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ORIGINAL STUDY

Dislocation of modern design rotating hinge total knee arthroplasty : case series and narrative review

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Knee dislocation is an infrequent complication after rotating hinge total knee arthroplasty (RHTKA). The aim of the present study was to describe our experience with dislocating RHTKA in a consecutive prospective large series, its occurrence rate, causative mechanisms and to perform a review of available literature.

In total, six dislocations were observed in 303 RHTKA procedures (NexGen RHK, ZimmerBiomet, Warsaw, Indiana, US) at a mean of 10 (range, 2 – 24) months after surgery. This results in a 2% dislocation rate, which is lower than the 3.1% cumulative rate reported earlier in literature. Men and women were distributed equally, with a mean age of 56 years old. The indication for RHTKA among the six dislocations was revision in 4 cases and primary arthroplasty for the other 2 cases.

Analysis revealed that the main mechanism of hinge dislocation was forced knee flexion with concomitant extensor mechanism insufficiency (4/6 cases). The second cause was unscrewing of the locking pin (2/6 cases). This is probably caused by the screw home mechanism that results in a counterclockwise torque- and therefore a loosening- effect on locking bolts, specifically in right-sided RHTKA. Obesity probably predisposes to hinge dislocation since 83% of patients in this series were obese (BMI, range 34 to 52).

The findings of this study suggest that dislocation of RHTKA is a rare complication that could happen to obsese patients without an adequate extensor mechanism.

Level of evidence : IV

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Keywords : total knee arthroplasty ; rotating hinge knee ; complication ; dislocation.

INTRODUCTION

Hinged total knee arthroplasty (TKA), as a fixed or rotating model, is a surgical option available for the more complex primary and revision arthroplasty cases where lower constraint TKA designs would be insufficient and the only other valid solution to be considered, would be arthrodesis. Typical hinge indications would be severe collateral ligament

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insufficiency or instability, gross flexion-extension gap imbalance, change of joint line position of more than 8 mm due to extensive bone loss and posterior capsule insufficiency with hyperextension *(6,19,26,30)*.

The results of hinged knees were disappointing in the past with especially high rates of aseptic loosening. The potential reason for this increased failure rate would probably be the transmission of constraint to the bone-implant interfaces. Rotating hinge knee (RHK) designs represent a third generation of hinged TKA that integrate the possibility of axial rotation combined with load sharing of the axle and the mobile polyethylene insert *(12)*.

Although the complication rate of hinged TKA remains high, this could also be related to non-implant design aspects such as increased patient morbidity *(18)*. Among the possible complications, hinge-post disengagement with dislocation of the knee ("hinge dislocation") is an infrequent phenomenon. Several predisposing and interrelated intrinsic and extrinsic factors have been described. Among the intrinsic factors there are mechanical implant failure of the central rotating peg design and disengagement within the tibia by the screw home mechanism of the knee *(4,7,10,17,25,27,29,32,34,39-41)*. Extrinsic factors are related to the peri-articular soft tissue quality (particularly extensor mechanism insufficiency) or large flexion gap inequality *(10,28, 29,9,40)*. This may lead to distraction-mediated disengagement that might occur by dislocation following enough distraction to lift the locking pin from the tibial cylinder. During the last decade there is a growing trend of increased use of third generation RHK for difficult primary and revision TKAs *(5,12,26)*.

The purpose of this study was to describe the surgical experience with modern design rotating hinge total knee arthroplasty and discuss dislocation in a consecutive prospective large series, its occurrence rate, causative mechanisms and known literature on the topic.

MATERIAL AND METHODS

Between May 2006 and November 2015 a total of 248 Rotating Hinge Knees (NexGen RHK, ZimmerBiomet, Warsaw, Indiana, US) were implanted at the Russian Research Institute of Traumatology and n.a. R.R. Vreden (Saint Petersburg, Russian Federation) for complex primary and revision knee arthroplasty. Likewise, 55 RHK-implants (all for revision cases, both aseptic and septic) were implanted at the Centre for Orthopedic Surgery OCON (Hengelo, The Netherlands) between January 2013 and November 2015. A detailed case analysis was performed for all patients regarding affected side, gender, age, Body Mass Index, indication for rotating hinge TKA, postoperative time to dislocation, dislocation mechanism and notable findings during revision surgery to explain the dislocation. Clinical outcome was evaluated with American Knee Society Score (KSS) *(22)* before hinge dislocation and after revision surgery at one year follow-up.

RESULTS

Six cases of hinge dislocation were identified in this prospective serie of 303 primary and revision

Figure 1.a – Case 1 : 5 month after surgery a fall occurred resulting in patellar tendon rupture and knee dislocation.

Table 1. — Demographics of patients with rotating hinge TKA dislocation

Case	1	2	3	4	5	6
Affected side	Right	Right	Right	Right	Right	Right
Gender	Male	Male	Female	Female	Male	Female
Age (years)	49	66	64	26	56	75
Indication for rotating hinge TKA	Primary TKA (both collateral ligament instability and flexion/extension gap mismatch)	Revision TKA with extensor mechanism re-construction using BTB allograft (second stage after infected revision hinge implant)	Revision TKA with F3 and T3 bone deficiency (femur and tibial bone defects were reconstructed by structural allografts)	Revision TKA after pathological femur fracture and concomitant loosening of both components of primary hinge implant	Primary TK (medial collateral ligament instability and extensive non-contained bone defect of lateral femoral condyle)	Revision TKA (collateral instability in morbid obesity)
Body Mass Index	34	41	35	22	39	52
Time of dislocation after surgery	20 weeks	18 months	8 weeks	24 months	40 weeks	11 weeks
Cause of dislocation	Acute fall during carrying a heavy object: patella ligament avulsion from tibial tuberosity	Acute fall during walking stairs: closed patella fracture with extensive fragment displacement**	Uncontrolled knee bending during sleep: patella ligament avulsion from tibial tuberosity	Deep squatting with acute patella dis-location. Patient with chronic patella alta due to tendon elongation in Gorham vanishing bone disease	Acute moment of giving way while walking without any trauma	Acute moment of giving way while standing without any trauma
Notable findings during revision to correct the dislocation	1. Full revision due to mechanical damage of hinge thread of femoral component and polyethylene in tibial rotational cylinder. 2. Extensor mechanism reconstruction using BTB* allograft	Patient refused surgery and was treated by closed reduction (of dislocation and patella) and cast immobilization for 6 weeks.	1. Polyethylene insert exchange for thicker one. 2. Extensor mechanism reconstructed using BTB* allograft.	1. Polyethylene insert exchange for thicker one. 2. Patelloplasty (partial margin resection) to improve anatomy	1. Locking pin unscrewed, replaced by new pin 2. Polyethylene insert exchange for thicker one. 3. Patella reshaped via patelloplasty (partial margin resection) to improve anatomy.	1. Locking pin unscrewed, replaced by new pin

* BTB, bone-patella-bone. ** In case 2 both femoral and tibial components were stable as well as bone structural allografts thus only poly insert was changed to the new one.

cases, resulting in a 2% dislocation rate. Patient characteristics are presented in Table 1. Men and women were distributed equally with a mean age of 56 (range, 26 to 75) years. The indication for RHK was revision in four cases (including one patient with a deficient extensor mechanism repaired with bone-patellar tendon-bone allograft reconstruction) and primary indication in two cases. The dislocations occurred at a mean of 10 (range, 2-24) months after surgery.

All six cases involved dislocation secondary to disengagement of the hinge mechanism. The causes of hinge disengagement varied between a minor trauma involving a fall (two, cases 1 and 2

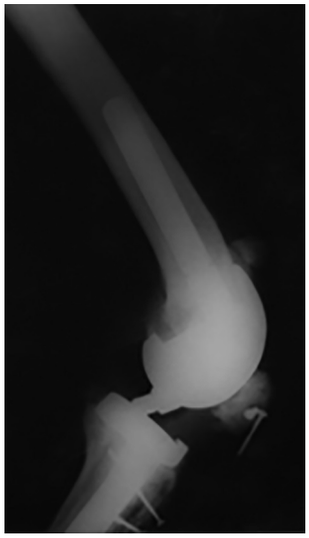

Figure 1.b – Case 2 : 18 months after surgery (also bone-patella-bone allograft of the patella tendon due to extensor mechanism), a fall occurred resulting in patella fracture and knee dislocation.

Figure 1.c – Case 3 : 2 months after revision TKA with structural allograft of both femur and tibia methaphysis patella tendon was torn after uncontrolled deep knee bending while sleeping with concomitant implant dislocation.

in Figure 1), deep knee flexion (two, cases 3 and 4 in Figure 1), and spontaneous (two, cases 5 and

Figure 1.d– Case 4 : 24 months after revision TKA the hinge dislocated during squatting.

Figure 1.e – Case 5 : 10 months after primary TKA the hinge mechanism unscrewed and knee dislocated without any trauma.

6 in Figure 1). Three patients experienced hinge disengagement with or after acute damage to the extensor mechanism : two had a rupture of the

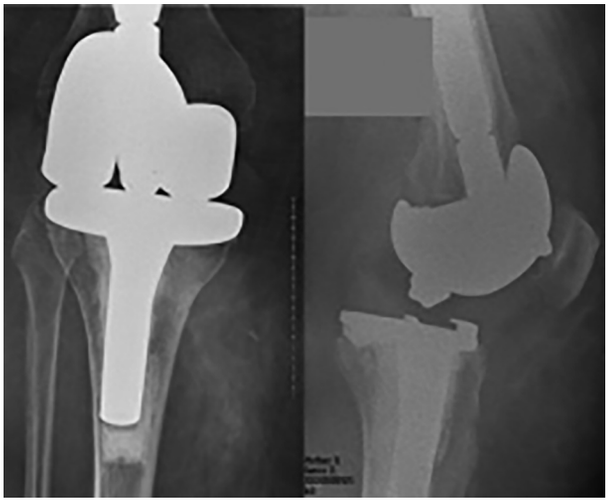

Figure 1.f– Case 6 : 11 weeks after revision TKA the hinge mechanism became loose and unscrewed resulting in dislocation of the knee without any trauma (patient had sudden pain while standing).

patellar tendon (cases 1 and 2) and one a patella fracture (case 3). Moreover, one patient (case 4) had a chronic extensor mechanism insufficiency due to Gorham vanishing bone disease (Figure 2 a-c). In this case hinge dislocation occurred during a squatting activity two years after the primary RHK (Figure 1 d), which was treated by a polyethylene insert exchange (thicker one) and patelloplasty to improve anatomy (partial margin resection). Only one mechanical implant failure was recorded due to a fall on the knee (case 1) resulting in a damaged hinge axle of the femoral component and a broken polyethylene liner in the tibial rotational cylinder.

After revision surgery, 4 patients were immobilized with a brace in full knee extension for six weeks followed by an extensive rehabilitation treatment (cases 1-4), while 2 cases were allowed normal mobilization (cases 5 and 6). One revision complication was recorded : case 6 developed an early deep periprosthetic joint infection with Staphylococcus aureus secondary to persistent wound drainage in a morbidly obese patient. This was treated with success after debridement, liner exchange and antibiotic treatment.

Excellent Knee Society Scores were observed in two cases (i.e. KSS 80-100 *(3)*), three patients had good to fair knee scores (i.e. KSS score 60-79 *(3)*), and one patient had a poor score (i.e. KSS score below 60 *(3)*). These scores were similar to the level before hinge disengagement, whereas the function score was much lower.

One patient (case 1) had a second fall at 10 months after revision surgery with recurrence of the extensor mechanism disruption and hinge disengagement. Knee fusion was scheduled because of lacking patient compliance due to severe alcohol abuse. The patient with Gorham's disease (case 4) experienced a pathological femoral fracture 15 months after revision (39 months after the primary RHK procedure), which was treated by open reduction and internal fixation together with complete revision to another RHK due to concomitant component loosening (Figure 2.4).

DISCUSSION

This study describes the dislocation rate following modern rotating hinge TKA in a large prospective case series as well as the causative mechanisms of dislocation. In this study, a 2% dislocation rate of the RHK NexGen implant (ZimmerBiomet, Warsaw, US) was found. To the best of our knowledge, this is the largest consecutive prospective series described in literature regarding dislocation of rotating hinge TKA. Biswas et al. also reported on the dislocation incidence of the same type of implant (RHK NexGen), but this involved only one case *(7)*. The observed 2% dislocation rate is lower than that reported in literature (Table 2). A literature review involving other types of rotating hinge designs, revealed a median dislocation rate of 6.6% (range, 1-18%) *(4,7,13,17,18,28,39,40)*. Combining all dislocations reported in modern literature about the RHK-design, but with elimination of the case reports *(7,34,39)*, we ended up with a cumulative rate of 3.1% (29/928) for this type of implant (Table 2). This finding implies that, despite that the RHK is a modern hinge, the dislocation rate is higher than the rate of non-constrained early design TKA (incidence ranging 1-2%) and more modern non-constrained TKA designs of today (incidence ranging 0.15-0.5%) *(2,8,11,20,21,24,33,35,37,38)*. For non-constrained designs, dislocation is mainly described in PS implants. This suggests that dislocation

Figure 2. — Conventional radiographs of a patient with Gorham vanishing bone disease. Before primary TKA (2 a), 6 weeks (2 b) and 3 years (2 c) after rotating hinge TKA, and 39 months postoperative after a fall led to a femoral fracture for which open reposition and plate fixation but also a full revision of the hinge TKA due to femoral and tibial loosening that was noted during fracture fixation (2 d).

Table 2. — Literature on dislocation of rotating hinge knee arthroplasty

	Number of cases	Percentage of dislocation	RHK type	Cause of failure or remarks
Crova M. et al. (*13*)	6	4.2% (6 out 142)	LINK Endo Model, Waldemar Link, Hamburg, Germany	N/A
Wang C.-J., Wang H.E. (*39*)	2	N/A	LINK Endo Model, Waldemar Link, Hamburg, Germany	Fracture of polyethylene bearing bush of femoral component on the metallic tibial stud, perhaps in one case following twisting the knee while getting up from a chair. Complaints started within five months postoperative.
Ward W.G. et al. (*40*)	4	2.2% (4 out 185 cases)	Six types used #	Three dislocations occurred within 3 months after surgery. Trauma mechanisms included a fall in the shower in one (while the patient was not wearing his prosthetic contralateral leg after below knee amputation due to osteosarcoma), one occurred simultaneous to an ipsilateral hip dislocation after a femoral replacement in a sarcoma, one had flexion instability resulting in distraction of the central rotational stem and fracture of the polyethylene post three months after surgery, and one case while swinging the leg into bed from a seated position.
Schwarzkopf R. et al. (*34*)	2	N/A	Noiles S-ROM, Depuy J&J, Warsaw, Indiana, USA	One traumatic (fall from stairs) and one spontaneous (knee gave way upon standing up) case, both resulting in fracture of the tibial metal yoke/post.
Pacha-Vicente D. et al. (*28*)	2	1% (2 out 192)	LINK Endo Model, Waldemar Link, Hamburg, Germany	Excessive flexion laxity may result in excessive distraction and loosening of the anti-dislocation mechanism
Bae D.K. et al. (*4*)	2	18% (2 out 11 cases)	LINK Endo Model, Waldemar Link, Hamburg, Germany	Causes not specifically described. All Charcot joint patients. Recommend using knee brace or immobilizer and limit overactivity as to prevent these early dis-locations.
Friesenbichler J. et al. (*17*)	5	9% (5 out 55 cases)	LPS/M.B.T. or S-ROM Noiles, DePuy J&J, Warsaw, Indiana, USA	Trauma (one), loosened femoral component (one), and fractures of metal yoke inside tibial insert of LPS/M.B.T. (three). Moreover, extensor mechanism reconstructed in two.
Friesenbichler J. et al. (*18*)	4	10% (4 out 40 cases)	LPS/M.B.T., DePuy J&J, Warsaw, Indiana, USA	All fractures of metal yoke at a mean of 29 months after surgery Re-fracture of the yoke occurred in two of the four cases.
Biswas D. et al. (*7*)	1	N/A	NexGen RHK, ZimmerBiomet, Warsaw, Indiana, USA	Spontaneous acute disengagement of hinge-post extension with extensor mechanism insufficiency, 10 months after surgery.
Present study	6	2% (6 out 303)	NexGen RHK, ZimmerBiomet, Warsaw, Indiana, USA	Trauma (fall) in two, spontaneous in two, and deep flexion in two. An extensor mechanism disruption was observed in four cases, three acute and one chronic.
TOTAL*	29*	3.1% (29 out 928)		

One dislocation out of 128 Kinematic II RHK (Howmedica, Rutherford, New Jersey). One dislocation out of 37 Noiles RHK (Techmedica- Intermedics/ Sulzermedica, Austin, Texas). No dislocation in the only LINK Endo-Model Rotational Knee included. No dislocations in 14 RHK Dow Corning Wright/ Wright Medical Technology, Arlington, Tennessee. One dislocation in four S-ROM Noiles Modular Rotating Hinged Knee (Joint Medical Products/Johnson and Johnson, Stamford, Connecticut). One dislocation in the only performed Finn Rotating Hinge Knee (ZimmerBiomet, Warsaw, Indiana), this involved a 22-mm polyethylene tray. * Case studies without description of total cohort were excluded, i.e. three articles describing five cases in total (*7, 34, 39*). N/A = not available or described

may be associated with resection of the PCL during primary TKA and probably to the consequently changes to the flexion gap because of it *(1)*.

The present series contains only one mechanical implant failure, i.e. damage of both hinge axles in the femoral component and polyethylene fracture of

the tibial rotational cylinder. This in contrast with literature that typically suggests mechanical failure as a causative mechanism of hinge dislocation, e.g. component fracture or polyethylene tibial peg insert fracture, failure of anti-dislocation mechanisms or polyethylene bearings *(4,7,17,34,40)*. The main reason for hinge dislocation observed in the current study was forced knee flexion with a concomitant extensor mechanism insufficiency (4/6 cases), i.e. a distraction-mediated disengagement mechanism. The second causative mechanism group (2/6 cases) involved hinge dislocation due to non-traumatic unscrewing of the locking pin, i.e. related to the screw home mechanism of the knee. These two mechanisms of hinge dislocation and the central rotating peg design mechanism will be discussed in detail next.

The first mechanism of distraction-mediated disengagement, refers to a dislocation caused by enough distraction to lift the locking pin from the tibial cylinder. It has been described to occur in combined severe insufficiency of the medial collateral ligament and posterior capsule, a large gap mismatch (flexion gap that is significantly larger than the extension gap), or an extensor mechanism insufficiency *(10,28,29,39,40)*. In these situations, the soft tissue envelope resistance is not enough to resist to the locking pin from jumping from the tibial cylinder. This implies that, even though hinge dislocation has been typically described to occur during a fall with forced deep knee flexion, events leading to extensor mechanism damage and/or the hinge locking pin lifting out of the tibial cylinder, dislocation may also happen *(25)*. In the current study, two cases experienced a distraction force due to a fall combined with forced knee flexion and simultaneous disruption of the extensor mechanism. In one case, the patellar tendon was avulsed from the distal attachment while the other case had a patella fracture with extensive fragment displacement. Two other cases had an extensor mechanism insufficiency that occurred during a non-traumatic event, i.e. a deep flexion of the knee. This occurred during sleep in one case only eight weeks after surgery in combination with a patellar tendon avulsion from the distal attachment. It is hypothesized that this avulsion occurred due to a weakened patellar tendon insertion secondary to extensive metaphyseal and cortical bone defects (AORI T3). The other case experienced dislocation during deep squatting. This case had a chronic patellar tendon elongation, resulting in patella alta, due to progression of Gorham vanishing bone disease. In our opinion, this patella elongation resulted in a functionally weakened extensor mechanism that predisposed for the hinge dislocation during the squatting activity. These four cases illustrate that, despite the fact that hinged implants are recommended for patients with primary extensor mechanism insufficiency, this kind of knee pathology can also be deleterious for constrained systems in both chronic or acute events *(9)*.

The second mechanism involves the unscrewing of the locking pin without precipitating trauma (two cases in the current study). This observation seems surprising as the locking pin was securely tightened according to the manufacturers' instructions up to the prescribed torque, but an explanation for this phenomenon has been proposed in literature *(7, 32)*. Rapuri et al. concluded that the kinematic "screw-home mechanism" pattern, which is retained in some degree in most TKA's as described by Dennis et al., might be the cause of the unscrewing of their locking bolts in five NexGen LCCK (ZimmerBiomet, Warsaw, US) cases *(15,32)*. Biswas and colleagues confirmed that the same mechanism also occured for the locking pin of the NexGen RHK, i.e. internal rotation of the femur during knee extension results into a counterclockwise torque effect on locking pin for right knees (resulting in possible unscrewing of the locked pin), while resulting in a clockwise screwing force in left knees (resulting in screwing the pin even more secure) *(7)*. Repeated cyclic movements during everyday movement therefore facilitate unscrewing of locking pin of a hinge mechanism in right knees, while preventing pin loosening in left knees. This does explain why right-sided RHK's seem more prone to pin loosening than left-sided RHK's, as in our series : both cases with non-traumatic pin loosening resulting in dislocation (10 months and 11 weeks after surgery) were right-sided RHKs. Nevertheless, unscrewing a locking pin in left knees may still be possible if a TKA shows reversed knee kinematics (i.e. reversed screw

home mechanism), supposedly occurring in nearly 50% of the knees after TKA according to Dennis et al. *(15)*. Furthermore, as there were no recorded pin fractures among the 303 procedures, the strength of the locking pin in the RHK system seemed sufficient in our series. Other hinge designs have shows a higher incidence of assembly breakage, between 2%-10% *(18,23,31,36)*.

The third dislocation mechanism described in literature refers to the design of the central rotating peg. This is probably not an issue in the present study. Experimental studies have shown that the resistance to disengagement of a vertically oriented post-in-channel mechanism depends on the length and shape of the central rotational peg and design of tibial rotational cylinder *(17,41)*. Tapered pegs appear less resistant to disengagement than cylindrically designed stems. Consequently, Ward et al. recommended using hinged implants with a cylindrically shaped rotational peg with a minimal length of 50 mm or equipped with specific anti-dislocation mechanism in patients with complete collateral ligaments and posterior capsule dysfunction, excessive flexion gap, extensor mechanism insufficiency or in mega-prosthesis implants *(40,41)*. The NexGen RHK, used in all 303 procedures of the current study, is equipped with a cylindrically shaped rotational peg with a length that depends on the thickness of the polyethylene insert to prevent dislocation but results in up to 40 mm jumping distance between femoral and tibial components.

Another striking finding of the present study was that most patients (five out of the six cases) were severely obese (BMI 34-52). This obesity probably facilitates and/or predisposes for hinge dislocation as well, not only due to an earlier and higher fulcrum effect of the large soft-tissue envelop in the posterior aspect of the knee during flexion, but obesity probably also facilitates earlier pin loosening due to inevitably increased torque forces in the screw home mechanism.

In conclusion, a rotating hinge dislocation rate of 2% (6/303 procedures) was found in this prospective consecutive case series. From the possible intrinsic and extrinsic factors that may predispose to dislocation the present study confirmed two mechanisms, i.e. a distraction-mediated disengagement mechanism due to forced flexion of the knee in extensor mechanism deficient knees and non-traumatic unscrewing of the locking pin. Rotating hinge TKA in patients with obesity should be considered with care, as severe obesity may predispose to hinge dislocation due to earlier and higher fulcrum effect of the large soft-tissue envelope during flexion and higher torque forces facilitating pin dislocation. However, when performed and indicated correctly, a rotating hinge remains a good arthroplasty solution for the most complex primary and revision cases where less constraint TKA designs are insufficient and the only other solution would be arthrodesis.

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