Outcomes of Varus Valgus Constrained Versus Rotating-Hinge Implants in Total Knee Arthroplasty

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abstract

The stability of a total knee arthroplasty is determined by the ability of the prosthesis components in concert with supportive bone and soft tissue structures to sufficiently resist deforming forces transmitted across the knee joint. Constrained prostheses are used in unstable knees due to their ability to resist varus and valgus transformative forces across the knee. Constraint requires inherent rigidity, which can facilitate early implant failure. The purpose of this study was to describe the comparative indications for surgery and postoperative outcomes of varus valgus constrained knee (VVK) and rotating-hinge knee (RHK) total knee arthroplasty prostheses. Seven retrospective observational studies describing 544 VVK and 254 RHK patients with an average follow-up of 66 months (range, 7-197 months) were evaluated. Patients in both groups experienced similar failure rates ($P=0.74$), ranges of motion ($P=0.81$), and Knee Society function scores ($P=0.29$). Average Knee Society knee scores were 4.2 points higher in VVK patients compared with RHK patients, indicating minimal mid-term clinical differences may exist ($P<0.0001$). Absent collateral ligament support is an almost universal indication for RHK implantation vs VVK. Constrained device implantation is routinely guided by inherent stability of the knee, and, when performed, similar postoperative outcomes can be achieved with VVK and RHK prostheses. [Orthopedics. 2016; 39(1):e140-e148.]

The stability of TKA is determined by the ability of the prosthesis components in concert with supportive bone and soft tissue structures (eg, ligament, envelope) to sufficiently resist deforming forces transmitted across the knee joint. In the presence of significant instability, implants with more constraint may be required. Implant constraint is understood as the effect of the elements of the knee implant design that provide needed stability in the presence of significant bony and/or soft tissue envelope defects. Varus valgus constrained knee (VVK) and rotating-hinge knee (RHK) prostheses are 2 constrained implants frequently used in the setting

Total knee arthroplasty (TKA) is among the fastest growing procedures in the United States. In 2011, it was the second most prevalent procedure after the cesarean section, with 711,398 patients undergoing TKA nationwide. Despite this success, TKA failure remains a major problem. The 5-year risk of revision following TKA is 3% to 4%. Instability of the implant is the second most common nonseptic reason for failure after aseptic loosening. Given previous reported trends, more than 45,000 TKAs per year may require revision due to instability within the next 20 years.
of severely compromised ligamentous and/or soft tissue support in the primary and revision settings. Varus valgus constrained knees are stabilized in the coronal and sagittal planes by a tall tibial post engaging in a deep femoral groove, in which the femoral and tibial components are not linked together. Rotating-hinge knees are fully stabilized in the coronal and sagittal planes, with tibial and femoral components mechanically linked by an axle.

Constrained prostheses tend to be larger and bulkier than unconstrained prostheses due to their complex tibiofemoral articulation that affords increased stability and rigidity; consequent limitations of constrained prostheses stem from the larger required bone stock for future revisions, poorer functional outcomes and a higher likelihood of failure), greater surface area (eg, greater nidus for infection), and a higher transmission of force across the knee joint to bone-implant interfaces that may necessitate the use of intramedullary stems. Elevated rates of failure and poor outcomes were reported following fixed hinged-knee TKA. With advancements in design, rigidity imposed by the hinged connection is now mitigated by rotation of the tibial bearing around a yoke on the tibial platform.

Individual and comparative outcomes of modern VVK and RHK arthroplasty are poorly studied but deserve attention given current advancements in prosthesis design and fixation. The purpose of this study was to systematically review and compare implant failure, indications for TKA, survival rates, and postoperative outcomes following VVK and RHK TKA.

**Materials and Methods**

A comprehensive search of PubMed, Cochrane, and Google Scholar computerized databases for case-control, cohort studies (both prospective and retrospective), and clinical trials comparing VVK and RHK was performed (Table 1). Studies that did not compare VVK to RHK were excluded. English-language studies of primary or revision TKA with a minimum average of 12-month follow-up were included. Articles describing fewer than 10 patients (ie, case reports and series) and cadaveric or biomechanical studies were also excluded. References from retrieved studies were further reviewed to identify articles of interest.

First, inclusion and exclusion criteria were applied to study titles and abstracts independently by 2 reviewers (T.L.M., R.S.) to identify potentially eligible studies; disagreements were settled and final selections were made by a third reviewer (S.S.B.). Those studies considered potentially eligible were retrieved in full for review. Again, 2 reviewers independently applied inclusion and exclusion criteria, and included studies were systematically reviewed for study (ie, year of publication, years of treatment, sample size, study type, inclusion criteria, and exclusion criteria); demographic (ie, age), and clinical (ie, follow-up period, implant type, preoperative diagnosis, implant selection criteria, ligamentous integrity, and Anderson Orthopaedic Research Institute [AORI] bone defect classification data). Anderson Orthopaedic Research Institute classification describes bone and soft tissue defects about the knee; increasing scores reflecting larger defects. The primary outcome was failure following VVK and RHK TKA. Secondary outcomes included indication for TKA, survival, range of motion (ROM), Knee Society knee score (KSKS), and Knee Society function score (KSFS).

Pooled statistical analyses were performed using Review Manager (RevMan) version 5.3 (The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark). Standard deviation was estimated according to methods described by Hozo et al when not reported. In the presence of significant heterogeneity, a random-effects model was chosen; otherwise, a fixed-effects model was used. In general, heterogeneity was deemed present when the I² test statistic was greater than 60%. Heterogeneity was also judged according to differences in the treatment methodology of each study.

### Table 1

<table>
<thead>
<tr>
<th>Internet Database</th>
<th>Search Schema</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cochrane</td>
<td>Title, Abstract, Keywords: Knee AND Title, Abstract, Keywords: hinge OR hinged OR constrained OR constrain OR rotating OR rotate AND Title, Abstract, Keywords: arthroplasty OR arthroplasties OR endoprosthesis OR endoprosthesis OR implant OR implants OR prosthesis OR prostheses OR replacement OR replacements OR surgeries</td>
</tr>
<tr>
<td>Google Scholar</td>
<td>allintitle: Knee (hinge OR hinged OR constrained OR constraint OR rotating OR rotate) (comparison OR comparisons OR compare OR compared OR versus OR trial)</td>
</tr>
</tbody>
</table>

*Search terms above were used to search the internet for comparative studies describing postoperative outcomes of varus valgus and rotating hinge total knee arthroplasty patients.*
RESULTS

Initial search results identified 294 studies. A total of 274 studies were excluded after reviewing titles and abstracts (κ=0.55, moderate agreement); these were studies that did not compare VVK and RHK TKA clinical outcomes, case studies, biomechanical analyses, and studies primarily evaluating other implant design systems (Figure 1). After reviewing the methods section of the 20 remaining studies, 13 were excluded (κ=0.79, good agreement). Nine reported noncomparative outcomes (eg, outcomes were not separately reported for RHK and VVK prostheses), and comparative data were not available for 4 studies. In total, 7 articles (798 patients) comparing VVK and RHK prostheses were found that met the criteria (Figure 1).17-23

Failure

Six studies reported TKA failure rates for a total of 528 VVK and 244 RHK knees, observed an average of 71 months (range, 1-200 months) after the primary procedure.17-23 Prostheses recipients were similar in age (P=.94) and length of follow-up (P=.26).17-23 Patients undergoing VVK and RHK implantation for revision TKA did so an average of 71 months (range, 1-200 months) after the primary procedure.17-23 Failure Six studies reported TKA failure rates for a total of 528 VVK and 244 RHK knees, observed an average of 68 months postoperatively (Figure 2).18-23 The odds of TKA failure were 9% higher following VVK TKA compared with RHK TKA; however, this was not a statistically significant finding (P=.74). Sixteen percent (n=83) and 12% (n=30) of VVK and RHK prostheses, respectively, were revised due to periprosthetic joint infection (PJI) (P=.55) (Table 3). Revision due to aseptic failure occurred in 4% and 6% of VVK and RHK prostheses, respectively (P=.50). Reasons for revision unrelated to sepsis included instability (n=6), periprosthetic fracture (n=5), and aseptic loosening (n=4) among VVK prosthesis recipients, and aseptic loosening (n=7), periprosthetic fracture (n=4), and patellectomy (n=3) among RHK recipients.

Indication for Surgery

Prostheses used, preoperative diagnoses, and implant selection criteria were described by 6 studies (Table 4). Most patients received either a second-generation VVK or third-generation hinged prosthesis.17-22 Fuchs et al17 and Hwang et al20 collectively found a preoperative diagnosis of PJI in 19% and 83% of VVK and RHK recipients, respectively (P<.0001).17,20 Farfalli et al19 reported 44% and 53% of VVK and RHK cases, respectively, were due to tumor resections.19 Five of 7 studies reported collateral ligament insufficiency/absence as criteria for RHK vs VVK selection.17,18,20-22 Implant selection was also made according to bone and soft tissue support. Vasso et al22 reported VVK (n=35) and RHK (n=18) knees affected by AORI II and AORI II-III bone loss, respectively. Shen et al23 reported that 27% (n=75), 50% (n=137), and 22% (n=61) of VVK knees had AORI I, II, and III bone loss, respectively; and 33% (n=31) and 67% (n=63) of RHK knees had AORI II and III bone loss, respectively.

Survival

No clear difference in survival of VVK and RHK prostheses could be extrapolated from the combined results shown by Hossain et al21 and Farfalli et al.19 Hossain et al21 and Farfalli et al19 reported contrary 10-year survival results with average rates 3.2% higher and 9.0% lower, respectively, of RHK vs VVK prostheses (Figure 3). Individual study results were not statistically pooled due a high degree of heterogeneity and a small number of studies (n=2).

Postoperative Range of Motion

Postoperative ROM was reported by 6 studies (n=431 knees) (Figure 4).17-22 Pooled

Figure 1: Study selection flowchart. Abbreviations: RHK, rotating-hinge knee; VVK, varus valgus constrained knee.
analysis of 271 VVK and 160 RHK implants showed similar knee ROM ($P=.81$).

**Knee Society Score**

Mean KSKS (n=355 knees) and KSFS (n=54 knees) are presented in Figure 5 and Figure 6, respectively. Pooled analysis showed a KSKS an average of 4.2 points higher in those with VVK vs RHK prostheses ($P<.0001$). Hossain et al$^{21}$ reported a KSKS an average of 4.9 points higher among VVK vs RHK prostheses ($P<.0001$), whereas Fuchs et al$^{17}$ and Hwang et al$^{20}$ found nonsignificant differences in KSKS between VVK and RHK prostheses. Knee Society function scores were similar between VVK and RHK prostheses ($P=.29$), albeit favoring VVK by an average of 3.1 points. Both Fuchs et al$^{17}$ and Hwang et al$^{20}$ found similar KSFS between VVK and RHK implant groups.

**Discussion**

This meta-analysis evaluating VVK and RHK prostheses found no clinically or statistically significant differences in implant failure rate, 10-year survival rate, postoperative ROM, or clinical outcome between the 2 implant designs. The equivocal differences in outcomes between RHK and VVK prostheses are underscored by the preponderance of ligamentous deficiency and prior PJI among

### Table 2

**Study Summary and Postoperative Results**

<table>
<thead>
<tr>
<th>Study</th>
<th>Study Period</th>
<th>Total Knees</th>
<th>VVK Group</th>
<th>RHK Group</th>
<th>Average Age (Range), y</th>
<th>Follow-up (Range), mo</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuchs et al$^{17}$</td>
<td>NS</td>
<td>26</td>
<td>16</td>
<td>10</td>
<td>68.5 (41-83)</td>
<td>20.4 (9-47)</td>
<td>Lower ROM in RHK vs VVK (96.5° vs 107.5°; $P&lt;.05$); similar HSS, KSKS, KSFS, VAS, TAS, and PS. Similar SF-36 mental component summary between RHK and age-matched normal population ($P=.46$).</td>
</tr>
<tr>
<td>Farid et al$^{18}$</td>
<td>2003-2009</td>
<td>15</td>
<td>6</td>
<td>9</td>
<td>60.2 (48-69)</td>
<td>34 (24-74)</td>
<td>Similar ROM and failure rate in RHK vs VVK. Preoperative low-dose irradiation in concert with RHK or VVK corrected preoperative flexion contractures by an average of 28°.</td>
</tr>
<tr>
<td>Farfalli et al$^{19}$</td>
<td>1989-2008</td>
<td>86</td>
<td>50</td>
<td>36</td>
<td>35 (8-84)</td>
<td>72 (7-197)</td>
<td>Lower instability rate in RHK vs VVK (0% vs 16%; $P=.034$); similar 10-year survival rates, MTS, and aseptic loosening rates between RHK and VVK. Greater residual knee instability in VVK group ($P=.034$). Higher APC fracture rate with short prosthetic stem ($P&lt;.0001$).</td>
</tr>
<tr>
<td>Hwang et al$^{20}$</td>
<td>1998-2006</td>
<td>28</td>
<td>15</td>
<td>13</td>
<td>65.8 (58-83)</td>
<td>30 (24-100)</td>
<td>Higher failure rate of RHK vs VVK (38% vs 0%; $P=.04$); no difference in KSKS, KSFS, ROM, or alignment.</td>
</tr>
<tr>
<td>Hossain et al$^{21}$</td>
<td>1999-2008</td>
<td>223</td>
<td>149</td>
<td>74</td>
<td>67.8 (32-94)</td>
<td>57.7 (12-120)</td>
<td>Higher ROM in RHK vs VVK (111.7° vs 106.1°; $P&lt;.0001$). Lower KSKS in RHK vs VVK (84 vs 88.9; $P&lt;.0001$); similar 10-year survival.</td>
</tr>
<tr>
<td>Vasso et al$^{22}$</td>
<td>2001-2009</td>
<td>53</td>
<td>35</td>
<td>18</td>
<td>72 (61-84)</td>
<td>108 (48-144)</td>
<td>Trend toward lower ROM in RHK vs VVK (107.5° vs 111.5°); similar KSKS, KSFS, and HSS scores.</td>
</tr>
<tr>
<td>Shen et al$^{23}$</td>
<td>2003-2009</td>
<td>367</td>
<td>273</td>
<td>94</td>
<td>66.67</td>
<td>71 (36-120)</td>
<td>In septic AORI II, greater KSKS improvement (47.2 vs 23.9, $P&lt;.05$); greater KSFS improvement (53.3 vs 15.0; $P&lt;.05$); greater SF-36 mental health (32.7 vs 23.0; $P&lt;.05$); greater WOMAC improvement (27.3 vs 19.7; $P&lt;.05$). In septic AORI III, greater WOMAC improvement in RHK vs VVK (24.2 vs 15.7; $P&lt;.05$). In aseptic AORI III, smaller KS improvement in RHK vs VVK (28.7 vs 42.0; $P&lt;.05$); smaller KSFS improvement (11.5 vs 21.6; $P&lt;.05$).</td>
</tr>
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</table>

**Abbreviations:** AORI, Anderson Orthopaedic Research Institute; APC, allograft-prosthesis composite; HSS, Hospital for Special Surgery score; KSFS, Knee Society function score; KSKS, Knee Society knee score; MTS, Musculoskeletal Tumor Society score; NS, not specified; PS, patella score; RHK, rotating-hinge knee prosthesis; ROM, range of motion; SF-36, Short Form 36; TAS, Tegner activity score; VAS, visual analog score; VVK, varus valgus constrained knee prosthesis; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.
RHK prosthesis recipients. In a review of 125 constrained prostheses, Luque et al.24 found septic loosening to have a statistically significant association with poor postoperative outcomes. Periprosthetic joint infection has been described as a function of increasing comorbid disease burden and is likely a marker of poor overall physical health.25,26 Fuchs et al.17,21 Hwang et al.20,21 Farid et al.18,21 and Vasso et al.22 all reported more extensive ligament or tendon deficiency among RHK prosthesis recipients than VVK prosthesis recipients. All RHK TKAs reported by Fuchs et al.17 and most RHK TKAs described by Hwang et al.20 were revision surgeries performed secondary to prior PJI. This relative distribution of preoperative diagnoses suggests less available native tissue about the knee and greater surgical and clinical complexity among patients chosen to receive RHK vs VVK prostheses. These findings do not seem confounded by operative technique. Higher rates of failure following single-stage constrained TKA performed for PJI have been reported.27 Vasso et al.,22 Hossain et al.,21 and Fuchs et al.17 performed 2-stage revision procedures for all patients undergoing revision TKA due to PJI; no significant conclusions regarding advantages or disadvantages of 1- vs 2- stage constrained revision TKA could be made from the studies included in this meta-analysis. Individual studies have also shown similar results after VVK and RHK implantation. Deehan et al.28 reported an aseptic failure rate of 4% following RHK TKA. Lee et al.29 reported that 3% of VVK prostheses developed either aseptic loosening or periprosthetic fracture postoperatively. Kim et al.30 reported a 10-year survival rate of 96% following VVK implantation. Böhm and Holy31 reported a 20-year survival rate of 94.4% in 422 RHK implants.

The statistically significant difference in KSKS (4.2 points) found in the current study between VVK and RHK prostheses does not seem to convey any clinically significant importance. There is no established minimal clinically important difference (MCID) for the Knee Society scores. However, the Knee injury and Osteoarthritis Outcome Score (KOOS) and the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) are both joint-specific outcome tools scored on a 100-point scale, with reported MCIDs ranging from 8 to 10 and 17 to 47, respectively.32,33 In addition, Escobar et al.33 found that the observed WOMAC MCID was larger in patients with higher preexisting joint disease; this finding further nullifies observed differences in KSKS of the current meta-analysis, as-
<table>
<thead>
<tr>
<th>Table 4</th>
<th>Prostheses, Preoperative Diagnoses, and Implant Selection Criteria</th>
</tr>
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<tbody>
<tr>
<td><strong>Prosthesis</strong></td>
<td><strong>Preoperative Diagnosis (No.)</strong></td>
</tr>
<tr>
<td>VVK Implants</td>
<td>Study by Vasso et al.</td>
</tr>
<tr>
<td>RHK Implants</td>
<td>Study by Vasso et al.</td>
</tr>
<tr>
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<td>RHK Implants</td>
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<td>VVK Implants</td>
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<td>RHK Implants</td>
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</tr>
<tr>
<td>VVK Implants</td>
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<tr>
<td>RHK Implants</td>
<td>Study by Farfalli et al.</td>
</tr>
<tr>
<td>VVK Implants</td>
<td>Study by Vasso et al.</td>
</tr>
<tr>
<td>RHK Implants</td>
<td>Study by Vasso et al.</td>
</tr>
</tbody>
</table>

**Abbreviations:** AORI, Anderson Orthopaedic Research Institute classification; MCL, medial collateral ligament; NS, not specified; PJI, periprosthetic joint infection; RHK, rotating-hinge knee prosthesis; TKA, total knee arthroplasty; VVK, varus valgus constrained knee prosthesis.

- **a** First-generation varus valgus constrained knee prosthesis.
- **b** Second-generation rotating-hinge knee prosthesis.
- **c** Third-generation rotating-hinge knee prosthesis
- **d** Second-generation varus valgus constrained knee prosthesis.
- **e** Insufficient information available for prosthesis generation determination.
Mitigation of instability is a delicate balancing act of managing soft tissue deficiency, intra-articular flexion and extension gaps, and extensor mechanism insufficiency. Preexisting bone and ligamentous deficiencies may drive selection of intrinsic implant design stability and rigidity; however, determinants of optimum pairing between natural defects about the knee and implant constraint remains to be fully delineated. In cases of collateral ligament inadequacy, linking femoral and tibial prosthesis components is believed to provide stability needed in the coronal and sagittal planes. Most studies described in the current meta-analysis reported RHK selection in the setting of collateral ligament insufficiency/absence. The role of bone loss is less clear in implant selection and determining postoperative outcomes. Intuitively, larger defects about the knee may lead to collateral ligament deficiency and thus should require more implant constraint. Bone loss may indicate collateral ligament deficiency because extensive bone loss can affect ligament origin or insertion. In patients with AORI III bone loss, Vasso et al used only RHK prostheses. Paradoxically, Shen et al observed better outcomes after VVK implantation compared with RHK implantation in aseptic AORI III knees; however, the authors reported that soft tissue imbalance was less severe in aseptic knees.

The introduction of third-generation hinged prostheses (eg, Finn; Biomet, Warsaw, Indiana; and S-ROM; DePuy, Warsaw, Indiana; and NexGen RHK; Zimmer, Warsaw, Indiana) and second-generation VVK (eg, Genesis II; Smith & Nephew, Memphis, Tennessee; and LCCK; Zimmer; and SSK; Biomet) began in the early to mid-1990s, respectively. Key advances present in third-generation hinged prostheses include prosthetic modularity, improved patellar tracking, and use of superalloys, polished tibial components, and congruent polyethylene bearings. Advancements characteristic of second-generation VVK prostheses include improved modularity and patellofemoral tracking, as well as an improved tibial baseplate locking mechanism; these devices embody the latest major advancements in constrained TKA. Most patients in the studies reviewed by the current meta-analysis underwent TKA with a second-generation fixed-bearing VVK prosthesis or third-generation RHK prosthesis. Five of 7 studies described outcomes of patients mostly from the year 2000 and onward.

**Figure 3:** Ten-year survival. Excluded studies were those not reporting final failure rates for varus valgus knee (VVK) and rotating-hinge knee (RHK) prostheses.

**Figure 4:** Range of motion. Excluded studies were those not reporting postoperative range of motion for varus valgus knee (VVK) and rotating-hinge knee (RHK) prostheses.

**Figure 5:** Knee Society knee score. Excluded studies were those not reporting postoperative Knee Society knee scores for varus valgus knee (VVK) and rotating-hinge knee (RHK) prostheses.

**Figure 6:** Knee Society function score. Excluded studies were those not reporting postoperative Knee Society function scores for varus valgus knee (VVK) and rotating-hinge knee (RHK) prostheses.
described outcomes of procedures dating back to 1989; however, all but 2 patients in the study received a third-generation RHK prosthesis.

The current study has several limitations. The largest stems from a paucity of preoperative and perioperative clinical information reported in the analyzed studies. As previously mentioned, the preponderance of PJI and excessive collateral ligament injury among RHK prosthesis recipients compared with VVK prosthesis recipients suggests much greater clinical and surgical complexity among patients selected to receive the RHK prosthesis. The extent of these clinical and surgical differences could not be determined with the data available. Also, the differential effects of underlying disease and suitability could not be elucidated but deserves continued attention. This may help to reduce the burden of unsuccessful complex and revision TKA. Other limitations of this study arise from the small number of studies compared and the inconsistency of reported knee-specific outcomes.

CONCLUSION
This meta-analysis provides a contemporary estimate of comparable outcomes following VVK and RHK TKA for properly indicated patients. Patients receiving the RHK prosthesis generally harbor more extensive pathology at baseline. Absent medial and lateral collateral ligament support is almost universally accepted as an indication for RHK implantation. The role of bony support is less clear and worthy of future investigation, and may be of use in further optimizing outcomes following VVK and RHK TKA. The results of this meta-analysis suggest that when implant selection is guided by inherent stability of the knee, VVK and RHK prostheses fare similarly following implantation.

REFERENCES
31. Böhm P, Holy T. Is there a future for hinged prostheses in primary total knee arthroplasty?


