Acta Orthop. Belg., 2020, **86 e-supplement** 3, 32-39

ORIGINAL STUDY

Excellent midterm clinical outcomes and restoration of native hip anatomy with a calcar guided short femoral stem in cementless THA

Roland S. Camenzind, Dimitris Dimitriou, Marion Röthlisberger, Alexander Antoniadis, Näder Helmy

From the Department of Orthopedic Surgery, Bürgerspital Solothurn, Solothurn, Switzerland

Restoration of the femoroacetabular offset and leg-length is critical in optimizing hip function following total hip arthroplasty (THA). The short femoral stems allow bone sparing and implantation through a minimally invasive approach ; however, they might not anatomically reconstruct the native hip anatomy. Therefore, the purpose of the present study was to investigate whether a calcar guided short femoral stem could restore hip anatomy and provide satisfactory clinical outcomes at a 5-years follow-up. A total of 114 consecutive patients treated with THA and a calcar guided short femoral stem with an average age of 67 years, and a median follow-up of 5 years were evaluated clinically and radiographically. All patients were operated either through a minimally invasive anterior or anterolateral approach. The contralateral native hip was used as reference to examine whether a calcar guided short femoral stem could restore the native hip anatomy. The Harris hip score improved significantly at an average of 45 points following the short-stem THA. The rest and loading pain decreased significantly from an average VAS of 4 and 7 points preoperative to VAS 0 and 0 points postoperative, respectively. Compared to the contralateral native hip the total offset was not significantly different, and the leg length increased by an average of 2 mm compared to the contralateral native hip. Although the minimally invasive anterolateral approach had similar functional outcomes and patient satisfaction with the anterior approach, it showed more discrepancies from the contralateral native hip in the total offset and leg length than the anterior approach. A calcar guided short femoral stem, implanted through a minimally invasive approach could restore native hip anatomy regarding total offset and leg length, and provide excellent functional outcomes and patient satisfaction 5-years following THA. Surgeons performing THA with minimally invasive anterolateral approach should be aware of the discrepancies in total offset and leg length to prevent a malalignment of the femoral component.

Keywords : Total hip arthroplasty; total offset ; leg length ; short stem ; clinical outcomes.

Funding : Mathys Ltd. Bettlach (Switzerland) is the sponsor of this study. The sponsor has been involved in the planning and evaluation of the study.
Conflict of interests : RSC, DD and AA declare that they have no conflict of interest. NH is a consultant for Mathys Ltd. Bettlach (Switzerland). MR is an employee of Mathys Ltd Bettlach (Switzerland), and she did the data analysis in the context of the diploma of advanced studies in applied statistics at the Institute of Mathematical Statistics and Actuarial Science (University of Berne, Switzerland).

■ Roland S. Camenzind[1],
■ Dimitris Dimitriou[1],
■ Marion Röthlisberger[2],
■ Alexander Antoniadis[1],
■ Näder Helmy[1]
[1]*Department of Orthopedic Surgery, Bürgerspital Solothurn, Schöngrünstrasse 38, 4500 Solothurn, Switzerland*
[2]*Institute of Mathematical Statistics and Actuarial Science, University of Bern, Sidlerstrasse 5, 3012 Bern, Switzerland*
Correspondence : Dr. med. Roland S. Camenzind, Department of Orthopedic Surgery, Bürgerspital Solothurn, Schöngrünstrasse 38, 4500 Solothurn, Switzerland. Tel : +41 79 762 63 43. Fax : +41 32 627 46 09,
E-mail : roland.camenzind@bluewin.ch
© 2020, Acta Orthopædica Belgica.

INTRODUCTION

Total hip arthroplasty (THA) is considered an effective procedure in providing pain relief, restoring hip function and improving the quality of life in patients suffering from end-stage hip osteoarthritis *(7)*. However, restoration of hip anatomy, including femoral offset, leg-length, and center of rotation is critical in optimizing hip function *(12,22)*. Evidence suggests that component malposition in THA might be associated with adverse clinical outcomes, such as hip impingement *(23)*, edge loading *(20)*, dislocation *(2)*, increased liner wear and periprosthetic osteolysis *(16)*.

Although THA was initially performed in elderly patients with low activity levels, the indications of THA have expanded to include both active and young patients. According to current estimations, 15% of THA are performed in active individuals, younger than 60 years *(17)*, and this number is expected to increase in the near future *(5)*. Even though young and active patients could also benefit from a THA, they might have a higher risk of implant failure and subsequent revision surgery *(10)*. Therefore, within this population, an effective THA should aim in preserving the metaphyseal bone, providing feasible femoral revision options and allowing easier implantation with less invasive procedures. Short cementless femoral components were developed to preserve metaphyseal bone through proximal load transfer and facilitate the femoral stem implantation through minimally invasive approaches. Nevertheless, due to the technically demanding minimally invasive approaches and the metaphyseal anchoring of the short stems, they might be susceptible to implantation in varus position *(11)* and therefore alter hip geometry regarding femoral offset, leg-length, and center of rotation.

Although recent studies demonstrated excellent short-term outcomes of several short stem designs *(1,9)* the current literature shows limited knowledge of postoperative results, in terms of restoring hip anatomy and midterm functional outcomes in short stem THA. Therefore, the aim of the present study was : 1) to investigate whether a calcar guided short femoral stem, implanted using a minimally invasive approach could reproduce the offset, leg-length, and vertical center of rotation compared to the contralateral native hip, 2) to investigate the effect of the surgical approach on the clinical outcome and on several radiologic parameters such as the leg length, total offset and center of rotation in short stem THA.

MATERIAL AND METHODS

The current study was approved by our institution's Internal Review Board and the ethical committee (Freiburg Ethics Commission International (feki), Germany, 010/2071). Each patient provided written informed consent before participation. This prospective, multicenter study was conducted in two Swiss and three German hospitals. From 12/2010 until 04/2012, all the patients presented in the clinic with symptomatic hip osteoarthritis waiting for a hip arthroplasty were considered as potential candidates for the study. From all included patients in the multicenter study, a subset of consecutive patients was selected to further analyze the X-rays.

The inclusion criteria were adult patients, between 18 and 85 years, who received a primary, unilateral THA and had no arthritis in the contralateral hip (Kellgren and Lawrence *(15)* : 0-1). Exclusion criteria were : patients older than 85 years, patients undergoing revision surgery, ASA score (American Society of Anesthesiologists) higher than 3, osteoarthritis of the contralateral hip (Kellgren and Lawrence ≥ 2) and patient conditions that did not allow for implantation of an uncemented short-stem femoral component, such as severe osteoporosis.

All cases were performed via a standardized minimally invasive direct anterior or anterolateral approach in a supine position under spinal or general anesthesia. The procedure was performed or supervised by experienced arthroplasty surgeons of each institution (>100 THA/yearly). The implants used in the current study included a cementless acetabular component (RM Pressfit vitamys, Mathys, Switzerland) and a cementless short femoral stem (optimys, Mathys, Bettlach, Switzerland). The optimys femoral stem is a meta-diaphyseal anchoring, partially femoral neck preserving, calcar guided, short-stem prosthesis, which allows good

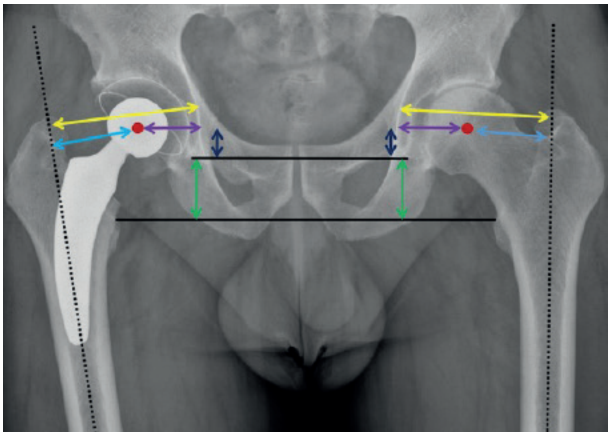

Figure 1. — Radiologic parameters measured on a standardized anteroposterior radiograph of the pelvis. The contralateral native hip was used as reference. The center of rotation is marked with a red circle. The anatomical axis of the femur is shown with a dotted black line. The more distal edge of the teardrops and the more proximal points of the lesser trochanter are connected with black lines (inter-teardrop and inter-trochanter lines, respectively). The leg length was defined as the distance between the inter-teardrop and inter-trochanter line (green arrow). The femoral offset is shown with a light blue arrow as the distance between the long axis of the femur and the center of the femoral head, whereas the acetabular offset with a purple arrow as the distance between the true floor of the acetabulum and the center of the femoral head. The vertical center of rotation is shown with a blue arrow as the distance between the inter-teardrop line and the center of the femoral head.

bone contact at the distal lateral and the proximal medial cortex with intact greater trochanter region. Additionally, its triple conical shape and the coating allows an good primary and secondary stability (Figure 1).

The patients were followed-up clinically and radiographically at 3, 6, 12, 24 and 60 months postoperatively. The clinical examination, visual analog scale (VAS) for pain at rest and pain under load and satisfaction, as well as the Harris hip score (HHS) was performed in a standardized matter. The patient satisfaction was assessed on a scale of 0 to 10. HHS was defined as followed : excellent HHS : 90 to 100, good HHS : 80 to 89 and fair HHS : 70 to 79.

For the pre- and postoperative radiographs, a standardized protocol have been applied by holding the lower limbs together in a positioning splint with 20° internal rotation, and the anterior superior iliac spine parallel to each other and the X-ray table. A standard AP pelvis and lateral radiograph of the hip were obtained at all follow-ups. The measurement of the radiological parameters was performed at the first follow-up. The contralateral native hip was used as reference. The femoral head (28mm, 32mm or 36mm) was used for calibration of the X-rays. Radiographs of each visit were then compared to the initial postoperative radiograph to evaluate for component loosening.

The total offset (TO) was defined as the perpendicular distance between the true floor of the acetabulum and the long axis of the femur. The femoral offset (FO) was defined as the distance between the long axis of the femur and the center of the femoral head (light blue arrow ; figure 1). The acetabular offset (AO) was defined as the distance between the true floor of the acetabulum and the center of the femoral head (purple arrow ; Figure 1). Leg-length (LL) was defined as the distance between the lines that connect the lowest edge the teardrops (inter-teardrop line) and the most proximal part of the lesser trochanter (inter-trochanter line) (green arrow ; Figure 1. The vertical center of rotation (vCOR) was defined as the vertical distance between the inter-teardrop line and center of the femoral head (dark blue arrow ; Figure 1). A negative difference between THA and contralateral native hip for the AO indicated that the acetabular cup was implanted more medial.

The postoperative X-rays were evaluated using the mediCAD Classic software (Version 2.50 ; Hectec GmbH, Landshut, Germany). Intra-observer and inter-observer reliabilities of the measurements were evaluated with two observers using Pearson correlation.

A power analysis was performed to estimate the required total sample size as a function of power 1-β with medium effect size and $\alpha = 0.05$, to detect a difference in LL, FO, AO, and vCOR using SCOPE (Vs. 2.0.2015, numerics data GmbH, Zurich, Switzerland). Descriptive statistics used median and range to present the data. The Wilcoxon signed-rank test was applied. Univariate logistic regression was used to determine radiological factors which correlate to clinical outcome as such as rest pain, load pain, unsatisfied patients, HHS or limping (out of HHS). All statistical analyses were performed using SAS 9.2 (SAS Institute Inc., Cary, North Carolina, USA).

RESULTS

According to the power analysis, a total of 106 patients were necessary to achieve a statistical power of 80%. The intra- and interobserver Pearson correlation coefficient ranged from 0.90 to 0.94, and 0.54 to 0.89, respectively.

A total of 114 consecutive patients (Male : 61, Female : 53) with an median age of 66.7 years (range : 43 to 85 years) met the inclusion criteria of the current study (table 1). Indication for surgery was in 103 cases (90%) osteoarthritis, in 5 cases (4%) avascular necrosis, in 4 cases (4%) congenital dysplasia and in 2 cases (2%) inflammatory arthritis (table 1). A minimally invasive anterior and anterolateral approach was performed in 72 (63%) and 42 (37%) cases, respectively. No patient was lost during the 5-years follow-up.

Table 1. — Patient characteristics, surgical approach, and diagnosis. The values were given in median and range. OA: Osteoarthritis, BMI: (Body mass index)

Patient demographics	Patients (n=114)
Age (Years)	66.7 (43.3, 85)
Gender	
Male (n)	53 (47%)
Female (n)	61 (53%)
Follow up (months)	57 (22, 86)
Surgical Approach	
Anterior (n)	72 (63%)
Anterolateral (n)	42 (37%)
Diagnosis	
Primary OA (n)	96 (84%)
Secondary OA (n)	7 (6%)
Osteonecrosis (n)	5 (4%)
Congenital dysplasia (n)	4 (4%)
Inflammatory arthritis (n)	2 (2%)

The average HHS improved significantly from 52 points (range, 11 to 84 points) preoperative to 100 points (range : 74 to 100 points ; p < 0.05) at the last follow-up, on average 5 years following THA (range : 22.0-86.0 months) (Table 2). At that time, 95.6 % of the patients showed excellent, 2.6 % good, and 1.8 % fair functional outcomes. The average pain at rest decreased from an average of 4 points (range : 0 to 10 points) preoperatively to 0 points postoperatively (range : 0 to 3 points ; p < 0.05), with 95.6 % of all patients having no pain at rest (Table 2). The loading pain improved from 7 points (range : 1 to 10 points) preoperatively to 0 points postoperatively (range : 0 to 4 points ; p < 0.05), with 84.2 % of all patients had no loading pain. The patient satisfaction improved significantly from an average of 3 points (range : 0 to 9 points) preoperatively to an average of 10 points (range : 7 to 10 points ; p< 0.05) postoperatively, with 83.3 % of all patients been extremely satisfied (satisfaction : 10/10) (Table 2).

At the first radiologic evaluation, the FO increased significantly at an average of 5 mm (range : -12 to 23 mm, p<0.05) in THA, compared to the contralateral native hip, with an average FO in THA and contralateral native hip of 44 mm (range : 25 to 69 mm) and 39 mm (range : 17 to 56 mm), respectively. The AO on the other hand decreased significantly at an average of -4 mm (range : -14 to -2 mm, p<0.05) in THA, compared to the contralateral native hip, resulting in medialization of the COR, with an average AO in THA and contralateral native hip of 29 mm (range, 21 to 39 mm) and 33 (range : 23 to 44 mm), respectively. As a result, no significant difference was observed

Table 2. — Clinical outcomes preoperatively and at the 5-years follow-up. The functional outcomes at 5-years follow-up were also presented according to the surgical approach. *Indicates statistically significant difference. Data reported as median (range)

Parameter	Preoperative	Postoperative	p-value	Anterior Approach postoperative	Anterolateral Approach postoperative	p-value
Harris Hip Score	51.5 (11, 84)	100 (74, 100)	**<.05***	100 (78, 100)	98 (74, 100)	**<.05***
Rest pain	4 (0, 10)	0 (0, 3)	**<.05***	0 (0, 2)	0 (0,3)	>.05
Loading pain	7 (1, 10)	0 (0, 6)	**<.05***	0 (0,3)	0 (0,4)	>.05
Satisfaction	3 (0,9)	10 (7,10)	**<.05***	10 (9,10)	10 (7,10)	>.05

Table 3. — Radiological parameters as measured at the first follow-up. *Indicates statistically significant difference. A negative difference between THA and contralateral native hip for the acetabular offset indicated that the acetabular cup was implanted more medial. Median (Range)

Parameter	**THA**	**Native contralateral hip**	**p-value**	**Anterior Approach**	**Anterolateral Approach**	**p-value**
				Difference between THA and native contralateral hip		
Leg length (mm)	36.5 (22, 56)	36 (22,51)	**<.05***	0 (-17, 11)	4 (-8, 16)	**<.05***
Femoral offset (mm)	44 (25, 69)	39 (17, 56)	**<.05***	3 (-12, 14)	10 (-3, 23)	**<.05***
Acetabular Offset (mm)	29 (21,39)	33 (23, 44)	**<.05***	-4 (-12, -4)	-4.5 (-14, -5)	>.05
Total Offset (mm)	73 (55, 98)	71 (53, 95)	>.05	-1,5 (-15, 11)	5.5 (-11, 22)	**<.05***
Vertical center of rotation (mm)	16 (4, 30)	12 (2, 22)	**<.05***	3 (-7, 20)	5 (-6, 15)	>.05

between THA and contralateral native hip regarding TO (1 mm increase, p>0.05), with an average TO of the THA and contralateral native hip of 72 mm (range : 55 to 98 mm) and 71 mm (range : 53 to 95 mm), respectively (Table 3).

The LL increased significantly at an average of 2 mm (range : -17 to 16 mm ; p< 0.05) in THA, compared to the contralateral native hip, with an average LL in THA and contralateral native hip of 38 mm (range, 22 to 56 mm) and 36 mm (range : 22 to 51 mm), respectively. Of the radiological parameters examined in the present study, the only significant correlation was between LL and loading pain. Specifically, the absolute LL difference was positively correlated with loading pain (p<0.05)

The vCOR increased significantly at an average of 4 mm (range : 2 to 22 mm, p<0.05) in THA, compared to the contralateral native hip, with an average vCOR in THA and contralateral native hip of 16 mm (range : 4 to 10 mm) and 12 mm (range : 2 to 22 mm), respectively.

At the last follow-up, patients treated through a minimally invasive direct anterior approach had an average HHS of 100 points (range : 78 to 100 points), rest pain of 0 points (range : 0 to 2 points), loading pain of 0 points (range : 0 to 4 points) and patient satisfaction of 10 points (range : 9 to 10 points). In comparison, patients treated with a minimally invasive anterolateral approach, reported an average HHS of 98 points (range : 74 to 100 points) ; p < 0.05), rest pain of 0 points (range : 0 to 3 points) ; p < 0.05), loading pain of 0 points (range : 0 to 5 points) ; p < 0.05) and an average patient satisfaction of 10 points (range : 7 to 10, p < 0.05) (Table 2).

In patients treated with the direct anterior approach and anterolateral approach, the average LL difference between THA and contralateral native hip was 0 mm (range : -17 to 11 mm. p>0.05) and 4 mm (range : -8 to 16mm, p < 0.05), respectively (Table 3). The TO decreased by an average of 1.5 mm (range : -15 to 11 mm, p<0.05) in the direct anterior approach group, whereas it increased by an average of 5.5 mm (range : -11 to 22 mm, p < 0.05) in the anterolateral approach group, compared to the contralateral native hip. The FO increased by an average of 3 mm (range : -12 to 14 mm, p<0.05) in the direct anterior approach group, whereas it increased by an average of 10 mm (range : -3 to 23 mm, p < 0.05) in the anterolateral approach group, compared to the contralateral native hip. Finally, the vCOR increased by an average of 3 mm (range : -7 to 20 mm) and 5 mm (range : -6 to 15 mm), with the anterior and anterolateral approach, respectively (p>0.05) compared to the contralateral native hip.

DISCUSSION

The surgical goal of total hip arthroplasty (THA) is to restore the native hip anatomy, especially the total offset (TO), leg length (LL), and center of rotation (COR). Although several studies examined, whether conventional stem with diaphyseal anchoring could reconstruct hip anatomy *(8,24)*, relatively few data are available regarding the postoperative results of a calcar guided short femoral stem, implanted through a minimally invasive approach regarding native hip anatomy restoration. Therefore, the aim of the present study was to investigate whether a calcar guided short femoral stem in combination with a monoblock cup, implanted through a minimally invasive approach could restore TO as well as LL, and provide satisfactory clinical outcomes at 5-years follow-up. The HHS improved significantly at an average of 46 points following the short-stem THA. The rest pain and loading pain decreased significantly from an average VAS of 4 and 7 points preoperative to VAS 0 and 0 points postoperative, respectively. The patient satisfaction improved significantly from an average of 3 points preoperatively to an average of 10 points postoperatively. Compared to the contralateral native hip the femoral offset (FO) increased at an average of 5mm, the acetabular offset (AO) decreased at an average of 4 mm, resulting in only 1 mm increase of the TO. The LL increased by an average of 2 mm compared to the contralateral native hip. The results of the present study might suggest that short-stem THA implanted through a minimally invasive approach could restore native hip anatomy in terms of TO as well as LL and provide excellent functional outcomes and patient satisfaction 5-years following THA.

To the current date, relatively few studies investigated the clinical outcomes following the short femoral stem THA, implanted through a minimally invasive approach. Specifically, Kutzner et al. *(18)* using the same short stem design, implanted using the standard anterolateral approach reported an increase of the HHS from 45.8 points preoperatively to 98.1 points, at 2-years postoperatively. The average satisfaction at 2 years following THA was 9.7/10. Regarding other short stem designs, a recent meta-analysis *(14)* reported similar functional outcomes in patients who underwent a THA with a short-stem and conventional stem design, but with significantly higher reported thigh pain in conventional stem THA (RR :0.15, P<0.05). In accordance with the literature, we reported excellent functional outcomes with 46 points average increase in HHS, no rest and loading pain, and an excellent patient satisfaction on average 5-year following the implantation of a calcar guided, short-stem THA, using a minimally invasive approach.

The calcar guided short femoral stem could reproduce hip anatomy in terms of total offset and leg-length in the majority of the patients. Kutzner et al. *(19)* using the same short femoral stem reported an average increase of 2 mm in total offset following THA compared to the preoperative osteoarthritic hip. The average leg-length discrepancy was 2.9 mm in the same study, with 18.3% discrepancies of more than 1 cm. Similarly, in the present study, we found no significant difference in TO between the calcar guided short-stem THA and contralateral native hip. The LL discrepancy increased at an average of 2 mm in our study with 11% showing a discrepancy of more than 1 cm. In the literature the average LL and FO difference and between right and left hip joints in healthy subjects was 2.5 mm (range : 0.2 to 10.3 mm) and 2.9 mm (range : 0 to 8.5 mm), respectively, with no clinical relevance in the majority of the cases *(6)*.

Another important point is that although the AO decreased at an average of 4 mm in THA, resulting in medialization of the COR, the calcar guided short femoral stem could compensate with an increase in femoral offset. As a result, no significant difference was observed in TO between the THA and contralateral native hip. A medialization of the COR is typical using cementless acetabular component implanted with the press-fit principle *(4)*, as it requires a sufficient cavity of the acetabulum to achieve a stable situation. Therefore, the femoral stem should compensate the loss of acetabular offset by increasing the femoral offset, in order to prevent a loss of total offset loss. In a recent study of 197 THA implanted using Metha (B.Braun Melsungen) and Mayo (Zimmer) short-stems with cementless press-fit cups, Höhle et al. *(13)*, reported an average reduction of the acetabular offset by 4.9 mm. However, the examined short-stems could not compensate for the loss of acetabular offset and showed an addition average loss of 0.7 mm in FO with a TO loss of 5.6 mm.

The minimally invasive anterior approach could better reconstruct hip anatomy regarding TO, LL and vCOR compared to the anterolateral approach, but both techniques showed excellent clinical outcomes 5-years postoperative. Patients who were treated through a direct anterior approach have slightly better clinical outcome values (HHS : anterior 98 vs. anterolateral 95). However the average HHS values were excellent for both groups and a clinical relevance of the observed difference is somewhat doubtful. This is also supported by the literature, as a recent meta-analysis *(21)* reported no difference in long-term outcomes of the anterior approach compared to other approaches. Regarding radiological parameters Bernasek et al. *(3)* compared the femoral stem alignment in 92 THA, performed through a minimally invasive anterolateral and lateral approach and reported an 18% and 0% varus stem implantation, respectively. Furthermore, the leg length discrepancy was 19% and 7% in a minimally invasive anterolateral and lateral approach, respectively. In our study, a significant difference was observed between the anterior and anterolateral approach regarding LL discrepancy and TO, between THA and native contralateral hips. In minimally invasive anterior approach, no LL discrepancy was observed, and the average TO decreased by 1.5 cm in THA, whereas in minimally invasive anterolateral approached an average LL increase of 4 mm, and 5.5 mm increase in TO was observed in the THA compared to the contralateral native hip. These data might suggest that the discrepancies in TO and LL should be considered during the minimally invasive anterolateral approach to prevent a malalignment of the femoral component and leg length discrepancy.

The present study should be interpreted in light of its potential limitations. The main drawback is the absence of another short-stem design or conventional stem as a control group. However, the purpose of this study was to report the midterm clinical outcomes and examine the reproducibility of hip anatomy using a calcar guided short femoral stem. Since there is no gold standard, short or conventional femoral stem used in THA, the comparison should have given the potential benefits or disadvantages of the calcar guided stem over the controlled stem design and the findings would not have been applicable in other stem designs. Furthermore, in the present study were included patients treated with a minimally invasive anterior or anterolateral approach. Therefore our results might not reflect stem alignment of patients treated with a different surgical technique. The current study investigated only the optimys short femoral stem. Although this design is similar to other short stem implants available, our findings might not apply to other stem designs.

In conclusion, a calcar guided short femoral stem, implanted through a minimally invasive approach could restore native hip anatomy in terms of TO as well as LL, and provide excellent functional outcomes and patient satisfaction 5-years following THA. Surgeons performing THA with minimally invasive anterolateral approach should be aware of the discrepancies in TO and LL to prevent a malalignment of the femoral component.

Acknowledgments

We thank Cagdas Kays for conducting the second measurements of the X-rays for the assessment of the inter-observer variability and Prof. em. Dr. Jürg Hüsler assisted with statistical analysis. We also thank the following medical advisors and their teams for the data collection : Prof. Joachim Pfeil, Prof. Werner Siebert, Dr. Dominique Bosson, and Dr. Franziska Juch

REFERENCES

1. **Acklin YP, Jenni R, Bereiter H, *et al.*** Prospective clinical and radiostereometric analysis of the Fitmore short-stem total hip arthroplasty. *Arch. Orthop. Trauma Surg.* 2016 ; 136 : 277-284.
2. **Barrack RL**. Dislocation after total hip arthroplasty : implant design and orientation. *J. Am. Acad. Orthop. Surg.* 2003 ; 89-99.
3. **Bernasek TL, Lee WS, Lee HJ, *et al.*** Minimally invasive primary THA : Anterolateral intermuscular approach versus lateral transmuscular approach. *Arch. Orthop. Trauma Surg.* 2010 ; 130 : 1349-1354.
4. **Bonnin MP, Archbold PHA, Basiglini L, *et al.*** Do we medialise the hip centre of rotation in total hip arthroplasty? Influence of acetabular offset and surgical technique. *Hip Int.* 2012 ; 22 : 371-378.
5. **Culliford D, Maskell J, Judge A, *et al.*** Future projections of total hip and knee arthroplasty in the UK : Results from the UK Clinical Practice Research Datalink. *Osteoarthr Cartil* 2015 ; 23 : 594–600.
6. **Dimitriou D, Tsai TY, Yue B, *et al.*** Side-to-side variation in normal femoral morphology : 3D CT analysis of 122 femurs. *Orthop. Traumatol.Surg. Res.* 2016 ; 102 : 91-97.

7. **Ethgen O, Bruyerè O, Richy F, *et al.*** Health-Related Quality of Life in Total Hip and Total Knee Arthroplasty : A Qualitative and Systematic Review of the Literature. *J. Bone Jt. Surg. - Ser A* 2004 ; 963-974.
8. **Flecher X, Ollivier M, Argenson JN**. Lower limb length and offset in total hip arthroplasty. *Orthop. Traumatol. Surg. Res.* 2016 ; S9-S20.
9. **Floerkemeier T, Budde S, Gronewold J, *et al.*** Short-stem hip arthroplasty in osteonecrosis of the femoral head. *Arch. Orthop. Trauma Surg.* 2015 ; 715-722.
10. **Garellick G, Kärrholm J, Rogmark C, *et al.*** Swedish Hip Arthroplasty Register - Annual Report 2009. 2010.
11. **Gustke K**. Short stems for total hip arthroplasty : initial experience with the Fitmore stem. *J. Bone Joint Surg. Br.* 2012 ; 94 : 47-51.
12. **Hill JC, Archbold HAP, Diamond OJ, *et al.*** Using a calliper to restore the centre of the femoral head during total hip replacement. *J. Bone Jt. Surg. - Ser B* 2012 ; 94 B : 1468-1474.
13. **Höhle P, Schröder SM, Pfeil J**. Comparison between preoperative digital planning and postoperative outcomes in 197 hip endoprosthesis cases using short stem prostheses. *Clin. Biomech.* 2015 ; 30 : 46-52.
14. **Huo SC, Wang F, Dong LJ, *et al.*** Short-stem prostheses in primary total hip arthroplasty A meta-analysis of randomized controlled trials. *Medicine (Baltimore)* 2016.
15. **Kellgren JH, Lawrence JS**. Radiological assessment of osteo-arthrosis. *Ann. Rheum. Dis.* 1957 ; 16 : 494-502.
16. **Kennedy JG, Rogers WB, Soffe KE, *et al.*** Effect of acetabular component orientation on recurrent dislocation, pelvic osteolysis, polyethylene wear, and component migration. *J. Arthroplasty* 1998 ; 13 : 530-534.
17. **Kurtz SM, Lau E, Ong K, *et al.*** Future young patient demand for primary and revision joint replacement : National projections from 2010 to 2030. *Clin. Orthop. Relat. Res.* 2009 ; 2606-2612.
18. **Kutzner KP, Hechtner M, Pfeil D, *et al.*** Incidence of heterotopic ossification in minimally invasive short-stem THA using the modified anterolateral approach. *Hip Int.* 2017 ; 2 : 162-168.
19. **Kutzner KP, Kovacevic MP, Roeder C, *et al.*** Reconstruction of femoro-acetabular offsets using a short-stem. *Int. Orthop.* 2015 ; 39 : 1269-1275.
20. **Kwon Y-M, Mellon SJ, Monk P, *et al.*** In vivo evaluation of edge-loading in metal-on-metal hip resurfacing patients with pseudotumours. *Bone Joint Res.* 2012 ; 1 : 42-49.
21. **Meermans G, Konan S, Das R, et al**. The direct anterior approach in total hip arthroplasty a systematic review of the literature. *Bone Jt J* 2017 : 732–740.
22. **Patel AB, Wagle RR, Usrey MM, et al**. Guidelines for Implant Placement to Minimize Impingement During Activities of Daily Living After Total Hip Arthroplasty. *J. Arthroplasty* 2010 ; 25 : 1275-81.
23. **Renkawitz T, Haimerl M, Dohmen L, *et al.*** The association between Femoral Tilt and impingement-free range-of-motion in total hip arthroplasty. *BMC Musculoskelet Disord.* 2012 ; 13.
24. **Tsai TY, Dimitriou D, Li G, *et al.*** Does total hip arthroplasty restore native hip anatomy? Three-dimensional reconstruction analysis. *Int. Orthop.* 2014 ; 38 : 1577-1583.