



Dislocation of rotating-hinge total knee arthroplasty

Carlos A. Encinas-Ullán¹

Primitivo Gómez-Cardero¹

Juan S. Ruiz-Pérez¹

E. Carlos Rodríguez-Merchán²

- The number of rotating-hinge total knee arthroplasties (RH-TKAs) is increasing. As a result, the number of complications related to these procedures will also increase.
- RH-TKAs have the theoretical advantage of reducing bone implant stresses and early aseptic loosening. However, these implants also have complication rates that cannot be ignored. If complications occur, the options for revision of these implants are limited.
- Dislocation of RH-TKAs is rare, with an incidence between 0.7% and 4.4%. If it occurs, this complication must be accurately diagnosed and treated quickly due to the high incidence of neurovascular complications.
- If the circulatory and neurological systems are not properly assessed or if treatment is delayed, limb ischemia, soft tissue death, and the need for amputation can occur.
- Dislocation of a RH-TKA is often a difficult problem to treat. A closed reduction should not be attempted, because it is unlikely to be satisfactory. In addition, in patients with dislocation of a RH-TKA, the possibility of component failure or breakage must be considered.
- Open reduction of the dislocation should be performed urgently, and provision should be made for revision (that is, the necessary instrumentation should be available) of the RH-TKA, if it proves necessary.
- The mobile part that allows rotation can have various shapes and lengths. This variance in design could explain why the reported outcomes vary and why there is a probability of tibiofemoral dislocation.

Keywords: rotating-hinge total knee arthroplasty; dislocation; diagnosis; treatment

Cite this article: *EFORT Open Rev* 2021;6:107–112.

DOI: 10.1302/2058-5241.6.200093

Introduction

Rotating-hinge total knee arthroplasties (RH-TKAs) are an evolution of fixed-hinge models. Second-generation

RH-TKA designs included a rotating-hinge platform with a metal-on-polyethylene bearing surface, allowing movement in two planes (flexion-extension and rotation). They had a transversely oriented (that is, horizontal) hinge axis for flexion-extension motion and a vertically oriented post-in-channel axis for internal and external rotation. These improvements ameliorated the mechanics of movement and diminished stress transmission, although suboptimal instrumentation and implant design led to high complication rates. Third-generation RH-TKA modular systems evolved further, incorporating modular stems and diaphyseal anchorage grooves for torsional stability, as well as metaphyseal filling and loading sleeves for the bony defects often encountered in revision total knee arthroplasty (TKA).

Despite the improved third-generation design, complication rates ranging from 9.2% to 63% have been reported with RH-TKAs, with infections and aseptic loosening the most frequent complications.¹ Patellar instability and prosthetic dislocation can also occur. The dislocation of a RH-TKA is a complication described in the literature (Table 1),^{2–14} with an incidence ranging between 0.7% and 4.4%.¹⁵ The RH-TKA design consists of a ‘post-in-channel’, in which a non-fixed post slides into the tibial component. This design allows for distraction (separation between the femoral and tibial components) of the joint, which is limited based on the integrity of the periarticular soft tissues. Regarding the femorotibial rotation axes, the rotation axis for flexion-extension is fixed, while the femorotibial axial rotation axis is of variable design.

The maximum amount of distraction before dislocation of the stem occurs is called the ‘jumping distance’. The length of the cylinder defines the jumping distance for femorotibial axial rotation systems without stop. Numerous RH-TKA models are available: implants with long and rotating tibiofemoral axes, implants with short and intraarticular axes, or implants with a fixed longitudinal axis. The mobile part that permits rotation can have various shapes and lengths. This variance in design could explain why the reported results vary and why there is a likelihood of tibiofemoral dislocation.¹⁶ Either the mobile part is fixed, or it is mobile with a possible femorotibial

Table 1. Dislocations after rotating-hinge total knee arthroplasty (RH-TKA) published in the literature ('megaprotheses' excluded)

Authors	Year	Revision implant design (case no.)	Time to dislocation	Management	Reason for dislocation	Dislocation direction
Wang and Wang ²	2000	Endo-Model (Waldemar Link GmbH y Co.KG) (2)	5 months	Revision TKA with a different prosthetic design	Both cases had a femoral channel polyethylene breakage	Posterior and posterolateral subluxation
Petrou et al ³	2004	Endo-model rotating-hinge (Waldemar Link GMBH & Co, Hamburg, Germany) (1:100); (1%)	Unknown	Unknown	Traumatic dislocation	Unknown
Ward et al ⁴	2005	S-ROM Noiles (Joint Medical Products/ Johnson and Johnson) (1)	3 months	Revision was performed to insert a custom tibial tray containing a full-length central metallic reinforcing post	The polyethylene post fractured at the inferior tip of the central reinforcing post	Posterior
Joshi and Navarro-Quilis ⁵	2008	Endo-Model (Waldermar Link GmbH & Co) (3)	Unknown	Another revision knee arthroplasty	Unbalanced gaps (flexion bigger than extension)	Unknown
Pacha-Vicente et al ⁶	2008	Endo-Model (Waldemar Link GmbH y Co.KG) (2)	More than 5 years after surgery	Case 1: The tibial polyethylene insert was exchanged to restore the anti-dislocation feature Case 2: The whole femoral component and the tibial polyethylene were exchanged Three months later, redislocated, and femorotibial arthrodesis was performed thereafter	Case 1: fatigue of the tibial anti-dislocation polyethylene component Case 2: Femoral component loosening, fatigue of the tibial anti-dislocation polyethylene component and fragmentation of the femoral rotational channel polyethylene component	Case 1: Posterior Case 2: Posterolateral
Schwarzkopf et al ⁷	2011	DePuy Noiles S-ROM (DePuy, Warsaw, Ind) (2)	Case 1: 3 years Case 2: approximately 3 years	Case 1: The old 12-mm tibial insert was explanted and replaced with a 21-mm insert Case 2: A revision procedure with another 23-mm tibial insert	Case 1: Gave way upon standing up while gardening with the tibial metal post fractured Case 2: by falling down a flight of stairs with the metal post in the tibial insert was fractured	Posterior
Biswas et al ⁸	2013	NexGen RH-TKA (1)	10 months	The polyethylene liner was exchanged from a 17-mm to a 20-mm insert and a new hinge-post extension was placed a revision reconstruction of the extensor mechanism with an extensor mechanism allograft	Atraumatic disengagement, persistent instability, particularly with an incompetent extensor mechanism, may act synergistically to disengagement of the locking screw	Posterior
Bistolfi et al ⁹	2013	Endo-Model (Waldemar Link GmbH and Co., Hamburg, Germany) (1:50) (2%)	Late complication	Revision	Unknown	Unknown
Sanguineti et al ¹⁰	2014	Endo-Model (Waldemar Link GmbH and Co., Hamburg, Germany) (2:45); (4.4%)	Case 1: 10 months Case 2: in the rehabilitation period	Case 1: Explantation of the device and revision procedure Case 2: Substitution of the polyethylene plateau	Case 1: Malposition of the polyethylene tibial plateau during the surgical procedure Case 2: Accidental trauma occurring in the rehabilitation period	
Cavaignac et al ¹¹	2014	NexGen RH-TKA (1, recurrent)	1 month	Completely revise the implant and replace it with a different revision-specific modular rotating-hinge design (GMRS-MRH®, Stryker, Kalamazo, MI, USA)	Ligamentous laxity during flexion	Posterior
Farid et al ¹²	2015	Biomet OSS implant, Warsaw, Indiana (1:142); (0.7%)	Late complication	Knee dislocation associated with deep infection required open reduction with irrigation and component retention	Fracture yolk	
Angelini et al ¹³	2016	IMPOL, São Bernardo, SP, Brasil (2)	Case 1: 1 year Case 2: 3 years	Implant revision	Trauma, suffered a fall Case 1: Presented breach of the polyethylene rotatory tibial basis Case 2: Breakage of the tibial component stem	Posterior
Gómez et al ¹⁴	2017	Rotax, FII SA®, Saint Just Malmont, France (1)	2.5 years	Revision with replacement of the broken polyethylene component	Breakage of the polyethylene yoke of the prosthesis	Posterior

Table 2. Minimal jumping distance to dislocation of various rotating-hinge total knee arthroplasty (RH-TKA) designs

Manufacturer	Jumping distance (mm)
Howmedica	52
Biomet (12-mm polyethylene tray)	44
Zimmer-NexGen (26-mm polyethylene tray)	41
Techmedica	40
Intermedics (Sulzer Medica)	40
Wright Medical Technology	39
Stryker—GMRS	38
Zimmer-NexGen (12-mm polyethylene tray)	36
Biomet (22-mm polyethylene tray)	33
PLUS Orthopedics-RT-Plu	30
DePuy—LPS/M.B.T.	27
DePuy—S-ROM Noiles	26
Link America	20*

*The implant has an anti-subluxation feature to prevent distraction, and it dislocates only if that feature fails.

translation of one cylinder; it is this design that results in RH-TKA dislocations. The cylinder is either connected to the femoral axis of rotation (Zimmer, de Puy, Biomet, Howmedica, Stryker) or part of the tibia (Link). Hinge-post modularity allows easy implantation without excessive distraction during component assembly, while maintaining an adequate jumping distance (Table 2). Two third-generation RH-TKA modalities are available: without an anti-dislocation mechanism, and with an anti-dislocation mechanism that prevents disconnection by distraction of the implant.

A biomechanical study determined the jumping distance of six RH-TKA designs.¹⁷ The LPS/MBT and S-ROM Noiles implants required at least 26 mm and 27 mm of distraction to dislocate, respectively. In contrast, the GMRS, NexGen (with a 12-mm polyethylene inlay) and RT-Plus models required 38 mm, 36 mm and 30 mm of distraction to dislocate, respectively. The RH-TKA NexGen with a 26-mm polyethylene inlay is dislocated at 42-mm distraction. The Link Endo-Model (Waldemar Link GmbH and Co. KG, Hamburg, Germany) and the GenuX (Implantcast GmbH, Buxtehude, Germany) were not suitable for biomechanical analysis due to their anti-dislocation mechanism, which prevents distraction. The conclusion was that RH-TKAs with long cylindrical pegs have the highest stability at any given amount of distraction. Designs with shorter and markedly tapered pegs can become unstable under conditions of mild joint distraction.¹⁷

Another biomechanical study established that some designs, the Howmedica Kinematic II, Techmedica, Wright Medical Technology Lacey, and Biomet (12-mm polyethylene tray design) rotating-hinge knee implants needed at least 39 mm of distraction for dislocation to occur.¹⁸ The Biomet 22-mm polyethylene tray design and S-ROM rotating-hinge knee implants required \leq 33 mm of distraction before dislocation occurred. The Link America



Fig. 1 Clinical deformity evident after a posterior rotating-hinge total knee arthroplasty (RH-TKA) dislocation.

(without the anti-subluxation shelf engaged) dislocated at 20 mm of distraction. The conclusion was that the designs that have a long, minimally tapered central rotational stem require greater distraction for dislocation to take place.¹⁸ The design of the peg plays a major role in the stability of a RH-TKA.

Diagnosis

In most cases, diagnosis of periprosthetic knee dislocation is simple. It is based on gross deformity of the joint associated with severe pain, limited mobility, and the fact that the patient can no longer stand (Fig. 1).

The dislocation typically occurs in the posterior direction. It is essential to perform a good neurovascular examination, palpating the distal pulses and ankle brachial index (normal $>$ 0.9), because in posterior dislocations, the post is located very close to the popliteal neurovascular structures (popliteal artery, common peroneal nerve, or tibial nerve). If the circulatory and neurological systems are not correctly assessed and treatment is deferred, resultant limb ischemia, soft tissue death, and the eventual need for amputation can occur.

Standard orthogonal radiographic projections of the knee are sufficient in most cases to determine whether the stem of the rotating hinge or hinge post have come out of the tibial socket (Fig. 2). A computed tomography (CT) scan is often employed in cases of doubt and can be useful for preoperative planning. It is very effective in visualizing component loosening associated with instability, and is useful in identifying malrotation. An angio-CT scan of the lower extremities can show vascular structures.

It is important to obtain a complete and accurate medical history, including the original reason for the knee replacement, previous knee procedures, details of the surgical technique, the type of prosthesis used, and whether the patient experienced any trauma to the knee. During the follow-up of patients with RH-TKA, we must assess whether there is a radiological sign of distraction that can predict a high risk of prosthetic dislocation.

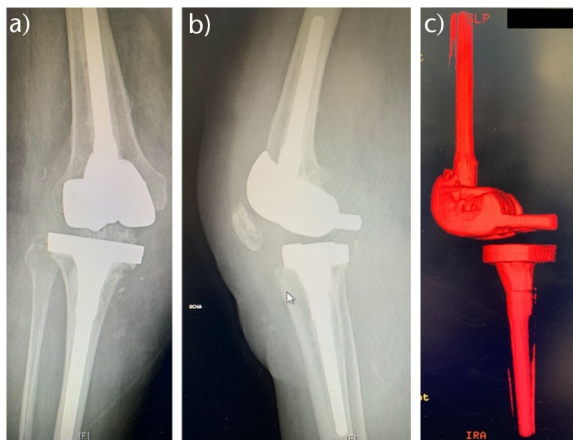


Fig. 2 Anteroposterior radiograph of the right knee shows a rotating-hinge total knee arthroplasty (RH-TKA) dislocation (a). Lateral radiograph of the right knee showing a RH-TKA dislocation (b). 3D reconstruction (c).

Risk factors

The most significant risk factors for dislocation of a RH-TKA are pre-existing instability prior to dislocation, iterative revision on multi-ligament knee, failure or malfunction of the extender device, and retraction in flexion of neurological (Parkinson's, Charcot) or rheumatologic (rheumatoid arthritis) origin. The following risk factors must be taken into account:

(a) Factors related to the patient's activity level

Dislocation can occur after low-energy or high-energy trauma.

(b) Factors related to the periarticular soft tissue quality

The risk of tibiofemoral distraction-mediated disengagement is increased in patients with knee instability. The instability can be due to insufficient ligamentous support and balance and weakness of the joint capsule in cases of multiple revised TKA, rheumatoid knees or neurologic disorders, dysfunction of the extensor mechanism, or massive bone loss. When a comprehensive resection of all the cruciate and collateral ligaments and much or all of the knee capsule is performed, these patients often have an imbalance between flexion and extension gaps. This imbalance occurs because the patients only have the skin, neurovascular package, extensor mechanism, and implant to maintain the balance. The lack of soft tissue restriction often allows for a slight distraction from the knee joint, especially when these patients sit with their knees bent and legs hanging down. The resulting laxity in flexion is mainly resisted by the tension of the extensor apparatus. It is crucial to analyse the functionality of the extensor apparatus. In case of a deficit of the extensor apparatus, a

concomitant reconstruction might be necessary (e.g. with mesh). Moreover, if the extensor mechanism is weakened or its lever arm is shortened because of patellectomy, soft tissue tension can be diminished even further.

(c) Factors related to the surgical technique as a cause of aggravating factors

These factors include excessive flexion gap instability, subsequent dislocating forces due to recurvatum, excessive joint distraction, and 'telescoping' after reduction of the prosthesis components and elevation of the joint line. It is paramount to avoid the two more important technical mistakes: excessive gap in flexion and inappropriate proximal joint space placement.

For correct implantation of a RH-TKA, it is crucial to achieve a balanced mid-lateral ligament and an adequate adaptation of the flexion-extension gap between the femur and the tibia to the dimension of the prosthesis. Imbalance of the flexion-extension gaps could lead to instability. Flexion and extension gaps must be balanced to avoid posterior capsular laxity. In addition, the soft tissues surrounding the joint must be rebuilt. Special care must also be taken to minimize the longitudinal 'telescoping' movement between the femoral and tibial components in extension during the reduction tests.

An adequate joint line is a critical factor in a correctly implanted RH-TKA. Elevation of the joint line is a more common occurrence than a lowering of it, especially after revision TKA. Malposition of the joint line is associated with inferior results and various problems, such as anterior knee pain, patella baja, and mid-flexion laxity. The forces transmitted to the hinged insert of a RH-TKA increase in cases of joint-line elevation due to the altered joint kinematics. Consequently, any angular or translational laxity that escapes the constraint articulation must be borne by the metal yoke of the RH-TKA, which can result in its fracture.

(d) Failure of the hinged mechanism

This factor includes rupture of the polyethylene axle casing, rupture of the metallic tibial post, fracture of the tibial insert, rupture of the anti-dislocation mechanism, and tibiofemoral distraction uncoupling. Sheer dislocation is much less common. This is the second long-term complication, and among the most frequent, after mechanical loosening. Some authors have reported that the polyethylene component of these hinges represents the most fragile part of the system, and it is thus the most common cause of revision.¹⁹

(e) Factors related to the extension post's geometry, namely its length and taper

In rotating-hinge designs, the shorter the central rotational stem and the greater the conical shape, the greater the instability and laxity present. Especially in patients

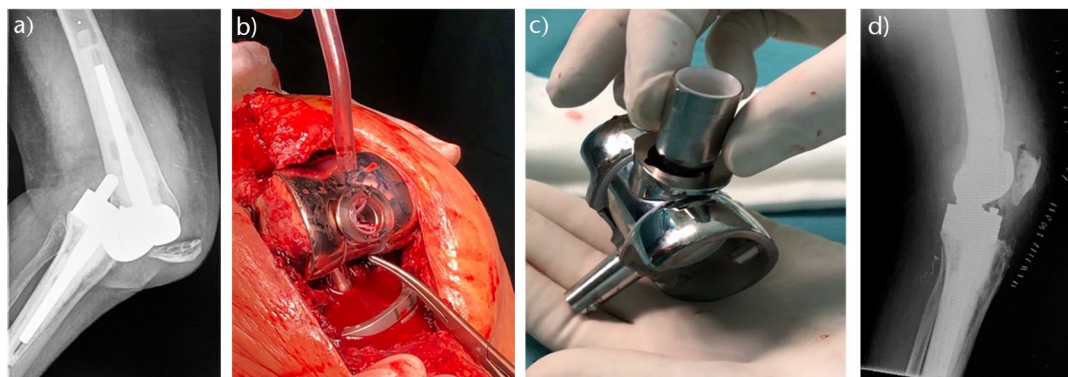


Fig. 3 Lateral radiograph of the right knee shows a rotating-hinge total knee arthroplasty (RH-TKA) dislocation (a). Intraoperative photograph showing the RH-TKA posterior dislocation with broken polyethylene bearing bush of the femoral component of the hinge (b). Change of polyethylene femoral bearing bush (c). X-ray check-up after open reduction (d).

with soft tissue involvement, this approach can allow distraction of the knee joint.¹⁷

(f) Equipment breakage

Most of the time equipment breakage is due to polyethylene wear in the mechanism and much more rarely to axis breakage.

Treatment

Curative treatment

Curative treatment can be either in emergency or delayed. Dislocation after RH-TKA is often a difficult problem to address. A closed reduction should not be attempted because it will probably not be satisfactory. In fact, in patients with dislocation of a RH-TKA, the possibility of component failure or breakage should be considered. Urgent open reduction of the dislocation should be performed, and it should be anticipated that a review of the RH-TKA might be necessary. A reduction trial is useless, an open reduction is required: urgently if there are local signs of neurovascular compression, otherwise after identification of the local problems accompanying the dislocation. Difficult revision surgery may be needed: it must be carried out under good conditions if a prosthesis change must be made. A hinged prosthesis with an anti-dislocation system may be utilized or an anti-dislocation mechanism may have to be changed. It is a difficult surgery that must be performed in centres equipped and trained to do so, that is to say, with teams experienced in knee prosthetic revision surgery. Other therapeutic possibilities must be considered: knee arthrodesis with intramedullary nail and above-the-knee amputation.

Proper identification of the causes leading to the dislocation of the RH-TKA is mandatory for successful treatment. If

the orthopaedic surgeon does not identify the cause of the prosthetic dislocation, they will probably repeat the same errors that led to the dislocation. If the prosthesis is well fixed and there is no evidence of infection or osteolysis and the dislocation is due to mechanical or anti-dislocation mechanism failure, only the broken device need be replaced to restore stability. It is important to rule out femoral channel polyethylene breakage, which would also require replacement (Fig. 3). As a rescue option, the prosthesis can be replaced with another rotating-hinge design; one that uses revision implants with grooved and fluted stems to provide rotational stability and metaphyseal sleeves to fill bone defects, as well as modular augmentation to preserve the joint line. Other options are an allograft–prosthesis composite, knee arthrodesis, or limb amputation.

Preventive treatment

Prevention is the best treatment. Wang and Wang² and Pacha-Vicente et al⁶ stressed the importance of the ligamentous balance, especially the flexion gap, and recommended a constrained prosthesis with an anti-dislocation device in cases of ligamentous insufficiency. Ward et al⁴ advised that a rotating-hinge knee mechanism that has a cylindrical, or nearly cylindrical, long (≥ 5 cm) metallic rotational post be employed to restore knee stability in patients with severe bone and/or soft tissue compromise.

The selection of the initial hinge prosthesis must be accommodated to each particular patient: an iterative revision, multi-ligament knee, progressive neurological damage, and important local ligamentous or osseous fragility should be managed with a rotating hinge with an anti-dislocation system. However, if there is significant intraoperative laxity, a rotating hinge with an anti-dislocation system or a long axial cone should be chosen to assure sufficient jumping distance and prevent dislocation.

Conclusions

RH-TKAs have their place in the orthopaedic surgeon's arsenal in the context of a TKA revision or a complex primary TKA. They should be used only when indicated and with proper technique. It is important that the balance of the ligaments, especially the flexion gap, be meticulous and precise; one must be aware of the high risk of complications in the postoperative period. The control of the ligament balance, in particular of the space in flexion balanced in relation to the space in extension, is paramount when utilizing a RH-TKA without an anti-dislocation system. RH-TKAs with a short jumping distance present more risks of dislocation (e.g. the Link) as both clinical studies and biomechanical research have demonstrated.

Excessive laxity in flexion or imbalance of the flexion-extension gap should be corrected, if possible, at the time of the primary TKA or revision TKA, because failure to do so can lead to a poor result, instability, or dislocation. The correct soft tissue and gap balancing, restoration of the joint line, and repair of bone defects are essential to achieving knee stability and minimizing dislocations in revision TKA. It is critical that surgeons using RH-TKA recognize this potential mode of failure. In addition, the manufacturer's implantation instructions must be followed, especially for the post-extension hinge. Surgeons must be aware of the variability in disengagement potential between manufacturers and should not rely solely on the intrinsic stability of the distraction of the anti-dislocation device that some RH-TKA models employ.

AUTHOR INFORMATION

¹Department of Orthopaedic Surgery, La Paz University Hospital-IdiPAZ, Madrid, Spain.

²Osteoarticular Surgery Research Hospital, La Paz Institute for Health Research – IdiPAZ (La Paz University Hospital – Autonomous University of Madrid), Madrid, Spain.

Correspondence should be sent to: Dr. E. Carlos Rodríguez-Merchán, Hospital La Paz Institute for Health Research – IdiPAZ (La Paz University Hospital – Autonomous University of Madrid), Paseo de la Castellana 261, 28046-Madrid, Spain.

E-mail: ecrmerchan@hotmail.com

ICMJE CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest relevant to this work.

FUNDING STATEMENT

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

OPEN ACCESS

© 2021 The author(s)

This article is distributed under the terms of the Creative Commons Attribution-Non Commercial 4.0 International (CC BY-NC 4.0) licence (<https://creativecommons.org/licenses/by-nc/4.0/>) which permits non-commercial use, reproduction and distribution of the work without further permission provided the original work is attributed.

REFERENCES

- Rodríguez-Merchán EC.** Total knee arthroplasty using hinge joints: indications and results. *EFORT Open Rev* 2019;4:121–132.
- Wang CJ, Wang HE.** Early catastrophic failure of rotating hinge total knee prosthesis. *J Arthroplasty* 2000;15:387–391.
- 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.
- Ward WG, Haight D, Ritchie P, Gordon S, Eckardt JJ.** Dislocation of rotating hinge knee prostheses: a report of four cases. *J Bone Joint Surg Am* 2005;87:1108–1112.
- Joshi N, Navarro-Quilis A.** Is there a place for rotating-hinge arthroplasty in knee revision surgery for aseptic loosening? *J Arthroplasty* 2008;23:1204–1211.
- Pacha-Vicente D, Malik A, Castellet-Feliu E, Nardi-Vilardaga J.** Dislocation of rotating-hinge knee prostheses with antidislocation mechanism. *J Arthroplasty* 2008;23:299–303.
- Schwarzkopf R, Chaudhry S, Kummer FJ, Marwin SE.** Failure of the tibial insert in a rotating hinge total knee arthroplasty. *J Arthroplasty* 2011;26:977.e5–977.e8.
- Biswas D, Haughom B, Mayle RE Jr, Della Valle CJ.** Case report: failure of rotating-hinge total knee prosthesis by disengagement of the hinge-post extension. *Clin Orthop Relat Res* 2013;471:1389–1392.
- Bistolfi A, Rosso F, Crova M, Massazza G.** Endo-Modell rotating-hinge total knee for revision total knee arthroplasty. *Orthopedics* 2013;36:e1299–e1306.
- 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.
- Cavaignac E, Tricoire JL, Pailhé R, et al.** Recurring intraprostatic dislocation of rotating-hinge total knee prosthesis: effect of implant design on intrinsic stability. *Orthop Traumatol Surg Res* 2014;100:835–837.
- 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.
- Angelini FJ, Helito CP, Veronesi BA, Guimarães TM, Pécora JR, Demange MK.** Knee arthroplasty revision with a constrained implant using hinge and rotating tibial basis. *Acta Orthop Bras* 2016;24:22–26.
- Gómez DJ, Garabano G, Senes S, Pesciallo CA.** Dislocation of hinged knee prosthesis. *Rev Asoc Argent Ortop Traumatol* 2017;82:294–298.
- Friesenbichler J, Schwarzkopf R, Sadoghi P, et al.** Failure rate of a rotating hinge knee design due to yoke fracture of the hinged tibial insert: a retrospective data analysis and review of the literature. *Int Orthop* 2012;36:993–998.
- Pasquier G, Ehlinger M, Mainard D.** The role of rotating hinge implants in revision total knee arthroplasty. *EFORT Open Rev* 2019;4:269–278.
- Friesenbichler J, Leithner A, Glehr M, et al.** Evaluation of stability of rotating hinge knee prostheses: a biomechanical study. *ISRN Orthop* 2013;2013:701693.
- Ward WG, Haight D, Ritchie P, Gordon S, Eckardt JJ.** Dislocation of rotating hinge total knee prostheses: a biomechanical analysis. *J Bone Joint Surg Am* 2003;85:448–453.
- Bistolfi A, Lustig S, Rosso F, Dalmaso P, Crova M, Massazza G.** Results with 98 Endo-Modell rotating hinge prostheses for primary knee arthroplasty. *Orthopedics* 2013;36:e746–e752.