



A prospective dual-energy X-ray absorptiometry study of bone remodeling after implantation of the Nanos[®] short-stemmed prosthesis

Alexander ZEH, Franziska PANKOW, Marc RÖLLINHOFF, Stefan DELANK, David WOHLRAB

From Martin-Luther-University-Halle-Wittenberg, Germany

The aim of this study was to analyze the bone remodeling around the Nanos[®] stem (Smith & Nephew, Marl, Germany) after primary total hip arthroplasty for coxarthrosis.

In 25 patients (15 male, 10 female, mean age 59.9 years) with the diagnosis of coxarthrosis, a DEXA scan was performed immediately after surgery, 97 days (SD 6.1 days) and 368 days (SD 6.2 days) after implantation of a Nanos[®] prosthesis. Plain radiographs were analyzed digitally for radiolucent lines, varus-valgus femoral stem alignment, measurement of stem migration and changes in varus-valgus femoral stem alignment. The position of the center of rotation (COR) and the offset were assessed pre- and postoperatively. Harris Hip Score was used to evaluate the clinical outcome.

The DEXA scan showed a significant and relevant increase in BMD (Bone Mineral Density) in Gruen-Zone 6 (12%) and a decrease in Zone 1 (15%), 2 (5%) and 7 (12%), which was interpreted as reflecting a distal load transfer in the metaphysis of the femur.

There was no clinically relevant migration or tilting of the Nanos[®] stem. Radiolucent lines were noted in 12 cases, mainly at the polished tip area of the prosthesis; this was not regarded as a sign of impaired osseointegration. There was no significant difference between the position of the COR and the pre- and postoperative offset.

The absence of stem migration, angulation, or relevant radiolucent lines is seen as evidence for an unimpaired osseointegration of the Nanos[®] stem approximately 12 months after implantation. It is concluded that the Nanos[®] prosthesis can reduce loss of

BMD of the proximal femur composed with conventional stems or other short-stemmed implants.

Keywords : DEXA ; Nanos ; bone remodeling ; THA.

INTRODUCTION

The use of short-stemmed femoral prostheses in hip arthroplasty has increased in the past few years, as shown by the development of several such stems by different manufacturers (12).

Short-stemmed femoral implants were designed to achieve a proximal load transfer in the femoral metaphysis. Metaphyseal fixation is seen as a precondition for exclusive metaphyseal load transfer. The preservation of the metaphyseal bone is

-
- Alexander Zeh, MD, Attending Orthopaedic Surgeon, Assistant Professor.
 - Franziska Pankow, Medical Student.
 - Marc Röllinghoff, MD, Orthopaedic Surgeon.
 - Stefan Delank, Professor, Chief of the Department.
 - David Wohlrab, Professor, Senior Attending Orthopaedic Surgeon.

Department of Orthopaedic Surgery and Traumatology, Martin-Luther-University of Halle-Wittenberg, Faculty of Medicine, Halle/Saale, Germany.

Correspondence : Alexander Zeh, MD, Department of Orthopaedic Surgery and Traumatology, Martin-Luther-University of Halle-Wittenberg, Faculty of Medicine, Halle/Saale, Germany. E-mail : alexander.zeh@uk-halle.de

© 2013, Acta Orthopædica Belgica.

regarded as advisable to facilitate an exchange from a short-stemmed to a conventional prosthesis, for instance, in aseptic loosening. For this reason, the short-stemmed prosthesis is increasingly recognized as a useful alternative for THA in young patients (12,18).

However, there are reports suggesting that short-stemmed implants cannot provide the postulated proximal load transfer and therefore do not allow for preservation of metaphyseal bone (10,19).

This study investigated the bone remodeling after implantation of a Nanos® prosthesis in order to analyze whether a proximal load transfer could be achieved with this short-stemmed femoral implant.

PATIENTS AND METHODS

A Nanos® short-stemmed femoral prosthesis (Smith & Nephew, Marl, Germany) was implanted in 25 patients, 15 male, 10 female, with an average BMI of 29 (SD 4.0) and an average age of 59.9 years (SD 8.2); the indication for arthroplasty was osteoarthritis: primary coxarthrosis in 21, secondary coxarthrosis in 4 (2 dysplasias, 1 AVN, 1 femoral head epiphysiolysis) patients. A Trilogy® cup (Zimmer, Warsaw, U.S.A.) was used in all cases. After surgery, all patients were mobilized, full weight bearing. A prospective follow-up (FU) was planned consisting of the assessment of the stem positioning, regarding varus and valgus, the measurement of longitudinal stem migration and tilt of the femoral stem at 3 and 12 months postoperatively and a DEXA scan (Lunar iDXA, Fa. Lunar Coop., Wisconsin, USA) of the operated hip immediately postoperatively and at 3 and 12 months postoperatively. BMD was measured in the anteroposterior x-ray films and associated with the Gruen Zones (11). Furthermore, the occurrence of radiolucent lines was noted 12 months postoperatively. The Harris Hip Score was assessed preoperatively and at 3 and 12 months postoperatively.

The preoperative anteroposterior radiographs of the operated hip and those taken 97 (SD 9.8) days postoperatively were analyzed regarding the CCD (caput collum diaphysis) angle, center of rotation (COR) and offset according to the method described by Jerosch *et al* (15).

The longitudinal migration as well as the varus or valgus tilt of the Nanos® Stem was determined by one examiner in the first post-surgical radiograph (FU 1), as well as in anteroposterior films after an average of 97 days (SD 6.1) (FU 2) and an average of 368 days (SD 6.2) (FU 3) using the Wristing® digital software (3).

The measurement of longitudinal migration was defined as a decrease in the distance between the tip of the lesser trochanter (a) and the tip of the prosthesis (b).

The magnification factor was determined on all AP x-ray images by measurement of the diameter of the implanted cup, the real outer diameter of which was known (Fig. 1a).

The tilt of the femoral stem was defined as the angle between the tangent to the medial implant surface and the proximal femur axis in the anteroposterior radiographs (Fig. 1b).

In order to calculate the positioning of the implant regarding varus/valgus, information from the manufacturer was obtained about the angle between the measured tangent at the medial implant surface and the centerline of the taper/neck of the implant. A calculated angle between the centerline of the taper/neck of the implant and the proximal femur axis in the anteroposterior x-rays below 125° was defined as neutral/varus positioning. If this angle was 125° or above, the implant positioning was defined as valgus.

As these measurements are potentially influenced by a different rotational positioning of the proximal femur, positioning aids during anteroposterior radiographs and DEXA of the hip joint were used routinely.

The error of the measurement of migration and angulation of a femoral stem by means of the Wristing® digital software was assessed as 2 mm and 3° respectively. Therefore, a significant migration or change of tilt of the femoral stem was defined as a difference of at least 2 mm or 3° respectively (22).

The incidence of periprosthetic radiolucent lines (RL) captured in the anteroposterior x-ray pictures was associated with the Gruen Zones (11). A radiolucency at least 1 cm long and 1mm thick between the prosthesis and the surrounding bone was defined as a radiolucent line (27).

The statistical analysis was performed with SPSS (IBM SPSS Statistics, Version 19, IBM Company). Significant differences for normal distributed data between different follow-ups were explored by paired t-tests and significant differences between different study groups (DEXA) by unpaired t-tests. If a normal distribution was not present, the Wilcoxon-Test and the Mann-Whitney-U-Test respectively were performed. The level of significance was defined as $p < 0.05$.

RESULTS

The assessment of the preoperative and postoperative offset and center of rotation did not show a significant difference (Table I).

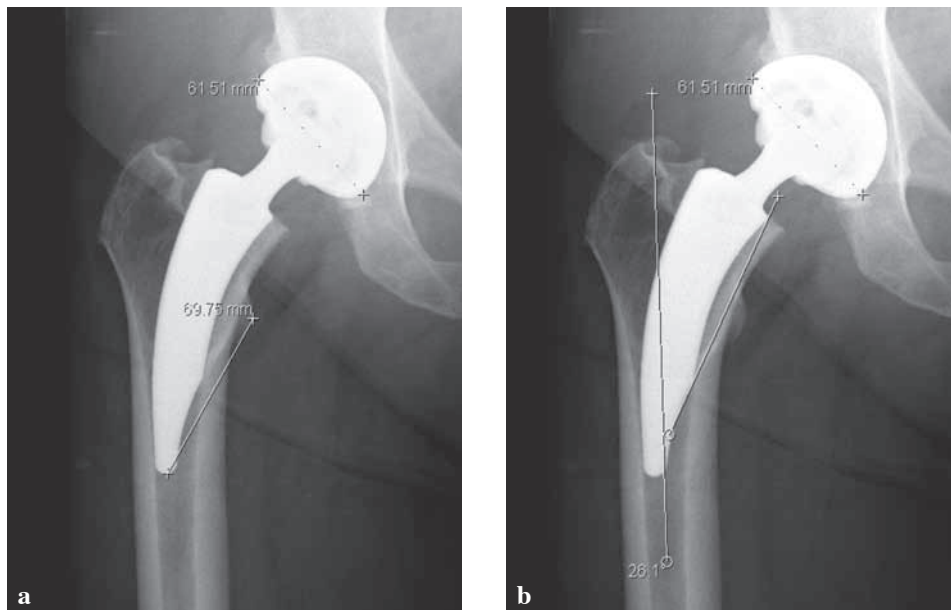


Fig. 1. — Measurement of distance „ab“ (left) and measurement of stem angulation (right)

Table I. — Migration and alignment of femoral component CCD, Off-set and COR

Follow-up on average	preop.	FU 1 4.6 days (sd = 1.2 days)	FU 2 97 days (sd = 6.1)	FU 3 368 days (sd = 6.2)
n	25	25	25	25
Distance „ab“* (mm)		50.1	50.6 $p=0.002^{\#}$	50.5 $p=0.5^{\#}$
sd		6.9	6.6	6.9
Stem alignment*		134.6°	134.0° $p=0.001^{\#}$	133.7° $p=0.001^{\#}$
sd		4.3°	4.6°	4.6°
CCD (°)	127 (sd= 7)	n.a.		
COR (mm)	20.3	21.0 $p=0.4^{\#}$		
sd	4.6	5.06		
Offset (mm)	45.9	45.6 $p=0.7^{\#}$		
sd	7.8	10.0		

(Distance „ab“= “ (tip of lesser trochanter – apex of femoral component).

* = average, # = result of paired t-test, postop. = postoperatively, FU = follow-up, sd = standard deviation, stem alignment = varus/valgus (increased values indicate varisation of femoral component).

CCD = caput collum diaphysis angle, stem alignment = varus/valgus (increased values indicate varisation of femoral component), COR = centre of rotation.

The statistical analysis of the measured stem migration and stem positioning showed a significant difference after 97 days (FU 2) and 368 days (FU 3) (Table II). These significant differences were regarded as clinically not relevant because they are

extremely small and within the measurement error for stem migration and angulation measurements of the Wristing® software (22).

The calculated postoperative CCD angle was 133° (sd = 4.6°). In none of the cases was a neutral

Table II. — Results of DEXA

	direct postop. BMD (g/cm ²) n = 25	BMD at FU 2 (97 days postop.) (g/cm ²) n = 19	BMD at FU 3 (368 days postop.) (g/cm ²) n = 23
Zone 1*(sd)	1.04 (0.2)	0.95 (0.2) ^{p=0.001}	0.88 (0.2) ^{p=0.001}
Zone 2*(sd)	1.79 (0.4)	1.69 (0.3) #	1.70 (0.3) ^{p=0.01}
Zone 3*(sd)	2.26 (0.3)	2.23 (0.2) #	2.22 (0.3) #
Zone 4*(sd)	2.13 (0.3)	2.03 (0.3) ^{p=0.001}	2.10 (0.4) #
Zone 5*(sd)	2.14 (0.3)	2.07 (0.3) #	2.13 (0.4) #
Zone 6*(sd)	1.58 (0.3)	1.71 (0.3) ^{p=0.004}	1.77 (0.4) ^{p=0.006}
Zone 7*(sd)	1.52 (0.2)	1.38 (0.2) ^{p=0.009}	1.34 (0.2) ^{p=0.001}

(* = average, # = not statistically different to study group (paired t-test, $p \geq 0.05$), p values = results of paired t-test, BMD = Bone Mineral Density, n preop. = preoperatively, postop. = postoperatively).

or varus stem positioning found following the definition used in this study (Table I).

Fifteen radiolucent lines were found in 12 cases on average 368 days postoperatively. In 8 cases, a radiolucent line was located at the polished tip area of the prosthesis only, which was not regarded as a sign for impaired osseointegration. In a further 2 cases, there was one additional radiolucent line in zone 4. In the remaining 2 cases, radiolucent lines were found in no more than in 2 non connected Gruen-Zones. None of the RL's exceeded 2 mm thickness.

The evaluation of the DEXA scan preoperatively and on average 97 days (FU 2) and 368 days (FU 3) postoperatively showed a significant difference in Zone 1, 2, 6, and 7. In Zone 1, 2 and 7, a constant significant decrease was detected, whereas Zone 6 showed a significant increase at FU. There was also a very small difference in the BMD in Zone 4 at FU 2, which was regarded to be clinically irrelevant. In addition, this difference was absent at FU 3. For organizational reasons, only 23 patients could be evaluated by DEXA at FU 3 (Table II).

Two of the patients (8%) showed an intra-operative fissure, which was treated as described in a previous publication (25). No other complications occurred.

For FU 2 and 3, an HHS of 83 (min = 48, max = 100, SD = 14) and 94 (min = 84, max = 100,

SD = 4) was calculated. There was a significant improvement during the follow-up (paired t-test).

DISCUSSION

In recent years, the use of short-stemmed prostheses has considerably intensified, which was demonstrated by the development of numerous models of this type of prosthesis from different manufacturers (12). Short-stemmed femoral implants were mainly designed to achieve a proximal load transfer to avoid a distal osseointegration, which is proven to lead to proximal femoral stress-shielding in so-called conventional stems (7,12,18,24).

It remains controversial whether the implantation of short-stemmed femoral prostheses leads to an exclusively metaphyseal stress distribution. Some authors (6,8,13,23,26) found evidence for a proximal load transfer and an increased or persisting high bone mineral density (BMD) of the femoral metaphysis after implantation of a short-stemmed femoral prosthesis; others could not confirm these findings (10,19).

In a prospective randomized trial, Hube *et al* (2004) investigated the osseointegration of the Mayo[®]-Stem (Zimmer, Warsaw, USA) compared with the ABG[™] - Prosthesis (Stryker GmbH & Co. KG, Duisburg, Germany) in 93 patients with the use of DEXA scans. They found an increase of BMD



Fig. 2. — Example of a DEXA of the Nanos™-prosthesis with defined modified Gruen-Zones.

after implantation of the Mayo®-Stem in the calcar region approximately 12 months after implantation (14). This was in contrast to the ABG™-Prosthesis, which showed a decrease of BMD in of the proximal femur suggesting a distal fixation of the implant. The authors interpreted this loss of bone mass as a proximal located stress-shielding (14).

Logroscino *et al* (2011) evaluated the osseointegration of two different partial neck retained stemless hip prostheses at one year after surgery, measured by the changes in periprosthetic BMD using dual-energy X ray absorptiometry. Thirty-two uncemented primary total hip arthroplasty (THA) patients allocated into 2 groups were evaluated. Both short-stemmed implanted prostheses (19 Proxima (De-Puy-J&J), 12 Nanos® (Smith & Nephew)) showed preservation of metaphyseal bone stock and increased periprosthetic BMD. With Nanos® prostheses, significantly higher BMD values were observed within the metaphysis of the femur (17).

DEXA scans are widely accepted to investigate the osseointegration of femoral stems (1,2,4,5,20). This method is regarded to assess accurately the BMD during the postoperative follow-up which

allows conclusions considering the load transfer induced by the femoral implant (21).

The finding of a significant and constant decrease of the BMD in Zone 1, 2, and 7 of 15%, 5%, and 12% in our study group during the follow-up is interpreted as a result of a distally located load transfer and a moderate proximally located stress-shielding. This conclusion is supported by the presence of a significant moderate increase of BMD in Gruen-Zone 6 of 12% at FU 3. According to the definition of the Gruen-Zones in this study, Zone 6 is located lower than the minor trochanter. This means that only a limited increase or preservation of bone mass at the calcar region can be achieved. The long-term preservation of bone of the calcar region is one of the main goals using short-stemmed prostheses instead of so-called conventional stems (12).

On the other hand, the bone loss in Gruen-Zone 7 was regarded as rather low after approximately one year postoperatively. This finding is in accordance with the report of Götze *et al* (2010) who found in their study on the osseointegration of the Nanos®-Prosthesis a bone loss of approximately 7% at the calcar region and 6% at the major trochanter (10).

Compared to results of other analyses of the osseointegration of short-stemmed femoral implants, these findings suggest only a moderate bone loss at the calcar region after implantation of the Nanos®-Stem approximately one year postoperatively. For the Mayo®-short-stemmed prosthesis, for instance, a bone loss between 15% and 18% was described previously (4).

Furthermore, we cannot endorse the conclusion of Götze *et al* (2010), as we did not find a significant increase in BMD in Gruen Zones 2 and 3, which correspond to the lateral aspect of the Nanos®-Stem. Götze *et al* (2010) found in their study a decreased BMD in Gruen-Zone 2 of approximately 10% and concluded that this change was caused by stress shielding. The authors therefore concluded that proximal fixation and force transmission cannot be achieved with the Nanos®-Prosthesis. The positioning of the Nanos®-Stem was not reported in their study.

One could assume that different stem positions could affect the DEXA results. The comparability

of studies on osseointegration of the Nanos[®]-prosthesis is limited if stem position is not reported. DEXA results of short-stemmed implants should be discussed with consideration of the stem position (10).

In this study in all cases, the Nanos[®]-Stem was implanted in a valgus position with an average post-operative CCD of 133°. The femoral offset of the Nanos[®]-Prosthesis can be adapted by different stem positioning. A reduction (valgus positioning) or increase (varus positioning) of the femoral offset compared to a neutral implantation can be achieved. In theory, the offset for a stem size 3 could be modified between 37 mm to 65 mm according to an extreme varus or valgus stem implantation, if anatomically possible (15). Considering the DEXA results, we conclude that valgus positioning of this stem does not lead to an increase in the distal lateral load transfer or extensive stress shielding of the calcar.

In two patients, an intraoperative fissure of the proximal femur occurred, which was treated with cerclaging as described for another short-stemmed femoral implant (25). In that study, no adverse effect on the osseointegration of a cerclaged intraoperative fissure of the proximal femur could be proven. Therefore, and because no increased migration/angulation of the Nanos[®]-Stem in the fracture cases was found, we expect no influence on our study result.

The significant improvement of HHS from 47 points to 94 points reflects the very good clinical result. This finding is in accordance with the results of other study groups with this specific implant (9,10).

This study has different limitations. The rather small number of patients limits the value of our conclusions. On the other hand, this is one of the first studies reporting on DEXA results after implantation of the Nanos[®]-Stem and the number of cases is in a range similar to others (10). In addition, the DEXA measurement is regarded as very reliable and unaffected by subjective errors (21).

The radiological measurement of stem migration and angulation was not performed by an established method like EBRA (16). However, the method used in this study was validated and successfully performed for other similar investigations (22,25,26).

The consecutive cases for this study were not randomized or specially selected. Short-stemmed implants are used at our department as implants of first choice up to the age of seventy. Therefore, no particular criteria of exclusion or inclusion were defined. Nevertheless, subjective factors of patient selection cannot be absolutely excluded with this study design.

The conclusions are limited by the length of follow-up of this study. The data suggest an ongoing remodeling during this postoperative time period insofar as the bone loss in Gruen-Zone 1 and 7 was significant throughout this follow-up. One has to assume that this process is continued further. This could hypothetically result in a higher percentage of bone loss as described for instance for the Mayo[®]-Stem (4).

In summary, we conclude that the Nanos[®] prosthesis can reduce loss of BMD of the proximal aspect of the femur compared with conventional stems and other short-stemmed implants. However, a complete prevention of stress shielding of the calcar region and the major trochanter is not achieved. In contrast to others, we found no evidence for a substantial distal load transfer (4,10,21).

REFERENCES

1. Arabmotlagh M, Hennigs T, Rittmeister M. [Femoral periprosthetic bone remodelling at the proximal femur after implantation of custom made anatomic and standard straight stem hip prostheses.] (in German). *Z Orthop Ihre Grenzgeb* 2003 ; 141 : 519-525.
2. Arabmotlagh M, Pilz M, Warzecha J, Rauschmann M. Changes of femoral periprosthetic bone mineral density 6 years after treatment with alendronate following total hip arthroplasty. *J Orthop Res* 2009 ; 27 : 183-188.
3. Barthels H. *Migrationsverhalten der Mayo-Kurzschafthoprothese. Dissertation.* Martin-Luther-Universität Halle-Wittenberg, 2008.
4. Chen HH, Morrey BF, An KN, Luo ZP. Bone remodeling characteristics of a short-stemmed total hip replacement. *J Arthroplasty* 2009 ; 24 : 945-950.
5. Cohen B, Rushton N. Accuracy of DEXA measurement of bone mineral density after total hip arthroplasty. *J Bone Joint Surg* 1995 ; 77-B : 479-483.
6. Decking R, Rokahr C, Zurstege M, Simon U, Dekking J. Maintenance of bone mineral density after implantation of a femoral neck hip prosthesis. *BMC Musculoskelet Disord* 2008 ; 9 : 17.

7. **Dohle J, Becker W, Braun M.** [Radiological analysis of osseointegration after implantation of the Zweymuller-Alloclassic total hip system.] (in German). *Z Orthop Ihre Grenzgeb* 2001 ; 139 : 517-524.
8. **Ender SA, Machner A, Pap G et al.** [The femoral neck prosthesis CUT. Three- to six-year results] (in German). *Orthopade* 2006 ; 35 : 841-847.
9. **Ettinger M, Ettinger P, Lerch M et al.** The NANOS short stem in total hip arthroplasty : a mid term follow-up. *Hip Int* 2011 ; 21 : 583-586.
10. **Gotze C, Ehrenbrink J, Ehrenbrink H.** [Is there a bone-preserving bone remodelling in short-stem prosthesis ? DEXA analysis with the Nanos total hip arthroplasty.] (in German). *Z Orthop Unfall* 2010 ; 148 : 398-405.
11. **Gruen TA, McNeice GM, Amstutz HC.** "Modes of failure" of cemented stem-type femoral components : a radiographic analysis of loosening. *Clin Orthop Relat Res* 1979 ; 141 : 17-27.
12. **Gulow J, Scholz R, von Salis-Soglio G.** [Short-stemmed endoprostheses in total hip arthroplasty.] (in German). *Orthopade* 2007 ; 36 : 353-359.
13. **Hube R, Hein W.** Die Mayo-Hüfte – eine neue Philosophie zur proximalen Femurverankerung. In : Perka C, Zippel H. (eds). *Trends und Kontroversen in der Endoprothetik des Hüftgelenkes*. Einhorn, Reinbeck 2002, pp 86-90.
14. **Hube R, Zaage M, Hein W et al.** [Early functional results with the Mayo-hip, a short stem system with metaphyseal-intertrochanteric fixation.] (in German). *Orthopade* 2004 ; 33 : 1249-1258.
15. **Jerosch J, Grasselli C, Kothny PC et al.** [Reproduction of the anatomy (offset, CCD, leg length) with a modern short stem hip design – a radiological study.] (in German). *Z Orthop Unfall* 2012 ; 150 : 20-26.
16. **Krismer M, Bauer R, Tschupik J et al.** EBRA : a method to measure migration of acetabular components. *J Biomech* 1995 ; 28 : 1225-1236.
17. **Logroscino G, Ciriello V, D'Antonio E et al.** Bone integration of new stemless hip implants (proxima vs. nanos). A DXA study : preliminary results. *Int J Immunopathol Pharmacol* 2011 ; 24 : 113-116.
18. **Morrey BF.** Short-stemmed uncemented femoral component for primary hip arthroplasty. *Clin Orthop Relat Res* 1989 ; 249 : 169-175.
19. **Neef R.** *Klinische, radiologische und osteodensitometrischen Ergebnisse der Behandlung mit Hüft- Kurzschaftprothesen vom Typ CFP und Mayo*. Dissertation. Martin-Luther-Universität Halle-Wittenberg, 2008.
20. **Okano T, Hagino H, Otsuka T et al.** Measurement of periprosthetic bone mineral density by dual-energy x-ray absorptiometry is useful for estimating fixation between the bone and the prosthesis in an early stage. *J Arthroplasty* 2002 ; 17 : 49-55.
21. **Roth A, Richartz G, Sander K et al.** [Periprosthetic bone loss after total hip endoprosthesis. Dependence on the type of prosthesis and preoperative bone configuration.] (in German). *Orthopade* 2005 ; 34 : 334-344.
22. **Schönrath F.** *Digitale Migrationsmessung in der Hüftendoprothetik am Beispiel der ABG-Prothese*. Dissertation. Martin-Luther-Universität Halle-Wittenberg, 2004.
23. **Thomas W, Lucente L, Mantegna N et al.** [ESKA (CUT) endoprosthesis.] (in German). *Orthopade* 2004 ; 33 : 1243-1248.
24. **Vervest TM, Anderson PG, Van Hout F et al.** Ten to twelve-year results with the Zweymuller cementless total hip prosthesis. *J Arthroplasty* 2005 ; 20 : 362-368.
25. **Zeh A, Radetzki F, Diers V et al.** Is there an increased stem migration or compromised osteointegration of the Mayo short-stemmed prosthesis following cerclage wiring of an intrasurgical periprosthetic fracture ? *Arch Orthop Trauma Surg* 2011 ; 131 : 1717-1722.
26. **Zeh A, Weise A, Vasarhelyi A et al.** [Medium-term results of the Mayo Short-Stem hip prosthesis after avascular necrosis of the femoral head.]. *Z Orthop Unfall* 2011 ; 149 : 200-205.
27. **Zweymuller KA, Schwarzingger UM, Steindl MS.** Radiolucent lines and osteolysis along tapered straight cementless titanium hip stems : a comparison of 6-year and 10-year follow-up results in 95 patients. *Acta Orthop* 2006 ; 77 : 871-876.