The Journal of Arthroplasty 28 (2013) 439–444

Contents lists available at SciVerse ScienceDirect

The Journal of Arthroplasty

journal homepage: www.arthroplastyjournal.org

Posterior Cruciate-Retaining Versus Posterior-Stabilized Total Knee Arthroplasty: A Meta-Analysis

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ARTICLE INFO

Article history:
Received 24 February 2012
Accepted 7 August 2012

Keywords:
total knee replacement
posterior stabilized
posterior cruciate retaining
prosthesis
metaanalysis

ABSTRACT

The objective of this meta-analysis was to compare outcomes of posterior cruciate-retaining and posterior stabilized prostheses. A computerized literature search was conducted to identify randomized controlled trials comparing the clinical outcomes of cruciate-retaining and posterior-stabilized designs. The table of contents of four major Orthopaedic journals and the references section of two arthroplasty text books were reviewed to identify other relevant studies. Ultimately, 1114 patients (1265 knees) were compared. Statistical analysis revealed a significant difference in flexion and range of motion in favor of posterior-stabilized knees, but no difference in complication rates. The clinical importance of this remains unknown. The decision to use one design versus the other should rest with the surgeon's preference and comfort with a particular design.

The debate continues today regarding the importance of preserving the posterior cruciate ligament in total knee arthroplasty. Both posterior cruciate ligament-retaining (CR) prostheses and posterior-stabilized (PS) prostheses have shown excellent long-term results in terms of survivorship and patient satisfaction [1–5]. Studies comparing the clinical outcomes of the two designs have borne out a wide range of results; some show no difference [6–8], some have favored CR designs [9], and others have questioned the importance of the cruciate ligament all together [10–12]. Still, proponents on both sides of the debate continue to argue the merits of their preferred designs [13,14]. Of particular interest is the effect of the prosthetic design on flexion and range of motion, as these are fundamental aspects of a successful knee replacement procedure [15,16]. Other important clinical outcomes include stability, stair-climbing ability, subjective patient scoring systems (e.g., WOMAC, SF-36) and complications.

While it was traditionally believed that CR designs could increase flexion and range of motion by restoring normal knee biomechanics and anatomical femoral rollback [17,18], more recent studies have shown that paradoxical anterior translation of the femur on the tibia occurs during knee flexion [19]. Proponents argue that despite this finding, CR designs better retain normal physiologic control of knee flexion. This may be clinically relevant during activities that require substantial biomechanical demands, such as squatting, kneeling and climbing stairs [13]. Conversely, proponents of PS designs argue that substituting the PCL with a post and cam improves range of motion secondary to mechanical enforcement of femoral rollback [14,17,20]. The posterior translation of the femur creates more clearance over the tibia, and theoretically, more flexion [19].

Several cohort studies [7,8] and randomized controlled trials studies have shown no difference in flexion or range of motion between the two designs [19,21–28]. Others have shown a slight improvement in favor of the PS designs [28–32], including one systematic literature review [33]. Unfortunately, much less is written about other clinical outcomes that satisfy criteria to be considered Level I evidence. These contradictory results have prevented a consensus. This meta-analysis attempts to accumulate the data from randomized controlled trials comparing CR and PS designs to provide more power to their results, thus enabling us to more accurately assess if there is a difference in the flexion and range of motion between the two designs. Given both the importance of flexion and range of motion to the overall success of the arthroplasty procedure, the objectivity of tests that measure these characteristics, and the relatively greater number of Level I studies, we decided to focus on these outcomes. This paper also attempted to discern a difference in other clinical outcomes, as well.

Methods

Search Strategy and Selection Criteria

We searched PubMed (MedLine), Ovid MEDLINE (R) and Cochrane Central Register of Controlled Trials for prospective randomized controlled trials comparing total knee arthroplasty with a CR

The Conflict of Interest statement associated with this article can be found at http://dx.doi.org/10.1016/j.arth.2012.08.008.
No external funding was provided for this study.
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0883-5403/2803-0010$36.00/0 – see front matter © 2013 Published by Elsevier Inc.
http://dx.doi.org/10.1016/j.arth.2012.08.008

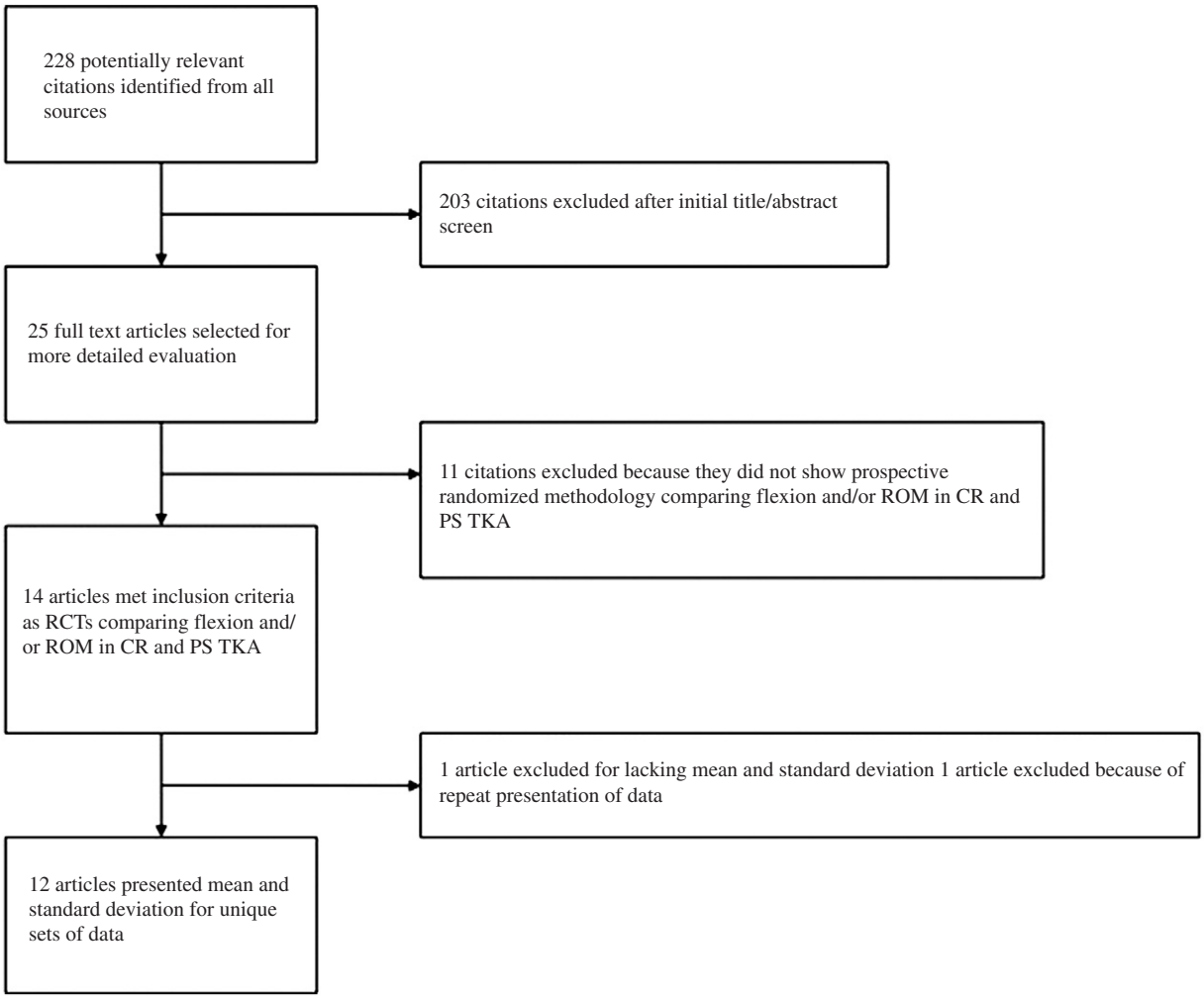


Fig. 1. Flow diagram showing details of literature search.

prosthesis and with a PS knee prosthesis. We conducted the search from January 1966 to December 2009 using the keywords, "Total Knee Arthroplasty," "Total Knee Replacement," "Posterior Stabilized," "Cruciate retaining," "Posterior Cruciate Ligament," and "Knee Prosthesis." We identified articles published in the English literature that met set inclusion criteria. These criteria included: (1) Study population – patients of any age, gender, or race with degenerative joint disease of one or both knees; (2) Intervention – total knee arthroplasty with a fixed PCL-retaining prosthesis versus a posterior stabilized prosthesis; (3) Outcome measure – some method of functional assessment; and (4) Methodological criteria – published prospective randomized clinical trials or quasi-randomized studies; quasi-randomized studies were defined as those in which allocation was not truly random, such as with allocation by date of birth, order of participation, or medical record number. Two of the authors (JP and MB) reviewed the references lists of all key articles for additional eligible articles.

We noted frequently cited articles and conducted a search of references and citations from these articles to locate potentially relevant studies that had cited them. Additional strategies to uncover relevant studies included: (1) Manual search of the bibliography of the selected articles with literature review to note all the quoted references; (2) Manual search of the bibliography of all the study articles to identify any additional potential studies; (3) Manual search of the table of contents of four major orthopedic journals, namely Journal of Bone and Joint Surgery (American and British volumes), Journal of Arthroplasty, and Clinical Orthopedics and Related Research from 1998 to March 2009; and (4) A references review of two major arthroplasty textbooks in orthopedics (Insall's The Knee and Campbell's Operative Orthopedics).

Two of the authors reviewed the title of the studies and the abstracts retrieved if possibility for inclusion existed.

The methodology of each study was then assessed using the Detsky quality scale for randomized trials [34]. Papers were included in the study regardless of their score on the Detsky quality scale. However, we believe grading the papers gave us a better assessment of the overall quality of the papers and, ultimately, of this study.

Data Extraction

Each article selected for inclusion in the study was reviewed to extract every pertinent detail including, but not limited to, demographics, range of motion (deg), flexion (deg), patient assessment scores (e.g., WOMAC, SF-36), radiographic values, and complications. The means and standard deviations for flexion and range of motion were gathered on each studied population. Personal communication with the authors of published eligible reports was attempted whenever the published information was not adequate for the analysis.

Outcomes

The primary outcomes assessed were flexion and range of motion. Data was also extracted from the papers on complications. For the purpose of this analysis, complications were not divided into

Table 1
Details of All Studies Included in Meta-Analysis.

	Author	Year of Study	Number of Patients	Number of Knees	PS	CR	Detsky Score	Findings
1	Clark, et al.	2001	128	128	69	59	13/21	No significant difference in ROM (PS>CR)
2	Tanzer, et al.	2002	37	40	20	20	14/21	No significant difference in flexion (CR>PS)
3	Straw, et al.	2003	108	108	42	66	13/21	No significant difference in ROM (PS>CR)
4	Catani, et al.	2004	40	40	20	20	12/20	Significantly greater ROM with PS knees; Equal number of complications
5	Maruyama, et al.	2004	20	40	20	20	14/20	Significantly greater ROM and flexion with PS knees; More complications in PS
6	Wang, et al.	2004	185	224	96	128	15/21	No significant difference in flexion (PS>CR); More complications in CR
7	Victor, et al.	2005	44	44	22	22	15/21	No significant difference in flexion (PS>CR)
8	Yoshiya, et al.	2005	18	36	18	18	11/20	Significantly greater flexion with PS knees; No complications
9	Chaudhary, et al.	2008	78	78	38	40	19/21	No significant difference in flexion (CR>PS); Greater percentage of complications in PS
10	Harato, et al.	2008	189	192	93	99	17/20	Significantly greater flexion with PS knees; More complications in CR
11	Kim, et al.	2008	68	136	68	68	15/21	No significant difference in flexion (PS>CR); More complications in PS
12	Snider, et al.	2009	199	199	99	100	11/21	No significant difference in flexion or ROM (CR>PS both)
Totals			1114	1265	605	660		

subcategories (e.g., major or minor). All complications were grouped together and compared. Other clinical assessments, such as stair-climbing ability, stability, and patient scoring systems (e.g., Knee Society score, WOMAC) were too inconsistently documented to allow for meta-analysis.

Statistical Analysis

Meta-analysis was performed using Revman software to compare CR devices with PS devices. For every variable that was examined, the heterogeneity was measured and provided. In this study, these values refer to variation in the study outcomes between studies and reflect inclusion of different cohorts, implants, and the use of various functional outcome instruments.

Results

Eligible Studies

Via our online searches, we initially identified 178 unique articles. Of these, 139 were excluded based on title. Of the remaining 39 articles, 24 were excluded after review of the abstracts. This left 15 articles remaining for a detailed review. 10 of these 15 articles would be included in the meta-analysis.

In addition to those studies found via the online search, the manual search and reference review produced 2 more studies for inclusion. A review of the table of contents of JBJS Am identified 19 new articles with potential for inclusion based on title, all of which were excluded after review of their abstracts. A review of the table of contents of JBJS Br identified 8 new articles with potential for inclusion based on title, and again all were excluded after review of their abstracts. The review of the table of contents for the Journal of Arthroplasty returned 17 new articles with potential for inclusion based on the articles' titles. Of these, 11 were rejected based on abstract. 6 were selected for further review, and ultimately 2 would be included in this meta-analysis. Clinical Orthopedics and Related Research returned 1 article based on its title after a review of its table of contents. This article was then excluded based on its abstract. A review of the relevant references sections in Insall's The Knee returned 4 new papers based on title, of which 1 was excluded after abstract review and 3 were rejected after paper review. A review of the relevant references sections in Campbell's Operative Orthopedics returned 1 new paper based on title, which was rejected after paper review.

Ultimately, there were 228 potentially relevant sources, from which 12 papers were selected (see Fig. 1) for comparison of flexion, ROM and complications. There were 8 papers that reported the means and standard deviations of flexion [19,23–25,28,30,31,35] and there were 6 papers that compared means and standard deviations of ROM [21,26–29,35]. Two papers compared both [28,35]. 7 of the aforementioned papers included complications. The published trials reported data on 1114 patients and 1265 knees (See Table 1). 770 patients and 853 knees had flexion (deg) reported. For ROM measurements, there were data on 563 patients and 651 knees. One study investigated the difference in proprioception and balance after

Table 2
Flexion Forest Plot.

	CR			PS				Mean Difference	Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Fixed, 95% CI	IV, Fixed, 95% CI
Chaudhary MD 2008	105.9	13	40	105.8	13.5	38	8.1%	0.10 [−5.79, 5.99]	
Harato K 2008	113.7	12.8	99	117	13.5	93	20.1%	−3.30 [−7.03, 0.43]	
Maruyama S 2004	122.3	15	20	131.3	13.4	20	3.6%	−9.00 [−17.82, −0.18]	
Snider M 2009	113.46	11.1	100	113.44	12.37	99	26.2%	0.02 [−3.25, 3.29]	
Tanzer M 2002	112	13	20	111	17	20	3.2%	1.00 [−8.38, 10.38]	
Victor J 2005	113.3	9.9	22	114.3	9.6	22	8.4%	−1.00 [−6.76, 4.76]	
Wang C J 2004	110.7	14.89	128	112.79	11.68	96	23.1%	−2.09 [−5.57, 1.39]	
Yoshiya S 2005	121	6	18	131	12	18	7.3%	−10.00 [−16.20, −3.80]	
Total (95% CI)			447			406	100.0%	−2.24 [−3.91, −0.57]	
Heterogeneity: Chi^2 = 11.68, df = 7 (P = .11); I^2 = 40%									
Test for overall effect: Z = 2.62 (P = .009)									

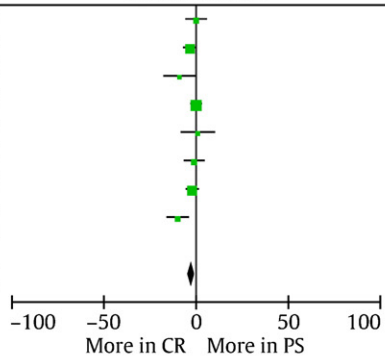
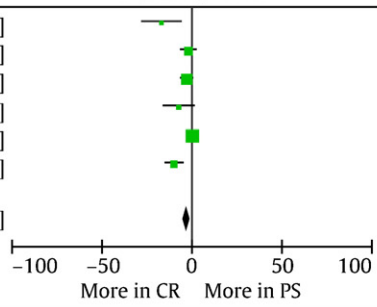


Table 3
Range of Motion Forest Plot.

Study or Subgroup	CR Mean	CR SD	CR Total	PS Mean	PS SD	PS Total	Weight	Mean Difference IV, Fixed, 95% CI
Catani F 2004	97	15	20	114	21	20	3.0%	−17.00 [−28.31, −5.69]
Clark C 2001	105	12	59	107	15	69	17.7%	−2.00 [−6.68, 2.68]
Kim Y H 2008	126	11.445	68	129	10.801	68	27.7%	−3.00 [−6.74, 0.74]
Maruyama S 2004	122.2	14.8	20	129.6	13.9	20	4.9%	−7.40 [−16.30, 1.50]
Snider M 2009	112.51	11.61	100	112.32	12.84	99	33.4%	0.19 [−3.21, 3.59]
Straw R 2003	100	12	66	110	15	42	13.4%	−10.00 [−15.38, −4.62]
Total (95% CI)			333			318	100.0%	−3.33 [−5.30, −1.36]

Heterogeneity: $Chi^2 = 16.77$, df = 5 ($P = .005$); $I^2 = 70\%$
Test for overall effect: Z = 3.32 ($P = .0009$)



CR versus PS total knee arthroplasty [12]. One study investigated patient preferences in knee prostheses [36]. However, given the paucity of other articles in which similar information was discussed, these were not included in any statistical analysis.

Flexion

Knee flexion is a continuous variable and results are represented as mean and standard deviation. Data was extracted from the 8 studies that included knee flexion in terms of mean and standard deviation (See Table 2: Flexion Forest Plot). The mean difference between flexion in CR and PS devices was 2.24 with a 95% confidence interval of 0.57–3.91), favoring PS devices. The p value is 0.009, which is statistically significant. In terms of heterogeneity of the study, I^2 is 40% and the p value for heterogeneity is 0.11, which is not significant.

Range of Motion

Range of motion is a continuous variable and results are represented as mean and standard deviation. Data was extracted from the 8 studies that included knee flexion in terms of mean and standard deviation (See Table 3: Range of Motion Forest Plot). The mean difference between flexion in CR and PS devices was 3.33 with a 95% confidence interval of 1.36–5.30), favoring PS devices. The p value is 0.0009, which is statistically significant. In terms of heterogeneity of the study, I^2 is 70% and the p value for heterogeneity is 0.005, which is significant.

Complications

7 of the 12 papers provided their complications (See Table 5 for complete list of complications). Complications are recorded on a dichotomous scale (i.e., the number of complications out of a total number of events). Data was extracted from the 7 studies that listed their complications (See Table 4: Complications Forest Plot). The test for the overall effect had a Z value of 0.90, with a p value of 0.37. This was not statistically significant. In terms of heterogeneity of the study, I^2 is 0% and the p value for heterogeneity is 0.84, which is not significant.

Discussion

Total knee arthroplasty is a safe and effective means of treating pain and functional limitation associated with arthritis of the knee [1–5]. Although general agreement exists on the success of this surgery, there is still great debate as to the best technique with which to perform it.

In order to quantify and analyze the success of varying knee replacement surgery techniques, the important outcomes must be defined. Relief of pain, implant stability, survival of the implant, the ability to perform physiologic actions such as stair-climbing, and lack

Table 4
Complications Forest Plot.

Study or Subgroup	CR Events	CR Total	PS Events	PS Total	Weight	Odds Ratio M-H, Random, 95% CI
Catani F 2004	2	20	2	20	6.6%	1.00 [0.13, 7.89]
Chaudhary MD 1998	1	40	1	38	3.6%	0.95 [0.06, 15.73]
Harato K 2008	17	99	13	93	45.8%	1.28 [0.58, 2.80]
Kim Y H 2009	3	250	4	250	12.4%	0.75 [0.17, 3.37]
Maruyama S 2004	0	20	1	20	2.7%	0.32 [0.01, 8.26]
Wang C J 2004	15	128	6	96	29.0%	1.99 [0.74, 5.34]
Yoshiya S 2005	0	22	0	22		Not estimable
Total (95% CI)		557		517	100.0%	1.27 [0.75, 2.17]
Total events	38		27			

Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 2.06$, df = 5 ($P = .84$); $I^2 = 0\%$
Test for overall effect: Z = 0.90 ($P = .37$)

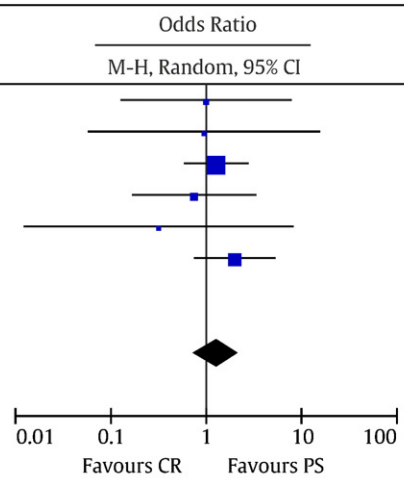


Table 5
Complications.

Study	Complications (CR)	Complications (PS)
Tanzer et al. (2002)(n = 20/20)	• No revisions	• No revisions
Catani et al. (2004)(n = 20/20)	• 2 lateral subluxation of patella requiring lateral release and resurfacing of patella	• 1 lateral subluxation of patella requiring lateral release and resurfacing of patella • 1 stiff knee requiring manipulation
Maruyama et al. (2004)(n = 20/20)	• None	• 1 superficial infection
Wang et al. (2004)(n = 128/96)	• 3 superficial wound infection • 3 delayed wound healing • 2 hematoma • 2 DVT • 2 arthrofibrosis • 1 dislocation • 1 posterior laxity • 1 peroneal nerve impingement	• 2 superficial wound infection • 1 hematoma • 1 DVT • 1 arthrofibrosis • 1 posterior laxity
Victor et al. (2005)(n = 8/7)	• No revisions	• No revisions
Chaudhary et al. (2008)(n = 48/43)	• 1 deep infection requiring removal of hardware	• 1 stiff knee requiring manipulation
Harato et al. (2008)(n = 99/93)	• Total of 6 additional operations or treatments (listed when available) • 7 stiff knees (5 required manipulation) • 5 anterior knee pain • 2 postoperative hemarthrosis • 1 infection (required a second procedure)	• Total of 7 additional operations or treatments (listed when available) • 3 infections (3 required a second procedure) • 2 anterior knee pain • 1 DVT • 1 stiff knee (1 required a manipulation) • 1 postoperative hemarthrosis

of post-operative complications have long been accepted as essential to a good outcome. Various scoring systems have been developed, such as the Knee Society score and the SF-36, that have attempted to standardize these results so comparisons can be made. Although these scoring systems are useful for comparing knee prostheses, they rely on subjective patient scoring.

Range of motion has been shown to have a significant effect on the on the subjective outcomes of knee replacement surgery [16]. Much thought and research goes into improving the range of motion and flexion allowed with prosthetic knees. For the purposes of this study, range of motion is a useful outcome to compare because in addition to being an important outcome for patient satisfaction, it is inherently objective.

Several Level I studies and cohort studies have been performed to investigate the differences in flexion and range of motion. Yet, due to small study sizes and the expected minimal difference between prosthetic designs, a conclusive answer to the question of which prosthesis provides greater flexion and ROM has yet to be determined. A previous systematic literature review within the Cochrane framework attempted to strengthen the data by combining the results of various papers. This study found greater flexion with PS devices, but was limited by heterogeneous study findings [33]. Thus, we set out to update the argument by performing a thorough review of the recent literature and applying strict inclusion criteria for articles included for review. In all, 1265 procedures were compared, including 660 with CR designs and 605 with PS designs.

Our findings suggest that there is a difference in the mean range of motion and flexion between CR and PS designs that favors PS designs. The clinical implications of this difference are still unclear. Ritter et al. showed a general trend of improved functional scores with greater range of motion, with significant compromise below 118 deg [15]. Many functional activities of daily life require less flexion than that. Knee range of motion in stair-climbing is about 90 deg [37]. In non-Western societies, however, where squatting and sitting cross-legged are more common culturally, flexion demands may go as high as 111–165 deg [38]. Intuitively, it makes sense that a knee replacement that more closely replicates the natural knee in terms of range of motion would best serve the patient's functional demands, albeit at the potential risk of increased stress to the implant and overall longevity. What is not yet known is whether the subtle differences in range of motion and flexion in the ranges shown here are noticeable to the patient and clinically relevant. Furthermore, the design itself may matter less than the patient's preoperative flexion and range of motion [39].

There were several limitations to this study. First, the reporting of data in the papers varied. While 2 papers provided information on both range of motion and flexion, the others reported on only one or the other. This diminished our ability to incorporate all potentially eligible patients into analysis of both results. Also, the quality of the trials incorporated into the meta-analysis was not uniform. There are several scoring systems for assessing the quality of randomized controlled trials. We used the Detsky system since we believe it provides a streamlined guide to assessing the most important elements of a proper randomized controlled trial into its scoring [34]. Setting the standard of >70% to be of high quality, only 6/12 of our papers graded as high-quality (50%). Varied quality may produce bias and reduce the strength of our findings. We did not exclude any papers based on their quality score. So, although it is not possible to determine the effect of the variation of quality on the statistical results of this meta-analysis, having a scoring system enables us to gauge the results with a more critical eye. Lastly, this paper was unable to assess the other aspects of a satisfactory knee replacement such as stability, relief of pain, and stair-climbing ability. These are not easily reported in an objective manner, and there were too few papers that provided good data on them to be analyzed appropriately.

In conclusion, our data shows a statistically significant trend of greater flexion and range of motion achieved with posterior stabilized total knee prostheses. However, the advantage is not great and may fall in a range that is not clinically significant. Since both total knee designs have shown excellent long-term results, there may not be much point in arguing for one design over the other. Rather, the surgeon should use the knee replacement with which he or she is most comfortable and which most consistently provides good results for his or her patients. In addition, more high quality, randomized controlled trials need to be performed that report comparable data on clinical features of knee replacements such as stair-climbing ability, stability, proprioception, and pain relief.

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