

Femoral neck prostheses: A systematic analysis of the literature

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Abstract

Primary total hip arthroplasty (THA) is one of the most successful surgical procedures. Considering the demographic change the use of new ultra-short femoral implants has gained importance especially when treating young patients. Main features are bone conservation, metaphyseal anchoring and thus reducing stress shielding by proximal load transferring. The objective of this study is to give an overview over the subject of femoral neck prostheses. A systematic review was conducted. A total number of 27 publications were taken into this systematic review. Over all, just a few follow-up, biomechanical and radiostereometric studies have been conducted in the past. Still no long-term results (>10 years of follow-up) are available. The available mid-term results indicate unsatisfactory survival rates. Aseptic loosening was the most common reason for revision. Valgus angle and good bone mineral density were considered to be crucial for primary stability of femoral neck prostheses. Register data report a very low percentage of femoral neck prostheses in THA with even more diminishing implantation rates. To conclude, further studies are necessary in order to provide evidence-based recommendations. Currently, due to the inhomogeneous and poor data a reasonable and legitimate recommendation cannot be given.

Introduction

Primary total hip arthroplasty (THA) is one of the most successful surgical procedures. It was even named being “the operation of the century”.¹

In 2016, total hip arthroplasty was with 233,424 interventions per annum and (1.4% of all procedures) one of the most common-

ly performed surgeries in Germany and the incidence of THA is increasing worldwide.²⁻⁴ In 2017, 400,331 primary THA (revisions and partial arthroplasty excluded) were performed in Australia, which corresponds to an increase of 36,770 compared to 2016 (363,561).^{5,6} From 2003 to 2016 there has been an increase in the number of hip replacement procedures of 73.7%.⁶ The National Joint Registry for England, Wales, Northern Ireland and the Isle of Man reports on 87,799 performed primary THA in 2016.⁷ In 2003 only 14,454 primary THA were performed.⁷ Considering the demographic change a further increase in primary THA is predictable.^{8,9} Estimations regarding THA in New Zealand indicate an increase of implantation rate up to 84.0% till 2026.¹⁰ Estimations for Australia indicate an increase of 66% concerning the incidence rate (interventions per 100,000 inhabitants) of primary THA from 2013 to 2046.³

On account of this trend and, associated therewith, the forthcoming increase in revision rates, bone stock conservation - especially when treating young patients - becomes necessary.^{11,12} The number of patients undergoing THA that are younger than 60 years is increasing and is assumed to be up to 20%.¹³

In this context, femoral neck prostheses have achieved importance concerning the treatment of young patients.¹⁴⁻¹⁶ The concept combines a bone conserving and minimal invasive technique with proximal load transferring by exclusive metaphyseal anchoring, which results in a more physiological loading pattern.¹⁶⁻¹⁹ Thus, biomechanical associated bony atrophy (“stress shielding”) is reduced.^{16,18,20} As a result, there is a better and bigger bone stock for future and unavoidable revision available.^{16,19,20} Especially when treating young patients with high activity levels, good survival rates become crucial. In addition, femoral neck prostheses were developed in order to extend the range of available types of prostheses and thereby close the gap between hip resurfacing implants and the meta-diaphyseal anchoring short stem implants.^{21,22} However, classification and nomenclature of femoral neck prostheses is inhomogeneous and difficult.²³ Jerosch *et al.* and Khanuja *et al.* have both classified hip implants according to their anchoring principles.^{13,16}

However, the design of femoral neck prostheses leads to a major issue concerning primary stability. Primary stability depends on bone quality, quality of implantation and on the extent of the implant-bone interface.^{16,24,25} Hence, an accurate implantation technique and patient preselection becomes even more important when using femoral

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neck prostheses since these prostheses only offer relatively small implant-bone interfaces.^{26,27}

In general, aseptic loosening is the most common cause for revision in THA.^{9,12} Main risk factors for aseptic loosening are male sex, high activity level and patient's age.⁸

Therefore, THA of younger and male patients is challenging. Femoral neck prostheses have been developed for the treatment of young and active patients.²⁸ Considering the possible limitations of femoral neck prostheses, long-term (>10 years of follow-up) results and meta-analyses that report the outcome are necessary, thus so far not existing.

The objective of this systematic analysis of the literature is to give an overview over available femoral neck prostheses, implantation rates, corresponding percentage in THA, survival rates, complications and results of biomechanical investigation.

Material and Methods

A systematic analysis using Medline, Cochrane Library and PubMed databases with defined search phrases was performed.

Initially, the following *inclusion criteria* were applied: i) Results of primary THA using femoral neck only prostheses; ii) Follow-up studies; iii) English or German articles; iv) Full text only; v) No limitations regarding: observation period, patients' age, tribological bearing, sample size, date of publication.

Applied search phrases using MeSH Terms were “((femoral neck prosthesis[MeSH Terms]) AND THA) NOT fracture” , “(ultra-short stem[MeSH Terms]) AND hip”, “(ESKA CUT prosthesis[MeSH Terms]) AND hip”, “(birmingham midhead resection[MeSH Terms]) AND hip”, “((silent hip prosthesis[MeSH Terms]) AND hip)” and “((spiron prosthesis[MeSH Terms]) AND hip)”.

Due to the small number of available studies search phrases and inclusion criteria were extended secondarily including any available biomechanical studies or radiostereometric analyses (RSA) as well as most recent register data from Australia (status 2017 and 2016), England, Wales, Northern Ireland and the Isle of Man (status 2017), Germany (status 2016), the USA (status 2017) and Sweden (status 2016 and 2015).

Target parameters during the analysis were: percentage of femoral neck prostheses in primary THA (register data); number of implanted femoral neck prostheses (register data, follow-up and clinical studies); mean patient's age at time of implantation (follow-up and clinical studies); sex distribution (follow-up and clinical studies); mean follow-up time (follow-up and clinical studies); loss to follow-up (follow-up and clinical studies); survival rate (follow-up and clinical studies); complications and revision rate (follow-up and clinical studies); main reason for revision (follow-up and clinical studies); biomechanical features.

Furthermore, reference lists of the included publications were scanned for any relevant studies, which could not be identified previously. Exclusion criteria were any not matching the defined inclusion criteria.

Results

During the literature study performed in February 2019 from initially 217 publications a total number of 27 publications were taken into account in this review: 12 clinical

follow-up studies, 6 Biomechanical studies, 2 radiostereometric analyses, 7 register reports; 190 were excluded, because of not matching inclusion criteria.

Available femoral neck (only) prostheses

According to the classifications of Jerosch *et al.* and Khanuja *et al.* available femoral neck prostheses (metaphyseal anchoring only), that do not alter the integrity of the lateral cortex are (Figure 1): Birmingham Mid Head Resection (BMHR) (Smith & Nephew, London, UK); CUT (ESKA Implants GmbH & Co., Lübeck, Germany); Silent-Hip (DePuy International Ltd., Leeds, UK); Spiron (K-Implant GmbH, Garbsen, Germany).

Register data

During the analysis of most recent register data obtained from Germany, the USA and England, Wales, Northern Ireland and the Isle of Man no specific information on the identified femoral neck prostheses were reported.^{7,29,30}

In the annual report for 2015 of the Swedish Hip Arthroplasty Register only the BMHR implant was mentioned.³¹ A decreasing implantation rate for this implant type was recorded during the observation period.³¹ In total, a number of 47 BMHR prostheses were implanted.³¹ In the annual report for 2016 this implant type was excluded.³²

The Australian National Joint Replacement Registry (status 2017) gives report on just two of the four identified femoral neck prostheses (BMHR, Silent).⁶ Both were listed with a higher rate of revision than anticipated.⁶ During the observation period three of 50 implanted Silent prostheses had to be revised.⁶ Concerning the BMHR (VST version) 21 of 260 implanted prostheses had to be revised during 1482 observation years, which corresponds to a hazard ratio of 2.02.⁶ As a result, both prostheses were ruled out for further use.⁶

Clinical (Follow-up) studies

Table 1 and Figure 2 show an overview over 14 studies and corresponding target parameters.

Reasons for revision were aseptic loosening, periprosthetic fractures, infection and persisting pain.^{11,14,33-36} Despite the short observation period most common factor for revision was aseptic loosening (mean over all 61.1%), especially while using the CUT implant caused by varus angle or varisation.^{14,33-35,37} Asaad *et al.* observed femoral neck osteolysis in 16%.³⁸ Table 2 gives a specific overview over complication rates and reasons for revision.

Biomechanical, finite-element and RSA studies

Olsen *et al.* were able to show, that implanting a femoral neck prosthesis in valgus angle acts protective against the occurrence of periprosthetic fractures.¹⁵ The biomechanical advantage of a valgus angle (a minimum of 10° of relative valgus) is on the one hand the increase of compressive forces of the proximal femur and on the other hand simultaneously reducing shear forces acting upon the femoral neck.^{15,43}

Furthermore, Olsen *et al.* could show that there is high correlation between bone mineral density (BMD) of the femoral neck and resulting fracture loads.¹⁵ BMD was thus considered as a prognostic factor regarding patient's preselection.¹⁵ In addition, implant size correlated negatively with fracture load.^{15,43} Whereas, Aghayan *et al.* found a positive correlation between implant size and fracture load.⁴⁴ In conclusion, due to inhomogeneous findings concerning implant size and fracture load, a clear recommendation cannot be given. For their investigations, all authors used the BMHR implant.^{15,44}

In a finite-element-study regarding the primary stability of the BMHR implant Dabirrahmani *et al.* found micromotions in the implant bone interface to be under the critical value of 150 µm.²¹ Itayem *et al.* found in a radiostereometric analysis using the BMHR implant with an observation period of two years, that initial settling of the implant occurred during the first two months.²⁶ There was no further settling observed afterwards.²⁶ During their biomechanical investigations using the CUT implant amongst other implants Wieners *et al.* found micromotions to be with 165 µm slightly over the critical value of 150 µm.⁴⁵

Steens *et al.* observed that the CUT implant causes no significant changes in bone mineral density after 60 months in most instances, which is an advantage compared to conventional implants.¹⁹ Ries *et al.* state, that applying a varus angle in patients with small center-collum-diaphyseal (CCD) angle can lead to consecutive increase of varus torque and thus to further varisation of the implant.²² There were no biomechanical or radiostereometric studies available that examined the Spiron implant.

Discussion

Femoral neck prostheses have been developed for the treatment of young and active patients. However, most studies were not able to give clear recommendations regarding the clinical use. The objective of

this study is to give a complete overview over all available studies concerning femoral neck prostheses and implantation rates as well as corresponding percentage in THA, survival rates, most common complications and results of biomechanical investigation.

Therefore, a systematic analysis of the literature with defined search phrases was performed in February 2019. On account of the inhomogeneous study designs and the small sample sizes of the included clinical studies register data as well as biomechanical and RSA studies have been included secondarily in order to give a holistic overview.

Register data

In total just two out of five registers recorded femoral neck prostheses.^{6,31} From the four identified femoral neck prostheses just two implants (BMHR, Silent) were mentioned in particular.^{6,31} In general, with less than 300 implanted prostheses during one observation period total numbers of implantation were very low.^{6,31} Furthermore, revision rates were considerably higher than expected, which led to exclusion of those femoral neck prostheses in the registers involved after just one observation period.^{6,32}

Clinical (Follow-up) studies

In the past, several follow-up studies have reported partially promising results regarding short-/mid-term survival rates of different femoral neck prostheses.

However, long-term results are still missing. There are no follow-up studies with a mean observation period exceeding ten years (Table 1).

There is just a small and unsatisfactory number of studies investigating femoral neck prostheses available. The CUT implant represents the best-examined implant, but then again, it shows insuffi-

cient survival rates and is therefore not recommended (Table 1). In total, 9 out of 12 studies showed unacceptable survival rates according to the National Institute for Health and Care Excellence (NICE) guideline TA304 (Figure 2).^{11,14,33-35,37,40,46} Having regard to the short observation periods just three studies showed sufficient survival rates that maintained the projected bench-

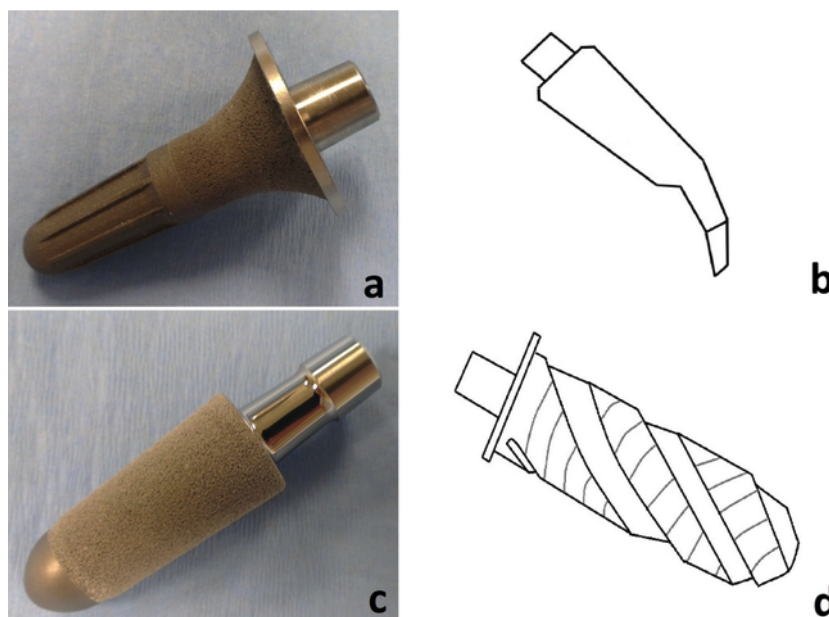


Figure 1. Available implants: (a) Birmingham Mid Head Resection (BMHR) (Smith & Nephew; photography); (b) CUT (ESKA Implants; sketch); (c) Silent-Hip (DePuy International Ltd.; photography); (d) Spiron (K-Implants; sketch).

Table 1. Overview including the available follow-up studies concerning femoral neck prostheses, including the type of implant, number of implants that have been included in each study, mean patient's age at the time of implantation, sex distribution, mean follow-up with loss to follow-up, survival rate and number of revisions.

Author (reference)	Year	Implant	No. implants	Mean age, years	Sex distribution, f/m	Mean follow-up, years	Loss to follow-up, %	Survival rate, %
McMinn <i>et al.</i> ¹¹	2011	BMHR	171	57	50/121	3.5	0	97.4
Rahman <i>et al.</i> ³⁹	2011	BMHR	35	50.4	18/16	2.8	0	100.0
Asaad <i>et al.</i> ³⁸	2015	BMHR	49	50	20/27	6.0	0	100.0
Mean BMHR			85	52.5	-	4.1	/	99.1±1.2
Thomas <i>et al.</i> ¹⁴	2004	CUT	130	54	69/61	3.5	2	97.0
Ender <i>et al.</i> ³³	2006	CUT	56	49	12/32	4.9	10.7	88.4
Ender <i>et al.</i> ³⁴	2007	CUT	120	53	NR	5.0	NR	89.0
Rudert <i>et al.</i> ³⁷	2007	CUT	49	45.1	9/27	3.1	NR	92.0
Ishaque <i>et al.</i> ³⁵	2009	CUT	82	51.3	38/41	8.0	NR	49.6
Steens <i>et al.</i> ³⁶	2010	CUT	99	50	50/36	6.0	NR	98.0
Nieuwenhuijse <i>et al.</i> ⁴⁰	2012	CUT	39	37	20/12	5.0	0	95.0
Mean CUT			82	48.5	-	5.1	/	87.0±15.7
Birkenhauer <i>et al.</i> ⁴¹	2004	Spiron	38	60.1	14/20	NR	5.3	97.4
Lugeder <i>et al.</i> ⁴²	2013	Spiron	28	51	11/15	NR	NR	NR
Mean Spiron			33	55.6	-	/	/	97.4

mark of 95% after 10 years (Figure 2).^{36,38,39,46} Especially when comparing the outcome of femoral neck prostheses with the outcome of established short-stem implants it becomes clear, that there is no evidence-based legitimation for clinical usage at present.⁴⁷ In two independent register-based studies all analyzed short-stem implants showed a survival rate exceeding 95% at 10 years and exceeding 90% at 15 years.^{48,49} The Australian National Joint Replacement Registry (status 2017) indicates a revision rate for “conventional” (including conventional stems as well as short-stems; excluding resurfacing implants) THA of 8.8% after 16 years.⁶ The femoral neck prostheses included in this systematic analysis of the literature show an overall revision rate of 8.8% after 4.5 years at a mean patient’s age at implantation of 50.7 years (Table 2).

Most common reason for revision of the analyzed femoral neck prostheses was aseptic loosening (mean over all 61.1%, Table 2), especially while using the CUT implant (Table 2). Varus angle and increasing variation were considered causative.^{14,33-35,37} A CCD-angle less than 110° respectively 120° or greater than 150° as well as a BMI greater than 30 kg/m², a manifest osteoporosis or patient’s biological age greater than 65 years are considered as contraindications for implantation.^{34,37,42,50} Further parameters such as bone stock and BMD, learning curve of the surgeons and the influence of tribological bearing were not assessed in the available clinical studies.

Biomechanical, finite-element and RSA studies

Literature provides just a small number of biomechanical and radiostereometric studies, which investigated the BMHR, CUT and Silent implant particularly. Valgus angle (a minimum of 10° of relative valgus) and good BMD were considered to be crucial for primary stability.^{15,43} Bone mineral density of the proximal femur seems to be less affected when using femoral neck prostheses compared to conventional implants.¹⁹

Since 2015 no studies of any kind con-

sidering femoral neck prostheses were published. In a systematic review 2014 van Oldenrijk *et al.* concluded that an overall recommendation concerning the implantation of femoral neck prostheses could not be made, on account of the insufficient survival rates.⁴⁷ Just three out of seven examined prostheses were considered to comply with the threshold of 90% survival after ten years after extrapolation.⁴⁷ The CUT implant was affected negatively in particular.⁴⁷ The authors – in contrast to this systematic analysis of the literature – took just clinical studies into account.⁴⁷ In another

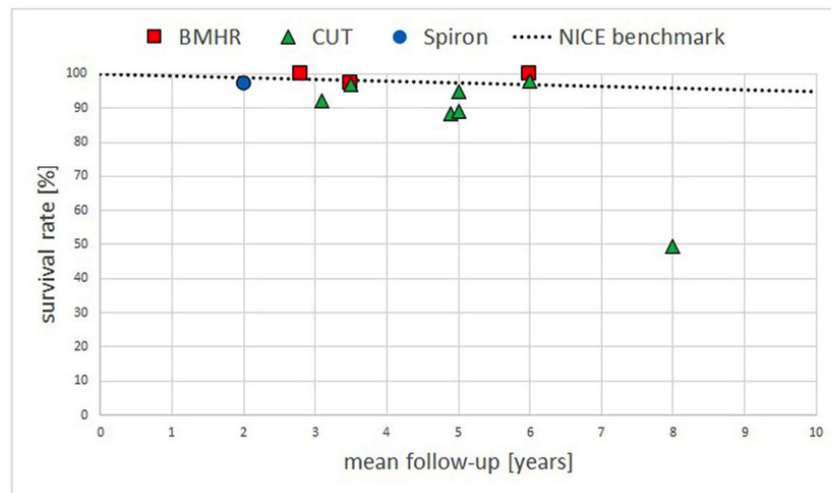


Figure 2. Survival rates of several femoral neck prostheses for each individual study with follow-up period; including a benchmark of 95% survival at ten years of follow-up (National Institute for Health and Care Excellence (NICE) guideline TA304).

Table 2. Complication rates and reasons for revision.

Author	Year	Implant	No. implants	Revision	Aseptic loosening, stem	Infection	Periprosthetic fracture	Others
McMinn <i>et al.</i> ¹¹	2011	BMHR	171	3	0	1	2	0
Rahman <i>et al.</i> ³⁹	2011	BMHR	35	0	0	0	0	0
Asaad <i>et al.</i> ³⁸	2015	BMHR	49	0	0	0	0	0
Total BMHR			255	3	0	1	2	0
Thomas <i>et al.</i> ¹⁴	2004	CUT	130	4	4	0	0	0
Ender <i>et al.</i> ³³	2006	CUT	50	5	4	0	0	1
Ender <i>et al.</i> ³⁴	2007	CUT	120	13	7	0	0	6
Rudert <i>et al.</i> ³⁷	2007	CUT	49	4	2	0	0	2
Ishaque <i>et al.</i> ³⁵	2009	CUT	82	32	25	3	0	4
Steens <i>et al.</i> ³⁶	2010	CUT	99	6	1	0	0	5
Nieuwenhuijse <i>et al.</i> ⁴⁰	2012	CUT	39	3	0	0	0	3
Total CUT			569	67	43	3	0	21
Birkenhauer <i>et al.</i> ⁴¹	2004	Spiron	38	1	0	1	0	0
Lugeder <i>et al.</i> ⁴²	2013	Spiron	28	1	1	0	0	0
Total Spiron			66	2	1	1	0	0
Total			820	72	44/72	5/72	2/72	21/72
				8.8%	61,1%	6,9%	2,8%	29,2%

Not reported (NR), others (including persisting pain, stem subsidence, impingement, varus angle, bone resorption, undersized femoral component).

systematic analysis 2014 Khanuja *et al.* criticized the low quality of evidence.¹⁶ Due to that, the authors could give just a weak or no recommendation for clinic usage.¹⁶ The authors concluded and requested stronger evidence by implementation of prospective and randomized multicenter trials in advance of further usage.¹⁶ The authors as well included just clinical studies.¹⁶

Considering the steadily rising number of implants Anand *et al.* observed, that most of the implants offered in Australia (from January 2001 till December 2007) were introduced without justifying evidence.⁵¹ Their results indicate that just 30% of the newly introduced implants were used for more than one hundred times and showed a significantly higher rate of revision compared to the established standard implants.⁵¹ Thus the purpose of improving clinical outcomes by introducing new implants was failed.⁵¹

In this context, the Silent implant *e.g.*, which had been in clinical usage, has already been withdrawn from the market. In addition, a similar trend is noticeable, when analyzing register data. Percentage of femoral neck prostheses is very low and even more diminishing. Our findings and consecutive suggestions match those of Hannan *et al.*⁵² Having regard to the clinical usage of new implants in THA without evidence for their safety or effectiveness the authors suggested that an ideal practice for introducing new implants should provide clinical evaluation by high-volume surgeons including RSA and biomechanical studies as well as implant retrieval and outcome assessment.⁵²

In conclusion, therefore, further studies are necessary in order to provide evidence-based recommendations concerning the implantation of femoral neck prostheses.

Currently, due to the inhomogeneous and poor data a reasonable and legitimate recommendation cannot be given.

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