

RESEARCH ARTICLE

Open Access



Long-term follow-up outcomes for patients undergoing primary total hip arthroplasty with uncemented versus cemented femoral components: a retrospective observational study with a 5-year minimum follow-up

Tiejian Liu^{1†}, Xiaoxiao Hua^{2†}, Weiguang Yu³, Jinluan Lin⁴, Mingdong Zhao^{5*}, Jun Liu^{6*} and Xianshang Zeng^{3*}

Abstract

Background: This retrospective analysis compared the long-term outcomes for patients with a femoral neck fracture (AO/OTA type 31B) treated with a primary unilateral total hip arthroplasty with uncemented or cemented femoral components (UTHA or CTHA, respectively).

Methods: We conducted a retrospective cohort study using the South China Hip Arthroplasty Database. We identified 422 patients with femoral neck fracture (AO/OTA type 31B) who were previously treated with primary unilateral UTHA or CTHA between 2007 and 2015, with follow-up until 2019. Follow-up occurred 1, 3, 6 and 12 months postoperatively and yearly thereafter. The primary outcome was the Harris hip score (HHS). The secondary outcome was the orthopaedic complication rate.

Results: In total, 324 patients (UTHA $n = 160$, mean age 68.61 ± 7.49 years; CTHA $n = 164$, mean age 68.75 ± 7.04 years) were evaluated for study eligibility. The median follow-up was 73.3 months (range, 11.6–89.2 months). At the final follow-up, HHS was 74.09 ± 6.23 vs 79.01 ± 10.21 (UTHA vs CTHA, $p = 0.012$). Significant differences were detected in the incidence of prosthetic revision, loosening, and periprosthetic fracture between the UTHA and CTHA groups (7.5% for UTHA vs 1.8% for CTHA, $p = 0.015$; 17.5% for UTHA vs 8.5% for CTHA, $p = 0.016$; 11.9% for UTHA vs 4.9% for CTHA, $p = 0.021$, respectively).

Conclusion: In this setting, CTHA demonstrated superiority to UTHA by improving functional outcomes and decreasing complication rates.

Keywords: Uncemented, Cemented, Total hip arthroplasty, Femoral neck fracture, Complication

Background

Femoral neck fractures potentially lead to catastrophic physical and functional impairment [1–4]. The demand for total hip arthroplasty (THA), which is an exceedingly successful surgery for femoral neck fractures, has gradually climbed in the elderly [1] and could increase by 174% by 2030 [5]. The increase in demand may also be contributing to the escalated implant-related failure rate. Total hip arthroplasty with an uncemented or cemented femoral component (UTHA or CTHA) is a relatively common procedure for the treatment of femoral neck fractures [6–8]. Prior studies [6, 9, 10] have shown perioperative

* Correspondence: zhaonissann@163.com; junliuzhshy@163.com; xianshangzh@126.com

[†]Tiejian Liu and Xiaoxiao Hua contributed equally to this work.

⁵Department of Orthopaedics, Jinshan Hospital, Fudan University, Longhang Road No. 1508, Jinshan District, Shanghai City 201508, China

⁶Department of Gynaecology and Obstetrics, The First Affiliated Hospital, Sun Yat-sen University, No. 58, Zhongshan 2nd Road, Yuexiu District, Guangzhou 510080, China

³Department of Orthopaedics, The First Affiliated Hospital, Sun Yat-sen University, No. 58, Zhongshan 2nd Road, Yuexiu District, Guangzhou 510080, China

Full list of author information is available at the end of the article



benefits of CTHA over UTHA are fewer complications and shorter recovery times, but these findings were based on studies with small sample sizes. Nevertheless, there remain concerns that longer-term outcomes of UTHA may not be as robust as those of CTHA, that UTHA increases the need for early revision (< 5 years) and that UTHA requires unnecessary interventions to maintain normal hip function [8, 11]. The risks of early revision and reintervention, as well as the excessive expense associated with these supplementary procedures, could offset the primary benefit obtained from UTHA [12, 13]. Furthermore, highly selective characteristics of the studied individuals tend to exist in previous studies [6, 12, 14]. Hence, the findings in those studies could fail to reflect the actual situation.

To date, there is no direct comparison regarding long-term outcomes following UTHA or CTHA in the Asian population. Furthermore, there remain limited data regarding long-term reinterventions for problems following UTHA or CTHA, such as prosthetic loosening and periprosthetic fracture. In the present study, we used data from the South China Hip Arthroplasty Database to compare long-term outcomes for patients with femoral neck fracture (AO/OTA type 31B) treated with primary UTHA or CTHA.

Materials and methods

Study population

We performed a retrospective analysis with an initial study cohort that included 422 individuals with femoral neck fracture (AO/OTA type 31B) from the South China Hip Arthroplasty Database who were previously treated with primary unilateral UTHA or CTHA between June 2006 and December 2017. Two cohorts were identified using the procedural code for primary THA (9 81.51), according to the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) [5]. THA was performed by the same medical team using a direct anterior approach (DAA) [15]. Perioperative management was similar between groups, as previously reported [6, 8, 16]. The inclusion criteria were as follows: patients aged ≥ 60 years old; patients who sustained femoral neck fractures (AO/OTA type 31B) confirmed with antero-posterior (AP) and lateral radiographs or with CT/MRI and underwent an initial unilateral UTHA or CTHA (uncemented or cemented femoral component: Stryker Orthopaedics, Mahwah, SM, USA; acetabular component: standard-device, Stryker, Mahwah, NJ); and patients who were ambulatory prior to the fracture without an aid, such as a cane or a walker. The main exclusion criteria included scanty clinical data, revision arthroplasty, poly-trauma (e.g. ipsilateral or contralateral fractures of the foot, ankle, knee or femur), active infection around the hip, abnormal gait,

osteomalacia, Paget's disease, rheumatoid arthritis [17], marked bone loss, planned surgery, pathological fractures, dyspraxia, inability to follow instruction, loss to follow-up, malignant tumour, injury severity score (ISS) ≥ 10 , presence of severe medical disease (e.g. poor long-term compliance with antihypertensive treatment and diffuse intravascular coagulation), body mass index (BMI) $> 35 \text{ kg/m}^2$, severe cardiac/respiratory impairment [18], mental illness preventing follow-up, vascular cognitive impairment (VCI) and dementia [19] and an American Society of Anesthesiologists (ASA) score of IV or V.

Method of assessment

The primary outcome was the HHS, which has scores ranging from 0 to 100 points, with higher scores indicating better function, and contains subscales for pain, function, deformity and range of motion. The HHS was assessed at 1, 3, 6 and 12 months postoperatively and yearly thereafter. The secondary outcome was the orthopaedic complication rate. Patient-related complications included prosthetic loosening, prosthetic revision, periprosthetic fracture, dislocation, femur shaft fracture, infection around the prosthesis, intolerable hip pain, lower limb shortening ($> 1.5 \text{ cm}$) and heterotopic ossification.

Statistical analysis

The differences in demographic data and main outcome measures for the two cohorts were assessed. In the primary analysis, follow-up was calculated from the date of primary THA to the date of either death or the last documented follow-up, whichever came first. Revision was defined as the removal of the prosthesis or exchange of a part or the whole prosthesis. Loosening and implant failure were defined in accordance with the previous reports [1, 20]. Heterotopic ossification was assessed per the Brooker classification system [21]. Continuous variables and categorical data were analysed using independent *t* tests and chi-squared tests, respectively. The two-tailed level of significance was set at $p < 0.05$ for all statistical comparisons. All analyses were conducted using SPSS software, version 24 (IBM Corp, Armonk, NY).

Results

In total, 324 patients had baseline data available from January 2007 to January 2015 (UTHA: $n = 160$, mean age, 68.61 ± 7.49 years; CTHA: $n = 164$, mean age, 68.75 ± 7.04 years). At the time of analysis, the median follow-up was 73.16 months (range 13.35–84.88 months) for UTHA and 73.25 months (range 14.21–86.43 months) for CTHA. The baseline data are summarised in Table 1.

Table 1 Patient demographics and outcomes

Variable	UTHA ^a (n = 160)	CTHA ^b (n = 164)	p value
Sex, M/F	97/63	92/72	0.409 ^{*c}
Age, years	68.61 ± 7.49	68.75 ± 7.04	0.215 ^{*d}
BMI, kg/m ²	27.11 ± 7.75	27.36 ± 8.12	0.322 ^{*d}
BMD	- 3.59 ± 0.45	- 3.64 ± 0.37	0.176 ^{*d}
Side, left/right	86/74	81/83	0.432 ^{*c}
Comorbidities, n%			0.296 ^{*e}
Hypertension	33 (20.6)	29 (17.7)	
Diabetes mellitus	37 (23.1)	38 (23.2)	
Cardiopathy	15 (9.4)	17 (10.4)	
Hypertension and diabetes mellitus	22 (13.8)	25 (15.2)	
Pulmonary	24 (15.0)	26 (15.8)	
Cerebrovascular accident	16 (10.0)	20 (12.2)	
Anaemia	11 (6.9)	15 (9.1)	
Mechanism of injury, n%			0.454 ^{*e}
Traffic-related injury	35 (21.8)	38 (23.1)	
Injury by falling	89 (55.6)	96 (58.5)	
Tamp injury	36 (22.6)	30 (18.4)	
ASA Index, n%			0.609 ^{*e}
I	45 (28.1)	47 (28.6)	
II	76 (47.5)	83 (50.6)	
III	39 (24.4)	34 (20.8)	
Preoperative HHS	57.82 ± 16.48	57.64 ± 15.88	0.231 ^{*d}
Follow-up period (months)	73.16 ± 11.72	73.25 ± 13.58	0.069 ^{*d}

UTHA uncemented femoral component total hip arthroplasty, CTHA cemented femoral component total hip arthroplasty, HHS Harris hip score, ASA American Society of Anesthesiologists, BMI body mass index, BMD bone mineral density

*No statistically significant values

^{a,b}Uncemented or cemented femoral component: Stryker Orthopaedics, Mahwah, NJ, USA; acetabular component: standard-device, Stryker Orthopaedics, Mahwah, NJ, USA

^cAnalysed using the chi-square test

^dAnalysed using an independent-samples t test

^eAnalysed using the Mann-Whitney test

Primary outcome

The HHS before and after treatment are summarised in Table 2. Significant improvements in the HHS after surgery were detected in the two groups. Approximately, 93% of the patients with femoral neck fracture (AO/OTA type 31B) treated with primary UTHA or CTHA had a satisfactory HHS at the final follow-up. In the first or third month postoperatively, a between-group significant difference was not observed. From the third month postoperatively to the final follow-up, it appears that CTHA yielded better functional outcomes than UTHA.

Secondary outcome

Thirty-six complications in 42 UTHA-treated patients versus 28 complications in 34 CTHA-treated patients were observed. Of the 36 complications in the UTHA-treated cohort, 12 (7.5%) required prosthetic revision, 28 (17.5%) were from prosthetic loosening, 19 (11.9%) were

from periprosthetic fracture and 27 (16.9%) were intolerable hip pain. Of the 28 complications in the CTHA-treated cohort, 3 (1.8%) were from prosthetic revision, 14 (8.5%) were from prosthetic loosening, 8 (4.9%) were from periprosthetic fracture and 22 (13.4%) were intolerable hip pain (Table 3). A significant difference was detected between groups in the revision rate at the final follow-up (7.5% for UTHA vs 1.8% for CTHA, $p = 0.015$). Approximately 82.1% of revisions for UTHAs were attributed to periprosthetic fractures compared with 73.5% of revisions for CTHAs ($p = 0.034$). Periprosthetic loosening was a more frequent reason for revision among UTHAs than among CTHAs ($p = 0.016$), which cannot be treated conservatively.

Discussion

Our analysis provides evidence that CTHA was superior to UTHA because of the significantly increased HHS

Table 2 Long-term follow-up: postoperative functional outcomes

Month(s)	UTHA ^a (n = 160)	CTHA ^b (n = 164)	p value
At 1	79.14 ± 8.23	79.25 ± 7.59	0.236
At 3	87.64 ± 7.52	87.77 ± 7.63	0.062
At 6	89.14 ± 11.92	91.45 ± 9.57	0.041*
At 12	88.75 ± 8.06	90.48 ± 8.91	0.043*
At 13	88.11 ± 8.47	90.42 ± 9.02	0.040*
At 15	87.54 ± 10.21	89.78 ± 9.83	0.042*
At 18	86.38 ± 11.25	88.74 ± 8.32	0.038*
At 24	85.56 ± 11.79	88.62 ± 9.01	0.036*
At 25	85.29 ± 12.33	87.47 ± 10.58	0.042*
At 27	84.54 ± 11.22	86.85 ± 12.15	0.043*
At 30	82.63 ± 12.16	85.68 ± 13.72	0.037*
At 36	81.66 ± 10.27	84.75 ± 9.75	0.036*
At 37	80.11 ± 13.39	84.56 ± 11.47	0.032*
At 39	78.76 ± 13.27	84.56 ± 12.53	0.029*
At 42	78.16 ± 14.60	83.17 ± 13.29	0.030*
At 48	77.13 ± 13.46	82.33 ± 12.02	0.032*
At 49	76.12 ± 12.16	82.16 ± 13.10	0.027*
At 51	75.31 ± 11.10	81.57 ± 10.39	0.014*
At 54	76.65 ± 10.70	81.10 ± 8.02	0.011*
At 60	75.92 ± 8.47	80.17 ± 7.06	0.013*
At final follow-up	74.09 ± 6.23	79.01 ± 10.21	0.012*

UTHA uncemented femoral component total hip arthroplasty, CTHA cemented femoral component total hip arthroplasty

*Statistically significant values

^{a,b}Uncemented or cemented femoral component: Stryker Orthopaedics, Mahwah, NJ, USA; acetabular component: standard-device, Stryker Orthopaedics, Mahwah, NJ, USA

and distinctly reduced orthopaedic complication rate associated with CTHA in an Asian population with femoral neck fracture (AO/OTA type 31B). Moreover, the present analysis was conducted with data from a cohort representative of the “real world” practice.

In several randomised controlled trials [6, 12, 14], UTHA tended to be associated with a higher prosthetic revision rate and moderately lower HHS in comparison with those of CTHA. Given this, the application of CTHA in individuals with femoral neck fractures could have a significant influence on postoperative complications. When analysing the impact of CTHA on clinical complications, we failed to detect an increased risk for unfavourable outcomes, particularly prosthetic revision and loosening. Furthermore, previous studies [6, 9, 22] observed a distinctly low risk for CTHA-related complications. Although CTHA improves clinical outcomes, one safety concern is that interference with the cemented femoral component could promote the destabilisation of bone and cement components and thus increase the risk for complications, such as prosthetic loosening, prosthetic revision, periprosthetic fracture, dislocation, femur shaft fracture, hip pain, lower limb shortening and heterotopic ossification [10, 23]. This is of specific concern, as undergoing a THA has been considered a potential risk factor for morbidity and mortality [8, 13]. Moreover, prior reports have conceded THA is associated with increased complications in the treated individuals [11, 24]. Early prosthesis revision is acknowledged as a key adverse event and has been the focus of several reports related to THA [10]. Although a recently published assessment of CTHA and UTHA demonstrated improved safety profiles with UTHA, some of the studies have a relatively small sample size, which renders their conclusions unconvincing [22, 25]. Although our study focuses on the early stages of follow-up and UTHA appears to be undifferentiated from CTHA regarding

Table 3 Long-term follow-up: prosthesis-related complications

Variable, n%	UTHA ^a (n = 160)	CTHA ^b (n = 164)	p value
Prosthetic revision	12 (7.5)	3 (1.8)	0.015 ^{*c}
Prosthetic loosening	28 (17.5)	14 (8.5)	0.016 ^{*c}
Periprosthetic fracture	19 (11.9)	8 (4.9)	0.021 ^{*c}
Dislocation	11 (6.9)	5 (3.0)	0.112 ^c
Femur shaft fracture	6 (3.8)	5 (3.0)	0.728 ^c
Infection around the prosthesis	2 (1.3)	2 (1.2)	1.000 ^c
Intolerable hip pain	27 (16.9)	22 (13.4)	0.385 ^c
Lower limb shortening (> 1.5 cm)	10 (6.3)	6 (3.7)	0.282 ^c
Heterotopic ossification	23 (14.4)	24 (14.6)	0.947 ^c

UTHA uncemented femoral component total hip arthroplasty, CTHA cemented femoral component total hip arthroplasty

*Statistically significant values

^{a,b}Uncemented or cemented femoral component: Stryker Orthopaedics, Mahwah, NJ, USA; acetabular component: standard-device, Stryker Orthopaedics, Mahwah, NJ, USA

^cAnalysed using the chi-square test

HHSs and complication rates, it will be of great consequence to determine whether resistance to bone microstructure occurs in the later stages of follow-up and, if so, by what mechanism [12, 25].

Two recent meta-analyses indicated that CTHA was as effective, if not more so, than UTHA [26, 27]. The improvement in HHS with CTHA was important, particularly since there were fewer early prosthetic revisions with CTHA than with UTHA [28, 29]. Although a high complication rate and poor quality of life were associated with UTHA [30], a rapid recovery process was observed, without significant differences in the HHSs at the first or second month after surgery. Because of the increasing complication rates, the ideal treatment strategy for femoral fracture is of concern. Prior randomised controlled studies [25, 31] with long-term follow-up demonstrated that UTHA had an influence on the treatment outcomes with regards to the increased incidence of complications, such as loosening of prostheses. Despite the clear benefit of CTHA, a growing, but still very limited body of literature, has shown a distinctly higher rate of early revision after CTHA treatment among patients in some other medical centres [14, 32].

There has always been an argument about the use of uncemented versus cemented femoral components in THA [33]. Although UTHA and CTHA have gained enormous popularity in recent decades, experiencing rapid adoption, there remains no consensus on which device should be used for femoral neck fractures, and it could be a long time before consensus is reached [34, 35]. Furthermore, the evidence based on the latest reports [22, 36] regarding whether initial UTHA or CTHA is the optimal strategy is unclear. The principles behind CTHA and the low friction of metal-polyethylene are extremely important for the modification of joint surgery [7]. However, long-term loosening is commonly deemed to be the main cause of CTHA failure [8, 12]. To date, CTHA remains considered the gold standard for assessing other prosthetic surgeries, and early weight-bearing is easier to achieve following CTHA than following UTHA [8, 9].

Several limitations should be acknowledged. First, selection bias seems impossible to avoid because a large number of patients were excluded. Furthermore, residual bias from confounding factors remains because some information was unavailable and therefore was excluded. Second, our analysis is a retrospective observational study with some problems inherent to the methodology. Confounders due to the research methods may have reduced the power to draw reliable conclusions, but well-matched cohorts rendered us able to draw conclusions that were irrespective of the baseline data. The purpose of our study was to compare the long-term clinical outcomes for patients with femoral neck fracture (AO/OTA

type 31B) treated with primary unilateral UTHA or CTHA. It is important to emphasise that we cannot provide a comprehensive recommendation to further improve outcomes for all individuals undergoing CTHA based on the current results.

Conclusions

The results reported in this study support a growing body of evidence that CTHA is superior to UTHA in an Asian population with femoral neck fracture (AO/OTA type 31B). To date, controversy remains about the use of CTHA or UTHA, and the type of surgical approach used should be fully evaluated, along with the patient's age, activity level, and life expectancy, with the aim of achieving the optimal clinical efficacy.

Abbreviations

AP: Antero-posterior; ASA: American Society of Anesthesiologists; BMD: Bone mineral density; BMI: Body mass index; CTHA: Cemented femoral component total hip arthroplasty; DAA: Direct anterior approach; HHS: Harris hip score; ISS: Injury severity score; SD: Standard deviation; UTHA: Uncemented femoral component total hip arthroplasty

Acknowledgements

The authors would like to thank Lei Cao for help with retrieval of patients' data.

Authors' contributions

TL and XH performed the data collection and analysis and participated in manuscript writing. WY and JLL performed the database setup and statistical analysis. WY, JLL, MZ and XZ performed the operations. TL, JL and XZ participated in the study design and coordination and helped to draft the manuscript. All authors have read and approved the final manuscript.

Funding

Funding for this research was received from the Shanghai Municipal Health and Family Planning Commission Fund Project (grant no. 201640057), and the National Natural Science Foundation of China (grant no. 81971315).

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author upon reasonable request.

Ethics approval and consent to participate

This study was approved by the Medical Ethics Committee (The First Affiliated Hospital, Sun Yat-sen University), and an exemption from informed consent was obtained from our responsible Investigational Ethics Review Board.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Author details

¹Department of Neurosurgery, The Third Affiliated Hospital of Southern Medical University, No.183, Zhongshan avenue west, Tianhe District, Guangzhou 510630, China. ²Department of Anesthesiology, The Guanghua School of Stomatology, Hospital of Stomatology, Sun Yat-sen University, No. 56, Lingyuan West Road, Guangzhou 510055, China. ³Department of Orthopaedics, The First Affiliated Hospital, Sun Yat-sen University, No. 58, Zhongshan 2nd Road, Yuexiu District, Guangzhou 510080, China. ⁴Department of Orthopaedics, The Affiliated Hospital of Fujian Medical University, Chazhong Road No. 20, Taijiang District, Fuzhou 350005, Fujian, China. ⁵Department of Orthopaedics, Jinshan Hospital, Fudan University, Longhang Road No. 1508, Jinshan District, Shanghai City 201508, China.

⁶Department of Gynaecology and Obstetrics, The First Affiliated Hospital, Sun Yat-sen University, No. 58, Zhongshan 2nd Road, Yuexiu District, Guangzhou 510080, China.

Received: 6 August 2019 Accepted: 14 October 2019

Published online: 15 November 2019

References

- Baker RP, Squires B, Gargan MF, Bannister GC. Total hip arthroplasty and hemiarthroplasty in mobile, independent patients with a displaced intracapsular fracture of the femoral neck - a randomized, controlled trial. *J Bone Joint Surg Am.* 2006;88A(12):2583–9.
- Bhandari M, Devereaux PJ, Tornetta P, Swiontkowski MF, Berry DJ, Haidukewych G, et al. Operative management of displaced femoral neck fractures in elderly patients - an international survey. *J Bone Joint Surg Am.* 2005;87A(9):2122–30.
- Ju DG, Rajaei SS, Mirocha J, Lin CA, Moon CN. Nationwide analysis of femoral neck fractures in elderly patients a receding tide. *J Bone Joint Surg Am.* 2017;99(22):1932–40.
- Healy WL, Iorio R. Total hip arthroplasty-optimal treatment for displaced femoral neck fractures in elderly patients. *Clin Orthop Relat Res.* 2004; 429:43–8.
- Schwartz BE, Phipps JH, Helder CW, Mayers WF, Gonzalez MH. Revision total hip arthroplasty in the United States: national trends and in-hospital outcomes. *Int Orthop.* 2016;40(9):1793–802.
- DeAngelis JP, Ademi A, Staff I, Lewis CG. Cemented versus uncemented hemiarthroplasty for displaced femoral neck fractures: a prospective randomized trial with early follow-up. *J Orthop Trauma.* 2012;26(3):135–40.
- Schmidt AH, Leighton R, Parvizi J, Sems A, Berry DJ. Optimal arthroplasty for femoral neck fractures: is total hip arthroplasty the answer? *J Orthop Trauma.* 2009;23(6):428–33.
- Yli-Kyyny T, Sund R, Heinanen M, Venesmaa P, Kroger H. Cemented or uncemented hemiarthroplasty for the treatment of femoral neck fractures? *Acta Orthop.* 2014;85(1):49–53.
- Khorami M, Arti H, Aghdam AA. Cemented versus uncemented hemiarthroplasty in patients with displaced femoral neck fractures. *Pak J Med Sci.* 2016;32(1):44–8.
- Chammout G, Muren O, Boden H, Salemyr M, Skoldenberg O. Cemented compared to uncemented femoral stems in total hip replacement for displaced femoral neck fractures in the elderly: study protocol for a single-blinded, randomized controlled trial (CHANCE-trial). *BMC Musculoskelet Disord.* 2016;17(1):398.
- Viberg B, Overgaard S, Lauritsen J, Ovesen O. Lower reoperation rate for cemented hemiarthroplasty than for uncemented hemiarthroplasty and internal fixation following femoral neck fracture 12-to 19-year follow-up of patients aged 75 years or more. *Acta Orthop.* 2013;84(3):254–9.
- Chammout G, Muren O, Laurencikas E, Boden H, Kelly-Pettersson P, Sjoor H, et al. More complications with uncemented than cemented femoral stems in total hip replacement for displaced femoral neck fractures in the elderly. A single-blinded, randomized controlled trial with 69 patients. *Acta Orthop.* 2017;88(2):145–51.
- Laupacis A, Bourne R, Rorabeck C, Feeny D, Tugwell P, Wong C. Comparison of total hip arthroplasty performed with and without cement—a randomized trial. *J Bone Joint Surg Am.* 2002;84A(10):1823–8.
- Langslet E, Frihagen F, Opland V, Madsen JE, Nordsletten L, Figved W. Cemented versus Uncemented Hemiarthroplasty for displaced femoral neck fractures: 5-year Followup of a randomized trial. *Clin Orthop Relat Res.* 2014; 472(4):1291–9.
- Ochi H, Baba T, Homma Y, Matsumoto M, Watari T, Ozaki Y, et al. Total hip arthroplasty via the direct anterior approach with a dual mobility cup for displaced femoral neck fracture in patients with a high risk of dislocation. *SICOT J.* 2017;3:56.
- Makela KT, Matilainen M, Pulkkinen P, Fenstad AM, Havelin L, Engesaeter L, et al. Failure rate of cemented and uncemented total hip replacements: register study of combined Nordic database of four nations. *BMJ.* 2014;348: f7592.
- Wang F, Zhang HF, Zhang ZY, Ma CB, Feng XM. Comparison of bipolar hemiarthroplasty and total hip arthroplasty for displaced femoral neck fractures in the healthy elderly: a meta-analysis. *BMC Musculoskelet Disord.* 2015;16(1):1–13.
- Achten J, Parsons NR, Edlin RP, Griffin DR, Costa ML. A randomised controlled trial of total hip arthroplasty versus resurfacing arthroplasty in the treatment of young patients with arthritis of the hip joint. *BMC Musculoskelet Disord.* 2010;11:8.
- Dao E, Hsiung GYR, Sossi V, Jacova C, Tam R, Dineley K, et al. Exploring the effects of coexisting amyloid in subcortical vascular cognitive impairment. *BMC Neurol.* 2015;15:197.
- Zeng X, Zhan K, Zhang L, Zeng D, Yu W, Zhang X, et al. Conversion to total hip arthroplasty after failed proximal femoral nail antirobotations or dynamic hip screw fixations for stable intertrochanteric femur fractures: a retrospective study with a minimum follow-up of 3 years. *BMC Musculoskelet Disord.* 2017;18(1):38.
- Saudan M, Saudan P, Perneger T, Riand N, Keller A, Hoffmeyer P. Celecoxib versus ibuprofen in the prevention of heterotopic ossification following total hip replacement - a prospective randomised trial. *J Bone Joint Surg Br.* 2007;89B(2):155–9.
- Song JSA, Dillman D, Wilson D, Dunbar M, Richardson G. Higher periprosthetic fracture rate associated with use of modern uncemented stems compared to cemented stems in femoral neck fractures. *Hip Int.* 2019;29(2):177–83.
- Eschen J, Kring S, Brix M, Ban I, Troelsen A. Outcome of an uncemented hydroxyapatite coated hemiarthroplasty for displaced femoral neck fractures: a clinical and radiographic 2-year follow-up study. *Hip Int.* 2012; 22(5):574–9.
- Hansen SK, Brix M, Birkelund L, Troelsen A. Can introduction of an uncemented, hydroxyapatite coated hemiarthroplasty for displaced femoral neck fractures be recommended? *Hip Int.* 2010;20(1):109–14.
- Inngul C, Blomfeldt R, Ponzer S, Enocson A. Cemented versus uncemented arthroplasty in patients with a displaced fracture of the femoral neck a RANDOMISED CONTROLLED TRIAL. *Bone Joint J.* 2015;97B(11):1475–80.
- Imam MA, Shehata MSA, Elsehili A, Morsi M, Martin A, Shawqi M, et al. Contemporary cemented versus uncemented hemiarthroplasty for the treatment of displaced intracapsular hip fractures: a meta-analysis of forty-two thousand forty-six hips. *Int Orthop.* 2019;43(7):1715–23.
- Kunutsor SK, Beswick AD, Whitehouse MR, Blom AW, Lenguerrand E. Implant fixation and risk of prosthetic joint infection following primary total hip replacement: meta-analysis of observational cohort and randomised intervention studies. *J Clin Med.* 2019;8(5):722.
- Palan J, Smith MC, Gregg P, Mellon S, Kulkarni A, Tucker K, et al. The influence of cemented femoral stem choice on the incidence of revision for periprosthetic fracture after primary total hip arthroplasty. *Bone Joint J.* 2016;98B(10):1347–54.
- Bozic KJ, Ong K, Lau E, Kurtz SM, Vail TP, Rubash HE, et al. Risk of complication and revision Total hip Arthroplasty among Medicare patients with different bearing surfaces. *Clin Orthop Relat Res.* 2010;468(9):2357–62.
- Ahmad R, Sharma V, Sandhu H, Bishay M. Leg length discrepancy in total hip arthroplasty with the use of cemented and uncemented femoral stems. A prospective radiological study. *Hip Int.* 2009;19(3):264–7.
- Flivik G, Kristiansson I, Ryd L. Positive effect of removal of subchondral bone plate for cemented acetabular component fixation in total hip arthroplasty. A randomised rsa study with ten-year follow-up. *Bone Joint J.* 2015;97B(1): 35–44.
- Scott CEH, MacDonald D, Moran M, White TO, Patton JT, Keating JF. Cemented total hip arthroplasty following acetabular fracture. *Bone Joint J.* 2017;99B(10):1399–408.
- Hernandez NM, Chalmers BP, Perry KI, Berry DJ, Yuan BJ, Abdel MP. Total hip Arthroplasty after in situ fixation of minimally displaced femoral neck fractures in elderly patients. *J Arthroplast.* 2018;33(1):144–8.
- Medda S, Snoap T, Carroll EA. Treatment of young femoral neck fractures. *J Orthop Trauma.* 2019;33:S1–6.
- Steele CE, Cochran G, Renninger C, Deafenbaugh B, Kuhn KM. Femoral neck stress fractures: MRI risk factors for progression. *J Bone Joint Surg Am.* 2018; 100(17):1496–502.
- Duffin M, Pilson HT. Technologies for young femoral neck fracture fixation. *J Orthop Trauma.* 2019;33:S20–56.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.