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Survival Rate of Short-Stem Hip Prostheses: A Comparative Analysis of Clinical Studies and National Arthroplasty Registers

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A B S T R A C T

Background: The primary aim was to evaluate the outcome of short-stem hip prostheses in terms of overall revision rates. Data were taken from published literature and national arthroplasty registers. The second study aim was to evaluate a potentially superior outcome of dependent compared to independent clinical studies.

Methods: All clinical studies on short-stem hip prostheses between 2006 and 2016 were reviewed and evaluated with a special interest on revision rates. Revision rate was calculated as “revision per 100 component years.” Short stems were divided into femoral neck retaining (NR), neck sparing (NS), and neck harming (NH) prostheses. Published literature was further classified into dependent and independent studies, and data were compared to the Australian National Arthroplasty Register.

Results: Fifty-two studies with 56 cohorts met the inclusion criteria and were therefore included in our study. All clinical studies showed a median revision rate of 4.8% after 10 years. NS and NH stems performed equally, whereas neck retaining prostheses were significantly inferior. Independent showed higher revision rates compared to dependent data without being statistically significant. The Australian register revealed a revision rate of 6.6% after one decade.

Conclusion: Similar low revision rates for NS and NH short-stem prostheses were found in the included data. Dependent studies seem not to be biased with regard to the longevity of short-stem hip replacement. Longer follow-up periods in clinical studies and more detailed information in arthroplasty registers would be desirable for future studies.

Total hip arthroplasty (THA) developed from a geriatric surgery to a lifestyle surgery during the last decades [1]. One suggested reason is a long-term survivorship of more than 95% after 15 years, which has led to an increased number of performed THAs in the younger and more active population [2,3]. Owing to the younger age at primary THA, this patient group is more likely to have revision surgery. This is why it has become a major issue to optimize the outcome of THA for young patients.

Short-stem prostheses for hip arthroplasty were introduced in the 1990s to preserve proximal bone stock for future revisions and to better reconstruct biomechanical proportions [4–7]. It has been postulated that conventional stems with diaphyseal or metadiaphyseal anchorage may lead to stress shielding and potential bone loss and may not retain enough intact bone for revision surgery [8]. In addition, a correct biomechanical reconstruction affects the survival rate of the implant. Another positive aspect of short-stem hip prostheses is the fact that a smaller prosthesis design makes it easier to allow tissue-sparing minimally invasive approaches [9].

Although no uniform classification is available for short-stem prostheses, depending on the femoral neck resection, they can be divided into femoral neck retaining (NR), femoral neck sparing (NS), and femoral neck harming (NH) short-stem prostheses as illustrated in Figure 1 [1]. Life expectancy of prostheses and their revision rates are of fundamental importance for surgeons, patient's satisfaction, and for economic reasons [10–12], and 2 major data sets are available for final evaluation: sample-based clinical studies and national arthroplasty registers. Studies try to extrapolate the results of a sample to the patient population [13].

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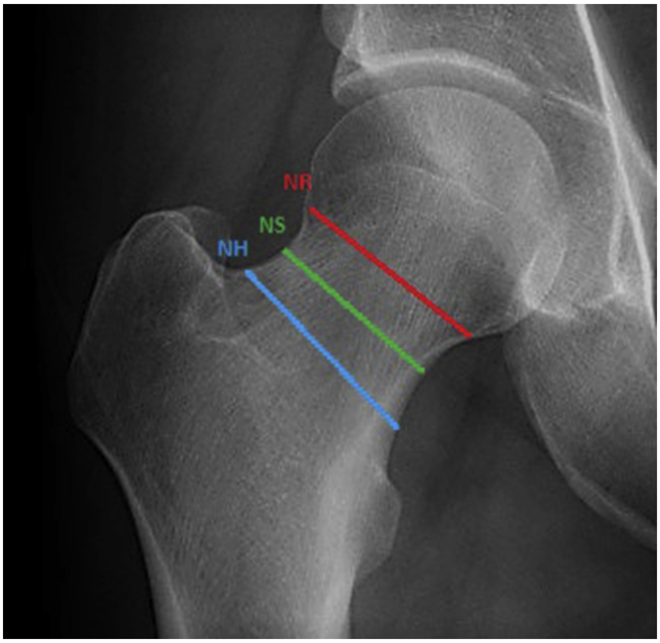

Fig. 1. Classification of short-stem hip prostheses depending on the femoral neck resection. NH, neck harming; NR, neck retaining; NS, neck sparing.

Registers include all surgeries performed in a certain region and represent the average outcome in average patient. Therefore, data sets of high-value registers can be used as a control group when compared to sample-based studies [12].

The primary aim of this study was to compare revision rates of short-stem prostheses, as presented in the literature of the past decade and in arthroplasty registers. The respective data were analyzed with regard to a potential difference of the percentage of performed revision surgeries as described in clinical studies. The intention was to reveal the characteristics of successful short-stem hip prostheses.

The second aim of this study was to evaluate a potentially superior outcome of short-stem hip prostheses described in dependent clinical studies compared to independent studies or arthroplasty registers.

Materials and Methods

Literature Selection

In June 2017, the electronic medical database PubMed was searched for the following search terms "(arthroplasty, replacement, hip)" AND "short stem OR mini stem." In addition, an individual search on all known systems of short-stem prostheses was carried out. After completion of the search, the search output was recorded. Scientific papers with no direct reference to the topic were excluded.

Finally, we checked the reference papers from included publications for their eligibility to join our study.

Each study was evaluated separately. Included prostheses were classified as either femoral NR, femoral NS, or femoral NH prosthesis. Included publications were divided into dependent studies or independent studies. If the implant developer was listed as an author or co-author, or the developing institution was indicated for correspondence, the study was rated as dependent.

Studies have had to meet the following criteria to be included: (1) a mean follow-up time of 24 months or more, (2) revision rates were either mentioned in the text or could be calculated from the available data, (3) the used implant must have been clearly specified as a short-stem prosthesis, (4) the presented data have had to be published in a MEDLINE-listed, peer-reviewed journal and to be written in English or German language, and (5) the date of publication was between 2006 and 2016. If there were multiple reports of the same study group published in this period, the report with the longest follow-up period was included.

Reports on custom-made short-stem prostheses as well as case reports, reviews, and former meta-analyses were excluded.

All included papers were reviewed for the following information: title, year of publication, origin of the corresponding author, publishing journal, study design, name of prosthesis, type of prosthesis, number of patients lost to follow-up, follow-up in months, number of revisions for any reason, reason for revision (if available), surgical approach (if available), and Harris Hip Score preoperative and postoperative (if available).

National arthroplasty register reports were scanned for data concerning revision rate of short-stem hip prostheses. The latest annual reports were taken from the European Federation of National Associations of Orthopaedics and Traumatology Website of the Network of Orthopaedic Registries of Europe [14]. Only the Annual Report of 2016, provided by the Australian Orthopaedic Association National Joint Replacement Registry published sufficient information and long-time data for our purpose [15].

Outcome Measurement

The main indicator evaluated was "revision for any reason." This is a recognized, well-defined, and objective parameter after primary hip arthroplasty that covers a variety of possible complications. This indicator clearly determines an event of failure and is therefore well suited for comparative analyses [10,13].

As included studies differ between number of implants and follow-up periods, we used the parameter "revision per 100 observed component years (CYs)" introduced by the Australian Joint Replacement Registry. This parameter normalizes separate studies and allows to compare revision rates of different clinical studies irrespective of different follow-up periods and different number of implants. The formula for the calculation is number of cases of revision surgery for any reason divided by the number of CY observed and multiplied by 100. A value of 1 represents a 1% revision rate at 1 year and a 10% revision rate at 10 years of follow-up [13].

The principle of the calculation means that there is a potential risk of reintervention from the time a prosthesis is implanted until revision surgery or death of the patient. The individual follow-up periods of all patients included are combined, and this cumulative figure of "observed CYs at risk" is then compared to the actual number of revision operations observed [16].

Publications were rated as successful if they presented a calculated 10% or lower revision rate at 10 years of follow-up.

Statistical Analysis

With regard to the methodology, we used the same criteria as already published by other investigations [11,12,17]. Since the included studies and register data represent real-life data, we do not work with "probabilities," and therefore, no calculation of *P* values is possible [17]. Thus, a difference factor by the ratio of 3 between the outcomes of the investigated groups was considered as significant. As described in quality of literature in arthroplasty [13], a different factor up to 3 (for instance, the revision rates of a data set are 3 times as high as in the control group) between the data sets is considered to be explicable by

Table 1
Included Clinical Studies With Stem Types in the Past Decade.

Study	Short Stem	Cases	Follow-Up (mo)	Revisions
Femoral neck retaining				
Steens et al (2010)	CUT	99	64.8	6
Ishaque et al (2009)	CUT	82	96	35
Ender et al (2007)	CUT	120	60	17
Rudert et al (2007)	CUT	49	37	4
Carlsson et al (2006)	GOT	20	24	0
Femoral neck sparing				
Kutzner et al (2016)	Optimys	204	30.4	1
Formica et al (2016)	CFP	194	111.6	17
Stadler et al (2016)	Nanos	84	27.7	0
Teoh et al (2016)	Corin mini-hip	265	37	2
Budde et al (2016)	Nanos	14	24	1
Kaipel et al (2015)	Nanos	49	24	0
You et al (2015)	CFP	46	91.2	1
Hutt et al (2014)	CFP	67	111.6	2
Mumme et al (2014)	Aida	52	41	1
Li et al (2014)	CFP	142	56.6	0
Lazarini et al (2013)	CFP	27	24	1
Ettinger et al (2013)	Nanos	202	35	3
Kendoff et al (2013)	CFP	117	134.4	11
Ghera et al (2013)	CFP	150	66	0
Budde et al (2012)	Delfi-M	15	37.2	2
Kress et al (2012)	CFP	38	84	1
Briem et al (2011)	CFP	151	74.3	3
Molfetta et al (2011)	Biodynamic neck sparing	153	41.8	2
Pons et al (2010)	CFP	134	38.3	3
Gill et al (2008)	CFP	72	43	1
Roehrl et al (2006)	CFP	26	24	0
Femoral neck harming				
Acklin et al (2016)	Fitmore	24	24	3
Kim et al (2016)	Proxima	530	213.6	2
Schnurr et al (2016)	Metha	1763	72	72
Choi et al (2016)	Proxima	56	55.2	0
Budde et al (2016)	Metha	59	45.6	6
Budde et al (2016)	Metha	58	45.6	2
Maier et al (2015)	Fitmore	94	39.6	0
Suksathien et al (2015)	Metha	85	24	0
Chammai et al (2015)	Metha	41	47.2	3
Chammai et al (2015)	Metha	41	54.1	4
Chow et al (2015)	Citation	148	67	2
Bause et al (2015)	Metha	105	60	3
Gruner et al (2015)	Metha	110	48	2
Salemyr et al (2015)	Proxima	25	24	1
Wittenberg et al (2015)	Metha	182	65.4	17
Kim et al (2013)	Proxima	114	90	0
Kim et al (2013)	Proxima	112	91.2	3
Ghanem et al (2013)	GHE	380	24	9
Thorey et al (2013)	Metha	151	69.6	3
Schmidutz et al (2012)	Metha	82	32.4	0
Kim et al (2012)	Proxima	70	54	1
Patel et al (2012)	Citation	65	35	0
Patel et al (2012)	Citation	95	36	0
Molli et al (2012)	Taperloc Microplasty	269	26.9	3
Toth et al (2010)	Proxima	41	26	0
Goebel et al (2009)	Mayo	29	81	3
Braun et al (2009)	Metha	50	28.8	4
Gilbert et al (2009)	Mayo	49	37.2	5
Hagel et al (2008)	Mayo	270	83.6	5
Falez et al (2008)	Mayo	160	56.4	4

Fifty-two studies with 56 study cohorts were used for further analysis. Classification was made with regard to resection height of the femoral neck.
CFP, collum femoris preserving.

individual expertise, circumstances in the particular hospital, and other potential confounders [17]. Revision rates between studies of developers, independent studies, and registry data exceeding the factor 3 are not explicable by the variability as explained previously. The Swedish and Danish hip arthroplasty registries have shown that the factor 3 covered the revision rate of every hospital compared to the national mean. In addition, single implant mean revision rates do not differ threefold among national registers [13,17].

Results

Literature Data Sets

Between 2006 and 2016, 52 studies with 56 cohorts could be identified fulfilling our inclusion criteria (Table 1). This represents a total number of 7521 primary cases and 271 revision cases. Sixteen different implants were used. The overall median revision rate per 100 observed CY was 0.48. The flow chart of the study identification is illustrated in Figure 2.

Stem Classification and Surgical Approach

The majority (30/56) of the implants used were NH short stems, followed by 21 NS, and 5 NR hip prostheses. The results of the evaluation of the literature are given in Table 2. NH and NS prostheses reported nearly identical low median revision rates per 100 CY (0.51 and 0.38, respectively), whereas NR stems performed significantly worse (2.65).

The surgical approach was available for 43 study cohorts, whereas only 36 could be used for further analysis as for the remaining 7, more than one approach was used. Study groups performed no direct anterior, 11 anterolateral, 8 direct lateral, and 17 posterior approaches. The median revision rates per 100 observed CY were 1.13, 0.73, and 0.32, respectively. Short-stem prostheses implanted through a posterior approach showed a significantly superior outcome than those using an anterolateral approach.

Characteristics of Successful Prostheses

Thirty-eight study cohorts were classified as successful as the calculated revision rate at 10 years of follow-up was lower than 10%. Eighteen of 21 (86%) NS short stems were rated as successful, compared to 19 of 30 (63%) NH and 1 of 5 (20%) NR prostheses.

With regard to the surgical approach, the posterior approach (15 of 17) (88%) was the most often mentioned approach in the successful group, followed by 5 of 8 (63%) using the direct lateral approach and 5 of 11 (45%) using the anterolateral approach.

Dependent vs Independent Publications in Literature Data

From the 56 investigated studies, 21 were rated as dependent and 35 as independent. The median revision rates per 100 observed CY for independent studies were lower (0.39 vs 0.50) but without reaching the criteria of our definition of significance. Although more than one-third (21 of 56) of the publications were classified as dependent studies, they only count for approximately a fifth (8449 of 38,409) of all observed CYs in this study as given in Table 2.

Registry Data

The 2016 annual report of the Australian National Register reported a total of 2102 short-stem prostheses since the beginning of recording. The 10-year cumulative percent revision rate was 6.6%. No data were found concerning patient-based outcome measurements.

Functional Outcome

A comparison between preoperative and postoperative Harris Hip Score was found in 36 publications. Thirteen dependent publications

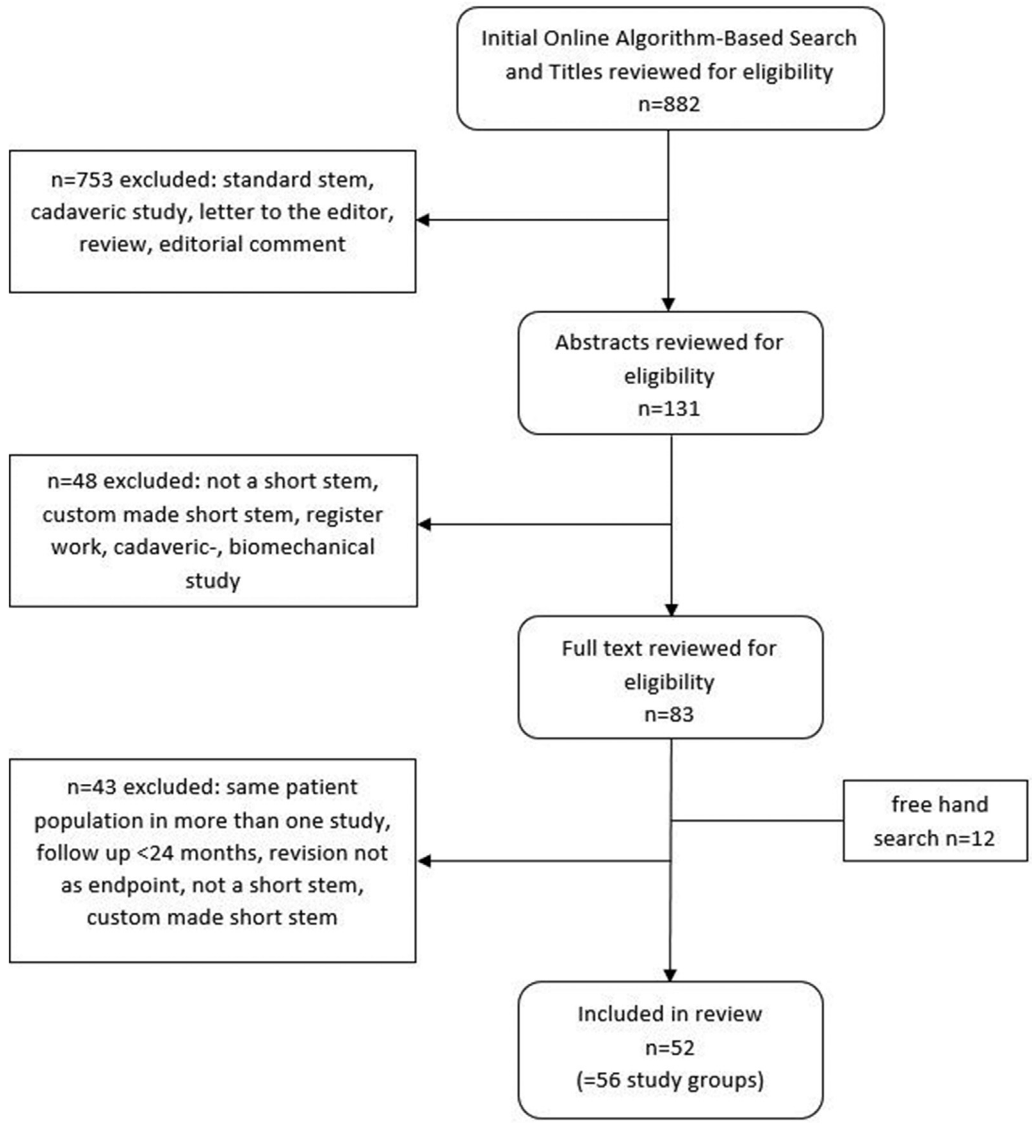

Fig. 2. Flow chart of the study identification.

showed a median postoperative improvement of 48.1 points. This was consistent to a median improvement of 49 points for independent publications. In general, a postoperative increase in Harris Hip Score of more than 20 points is considered successful. However, no firm conclusion can be drawn with these results due to the various numbers of implants and different follow-up periods. The Australian Arthroplasty Register did not provide any data about clinical outcome scores.

Discussion

The primary aim of this study was to compare revision rates of short-stem prostheses, as presented in the literature of the past decade, as well as in arthroplasty registers. The respective data were analyzed with regard to a potential difference of the percentage of performed revision surgeries as described in clinical studies. We had a special interest on the characteristics of

Table 2
Evaluation of Short-Stem Hip Prostheses Using Clinical Literature Data Sets.

	Total Study Groups	Neck Retaining	Neck Sparing	Neck Harming	Dependent Study Groups	Independent Study Groups
Primary implants	7521	370	2202	4949	2164	5357
Revisions	271	62	52	157	67	204
Median follow-up (mo)	46	60	41	48	40	55
Observed CY	38,409	1982	10,576	25,851	8449	29,960
Median revisions/100 CYs	0.48	2.65	0.38	0.51	0.50	0.39
Number of study groups	56	5	21	30	21	35

Revisions per 100 observed component years show statistically significant differences between stem types. The difference between dependent and independent studies is not significant.
CYs, component years.

short-stem hip prostheses with low revision rates. The secondary aim of this study was that there is a superior outcome of short-stem hip prostheses described in dependent clinical studies compared to independent studies or arthroplasty registers.

Our findings indicate that NS short-stem hip prostheses implanted through a posterior approach have the lowest failure rates. Revision rates for NS and NH prostheses were equal and both significantly superior compared to NR stems. Only 9% of all cohorts used an NR prosthesis and both implants described are no longer available in the market. No data were found about other NR stems, which are still available (ie Spiron, Silent) and meet our inclusion criteria. In general, NR prostheses are suitable for a small and strict range of indications and surgeons need sufficient training, which may lead to poorer results and the lack of data in this analysis [1]. The superiority of the outcome of the posterior approach compared to the anterolateral and direct lateral approach was statistically significant with respect to the anterolateral approach. This may be due to the fact that the amount of studies was low and that we summarized both, the conventional and the minimally invasive anterolateral approach, as one common approach. A recent study with conventional THA has shown that revision rates with minimally invasive anterolateral approaches were not increased in comparison to posterior and direct lateral approaches [18]. It has also been found that the conventional anterolateral approach and the posterior approach do not differ in terms of revision rates [19].

The results of this study demonstrate that the outcome of both independent studies and dependent studies seem not to be biased. Although revision rates differ between the various reports, they do not reach our defined level of significance. Furthermore, our results seem to confirm the observations of previous investigators [11,12]. We expected a superior outcome for dependent studies, but to our surprise, independent clinical studies have shown even lower revision rates in our analysis. However, these differences were not statistically significant. The reported revision rates from the Australian Arthroplasty Register were similar to the results of included clinical studies and seem to confirm the overall revision rate for short stems as described in the investigated literature.

The primary parameter in this study was “revision per 100 observed CY.” This method allows the comparison between studies with different numbers of cases and follow-up periods. However, the assumption of a linear distribution of revisions for any reasons is a simplification of real life [12]. There is a higher risk for septic revision within the first weeks after surgery, whereas aseptic loosening, migration, subsidence, or osteolysis mostly occur later [12]. In addition, data from arthroplasty registers have shown relatively more revisions within the first year after implantation [20].

We observed a big difference concerning the total amount of observed CY between dependent and independent studies. Included developer reports showed shorter follow-up periods and a smaller number of implanted prosthesis. However, an analysis of the revision rate per 100 observed CY is more appropriate with larger cohorts and long-term follow-up and was therefore used in this study. In such cases, the denominator is relatively big and one revision does not have such high impact or consequence [20]. We suspect that this limitation of our used indicator causes the higher revision rate for dependent publications.

In this study, the evaluation of short-stem hip prostheses using national register data sets was only performed with the Australian data as for the inclusion criteria. The Emilia-Romagna (Italy) Register of Orthopaedic Prosthetic Implants provides only revision data exclusively for the collum femoris preserving short stem with a 96% survival rate after 10 years [21]. This short stem is the most used implant in our included clinical trials with a calculated 3.5% median revision rate at 10 years of follow-up. In addition, the collum femoris preserving and the Fitmore hip prosthesis are listed in the latest annual report of the Swedish Hip Arthroplasty Register with a 2-year survival rate of 97.6% and 98.3%, respectively [22]. It can be assumed that more arthroplasty registers will list short-stem prostheses in the near future and give more detailed information, as the trend goes towards implantation of metaphyseal stems in younger patients.

Since the 2015 Australian annual report, ministems are mentioned separately and showed no difference in the outcome compared to conventional femoral stems: the 10-year cumulative percent revision for total conventional hip replacement using a ministem is 6.6% compared to 5.1% for other femoral stems [15]. This is comparable with a 5.2% 10-year cumulative percent revision rate for conventional hip stems in the 2017 annual report of the National Joint Registry for England, Wales, Northern Ireland, and the Isle of Man [23]. The 18-year report of New Zealand reveals a value of 0.73 in the calculation “revision per 100 observed CY with standard stems,” according to a 10-year revision rate of 7.3% [24].

Since we had a special interest on “revision for any reason,” we did not focus on different revision causes in particular. Revision surgery was defined as the exchange of at least one prosthesis component. We did not count it as revision surgery, if there were nonimplant associated procedures (eg surgical management of superficial wound issues). Most of the included studies gave information about reasons for revisions or type of resurgery, but given data were not precise enough for adequate subgroup analysis. With the available information, we made a top-5 ranking regarding reasons for revision. By far the most common reason for revision surgery was aseptic loosening, followed by deep infection, fracture, dislocation, and pain. We compared these findings with revision reasons for conventional stems in arthroplasty registers and observed identical results [25]. The latest hip arthroplasty reports from New Zealand, Australia, Sweden, and Norway mention these complications as main reasons for reoperation with the same ranking as in our study [15,22,24,26].

Revision surgery clearly determines a point of failure, but it does not give any information about the quality of life and patient's satisfaction until this time. Although revision rates differ between dependent and independent groups, the Harris Hip Score was similar in all reports. A low revision rate of an implant does not automatically represent a good value in patient-based outcome measurements, which was already stated by Beverland [27]. This author reported similar revision rates in comparison of hip and knee arthroplasties, although the percentage of “very happy” patients was 54% vs 4% in favour of hip replacements [26].

We want to outline the following limitations of our work. One limitation of this study is the relatively small number of hip prostheses in some of the investigated studies. This fact may have led to biased results in terms of higher revision rates. Next, due to the study design, we could not determine possible outcome differences with respect to various parameters such as porosity of the stems, biomechanical characteristics, and stem length. Concerning the surgical approach, we only evaluated revision rates and we cannot make any statements regarding patient's satisfaction or functional outcomes. Moreover, data were only available for 36 cohorts, so it was no possible to reveal definite benefits or disadvantages of certain approaches, which might lead to undersizing of the femoral component or misplacement of the cup, respectively. Besides, our analysis revealed no difference between reasons for revisions. As a natural limitation of every meta-analysis and systematic review, the quality of data depends on the publications included. Most of the clinical trials take place at centers of excellence by a small number of surgeons with high personal expertise in a predefined setting, whereas register data consist of many centers and surgeons for a more heterogeneous patient population.

Conclusion

We conclude that the described revision rates in dependent and independent publications do not differ significantly and that the revision rates of short-stem hip replacements do not significantly differ from conventional systems. The authors want to recommend both NS and NR short stems in THA and believe that the posterior approach is to be preferred in terms of revision rates. As short stems are barely mentioned in national arthroplasty registers, more detailed information on used arthroplasty systems would be desirable in the future.

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