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ORIGINAL STUDY

Long term results of rotating hinge total knee arthroplasty in complex primary and revision cases

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Rotating Hinge Knee prosthesis in total knee arthroplasty has shown good long-term outcome and survival. The purpose of this study was to evaluate the long term outcome and survival of Rotating Hinge Knee prosthesis in complex primary and revision cases.

A retrospective study was performed on 111 patients (117 knees) operated using a NexGen Rotating Hinge Knee prosthesis between 2002 and 2010. Clinical assessment was done evaluating Knee Society scores and range of motion preoperatively and at latest follow-up. Radiological assessment was done using Anteroposterior and Lateral radiographs of the knee joint. 10 year survival of the prosthesis was calculated using the Kaplan-Meier method.

The mean Knee Society Knee score and Function score improved significantly from a preoperative value of 34 to 80 and from 16 to 60 respectively (p value < 0.05). The mean range of motion also improved significantly from a preoperative value of 50 degrees to 95 degrees (p value < 0.05). 10 years survival of the prosthesis was 90.65%. A complication rate of 11.7% was encountered.

Use of NexGen Rotating Hinge Knee prosthesis has been associated with highly satisfying clinical and functional outcomes in both complex primary and revision cases.

Keywords : Complex primary knee replacement ; revision knee replacement ; Rotating Hinge Knee prosthesis ; long term outcome ; survival rate.

INTRODUCTION

Total knee arthroplasty (TKA) in primary cases has shown excellent outcome with survivorship of 95% at 15 years follow-up *(27)*. However, with the increase in the number of primary TKA surgeries there has been a corresponding increase in the incidence of revision TKA surgeries being performed, ranging from 8.2% to 12.6% *(20,22)*. In revision TKA surgeries, the choice of implant with adequate constraint is important to deal with situations like poor ligament stability, aseptic loosening with severe bone loss, compromised extensor mechanism, prosthesis malalignment, periprosthetic fractures and periprosthetic joint infections *(14,30)*. Rotating Hinge Knee (RHK) prosthesis offers a good option in such situations providing a high degree of constraint and good inherent stability *(3,7,12,13)*. The indication for RHK is not limited to revision TKAs but it may also be useful in a myriad of other indications. These

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Table I. — Demographic Data

	Primary cases	Revision cases	Total
Number of patients	33	78	111
Number of procedures (RHK)	36	81	117
Gender			
Male	13	23	36
Female	20	55	75
Mean age (Range)	61	68	66 years (22 to 88)
Mean follow-up period (Range)	126	120	123 months (96 to 168)

Table II. — Indications for surgery

Primary surgery	Non-union/Malunion of distal femoral condylar fractures with advanced osteoarthritis (14 cases) Malunion of tibial condylar fractures with advanced osteoarthritis (4 cases) Advanced Rheumatoid arthritis with severe varus deformity and significant medial tibial bone loss and global instability (4 cases) Advanced Rheumatoid arthritis with Flexion deformity of 60 degrees (2 cases) Advanced Primary Osteoarthritis with severe deformity, bone loss and instability (7 cases) Post traumatic extensor mechanism insufficiency (1 cases) Giant cell tumour Distal femur (4 cases)
Revision surgery	Aseptic loosening with severe bone loss (23 cases) Prosthetic Joint Infection (Stage II surgery) (21 cases) Medial collateral ligament incompetency (9 cases) Subluxations/Dislocations with both medial and lateral ligament insufficiency (7 cases) Periprosthetic fractures (21 cases)

include oncologic reconstructions *(6)*, complex primary cases with severe varus/valgus deformities, severe rheumatoid arthritis cases with collateral ligament insufficiencies, comminuted distal femur fractures or distal femur nonunion in elderly patients, ankylosed knees and extensor mechanism disruption requiring reconstruction in an unstable knee *(1,11)*.

Disappointing results have been reported in such cases managed with fixed axis hinged knee prosthesis due to the constrained nature of construct and lack of rotation. These first generation hinged knee prosthesis allowed motion only in one plane i.e. flexion extension movement, thus resulting in early loosening, osteolysis and high failure and complication rates *(10,15,16)*.

Improvements in modern day Rotating Hinge Knee designs feature a deep anatomic trochlear groove for improved patellofemoral articulation, modular fluted stems with variable offsets to improve alignment, addition of metaphyseal sleeves/cones and availability of modular augments for filling large bone defects. All these improvements are an effort to reduce failure rates while using hinged prosthesis and improve the articulation between the mobile bearing element and the tibial component *(1,9,11,26)*. Despite these developments, many studies still report high complication and mechanical failure rates with the RHK prosthesis *(18,24)*.

The aim of this study was to evaluate long term results and survivorship of the NexGen Rotating Hinge Knee prosthesis (Zimmer, Warsaw, USA) in complex primary and revision total knee arthroplasty cases and to compare our outcomes with the available current literature.

PATIENTS AND METHODS

After institutional review board approval, a retrospective, non-randomized study was performed on a cohort of 119 patients (125 knees) who underwent knee replacement surgery using Rotating Hinge Knee prosthesis of a single design (NexGen, Zimmer, Warsaw, USA) for either complex primary or revision knee cases between 2002 and 2010. The mean follow-up period was 123 months (range 96

to 168 months) and the minimum follow-up period was 96 months. Out of 119 patients, 3 patients died from unrelated causes and 5 patients were lost to follow-up before the minimum follow-up period and were thus excluded from the study leaving a cohort of 111 patients (117 knees) for the study.

There were 36 male and 75 female patients in the study. 36 surgeries were performed in primary cases and 81 surgeries were done in revision cases. Mean age of the cohort was 66 years (range 22 to 88 years) in which the mean age of primary and revision cases was 61 and 68 years respectively. Patient demographic data is described in Table I and the indication for surgery in primary and revision knee replacement cases is mentioned in Table II.

All the surgeries were performed by the senior author using an anterior midline incision and medial parapatellar arthrotomy with lateral subluxation of patella. Previous scar (most lateral one in case of multiple scars) was included in the incision in case of revision surgery. In cases with stiff knee or difficult exposure, either rectus snip or femoral peel was performed. Tibial tubercle osteotomy was not required in any case. In revision cases, pre-existing implants and cement mantle were removed while taking care to preserve as much bone stock as possible. Thorough debridement of local tissue and bone surfaces was carried out additionally in cases with periprosthetic joint infection. A combination of both intramedullary femoral and extramedullary tibial alignment guides was used. Bone cuts were performed using finishing blocks. In all cases, pulsatile lavage was used and cementing was done using gentamicin impregnated bone cement by first generation digital pressurisation technique. Patellar resurfacing was not done in any of the cases. Lateral release was performed, if required, to ensure normal patellar tracking. Tibial and femoral stems of length sizes 30 mm, 100 mm, 155 mm were available for metaphyseal fixation with both tibial and femoral components. In most patients a short stem (30mm) was used. In patients with periprosthetic fractures, 100mm or 155mm stem was used. The short stems were fully cemented and the longer stems were implanted using a hybrid fixation. Femoral and/or tibial augments (trabecular metal cones and tibial wedges) were used in 24 knees to supplement the area of bone loss. (Table III)

Table III. — Augments used

	Primary cases	Revision cases	Total
Trabecular metal cones (tibial)	nil	4	4
Trabecular metal cones (femoral)	nil	7	7
Femoral Augments	3	6	9
Tibial Augments	nil	4	4
Tibial Wedge	1	3	4

Standard antibiotic, thromboprophylaxis and physiotherapy rehabilitation protocol were followed in all cases except in cases that underwent two-stage revision surgeries for periprosthetic joint infection or in primary cases that were operated for infected non-union. In these cases, antibiotic protocol was modified as per culture reports. Standard two-stage revision surgery was performed in all cases of periprosthetic joint infection.

Clinical assessment was done at the preoperative stage, at regular intervals post-operatively and at final follow-up evaluating Knee Society Score (KSS) (knee score and function score), and range of motion (ROM). Radiological assessment was done using anteroposterior (AP) and lateral radiographs of the knee joint at each follow-up and at last follow-up to see for signs of loosening such as progressive radiolucent lines, osteolysis, polyethylene wear, dislocation or breakage of the implant, and for assessment of alignment comparing the earliest postoperative radiographs. Preoperative and post-operative Knee Society scores were compared utilizing a paired t-test. A p value of 0.05 or less was considered significant.

Prosthesis survival was analysed using the Kaplan-Meier method, a statistical method that enables calculation of prosthesis survival after a defined period of time (usually 10 years survival rate). Prosthesis failure was defined as revision or reoperation due to any reason as the end point. Revision of either tibial or femoral component or reoperation due to any reason was considered as part of prosthesis failure.

RESULTS

Overall, there was a significant improvement in mean Knee Society scores (KSS). The mean Knee Society Knee score of the cohort improved from a preoperative value of 34 to a postoperative value of 80 (p value <0.05) with improvement from 36 to 83 points in primary cases

(p value <0.05) and from 33 to 78 points in revision cases (p value <0.05). Similarly, there was a significant improvement in the mean Knee Society Function score of the cohort from a preoperative value of 16 to a postoperative value of 60 (p value <0.05) with improvement from 19 to 63 points in primary cases (p value <0.05) and from 14 to 58 points in revision cases

(p value <0.05). The mean flexion range of motion of the cohort improved from 50 degrees preoperatively to 95 degrees postoperatively (p value <0.05) with improvement from 53 to 97 degrees in primary cases (p value <0.05) and from 48 to 94 degrees in revision cases (p value <0.05). Extension deficits were present in 5 knees in the range of 5 to 10 degrees. (Table IV)

At the latest follow-up, out of 111 patients, 45 patients did not use any support for walking, 36 patients were walking with the aid of a cane, 24 patients used a walker support and 6 patients were wheel chair bound likely because of medical comorbidities and involvement of other joints.

In the radiographic analysis of the cohort, the latest radiographs of the patients did not show any signs of instability, loosening or polyethylene wear except in 1 knee which was revised at 118 months post-operatively because of aseptic loosening. In comparison to previous postoperative radiographs, there was no loss of alignment in the latest radiographs. In 10 knees, there were radiolucent lines along the tibial component in 4 knees (2 each in primary and revision cases) and in 6 knees along the femoral component (2 in primary cases and 4 in revision cases). However, the lines were non progressive during the period of study and hence did not require any intervention till the last follow-up. (Fig. 1-8).

Kaplan-Meier survival analysis was performed to calculate the 10 years survival rate of the prosthesis with failure due to any reason as the end point and the 10 years survival rate was 90.65%. (Fig. 9).

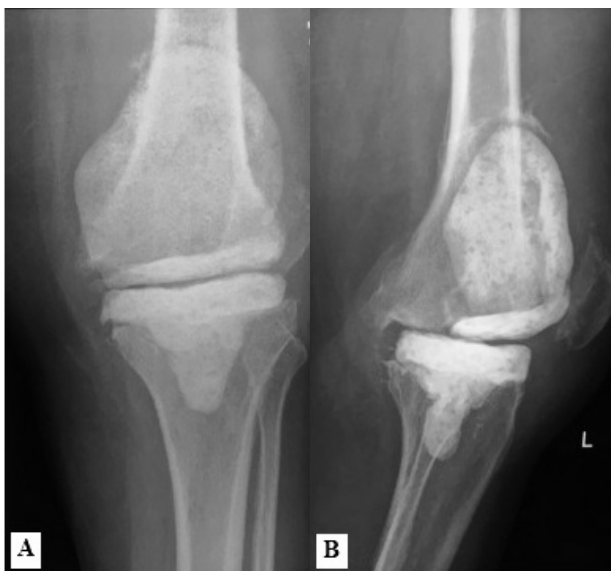

Fig. 1. — Stage 1 procedure following infected primary total knee replacement. Pre operative radiographs. A: AP view. B: lateral view.

Table IV. — Results

Parameter		Primary cases	Revision cases	Overall
Mean Knee Society knee score	Preoperative	36	33	34
	Postoperative	83	78	80
	p value	<0.05	<0.05	<0.05
Mean Knee Society function score	Preoperative	19	14	16
	Postoperative	63	58	60
	p value	<0.05	<0.05	<0.05
Mean range of motion (degrees)	Preoperative	53	48	50
	Postoperative	97	94	95
	p value	<0.05	<0.05	<0.05

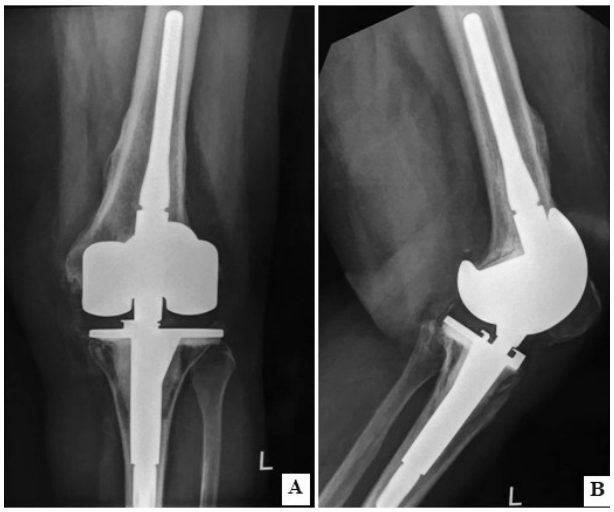

Fig. 2. — Stage 2 procedure following infected primary total knee replacement after RHK prosthesis. 10 years post operative radiographs. A: AP view. B: lateral view.

Fig. 3. — Non union distal femoral fracture with arthritis. Pre operative radiographs. A: AP view. B: lateral view.

Overall, we encountered a complication rate of 11.7% in our study. The complication rates in primary and secondary cases were 9.09% and 12.82% respectively. There were 2 intraoperative complications of medial tibial condyle fracture (1 each in primary and revision case) which were treated with cancellous screw fixation and both fractures healed well subsequently. Postoperative complications were seen in 11 patients. An infection

Fig. 4. — Non union distal femoral fracture with arthritis after RHK prosthesis. 12 years post operative radiographs. A: AP view. B: lateral view.

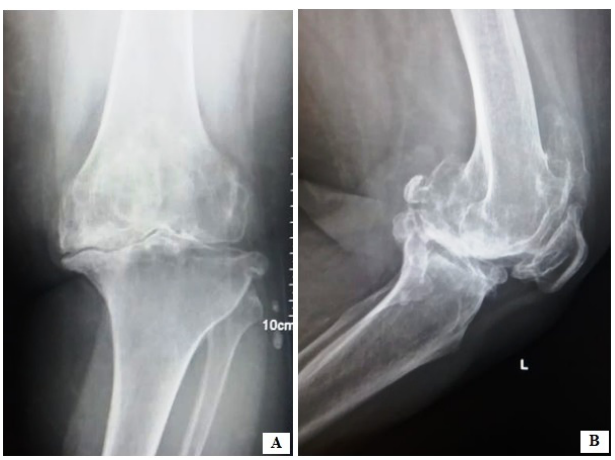

Fig. 5. — Advanced Degenerative Joint Disease with gross ligament instability. Pre operative radiographs. A: AP view. B: lateral view.

rate of 3.03% was seen in primary cases while 5.12% was seen in revision cases. Superficial infection was encountered in 3 revision cases that were managed with oral antibiotics and did well subsequently with no recurrence. Deep periprosthetic infection

Fig. 6. — Advanced Degenerative Joint Disease with gross ligament instability after RHK prosthesis. 9 years post operative radiographs. A: AP view. B: lateral view.

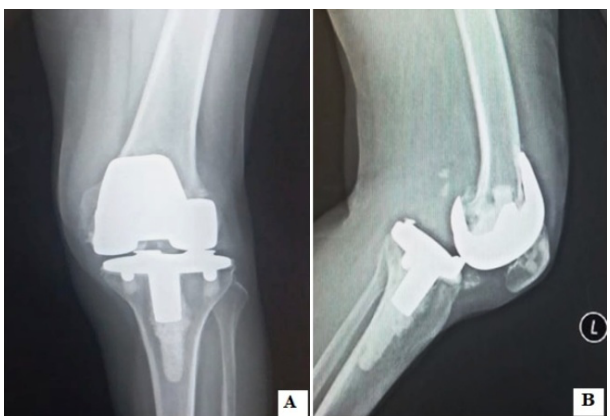

Fig. 7. — Knee dislocation following primary total knee replacement. Pre operative radiographs. A: AP view. B: lateral view.

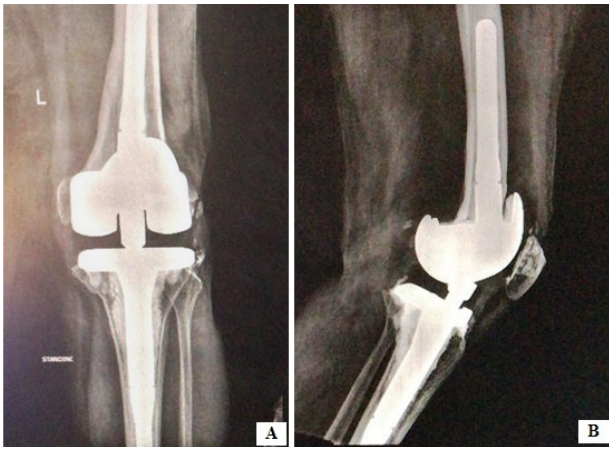

Fig. 8. — Knee dislocation following primary total knee replacement after RHK prosthesis. 10 years post operative radiographs. A: AP view. B: lateral view.

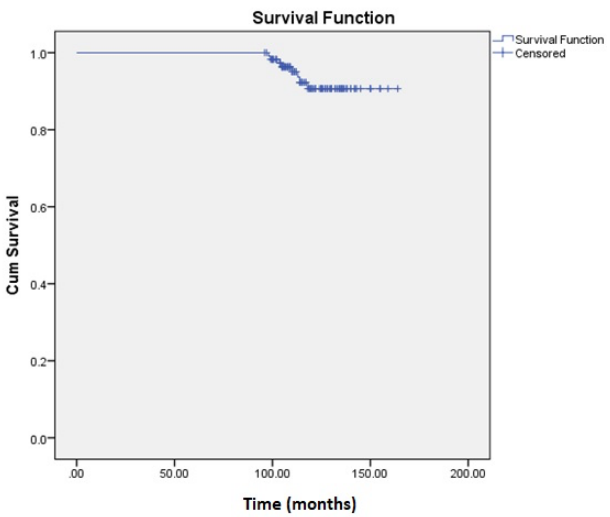

Fig. 9. — 10 years survival of the prosthesis with revision or reoperation due to any reason as the end-point was 90.65%.

was seen in 2 patients. One patient who underwent primary RHK for nonunion of distal femoral fracture with pre-existing severe osteoarthritis developed a deep periprosthetic infection at 98 months which was treated by an arthrodesis after failed salvage procedures. The second patient was a case of a two stage revision surgery for periprosthetic joint infection which developed a re-infection after a symptom free period of 104 months. This patient was advised surgery but refused treatment and was lost to follow-up. 1 patient each of hinge dislocation and aseptic loosening at 105 and 118 months respectively was encountered in our study for which they underwent revision surgery and at last follow-up both patients were doing well. Periprosthetic fracture of the femur was encountered in 2 patients of which 1 patient was managed with open reduction and internal fixation of fracture and revision of femoral component at 114 months and at last follow-up was doing well. Another patient with periprosthetic femur fracture with a concomitant foot drop was advised surgery, but refused treatment

Table V. — Complications

	Primary case	Revision case	Treatment
Medial tibial condyle fracture (intra-operative)	1	1	Cancellous screw fixation
Hinge dislocation	1	Nil	Treated with revision surgery
Aseptic loosening	Nil	1	Treated with revision surgery
Superficial infection	Nil	3	Treated with oral antibiotics
Deep Periprosthetic Joint infection	1	1	Primary case was managed with arthrodesis when other salvage options failed, Revision case refused treatment and was lost to follow-up.
Periprosthetic fracture femur	Nil	2	1 patient was managed with revision of femoral component and ORIF femur, 1 patient with concomitant foot drop refused treatment and was lost to follow-up.
Patellar subluxation	Nil	2	No treatment done for mild subluxation.

and was lost to follow-up. 2 patients had mild patellar subluxation at 90 degrees of flexion but this did not interfere with their activities of daily living and therefore no further treatment was done. (Table V).

DISCUSSION

Rotating Hinge Knee prosthesis has been widely used in complex primary and revision TKA situations when there is concomitant severe bone loss and gross ligament instability. Prior designs of hinge knee prosthesis had resulted in high rates of early aseptic loosening and implant failure as a result of the high stresses placed on the bone-cement interface secondary to the lack of rotation of the central hinge *(1,2,10,15,16)*. Hui and Fitzgerald reported a 23.4% complication rate with the Guepar and the Walldius prosthesis *(15)*. Second-generation implants such as the Noiles prosthesis had significant complications as well *(19)*. With the introduction of 3rd generation RHK prosthesis designs, there has been an increase in survival rates and fall in complication rates *(3,7,8,9,21,23,26,28)*. Controversy still exists as to the indications, outcome and long term survival of RHK prosthesis *(18,24)*. Our study was carried out to determine the clinical, functional and radiological outcome and survival rate in a cohort of patients who were operated using the NexGen RHK prosthesis either for primary or revision knee replacement surgery.

The design features of the NexGen RHK prosthesis have many advantages. A modular hinge mechanism has been incorporated which results in 95% of the load being carried by the tibial condyles. The basic bone cuts for the NexGen RHK are the same as those made for NexGen primary system components, thus minimising bone loss. The trochlear groove in the femoral component allows the patella to track deeply. This helps in increasing the resistance to lateral subluxation and providing a smooth transition from flexion to extension. A minimum "jump height" of 40 mm in the NexGen RHK locking mechanism design helps to resist subluxation. A Conformity ratio of 1:1 between femoral condyles and tibial articular surface results in distribution of stresses across a larger surface area *(26)*.

In our retrospectively conducted study, we evaluated the clinical and radiological outcome and survivorship of the prosthesis in 111 patients (117 knees). The mean KSS (knee score) was 80 and mean KSS (function score) was 60 postoperatively at the final follow-up. The 10 years prosthesis survival was 90.65% in our study. Revision surgeries were performed in 4 cases, 1 each for periprosthetic fracture, hinge dislocation, aseptic loosening and deep periprosthetic infection. Complication rate of 11.7% was encountered in our study (9.09% in primary cases and 12.82% in secondary cases).

The results of our study are in accordance with published literature on RHK with both medium and

long term follow-up *(3,7,9,21,23,28)*. Cottino et al *(7)* in their study of 408 cases with RHK of various designs, found a significant improvement in clinical outcomes and excellent survivorship free from revision for aseptic loosening with contemporary rotating hinge constructs. The mean Knee Society Knee score and Function score in that study was reported to be 81 and 36 respectively with a complication rate of 12%. The 5 year survival was 84.5% and 10 year survival was 71.3% in that study. Another study by Farid et al *(9)* retrospectively reviewed 142 single design third generation rotating hinge prosthesis and reported implant survival of 73% at 5 years with mean Knee Society Knee score of 77 and Function score of 57. Similar study by Sanguineti et al *(28)* in which 123 rotating hinge Endo-model prosthesis were implanted, reported a mean Knee Society Knee score and Function score of 94.2 and 78.7 respectively with 5 year survival of 93% at an average follow-up of 42.2 months.

Neumann et al *(21)* in a series of 24 knees, found a mean Knee Society Knee score of 91 and Function score of 85 with 100% survivorship at a mean follow-up period of 4.6 years. In that study, aseptic causes were the only indication for surgery. A small cohort of patients and short follow-up period may have contributed to the good results. Similar results were reported by Petrou et al *(23)* in 100 primary cemented rotating hinge total knee replacement and they found surprisingly good or excellent results in 91% knees and 15 years survival of 96.1% with a mean Knee Society Knee score and Function score of 93.4 and 69.7 respectively. However, their study included only primary replacement cases. This may explain the discrepancy between their outcomes and those of Pradhan and Bale *(25)* who used the same implant as used by Petrou et al *(23)* in their study and concluded that at an average follow up of 4 years, hinge prosthesis in infection were less likely to yield satisfactory outcomes compared to aseptic revisions and that patients should be properly consented and counselled.

Perhaps another example of mismatched results for use of the same prosthesis among the available literature can be seen in comparing our results to that of Kearns et al *(18)*. In 2018, Kearns et al *(18)* reported study of 79 cases of TKA using NexGen RHK prosthesis at mean follow-up of 55.2 months and found that the mean Knee Society score was 66.2 and 5 year survival was 70.7%. They reported a complication rate of 38.7% which was higher in comparison to our study. This included 6 cases of periprosthetic fractures, 5 cases of extensor mechanism rupture, 4 cases of deep periprosthetic joint infection, 3 cases of mechanical hinge failure and 1 case of aseptic loosening. In our study, we had 2 cases each of periprosthetic fracture, periprosthetic joint infection and patellar subluxation, and 1 case each of hinge dislocation and aseptic loosening. The study by Kearns et al *(18)* had preoperative concomitant extensor mechanism insufficiency in significant proportion of their patients for which extensor mechanism allografts were used. In the same study high number of extensor mechanism allograft failure and periprosthetic fractures accounted for increase in complication rates which may be a big confounding factor. In our series extensor mechanism allograft was not used in any of the patients. Brown et al *(4)* has reported a failure rate of 38% with extensor mechanism allograft reconstruction in TKA. Burnett et al *(5)* found that loosely tensioned allografts result in a persistent extension lag and clinical failure thus explaining the cause of high rate of complication associated with use of extensor mechanism allograft. The studies by Smith et al *(29)* and Pour et al *(24)* had reported a complication rate of 24% and 32% respectively, and an overall survivorship for rotating hinge TKA components of 54% at 4 years and 68.2% at 5 years respectively. We believe that such discrepancy in outcomes may be explained by the indications, patient characteristics, surgical technique and inclusion criteria respectively. Studies with large cohort of patients and longer follow-up have shown matching results *(7,9)*, thus emphasizing the need to figure out other confounding factors which may be responsible for discrepancy in outcome with same or similar implants.

Apart from the role of RHK in revision knee surgery, the role of RHK in complex primary cases has been evaluated in a few studies and has reported acceptable outcome. Petrou et al *(23)* reported good or excellent outcome with the use of RHK in primary cases with 15 years survival of

96.1%. Similarly, Yang et al *(31)* in a retrospective review of 50 patients who underwent primary TKA using Endo model rotating hinge knee prosthesis at a mean follow up of 15 years found significant improvement in Knee Society knee score and a 10 year survivorship of 87%. The results of these studies are similar with our outcomes.

In our study we did not encounter any case of early loosening or implant failure due to abnormal stress transfer at bone cement interface, despite having high degree of constraint nature of this prosthesis. Also, we found that the mean Knee Society function score in our study was better than the other studies *(7,31)* which could be attributed to the associated comorbidities of the cohort that impair the general mobility in the evaluated series. Though it is difficult to compare different kinds of prosthesis even if they share the same design, among the currently available literature for various types of prosthesis with rotating hinge design, the results and survival rates with the use of NexGen prosthesis has limited variability among different series *(3,7)* with few exceptions *(18)*. Bistolfi et al *(3)* in their study of 29 patients used 31 NexGen Rotating Hinge Knee prosthesis for revision total knee arthroplasty in patients with severe ligament instability and bone loss and found acceptable mid-term outcomes with increase in Hospital for Special Surgery Knee Score results from 65.5 preoperatively to 88.4 postoperatively.

The limitation of our study was its retrospective nature. Patellar resurfacing was not done in any of our cases, although the surgeon did pay attention to correct patellofemoral alignment and patellar tracking. This is in contrast with Kajino et al *(17)* who stated that even with correct patellar tracking, patellofemoral pain occurs without patellar replacement. The strong points of our study are a large patient cohort and a long follow-up period.

In conclusion, use of a NexGen RHK prosthesis in our study, was associated with highly satisfying clinical, functional and radiological outcomes in complex primary and revision cases. Our results support the use of the NexGen RHK prosthesis in patients with severely deformed or malaligned knees, in the presence of major bony defects and ligamentous insufficiency, both in primary and revision surgery. While attention should always be paid to adequate surgical technique and correct indications for surgery, the NexGen prosthesis remains a viable option in knee surgery for difficult cases which otherwise may be candidates for either arthrodesis or amputation.

REFERENCES

1. **Barrack RL**. Evolution of the rotating hinge for complex total knee arthroplasty. *Clin. Orthop. Relat. Res.* 2001 ; 392 : 292–299.
2. **Barrack RL**. Rise of the rotating hinge in revision total knee arthroplasty. *Orthopedics* 2002 ; 25 : 1020-1058.
3. **Bistolfi A, Massazza G, Rosso F, Crova M.** Rotating-hinge total knee for revision total knee arthroplasty. *Orthopedics* 2012 ; 35 : 325-330.
4. **Brown NM, Murray T, Sporer SM *et al.*** Extensor mechanism allograft reconstruction for extensor mechanism failure following total knee arthroplasty. *J. Bone Joint Surg. Am.* 2015 ; 97 : 279-283.
5. **Burnett RS, Berger RA, Della Valle CJ *et al.*** Extensor mechanism allograft reconstruction after total knee arthroplasty. *J. Bone Joint Surg. Am.* 2005 ; 87 Suppl 1 : 175-194.
6. **Choong PF, Sim FH, Pritchard DJ, Rock MG, Chao EY.** Megaprostheses after resection of distal femoral tumors. A rotating hinge design in 30 patients followed for 2-7 years. *Acta Orthop. Scand.* 1996 ; 67 : 345-351.
7. **Cottino U, Abdel MP, Perry KI *et al.*** Long-term results after total knee arthroplasty with contemporary rotating-hinge prostheses. *J. Bone Joint Surg. Am.* 2017 ; 99 : 324-330.
8. **Deehan DJ, Murray J, Birdsall PD, Holland JP, Pinder IM.** The role of the rotating hinge prosthesis in the salvage arthroplasty setting. *J. Arthroplasty* 2008 ; 23 : 683-688.
9. **Farid YR, Thakral R, Finn HA.** Intermediate-Term Results of 142 Single-Design, Rotating-Hinge Implants: Frequent Complications May Not Preclude Salvage of Severely Affected Knees. *J. Arthroplasty* 2015 ; 30 : 2173-2180.
10. **Freeman PA.** Walldius arthroplasty. A review of 80 cases. *Clin. Orthop. Relat. Res.* 1973 ; 94 : 85-91.
11. **Gehrke T, Kendoff D, Haasper C.** The role of hinges in primary total knee replacement. *Bone Joint J.* 2014 ; 96-B : 93-95.
12. **Gudnason A, Milbrink J, Hailer NP.** Implant survival and outcome after rotating-hinge total knee revision arthroplasty: a minimum 6-year follow-up. *Arch. Orthop. Trauma Surg.* 2011 ; 131 : 1601-1607.
13. **Hernández-Vaquero D, Sandoval-García MA.** Hinged total knee arthroplasty in the presence of ligamentous deficiency. *Clin. Orthop. Relat. Res.* 2010 ; 468 : 1248-1253.

14. **Hommel H, Wilke K, Kunze D, Hommel P, Fennema P.** Constraint choice in revision knee arthroplasty: study protocol of a randomised controlled trial assessing the effect of level of constraint on postoperative outcome. *BMJ Open* 2017 ; 7 : e012964.
15. **Hui FC, Fitzgerald RH Jr.** Hinged total knee arthroplasty. *J. Bone Joint Surg. Am.* 1980 ; 62 : 513-519.
16. **Jones EC, Insall JN, Inglis AE, Ranawat CS.** GUEPAR knee arthroplasty results and late complications. *Clin. Orthop. Relat. Res.* 1979 ; 140 : 145-152.
17. **Kajino A, Yoshino S, Kameyama S, Kohda M, Nagashima S.** Comparison of the results of bilateral total knee arthroplasty with and without patellar replacement for rheumatoid arthritis. A follow-up note. *J. Bone Joint Surg. Am.* 1997 ; 79 : 570-574.
18. **Kearns SM, Culp BM, Bohl DD *et al.*** Rotating Hinge Implants for Complex Primary and Revision Total Knee Arthroplasty. *J. Arthroplasty* 2018 ; 33 : 766-770.
19. **Kester MA, Cook SD, Harding AF, Rodriguez RP, Pipkin CS.** An Evaluation of the mechanical failure modalities of a rotating hinge knee prosthesis. *Clin Orthop Relat Res* 1988 ; 228 : 156-163.
20. **Labek G, Thaler M, Janda W, Agreiter M, Stöckl B.** Revision rates after total joint replacement: cumulative results from worldwide joint register datasets. *J. Bone Joint Surg. Br.* 2011 ; 93 : 293-297.
21. **Neumann DR, Hofstaedter T, Dorn U.** Follow-up of a modular rotating hinge knee system in salvage revision total knee arthroplasty. *J. Arthroplasty* 2012 ; 27 : 814-819.
22. **Ong KL, Mowat FS, Chan N *et al.*** Economic burden of revision hip and knee arthroplasty in Medicare enrolees. *Clin. Orthop. Relat. Res.* 2006 ; 446 : 22-28.
23. **Petrou G, Petrou H, Tilkeridis C *et al.*** Medium-term results with a primary cemented rotating-hinge total knee replacement. A 7- to 15-year follow-up. *J. Bone Joint Surg. Br.* 2004 ; 86 : 813-817.
24. **Pour AE, Parvizi J, Slenker N, Purtill JJ, Sharkey PF.** Rotating hinged total knee replacement: use with caution. *J. Bone Joint Surg. Am.* 2007 ; 89 : 1735-1741.
25. **Pradhan NR, Bale L, Kay P, Porter ML.** Salvage revision total knee replacement using the Endo-Model rotating hinge prosthesis. *Knee* 2004 ; 11 : 469-473.
26. **Rajgopal A, Vasdev A, Chidgupkar AS, Dahiya V, Tyagi VC.** Mid-term results of rotating hinge knee prostheses. *Acta Orthop. Belg.* 2012 ; 78 : 61-67.
27. **Ranawat CS, Flynn WF Jr, Deshmukh RG.** Impact of modern technique on long-term results of total condylar knee arthroplasty. *Clin. Orthop. Relat. Res.* 1994 ; 309 : 131-135.
28. **Sanguineti F, Mangano T, Formica M, Franchin F.** Total knee arthroplasty with rotating-hinge Endo-Model prosthesis: clinical results in complex primary and revision surgery. *Arch. Orthop. Trauma Surg.* 2014 ; 134 : 1601-1607.
29. **Smith TH, Gad BV, Klika AK *et al.*** Comparison of mechanical and nonmechanical failure rates associated with rotating hinged total knee arthroplasty in nontumor patients. *J. Arthroplasty* 2013 ; 28 : 62-67.
30. **Vasso M, Beaufils P, Schiavone Panni A.** Constraint choice in revision knee arthroplasty. *Int. Orthop.* 2013 ; 37 : 1279-1284.
31. **Yang JH, Yoon JR, Oh CH, Kim TS.** Primary total knee arthroplasty using rotating-hinge prosthesis in severely affected knees. *Knee Surg. Sports Traumatol. Arthrosc.* 2012 ; 20 : 517-523.