a single surgeon under combined effect of spinal and epidural anesthesia, following detailed pre-operative evaluation. There were, in total, 27 bilateral knee joint replacements and 4 unilateral replacements. Posteriorly stabilized cruciate sacrificing total condylar prosthesis were used for all cases.

All total knee replacements were performed with computer assisted navigation technology. Medial parapatellar approach to the knee joint was used in all cases.

All patients were followed up at 6 months from their respective date of surgery.

Two different types of implants were used in this study. Osteoarthritic knees in group 1 were implanted with Stryker Scorpio NRG PS design(Mahwah, NJ, USA)while those in group 2 were implanted with Freedom multi radii PS design from Maxx Orthopedics (Massachusetts, USA).

The wound was inspected on the 1st post-operative day and at the same time, the drain was removed. Patient was made to stand and bear full weight in extension knee brace after the dressing check and exercises for the quadriceps and range of motion (ROM) were commenced on the same day. Patient started walking with help of a walker from the 2ndpost operative day and began climbing and descending stairs with rail support from 5thpost operative day.

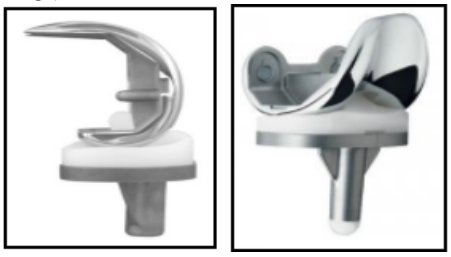
On 14th day, stitches were removed. Mobilization with walker was discontinued and the patient usually managed stair climbing without support by then. Thereafter, the exercises were continued and on subsequent follow ups, the patient was evaluated regarding his/her progress of rehabilitation and sparing exercises for quadriceps, all other exercises were discontinued once the patients started walking comfortably and started going about their routine unhindered.

FOLLOW-UP
Following suture removal at 2 weeks, all patients were followed up in the outdoor patient department 3 monthly till 6 months. Post operative evaluation for each knee was performed by an independent observer at final follow up (6 months) on the basis of criteria given by Insall.

SINGLE RADIUS V/S MULTI RADIUS FEMORAL DESIGN IMPLANT
As life expectancy increases, the number of patients with total knee arthroplasty and functional expectations of improvement is expected to rise. Therefore, a design which has both excellent survivorship and better function is needed. Currently, multi-radius femoral designs are usually used to provide the J-shape curve of the normal knee joint, which is similar to the normal curve, with a large axis in the front and a decrease in the back at the sagittal plane but in the multi-radius femoral design, the recovery of the quadriceps and extensor mechanism is slow and this can affect the outcome of the postoperative knee function[14,15].

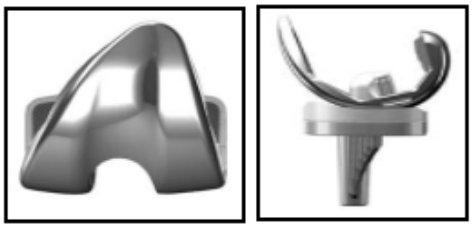
As the length of the ligament changes at mid-flexion of the knee joint in multi-radius TKA and as the momentary axis changes from a long one to a short one, it may result in instability. This can affect the activities of daily life such as stair climbing and standing up from the sitting position.[16,17]

Images of Freedom Maxx Orthopedics total knee system (Multi radius femoral design).



Based on a recent report, the single-radius femoral design was developed to overcome these flaws in the multi-radius femoral design.[14,18]In the single-radius design, there is only one flexion-extension axis in the knee joint. As the single-radius femoral design has a fixed main axis which maintains the tension of the collateral ligaments during the movement, it can theoretically provide sustained stability.[14,18] In a cadaveric study, the single-radius femoral design was reported to require less quadriceps torque to make proper movements for knee extension during stair climbing than the multiradius design.[19]

Images for Stryker Scorpio NRG total knee system (Single radius femoral design)



The femoral components of total knee arthroplasties (TKA) were originally designed for an elderly population. The aim was to reproduce the then-accepted anatomic shape.20 Despite good survivorship data and the introduction of "high-flexion" designs intended to improve function21,22 many patients remain dissatisfied with the level of function achieved post TKA. TKA procedures are being offered to a younger population, who desire a higher level of function in addition to pain relief. Therefore, newer knee designs must not only match the excellent survivorship of existing implants but should also offer improved functional performance without adverse biomechanical effects.

The use of a "single-radius" femoral component has been proposed to ensure consistent tension in the collateral ligaments throughout the functional range of movement. This philosophy is based on the isometry of the superficial medial collateral ligament (sMCL), and that is widely accepted as a basis of soft tissue tensioning in TKA. The femoral attachment of the sMCL is around the flexion axis, so the anterior fibers lengthen during 90 degrees flexion, while the posterior fibers shorten.23The single-radius TKA has been reported to improve anterior knee function, stability, and flexion with greater proprioception.24 This should also address the patient's perceptions of instability when the partly flexed knee is loaded, such as when descending stairs.

Many contemporary femoral designs attempt to reproduce normal knee kinematics using different rotation axes of knee flexion and extension. Condylar radius forces vary in the femoral component to accommodate this multiaxial requirement in the multi radius (MR) designs, while patellar symptoms are minimized by more anatomic designs of the femoral trochlea. In contrast, single-radius (SR) systems

pursue a longer extensor moment arm by incorporating a femoral design with a single radius of knee flexion and extension through a more distal and posterior axis. The purported advantages of the SR design include a decrease in the patellar load due to an increased extensor moment arm; a decrease in the required muscular strength for knee extension, and better ligament stability based on a maintained isometry during the whole ROM (related to a single radius in the sagittal, distal femur).

One resulting major biomechanical difference between the SR and the MR design of this study that could lead to functional performance differences is that the KF/KE axis of the SR design is more posterior than the axes of the MR design. This has been shown to increase the quadriceps moment arm for cadaver knees loaded dynamically to simulate stair climbing. Consequently, less quadriceps muscle force was required to produce a 40 N d m_1 knee extensor moment during the SR compared to the MR condition.

Second, an SR design is hypothesized to improve varus-valgus stability. Because of the differing radii of curvature within an MR design, it is surmised that abruptly shifting from a longer to a shorter radius during knee flexion may create temporary varus-valgus knee instability. For the MR TKAs used in this study, the shift from the first KF/KE axis to the second usually occurs between approximately 30 degree and 45 degree of clinical knee flexion (full extension, 0 degree). Although not conclusively associated, this axis shift appears to correspond approximately to the knee position when mid-flexion instability occurs to some MR patients during movements that require raising or lowering the body.

In an otherwise satisfactory total knee arthroplasty (TKA) (well aligned, well fixed, stable, and with good flexion), symptoms related to extensor mechanism function and the patellofemoral articulation, including anterior knee pain, are the prevalent issues after TKA. Several reports indicate that TKAs with a multi radius sagittal profile do not restore extensor mechanism moment arms to normal, with the greatest reduction occurring in the last 30° of extension .The validity of the anatomic observations that are the foundation for the changing instant centers of rotation have been challenged. Other anatomic studies indicate that knee motion occurs around a single, fixed flexion-extension axis located in the posterior condyles. This single flexion-extension axis is approximated by the trans epicondylar axis. The relatively anterior axis of rotation in multi radius TKAs may account, as least in part, for why extensor mechanism moment arms are shorter after TKA. All other factors being equal, a relatively posterior flexion-extension axis would lengthen the extensor mechanism moment arms and improve extensor mechanism function.

The analysis of outcome of total knee replacement has also evolved. These outcome measures emphasized the severe pain and disability associated with knee arthritis compared with common surgical and medical conditions. Over the years various scoring systems have evolved like the Hospital for special surgery (HSS) scoring system, Oxford knee score and WOMAC score but the knee society score proposed by the American knee society is the most widely used score worldwide for evaluating knee arthroplasty outcome.

The Knee society has proposed rating system to be simple but more exacting and more objective. The rating is divided into separate knee and patient function scores. Thus, increasing age or a medical condition will not affect the knee score. This study was a prospective clinical study which was carried out to evaluate the functional results of total knee arthroplasty between two femoral design components, with varying radii of curvature. Patients in group 1 were operated using a single radius total knee system (Stryker Scorpio NRG PS) while patients in group 2 were operated using a multi radius total knee system (Freedom Maxx Orthopedics PS design). Patients were evaluated preoperatively and post surgery at 6 month follow up using the knee society scoring system.

RESULTS

In this prospective study, 60 knees of 32 patients were operated, 30 each with a single radius and a multi radius femoral design component. We lost one patient to follow up from group 2 who had undergone bilateral total knee replacement in the same sitting. Hence final sample for statistical analysis comprised of 58 knees in 31 patients.

Mean age was 63.84 years, mean height was 160.64cm, mean weight was 8.99 kg and mean BMI was 27.71 kg/m2.

In group 1(SR) patients, out of 30 knees which underwent total knee arthroplasty with single radius femoral component, there were 22 female knees(73.3%) and 8 male knees(26.7%).

In group 2(MR) patients, out of 28 knees with multi radius femoral component, there were 22 female knees(78.6%) and 6 male knees(21.4%).

In all, out of 58 knees, there were 44 female knees(75.9%) and 14 male knees(24.1%), demonstrating a female predominance in our study population.

There were 15 knees each, left and right sided in group 1(SR) while there were 16 left sided and 12 right sided knees in group 2(MR). This was statistically not significant (P-value >0.05).

The mean difference in KSS knee and function score, between pre-operative and post-operative values in group 1(SR), were 27.57 and 56.67 respectively while in group 2(MR) they were 29.21 and 60.71. This data was comparable between the two groups and was statistically not significant (P-value >0.05).

In group 1(SR), the mean KSS knee score increased from 56.27 pre-operatively to 83.83 post-operatively while the mean KSS function score increased from 26.67 pre-operatively to 83.33 post-operatively. This difference in mean values was statistically significant (P-value <0.05).

In group 2(MR), the mean KSS knee score increased from 54 pre-operatively to 83.21 post-operatively while the mean KSS function score increased from 22.86 pre-operatively to 83.57 post-operatively. This difference in mean values was statistically significant (P-value <0.05).

The pre-operative mean values for maximum knee flexion in groups 1(SR) and 2(MR) were 107.83 and 107.85 respectively. This was statistically not significant (P-value >0.05).

The post-operative mean values for maximum knee flexion in groups 1(SR) and 2(MR) were 117.3 and 122 respectively. This data was statistically significant (P-value <0.05).

In group 1(SR), the mean values for maximum knee flexion increased from 107.83 pre-operatively to 122 post-operatively. This data was statistically significant (P-value <0.05).

In group 2(MR), the mean values for maximum knee flexion increased from 107.85 pre-operatively to 117.3 post-operatively. This data was statistically significant(P-value<0.05).

DISCUSSION

This study was performed to compare the functional outcomes between femoral design implants of varying radii in TKA. It has been observed in various studies that a single radius femoral design implant offers multiple advantages over the conventional multi radius design in form of better improvement in knee society scores, faster recovery of quadriceps mechanism and better stability. The results extracted from this study corroborate the clinical data reported by other investigators with respect to improvement in the knee flexion compared between the two types of implant.

In this prospective study, 60 knees in 32 patients were operated, 30 each with a single radius and a multi radius femoral design component. We lost one patient to follow up from group 2 who had undergone bilateral total knee replacement in the same sitting. Hence final sample for statistical analysis comprised of 58 knees in 31 patients. On the day of final follow up at 6 months, post-operative knee score and function score were evaluated as during the pre-op stage according to the criteria given by Insall. The results were compiled and analyzed to arrive to a conclusion in this study.

Our results showed that patients who received a single radius femoral implant had better knee flexion postoperatively relative to patients who received an multi radius implant. These data provide clinical support to the previously reported theoretical advantages described for single radius femoral components.

AGE DISTRIBUTION

Study	No of TKA	Average age
Reum Jo et al[25] (2014)	116	67.5
Cook et al[26] (2012)	559	65.7
Barrena et al[27] (2009)	60	73.2
Jenny et al[28] (2012)	430	68
Palmer[29] (2014)	1012	69.4
Our Study (2016)	58	63.8

Mean age in our study was similar to other studies.

SEX DISTRIBUTION

There was a female predominance in this study which is also observed in other studies.

Study	No of TKA	M:F Ratio
Reum Jo et al[25] (2014)	116	0.68402778
Cook et al[26] (2012)	559	237:322
Barrena et al[27] (2009)	60	18:42
Jenny et al[28] (2012)	430	134:296
Palmer[29] (2014)	1012	385:627
Our Study (2016)	58	14:44

KSS SCORES

In our study, there was statistically significant improvement in KSS knee and function scores in both groups at final follow up as was also observed in the other studies listed above.

However, the improvement in scores, when compared between the two groups in our study was found to be insignificant (P-value >0.05). This may be attributed to the small sample size and to the short period of follow up.

	No of TKA	SR Group		MR Group	
Cook et al26 (2012)	559	57.5/52.8	90.1/80.6	58.2/47.8	81.9/68.2
Jenny et al28 (2012)	430	38/47	93/87	43/42	88/71
Palmer29 (2014)	1012	41.3/49.7	88.4/72.5	37.5/44.2	82.9/69.7
Our Study (2016)	58	56.27/26.67	83.83/83.33	54/22.86	83.21/83.57

KNEE FLEXION

In our study, there was statistically significant improvement in knee flexion in both groups at final follow up (P-value <0.05) as was also observed in Jenny et al's28 study and Palmer's29 SR group. However in Palmer's MR group, there was a significant decrease in knee flexion in post- operative period.

Comparing the two groups, it was observed that improvement in knee flexion in the SR group was statistically significant than in the MR group. (P-value<0.05)

	No of TKA	SR Group	MR Group
Jenny et al[28] (2012)	430	112/118	107/114
Palmer[29] (2014)	1012	105.4/107.2	107.3/104.8
Present Study (2016)	58	107.83/122	107.85/117.32

CONCLUSIONS

1) In our study, we discovered that at final follow-up there was significant increase in KSS knee and function scores in both groups.
2) The SR TKA group showed significant increase in maximal knee flexion relative to the MR TKA group.
3) There was no significant difference in terms of comparison of increase in KSS knee and function score between the two groups.

LIMITATION

1. Six months of follow up is a relatively short period. A longer follow up would have been more beneficial in yielding accurate results.
2. Larger number of sample size or a multicentric study would have been more conclusive with respect to the conducted study.

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