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Good clinical and radiological results of total knee arthroplasty using varus valgus constrained or rotating hinge implants in ligamentous laxity

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Abstract

Purpose The optimal degree of constraint of a total knee arthroplasty for treatment of knee osteoarthritis with ligamentous laxity is under debate. While varus valgus constrained knees require a minimum level of ligamentous stability, rotating hinge knees can even be implanted if the collateral ligaments have been lost completely. It seems plausible that joint kinematics are determined by implant design in rotating hinge knees, whereas varus valgus constrained knees may be influenced by remaining stabilizers. This may result in more predictable clinical results of hinge knees. The hypothesis of the present study, therefore, was that stability and clinical outcome are better after total knee arthroplasty using rotating hinge knees than after using varus valgus constrained knees.

Methods All patients who were treated using a mobile-bearing varus valgus constrained knee or a rotating hinge knee for treatment of end-stage osteoarthritis and ligamentous laxity were included. At follow-up, clinical scores were determined (WOMAC, VAS, KSS, FJS, Lysholm). Furthermore, body mass index, operating time, and postoperative complications were documented. Whole leg radiographs as well as patella axial radiographs were analyzed for implant alignment and patella tracking.

Results Eighty-five patients were included in this retrospective study. Both groups showed an average range of motion of 113°. No significant difference between the two groups was observed for any of the scores recorded. In the rotating hinge knee group, a more precise tibia positioning in relation to the mechanical axis but also a significant lateralisation and tilting of the patella were seen, compared with the varus valgus constrained knee group.

Conclusions Rotating hinge knees did not perform better than mobile-bearing varus valgus constrained knees clinically. Both prosthesis types showed equally good clinical outcomes with regard to stability, mobility, satisfaction, pain and operating time.

Level of evidence Retrospective case series, Level IV.

Keywords Total knee replacement · TKA · RHK · Rotating hinge knee · Varus valgus constrained · Fully constrained

Introduction

Ligamentous instability after total knee arthroplasty (TKA) is a common reason for early revision [12, 23, 26]. 7–20% of total knee revisions are performed for instability of the primary implant [1, 2, 25, 26].

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The optimal level of constraint in knees with ligamentous laxity is not clearly defined. Varus valgus constrained (VVC) implants typically are used for patients with coronal plane instability, which cannot sufficiently be balanced using a cruciate-retaining or posterior-stabilized implant. Rotating hinge knees (RHK) are recommended for patients with severe deformity or instability that cannot be managed using a VVC implant [3, 5, 19]. While RHK offer the greatest stability without the need for extensive soft tissue releases, it is claimed that they only achieve moderate clinical outcomes with high rates of early loosening [8, 24]. In contrast to this, VVC knees are commonly recommended in case of instability and produce better results than RHK [6, 11, 13, 15, 18]. RHK therefore have a selection bias in all publications, resulting from the fact that they are only used in disastrous cases as "salvage" implants [3, 4, 7, 9, 14, 21]. In a European context, the use of RHK is more popular for historical reasons. More recent studies have thus confirmed good to very good survival rates with good function after implantation of constrained prostheses [3, 4, 7, 9, 15, 16, 21].

Up to today, no clear recommendation is available about the appropriate degree of constraint (mobile or fixed VVC vs. second or third generation RHK) based on the level of instability (Table 1). According to the current literature, the indications for implantation of a VVC TKA are end-stage varus or valgus osteoarthritis of the knee accompanied by insufficient but still present collateral ligaments or a flexion/extension gap mismatch with a "jumping distance" less than 2 cm [7, 10, 11, 19]. Up to now, few studies have been able to demonstrate a superiority of one of the two prosthesis types. All of the studies published to date either have no control group or compare different indications for a certain degree of constraint (Table 2). While the constraint mechanism of a VVC enforces a rollback but enables an anterior drawer, the kinematics of an RHK are determined by the specific mechanism over the entire range of motion. In addition, based on the indication for VVC or RHK, the VVC requires soft tissue releases and produces gap stability by metal augments and inlay height. This may result in a pseudopatella baja in some cases [18–20]. In contrast, RHK rarely have to be released, but only a hyperextension should be prevented by implant positioning. In VVC, in contrast to RHK, a secondary instability can also result in the event of elongation or rupture of an intraoperatively already insufficient ligament structure, malrotation, malalignment or flexion/extension mismatch. It is therefore conceivable that, regardless of capsule and ligament apparatus, kinematics and function will be predetermined by implant design after RHK, in contrast to VVC. Therefore, the hypothesis of the present study was that knee stability and clinical outcome are better after second-generation RHK than after mobile-bearing VVC.

Table 1 Types of constrained knee systems

VVC (CCK) fixed	VVC (CCK) mobile	RHK second generation	RHK third generation
Condylar constrained fixed bearing	Condylar constrained mobile bearing	Started in the early 1970s	Started in the early 1990s
Fixation of femorotibial rotation over the whole ROM	Femorotibial rotation	Freedom of rotation, start of modularity	Freedom of rotation, high modularity
Balance of the knee in a frontal and coronal plane	Balance of the knee in a frontal and coronal plane	Stability in all planes, varus/valgus motion and modest axial rotation	Stability in all planes, support of patella tracking
Possibility of wedges or cones	Possibility of wedges or cones	Possibility of sleeves and wedges	Possibility of sleeves, wedges or cones

Table 2 Literature review of primary TKA with rotating hinge knee

Author	Year	Type of prosthesis	FU in years	*n*	Results
Petrou et al. [20]	2004	Endo Model	7–15	100	11-year survival rate: 96%
Yang et al. [27]	2012	Endo Model	15	50	14% infection rate
Mavrodonitidis et al. [17]	2008	Endo Model	8–15	136	Excellent HHS score in 83%
Gehrke et al. [7]	2014	Endo Model	13.5	238	Survival rate: 90%, excellent HHS score in 54%
Bistolfi et al. [4]	2013	Endo Model	5 to 15	98	10-year survival rate: 80%
Guenoun et al. [8]	2009	Endo Model	3	85	Complication rate: 28.2%
Literature review of primary TKA with condylar constrained knee					
Sabatini et al. [22]	2017	Zimmer CCK/DePuy TC3	2.7	28 (10/18)	KSS 92.1 points, no infection or loosening
Feng et al. [6]	2016	NexGen® Legacy® CCK	5.9	48	6-year survival rate: 97.9%
Lachiewicz et al. [11]	2006	Total Condylar III J&J and Insall-Burstein II Zimmer	5–16	54	10-year survival: 96%

Materials and methods

In this retrospective study, fifty-three patients were treated using a mobile-bearing VVC prosthesis from 2009 to 2014. The study had the approval of the local ethics committee of the Friedrich-Schiller University, University Hospital Jena (4632-12/15). Written informed consent was obtained from each patient. Between 2013 and 2015, 33 patients were treated with a second-generation RHK. No indication for mobile VVC was seen in 2015. A different type of second-generation RHK was used from 2009 to 2012, so that these patients were not included in the RHK group. In contrast to other studies, it was possible to minimize any inclusion bias by implanting the prosthesis types in a comparable indication. Before 2014, all included knees were treated with varus valgus constrained knees. Starting in 2014, similar cases were treated using rotating hinge knees in the Orthopaedic Department of the Waldkliniken Eisenberg. A bias of implant choice from using VVC or RHK in different indications could therefore be excluded in the present study. All patients with osteoarthritis of the knee and ligamentous laxity who were treated using a modular VVC knee (DePuy, Warsaw, USA) with a mobile-bearing and cemented stems or a second-generation modular RHK (Waldemar Link, Hamburg, Germany) with cemented stems in the period between 2009 and 2015 were included in this retrospective study (Fig. 1a, b). There were no exclusion criteria in either group. Mean follow-up was 41 months for the VVC group and 20 months for the RHK group. Patient's age at operation, body mass index (BMI), and peri- and postoperative complications were documented in the patients' record. Additionally, operating times were compared between RHK and VVC implantations (Table 3). Clinical scores were evaluated at follow-up using the Lysholm, VAS, FJS, KSS and SF-36 scores (Table 4).

All patients were evaluated using plain radiographs. The leg axis was determined on a standardized whole leg radiograph. Measurements of patella tilt and patella shift were performed using patella axial radiographs (Table 5). The DICOM files were imported in ImageJ (https://imagej.nih.gov/ij) and the mechanical alignment of the tibial and the femoral implants was calculated in relation to the mechanical femoral and tibial axis. The angles were calculated (Excel, Microsoft) based on the following points, which were registered consecutively: hip centre, knee centre, ankle centre, tibial implant medial and lateral, femoral implant medial and lateral. The tilt and shift of the patella were calculated based on the following points: femoral

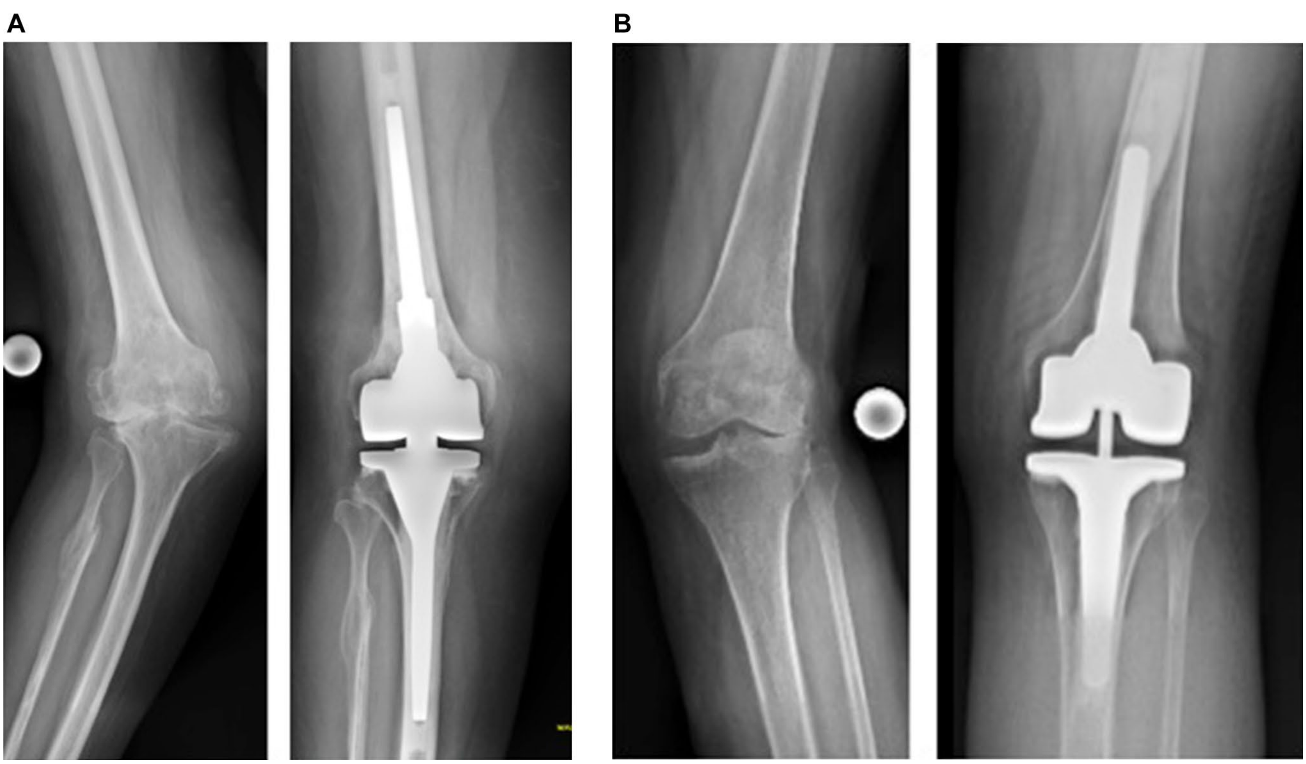

Fig. 1 **a** Unstable osteoarthritic valgus knee with implantation of a rotating hinge prosthesis. **b** Unstable osteoarthritic valgus knee with implantation of a semi-constrained prosthesis

Table 3 Patient demographics

	HK	VVC	*p* values
Number	33	53	
Male	12	13	n.s
Female	21	40	n.s
Age (years)	65.6 ± 10	68.5 ± 9	n.s
BMI	31 ± 6	33 ± 6	n.s
Years of surgery	2013–2015	2009–2014	
Follow-up in months	20	41	n.s
Operating time (minutes)	119 ± 42	128 ± 39	n.s
Number of complications	0	2 (soft tissue infection)	n.s

Table 4 Functional outcome after surgery

	HK	VVC	*p*- values
ROM	113 ± 12°	113 ± 9.5°	n.s
KSS knee	73.1 ± 18	75 ± 19.5	n.s
KSS function	63.6 ± 18	67.6 ± 19	n.s
Lysholm	66.2 ± 20.8	69.7 ± 22.8	n.s
FJS-12	38.9 ± 33.6	48.6 ± 35	n.s
WOMAC pain	4.9 ± 5.5	4.9 ± 5.9	n.s
WOMAC function	19.9 ± 18.4	20.5 ± 21.5	n.s
VAS satisfaction	2.6 ± 1.5	2.5 ± 1.3	n.s
VAS pain knee	3.8 ± 3.1	3.3 ± 3	n.s

Table 5 Radiographic outcome after surgery

	HK	VVC	*p* values
Mechanical alignment	0.6 ± 2.7° valgus	1.3 ± 3.4 varus	n.s
Outliers > 3° to mech. axis	7 of 33 (21%)	21 of 53 (43%)	0.001
Femoral angle	0 ± 2.4°	0.4 ± 2.1°	n.s
Tibial angle	0.2 ± 2.7° valgus	2.5. ± 4.3° varus	0.019
Patella tilt	7.5 ± 6.5°	4.8 ± 3.9°	0.002
Patella shift	53 ± 10%	48 ± 5%	0.004

implant trochlea medial and lateral, patella medial, lateral border, and dome. All points were registered with an accuracy of less than 1 mm. The angles were calculated using standard trigonometry, so that the resulting values should have an accuracy of less than 1°. The inaccuracy of long standing radiographs regarding rotation and flexion of the leg was addressed by performing the radiographs in a standardized manner.

Statistical analysis

The groups were compared using the Mann–Whitney *U* test for unpaired non-parametric values (clinical scores, ROM). Given a typical relative standard deviation for clinical scores of 15%, a clinically relevant effect of 10% improvement, a power of 80% and a level of significance of 5%, the necessary sample size was calculated to be a minimum of 29 in each group. The prevalence of alignment outliers was compared using a Chi-squared test at a level of significance of 5%.

Results

No patient was lost to follow-up. None of the knee prostheses showed aseptic loosening or periprosthetic infection. No cases of thrombosis were present. Postoperatively, two patients in the VVC group experienced a superficial wound healing disorder, which was treated surgically. Both healed uneventfully. Patient demographics did not differ between the two groups and are summarized in Table 1. The average operating time was 128 ± 39 min for the VVC group and 119 ± 42 min for the RHK group, *p* values are not significant (Table 3).

The clinical scores (Lysholm, VAS, FJS, KSS and SF-36) were not significantly different between the two groups (Table 4).

In the RHK group, the tibial components were significantly better mechanically aligned (0.2° ± 2.7° of valgus) than in the VVC group (2.5° ± 4.3° of varus, $p = 0.019$). This resulted in a significantly lower number of outliers of a neutral mechanical leg axis in the RHK group. Here, only 7 of 33 (21%) were outside a range of ± 3°, in contrast to 21 of 53 (43%) in the VVC group, $p = 0.001$. The patella was more lateralized and tilted in the RHK compared to the VVC group, $p = 0.004$ and $p = 0.002$ (Table 5).

Discussion

The most important finding of the present study is that knee stability and clinical outcome are not better after second-generation RHK than after mobile-bearing VVC. RHK knees had a better mechanical alignment of the tibial component and an increased tilt of the patella compared to VVC knees. No differences were found between mobile-bearing VVC and second-generation RHK with regard to stability, function and patient satisfaction. Surprisingly, the RHK group achieved a more precise mechanical implant and overall alignment of the leg compared to the VVC group. This may be explained by the longer stems in the RHK knees in comparison to the VVC knees. All stems were cemented in all cases, so that they could not self-align the implant by fit and fill of the medullary canal. An increased lateralisation and tilting of the patella was observed in the RHK group. This might result from the complete loss of collateral ligaments in the RHK group, which plays a key role in stabilizing femorotibial rotation and thereby the dynamic distance between the tibial tuberosity and the trochlear groove (TTTG) over the entire range of motion [8, 15, 20, 24]. Another explanation might be the use of a mobile-bearing VVC implant. Rotational malalignment of the tibial component can be partially corrected by the mobile bearing. In contrast to this, in this specific RHK design, the tibia starts to rotate against the femur at 10° of flexion. Between 0°–10° of flexion, rotation is prevented by the insert geometry, so that the implant behaves like a fixed hinge. Rotational malalignment of the tibial component therefore has a greater impact in this specific RHK than in a mobile-bearing VVC. This may have a negative effect on the TTTG in a position close to extension and thus on patella catching [23].

This study has some limitations. One weakness of the present study is its retrospective design, with the limited number of cases and different follow-up times. The amount of preoperative ligamentous laxity as well as preoperative clinical scores was not available, given the retrospective design. Additionally, two different prosthesis designs were compared, with the appropriate but differing operative techniques. Before 2014, all included knees were treated with varus valgus constrained knees, but starting in 2014 similar cases were treated using rotating hinge knees for the same indication in the Orthopaedic Department of the Waldkliniken Eisenberg. Therefore, an inclusion bias can be excluded. These studies data concur with the results of a meta-analysis of Malcolm et al. [15]. After exclusion criteria had been applied, 7 studies were included in this analysis. 544 VVC and 254 RHK were compared with regard to survival rate and function. The two groups had a comparable complication rate. They were also found to be comparable in terms of range of motion, the Knee Society function score, and the 10-year survival rate [15].

Martin et al. [16] compared 28,667 primary knee prostheses (27,994 unconstrained knees, 427 VVC, and 246 RHK) after 10 and 20 years. Here, the VVC group performed better than the RHK group with regard to complication and survival rate (10-year survival rate: VVC 90% vs. RHK 75%; 20-year survival rate: VVC 73% vs. RHK 40%) [16]. However, these results are limited by the inclusion bias. Patients receiving an RHK suffered from a higher degree of preoperative laxity or malalignment compared to the VVC group [16]. This selection bias is typical for almost all studies that compare unconstrained implants with implants of different levels of constraint. More recent studies show better survival rates with good functional outcomes for RHK in primary arthroplasty. Bistolfi et al. [4] included 98 RHK in their study. The 10-year survival rate was 80%. The HHS knee score improved significantly, and the range of motion improved from 88° preoperatively to 110° postoperatively [4]. This is in line with the postoperative results of the present study (Table 4).

Instability is difficult to measure in a reproducible way, except in full extension and in 90° flexion. Additionally, rotational stabilizers (popliteus tendon, biceps femoris muscle, iliotibial band and others) cannot be sufficiently evaluated. Both types of implants can be used for significant ligamentous laxity. A clear and evidence-based algorithm to choose the appropriate level of constraint is still missing. In case of doubt, a higher constrained level should be used.

Conclusions

The present retrospective study demonstrates comparably good functional scores and patient satisfaction after cemented mobile VVC vs. second-generation rotating hinge knees for treatment of knee osteoarthritis with ligamentous laxity. The results confirm that both types of implants can be recommended for the therapy of end-stage knee osteoarthritis with significant ligamentous laxity.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval The study had the approval of the local ethics committee of the Friedrich-Schiller University, University Hospital Jena (4632-12/15).

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