Primary

HIP International

HIP International
2022, Vol. 32(2) 160–165
© The Author(s) 2020
Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/1120700020940276
journals.sagepub.com/home/hpi
SAGE

Defining ‘undersizing’ in short-stem total hip arthroplasty: the importance of sufficient contact with the lateral femoral cortex

Karl P Kutzner[1], Tobias Freitag[2] and Ralf Bieger[2]

Abstract

Introduction: Undersizing is 1 of the main reasons for early implant failure. Adequate sizing in short-stem total hip arthroplasty can be challenging and, so far, lacks key decision criteria.

Methods: We included 191 calcar-guided short stems. All patients underwent standardised digital anteroposterior imaging pre- and post-surgery and during follow-up. Preoperative planning was performed digitally. Planned stem sizes were retrospectively assessed and compared with the implanted sizes. Additionally, adequate sizing was analysed by determining whether the stem made intraoperative contact with the lateral distal femoral cortex. Implant migration was assessed by Ein-Bild-Roentgen-Analysis Femoral-Component-Analysis 5 years after surgery. Influence of different Dorr types and postoperative centrum-collum-diaphyseal angle (CCD) categories on lateral femoral cortical contact were analysed. Additionally, the Harris Hip Score (HHS) was assessed at final follow-up. Stem-revision rate was documented.

Results: Implanted stems were at least 2 sizes smaller than those at the preoperative planning in 49 (25.7%) cases. The stem made contact with the lateral distal femoral cortex in only 130 hips (68.1%). Mean subsidence was significantly higher in the no-contact group (2.07 mm, range −7.7 to 1.7) than in the contact group (1.23 mm, range −4.5 to 1.8) at the final follow-up ($p = 0.0018$). Stems at least 2 sizes smaller than those at preoperative planning showed a significantly higher prevalence of non-contact (46.9% vs. 26.8%) ($p = 0.009$). Those undersized stems were more likely found in varus hips. No influence of the Dorr classification and the different CCD categories on the probability of achieving sufficient cortical contact was found. HHS showed no intergroup differences.

Conclusions: Stems that did not make intraoperative contact with the lateral femoral cortex showed significantly increased axial migration at mid-term follow-up. Thus, the investigated criteria regarding the definition of undersizing in short-stem THA should be acknowledged. No obvious mid-term consequences were noted regarding revision rate. Long-term results are mandatory.

Keywords

EBRA, migration, short stem, total hip arthroplasty, undersizing

Date received: 15 October 2019; accepted: 11 May 2020

Introduction

Cementless fixation of femoral stems in total hip arthroplasty (THA) is 1 of the most successful procedures in orthopaedic surgery.[1] Data for long-term survival (>95%) of conventional cementless stems at 10 years postoperatively can be found in both national registries as well as case series.[2] However, data on the 10-year survival rate of shorter stems are relatively scarce. In a recent review of national registry data as well as case studies, a revision rate

[1]Department of Orthopaedic Surgery, St. Josef's Hospital Wiesbaden, Wiesbaden, Hessen, Germany
[2]Department of Orthopaedic Surgery, University of Ulm, Ulm, Baden-Württemberg, Germany

Corresponding author:
Karl P Kutzner, Department of Orthopaedic Surgery, St. Josef's Hospital Wiesbaden, Beethovenstraße 20, Wiesbaden, Hessen 65189, Germany.
Email: kkutzner@joho.de

of approximately 5% after 10 years was found for several conservative implants.[3] However, longer-term data are not yet available and hence, it is yet unpredictable whether this new group of femoral implants will perform as well as conventional stems with a 25-year survival rate of 60%.[4]

Published data evaluated patient-specific factors such as body mass index (BMI), age, and sex that influence primary stability and thus potentially the long-term survival of short-stem prostheses.[5] The dependence of the implant position on the postoperative outcome and especially on the primary stability of the implant has so far only been investigated by an analysis of the stems' varus/valgus position in the femoral cavity.[6] However, in case of conventional stems, it is known that the initial amount of cortical contact between the stem and femur has a significant influence on the survival rate of the femoral device.[7] Furthermore, undersized implants showed a significantly higher revision rate in the third decade than correctly dimensioned implants.[8] In addition, an initially more pronounced migration was associated with a higher risk of aseptic loosening for cementless CLS stems.[9] The authors correlated an axial migration of >2.7 mm within the first 2 postoperative years with a survival rate of 29% at postoperative 18 years than the 95% rate in the group of implants with less extensive migration.[9]

Therefore, the initial positioning and sizing of the implant in the femur seems to influence the long-term outcome. Given a more individualised implantation technique in short-stem THA along with different varus and valgus stem alignment, adequate sizing can be challenging and involves a learning curve.[10] Preoperative planning and its implementation in the operating theatre appear to be important in clinical decision making. To our best knowledge, intraoperative key decision criteria with respect to choosing the right size and position are not available.

We hypothesised that undersized stems would show a greater axial migration than preoperatively sufficiently dimensioned and radiologically templated prostheses. Furthermore, it was postulated that sufficient contact with the lateral cortex would positively influence primary stability of the implant.

Methods

Following approval by the local ethics review board (University of Ulm; 323/13), 216 consecutive short-stem implantations in 162 patients were included in this study. Written consent to participate was obtained from all patients. The inclusion criteria were as follows: a preoperative radiograph with digital planning of the implantation, a minimum observation period of 5 years, a series of at least 3 consecutive standardised radiographs validated by the Einzel-Bild-Rontgen-Analyse femoral-component analysis (EBRA-FCA) software, and acceptance of the direct postoperative and postoperative 5-year follow-up observation.

At the final follow-up, 191 hip joints of 142 patients were examined. Nine patients (12 hips) died independently of the surgical intervention. 13 hips either had an incomplete radiological series or the analysis was rejected by the software. No stem required revision surgery during the study period.

Figure 1. The Optimys stem (Mathys Ltd., Bettlach, Switzerland).

All patients received a cementless short stem (optimys, Mathys AG Bettlach, Switzerland) (Figure 1) classified as type 2B according to Khanuja et al.[11] The Optimys short stem implant is made of a titanium alloy and has a tapered, trapezoidal cross-section in 3 planes. The surface is plasma-sprayed and coated with calcium phosphate. The implant is available with 2 offset versions to reconstruct the individual anatomy. In all cases, the acetabular component was a cementless press-fit cup (RM Pressfit vitamys, Mathys AG Bettlach or Fitmore cup, Zimmer, Warsaw, IN, USA) and the bearing was a 28-mm alumina-on-highly-cross-linked polyethylene.

Preoperative templating of the operation was performed by the surgeon with the mediCAD II software (Hectec, Landshut, Germany), based on standardised anteroposterior (AP) view radiographs of the pelvis. Dorr classification was used to categorise all hips into types A, B and C. All operations were performed in the supine position using an anterolateral approach. Intraoperative radiological imaging was used. Full-weight-bearing on 2 crutches was immediately allowed postoperatively.

The follow-up periods were postoperative, 6 weeks, 6 months, 12 months, 2 years, and 5 years. Radiological AP images of the pelvis and an axial image of the affected hip were obtained at each follow-up. All hips were classified according to the postoperative centrum-collum-diaphyseal angle (CCD) and categorised in 5 groups (A–E: <124.9° [A]; 125°–129.9° [B]; 130°–134.9° [C]); 135°–139.9° [D]; >140° [E]) as published previously.[6] The radiographic examinations were analysed after signs of implant failure.

The EBRA-FCA was used to determine the axial migration of the stem with respect to the direct postoperative condition. Radiographs with significant positioning artefacts were excluded by the EBRA-FCA software. The standard protocol of the software developers was used after adaption to the shorter stem prosthesis.[12,13]

1. Implant undersizing was defined to determine the difference in axial migration between correctly implemented templating (group A) and undersizing if the stem size used was at least 2 sizes smaller than in the preoperative planning (group B).
2. The influence of sufficient contact with the lateral cortex on the primary stability was assessed using postoperative AP images of the pelvis. A sufficient contact was defined as the distance between the most lateral point of the stem and the inner lateral femoral cortex being <1 mm (Figure 2). A distance of $\geqslant 1$ mm was defined as insufficient (Figure 3). Thus, 2 groups were compared: group C with sufficient lateral cortical contact with the implant and group D without sufficient lateral contact with the femoral cortex.
3. In addition, an analysis of the combination of planning implementation and extent of contact with the lateral cortex was performed to record the influence of undersizing on this specific postoperative radiological outcome.

To investigate the influence of the preoperative bone quality and different varus, neutral or valgus stem alignment, intergroup differences regarding Dorr types and CCD categories were analysed.

The clinical outcome was measured by the Harris Hip Score (HHS).

Statistical evaluation was performed with SAS software 9.4 (SAS Institute, Cary, North Carolina, USA). All analyses were performed using standard descriptive statistics. The values are given as mean values and range, and qualitative categorical values are shown as number and percentage. The group differences were compared with the nonparametric Wilcoxon 2-sample test or Kruskal-Wallis test; the latter was used for more than 2 groups. Comparisons in follow-up studies, such as differences with the baseline, were performed using paired *t*-tests. Association tests between discrete variables were carried out using chi-square tests. A p-value <0.05 was considered to indicate statistical significance.

Results

Influence of undersizing on migration pattern of the implant

Preoperative planning ±1 implant size was achieved in 142 of 191 cases (74% in group A). A final implant at least 2 sizes smaller than templated was used in 49 hips (26% in group B) (Table 1). Axial migration 5 years postoperatively tended to be more pronounced in the group of undersized procedures ($p=0.349$) (Figure 4).

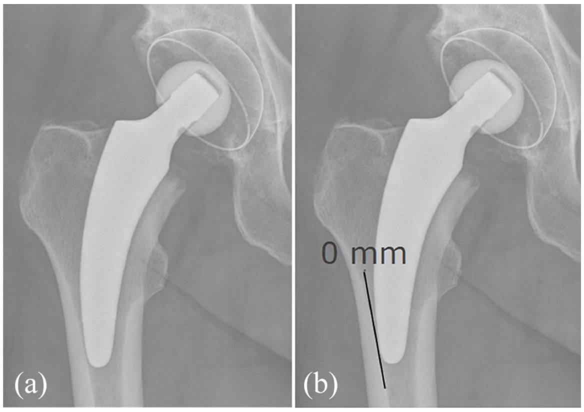

Figure 2. Sufficient contact of the short stem with the lateral femoral cortex (a: direct postoperative radiograph; b: measurement of the distance between the inner lateral cortex and the most lateral point of the stem = 0 mm).

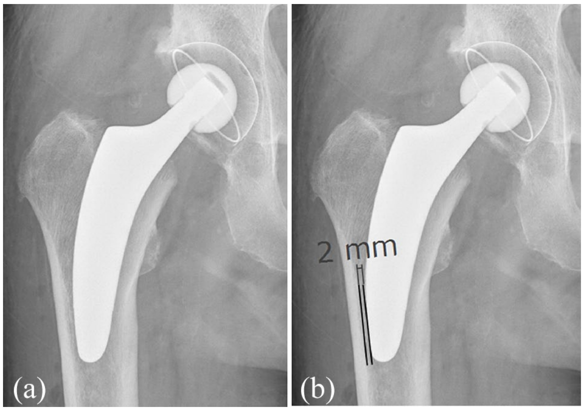

Figure 3. Missing contact of the short stem with the lateral femoral cortex (a: direct postoperative radiograph; b: measurement of the distance between the inner lateral cortex and the most lateral point of the stem = 2 mm).

Influence of sufficient contact with the lateral cortex on migration pattern of the implant

Lateral femoral cortical contact of the implant with the femur on postoperative radiographs was achieved in 130 cases (68% in group C). Missing lateral femoral cortical contact was observed in 61 (32% in group D) hips (Table 2). Axial migration at postoperative 5 years was significantly greater in group D than in group C ($p=0.0018$) (Table 2) (Figure 5).

Table 1. The mean axial implant migration 5 years postoperatively. Group A showing implants with a difference between preoperative templating and stem size using ±1 size, and Group B showing implants undersized by >1 size compared with the preoperative templating.

Group	Subsidence (mm)					
	n Obs	Mean	SD	Median	Min	Max
A	142	−1.42	1.45	−1.25	−6.40	1.80
B	49	−1.71	1.55	−1.30	−7.70	0.40
Total	191	−1.50	1.48	−1.30	−7.70	1.80

Wilcoxon 2-sample test (2-sided): $p = 0.349$.

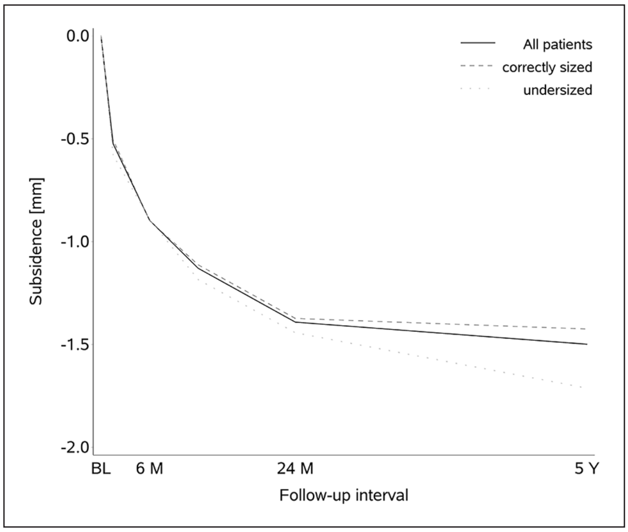

Figure 4. Mean plot of axial migration in a 5-year follow-up (Group A: correctly sized compared to the preoperative planning; Group B: undersized compared to the preoperative planning).

Table 2. The mean axial implant migration 5 years postoperatively. Group C showing implants with sufficient contact to the lateral cortex and Group D with missing lateral femoral contact.

Group	Subsidence (mm)					
	n Obs	Mean	SD	Median	Min	Max
C	130	−1.23	1.19	−1.00	−4.50	1.80
D	61	−2.07	1.85	−1.80	−7.70	1.70
Total	191	−1.50	1.48	−1.30	−7.70	1.80

Wilcoxon 2-sample test (2-sided): $p = 0.0018$.

Influence of undersized implants on the contact with the lateral femoral cortex

Undersized femoral stems (group B) showed significantly more frequent insufficient contact with the lateral femoral cortex than correctly sized implanted stems (group A) ($p = 0.009$) (Table 3).

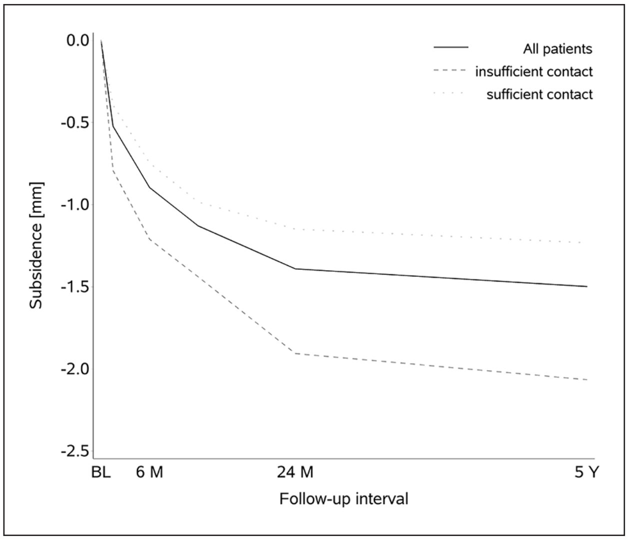

Figure 5. Mean plot of axial migration in a 5-year follow-up (Group C: sufficient contact with the lateral femoral cortex; Group D: insufficient contact with the lateral femoral cortex).

Table 3. Sufficiency of the lateral femoral cortical contact depending on the implementation of preoperative templating. Group A showing implants with a difference between preoperative templating and used stem size of ±1 size, and Group B showing implants undersized by >1 size compared to the preoperative templating.

Lateral femoral cortical contact			
Group	Hips	No	Yes
A	142	38 (26.8%)	104 (73.2%)
B	49	23 (46.9%)	26 (53.1%) $p = 0.0090$

The distribution of different Dorr types and CCD categories of the study cohort is shown in Table 4. There was no difference between the subgroups analysed regarding Dorr types (group A vs. group B: $p = 0.139$; group C vs. group D: $p = 0.572$). No influence of the different CCD categories on the probability of achieving sufficient contact with the lateral femoral cortex was found (group C vs. group D: $p = 0.582$). However, CCD categories A and B show high prevalences of undersizing compared to the preoperative planning, whereas categories C, D and E show better implemented templating. These findings are statistically highly significant (group A vs. group B: $p < 0.0001$) (Table 4).

The mean HHS improved significantly from 46.0 (range 7.0–88.0) preoperatively to 97.9 (range 65.0–100.0) 5 years after surgery ($p < 0.0001$). Again, there was no difference between the subgroups analysed (group A vs. group B: $p = 0.759$; group C vs. group D: $p = 0.307$).

Table 4. Intergroup differences of the investigated groups A–D regarding Dorr classification and CCD categories.

	Group A	Group B	Total	Group C	Group D	Total
Dorr classification						
A	95 (70.4%)	40 (29.6%)	135 (70.7%)	41 (30.4%)	94 (69.6%)	135 (70.7%)
B	46 (83.6%)	9 (16.4%)	55 (28.8%)	20 (36.4%)	35 (63.6%)	55 (28.8%)
C	1 (100.0%)	0 (0.0%)	1 (0.5%)	0 (0.0%)	1 (100.0%)	1 (0.5%)
Total	142 (74.3%)	49 (25.7%)	191 (100.0%)	61 (31.9%)	130 (68.1%)	191 (100.0%)
CCD category						
A	3 (27.3%)	8 (72.7%)	11 (5.8%)	8 (72.7%)	3 (27.3%)	11 (5.8%)
B	21 (51.2%)	20 (48.8%)	41 (21.5%)	28 (68.3%)	13 (31.7%)	41 (21.5%)
C	67 (79.8%)	17 (20.2%)	84 (44.0%)	55 (65.5%)	29 (34.5%)	84 (44.0%)
D	38 (90.5%)	4 (9.5%)	42 (22.0%)	32 (76.2%)	10 (23.8%)	42 (22.0%)
E	13 (100.0%)	0 (0.0%)	13 (6.8%)	7 (53.8%)	6 (46.2%)	13 (6.8%)
Total	142 (74.3%)	49 (25.7%)	191 (100.0%)	130 (68.1%)	61 (31.9%)	191 (100.0%)

CCD, postoperative centrum-collum-diaphyseal angle.

Discussion

Cementless fixation of THA stems is a popular and successful technique. According to the German registry 'Endoprothesenregister Deutschland (EPRD)', 77% of all stems included in the 2017 registry were cementless.[14] In addition, 9.4% of all THAs were performed with a cementless short stem, which demonstrates the importance of this fixation strategy. To date, a number of patient-specific factors have been associated with a pronounced early axial migration, potentially resulting in an increased rate of complications and implant failure when using cementless short stems.[5] However, procedure-specific factors have only been studied to a limited extent.[6] The present study investigated the significance of implementation of preoperative radiological templating and sizing on the amount of medium-term migration and the influence of implant positioning in the femoral cavity. An insignificant tendency towards a lower axial migration could be observed by implementing templating with an adequately sized implant. Stems that failed to make lateral femoral cortical contact showed significantly greater axial migration than those that made sufficient contact.

In 74% of included hips, the preoperative planning could be intraoperatively implemented with a difference not greater than ±1 size. The mean axial migration 5 years postoperatively was -1.42 mm, while that in favour of adequately templated cases was −1.71 mm. Moreover, sufficient contact with the lateral cortex was significantly more frequent with correctly sized than with undersized implants. In a recent study, the accuracy of digital templating of uncemented THA stems was investigated, wherein the authors came to a better agreement between planning and used stem sizes ±1 than that used in this study (87% vs. 74%).[15] In the cited publication, standard straight stems were used instead of the Optimys short stem used in the present investigation. The influence of stem geometry on the quality of templating was already evident when comparing a short stem with a straight stem.[16] The accuracy of straight stem templating was significantly higher than that of a short stem. These results highlight the greater difficulty in implementing preoperative templating; hence, more individualised operation techniques are required with short-stem implants. According to the present results, particularly in varus hips with CCD category A and B (<124.9° and 125–129.9°) a high rate of undersized stems compared to the preoperative planning is remarkable. However, we note that in many cases of templating, a tendency towards more neutral or valgus alignment was observed. In order to achieve a fit and fill in the proximal diaphysis, generally larger stems were used for templating in those cases. Intraoperatively despite the planning, more often a pronounced varus alignment is aimed for, which results in smaller stem sizes, compared to the preoperative planning, before cortical contact is reached.

However, undersizing resulted in a significantly lower degree of sufficient lateral femoral contact than in the preoperative templating of the stem. For cementless straight stems, a correlation between the extent of cortical contact with the femur and the long-term performance has already been demonstrated.[7] The authors showed a 4.2-fold increased revision rate in undersized implants, 20–25 years after surgery. Furthermore, it could be shown that increased axial migration of a cementless straight stem within the first 2 postoperative years is associated with significantly higher aseptic loosening rates.[9] Thus, an axial migration >2.7 mm within 2 years postoperatively was associated with an implant failure rate of 71%, as against 5% for implants with less pronounced subsidence 18 years postoperatively.

Although none of the implants investigated in this study group have required revision surgery to date, differences in migration behaviour of the stems should be monitored especially in cases with increased subsidence. Even more relevant than the implementation of the preoperative templating on the migration behaviour, was the impact of sufficient contact with the lateral cortex on axial migration in the 5-year course. Implants without cortical contact showed a migration of 2.10 mm 5 years postoperatively as against 1.23 mm in the group with sufficient lateral cortical contact. According to the results presented, the contact of the stem to the lateral femoral cortex in short-stem THA should be considered one of the main criteria regarding adequate sizing and positioning. These findings seem to be independent of bone quality and stem alignment. Sufficient contact should always be the intraoperative aim, especially in cases where an undersized implant would be used. Therefore, intraoperative imaging should be considered mandatory.[17]

Our study has 2 main limitations. First, the method of measuring sufficiency of the stem's contact to the lateral femoral cortex has not yet been validated. However, the aim of the study was to describe key decision criteria that are suitable for intraoperative use by all surgeons, solely by performing intraoperative imaging. Second, the 5-year follow-up does not allow for the establishment of reliable predictive criteria concerning aseptic loosening and implant failure in the migration analysis of this specific short-stem design. However, EBRA-FCA in the past has been established as one of the main predictive tools, helping to estimate long-term survival of conventional stem designs. Given that none of the stems, investigated in the present study have required revision surgery, its reliability for specific short-stem designs remains to be proven in the future.

Conclusion

Adequate implant positioning is crucial for primary stability in short-stem THA. Radiological templating of the surgery should be performed and undersizing should be avoided intraoperatively. The investigated criteria regarding the definition of undersizing in short-stem THA should be seriously considered in clinical decision-making. The use of intraoperative imaging verifies the sizing, implant position, and sufficient contact with the lateral cortex.

Declaration of conflicting interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: KPK: is an instructor for Mathys Ltd., Bettlach, Switzerland.
All other authors declare that there is no conflict of interest.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by Mathys Ltd., Bettlach, Switzerland.

ORCID iD

Karl P Kutzner https://orcid.org/0000-0001-6363-8165

References

1. Learmonth ID, Young C and Rorabeck C. The operation of the century: total hip replacement. *Lancet* 2007; 370: 1508–1519.
2. Kärrholm J, Lindahl H, Malchau H, et al. *Swedish hip arthroplasty register: annual report 2015*. Sahlgrenska: Sahlgrenska University Hospital, 2016.
3. Hauer G, Vielgut I, Amerstorfer F, et al. Survival rate of short-stem hip prostheses: a comparative analysis of clinical studies and national arthroplasty registers. *J Arthroplasty* 2018; 33: 1800–1805.
4. Evans JT, Evans JP, Walker RW, et al. How long does a hip replacement last? A systematic review and meta-analysis of case series and national registry reports with more than 15 years of follow-up. *Lancet* 2019; 393: 647–654.
5. Kutzner KP, Kovacevic MP, Freitag T, et al. Influence of patient-related characteristics on early migration in calcar-guided short-stem total hip arthroplasty: a 2-year migration analysis using EBRA-FCA. *J Orthop Surg Res* 2016; 11: 29.
6. Kutzner KP, Freitag T, Donner S, et al. Outcome of extensive varus and valgus stem alignment in short-stem THA: clinical and radiological analysis using EBRA-FCA. *Arch Orthop Trauma Surg* 2017; 137: 431–439.
7. Streit MR, Innmann MM, Merle C, et al. Long-term (20- to 25-year) results of an uncemented tapered titanium femoral component and factors affecting survivorship. *Clin Orthop Rel Res* 2013; 471: 3262–3269.
8. Evola FR, Evola G, Graceffa A, et al. Performance of the CLS Spotorno uncemented stem in the third decade after implantation. *Bone Joint J* 2014; 96–B: 455–461.
9. Streit MR, Haeussler D, Bruckner T, et al. Early migration predicts aseptic loosening of cementless femoral stems: a long-term study. *Clin Orthop Relat Res* 2016; 474: 1697–1706.
10. Kutzner KP and Pfeil J. Individualized stem-positioning in calcar-guided short-stem total hip arthroplasty. *J Vis Exp* 2018; 132: 56905.
11. Khanuja HS, Banerjee S, Jain D, et al. Short bone-conserving stems in cementless hip arthroplasty. *J Bone Joint Surg Am* 2014; 96: 1742–1752.
12. Kutzner KP, Freitag T, Kovacevis MP, et al. One-stage bilateral versus unilateral short-stem total hip arthroplasty: comparison of migration patterns using Ein-Bild-Roentgen-analysis femoral-component-analysis. *Int Orthop* 2017; 41: 61–66.
13. Biedermann R, Krismer M, Söckl B, et al. Accuracy of EBRA-FCA in the measurement of migration of femoral components of total hip replacement. Einzel-Bild-Rontgen-analyse-femoral component analysis. *J Bone Joint Surg Br* 1999; 81: 266–272.
14. Grimberg A, Jansson V, Liebs T, et al. *Endoprothesenregister Deutschland-Jahresbericht 2017*. Berlin: EPRD Deutsche Endoprothesenregister gGmbH, 2018.
15. Holzer LA, Scholler G, Wagner S, et al. The accuracy of digital templating in uncemented total hip arthroplasty. *Arch Orthop Trauma Surg* 2019; 139: 263–268.
16. Jung S, Neuerburg C, Kappe T, et al. Validity of digital templating in total hip arthroplasty: impact of stem design and planner's experience. *Z Orthop Unfall* 2012; 150: 404–408.
17. Loweg L, Kutzner KP, Trost M, et al. The learning curve in short-stem THA: influence of the surgeon's experience on intraoperative adjustments due to intraoperative radiography. *Eur J Orthop Surg Traumatol* 2018; 28: 269–275.