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Comparative Analysis of the Reconstruction of Individual Hip Anatomy Using 3 Different Cementless Stem Designs in Patients With Primary Hip Osteoarthritis

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ABSTRACT

Background: We questioned whether there was a radiographic difference in hip geometry reconstruction and implant fixation between 3 different cementless stem design concepts in patients with primary end-stage hip osteoarthritis.
Methods: We retrospectively evaluated the preoperative and postoperative radiographs by 2 independent and blinded reviewers in a series of 264 consecutive patients who had received either a straight double-tapered stem with 3 offset options (group A), a straight double-tapered stem with 2 shape options and modular necks (group B), and a bone-preserving curved tapered stem with 4 offset options (group C). The following parameters were assessed: acetabular, femoral and hip offset (HO), center of rotation height, leg length difference (LLD), and the endosteal fit of stem in the proximal femur (canal fill index). Group comparisons were performed using a one-way analysis of variance and subsequent pairwise comparisons (*t*-test).
Results: Postoperatively, HO could be equally restored with all 3 stem designs ($P = .079$). The postoperative LLD was smaller in group C compared to group A (0.8 mm [standard deviation, 3.2] vs 2.6 mm [standard deviation, 4.5], $P = .002$). Best combined reconstruction of HO and LLD could be achieved with the short curved stem by junior and senior surgeons (HO: −2.0 and −2.1 mm; LLD: 1.9 and 0.7 mm, respectively). The proximal and mid-height canal fill indexes were higher in groups B and C compared to group A, indicating a better metaphyseal and diaphyseal fit in the proximal femur (both $P < .001$).
Conclusion: All 3 cementless stem designs allowed for good hip geometry reconstruction. Multiple shape and offset options allowed for a better metaphyseal stem fit and offered minor clinical advantages for leg length reconstruction. Modular necks did not provide reconstructive advantages in patients with primary hip osteoarthritis.

In primary total hip arthroplasty (THA), adverse outcomes such as impingement, dislocation [1,2], abductor weakness [2,3], and leg length differences (LLD) [4] can occur as a result of inaccurate hip geometry reconstruction. Implant positioning and fixation should be optimal to minimize liner wear and the potential risk of aseptic loosening [5–8]. Therefore, surgeons aim for both reconstruction of individual hip geometry and optimal endosteal stem fit to achieve good abductor muscle strength with equal leg length (LL) and concomitant secure fixation of the implant. However, only few studies have addressed this subject with regard to differences in the reconstructive potential of

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Ethical review committee statement: Institutional review board–approved study.

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Table 1
Demographic Data and Preoperative Radiographic Measurements.

Variable	Group A (Nonmodular Tapered Stem)	Group B (Modular Tapered Stem)	Group C (Nonmodular Short Curved Stem)	*P* Value (ANOVA)	*P* Value Pairwise Comparisons of Groups A/B/C (*t*-Test)
Number of hips	98	66	100	—	—
Side (R:L)	53:45	32:34	59:41	.412	—
Gender (F:M)	45:53	38:28	50:50	.343	—
Age (y)	66.2 ± 8.9 (37-85)	73.1 ± 7.6 (49-88)	64.9 ± 9.6 (32-88)	<.001	A vs B: <.001; A vs C: n.s.; B vs C: <.001
Body mass index (kg/m^2) at surgery	27.6 ± 4.6 (16.1-43.6)	27.3 ± 5.8 (18.3-47.5)	26.0 ± 4.0 (18.0-37.5)	.051	—
Harris hip score at surgery	47 ± 17 (15-83)	44 ± 18 (9-79)	59 ± 15 (19-90)	<.001	A vs B: n.s.; A vs C: <.001; B vs C: <.001
Devane activity score at surgery	2.7 ± 0.7 (1-4)	2.3 ± 0.7 (1-4)	2.6 ± 0.7 (2-4)	.001	A vs B: .001; A vs C: n.s.; B vs C: .003
Hip offset	71.2 ± 9.3 (51.1-97.5)	72.1 ± 10.6 (45.7-92.4)	72.9 ± 8.8 (55.9-90.6)	.449	—
Femoral offset	36.0 ± 6.9 (20.7-58.7)	37.4 ± 7.9 (17.4-51.9)	37.1 ± 6.9 (19.0-59.7)	.435	—
Acetabular offset	35.2 ± 5.9 (22.2-53.0)	34.7 ± 6.0 (17.7-48.5)	35.9 ± 5.9 (23.9-50.9)	.442	—
Vertical position of the center of rotation (COR)	16.2 ± 3.8 (4.8-29.2)	16.3 ± 4.1 (5.3-27.8)	16.2 ± 3.5 (6.5-31.0)	.982	—
Leg length difference	−4.2 ± 6.4 (−22.0 to 12.0)	−4.2 ± 5.0 (−21.0 to 7.0)	−3.0 ± 5.3 (−22.0 to 20.0)	.261	—
Canal to calcar isthmus ratio	0.7 ± 0.1 (0.5-1)	0.7 ± 0.07 (0.6-0.9)	0.7 ± 0.09 (0.5-1)	.485	—
Cortical index	0.59 ± 0.07 (0.4-0.9)	0.56 ± 0.07 (0.4-0.7)	0.58 ± 0.7 (0.4-0.7)	.012	A vs B: .009; A vs C: n.s.; B vs C: .009

ANOVA, analysis of variance; R, right; L, left; F, female; M, male; n.s., not significant.

femoral implant concepts [9]. In the present retrospective comparative study, we therefore questioned whether there is a difference in the reconstruction of hip geometry and cortical stem fit between 3 different stem designs comparing a straight double-tapered nonmodular stem (group A), a straight double-tapered stem with modular necks (group B), and a bone-preserving curved double-tapered nonmodular stem with different curvatures (group C).

Materials and Methods

Study Cohort

The present retrospective comparative study included 264 consecutive patients in 3 subgroups defined by the stem type used for primary cementless THA. Patients were followed prospectively with our institutional database. The study design was set up after the first patient was enrolled.

Inclusion criteria were defined as diagnosis of unilateral primary osteoarthritis or avascular necrosis of the femoral head or mild dysplasia of the hip (Crowe I), contralateral native hip without relevant deformity and cementless THA between 2007 and 2010 at our institution with a straight double-tapered nonmodular stem (group A) or straight double-tapered stem with modular neck (group B), or a short curved tapered nonmodular stem (group C) in combination with a cementless press-fit cup. Exclusion criteria were defined as a history of hip surgery before THA, severe dysplasia of the hip (Crowe > I) [10], metabolic disease leading to THA, bilateral hip disease, and missing preoperative or postoperative radiographs. In total, 98 consecutive patients were included in group A, 66 in group B, and 100 in group C. Demographic data are given in Table 1. Radiographic measurements were performed on preoperative and 1-week postoperative anteroposterior (AP) radiographs of the pelvis. Preoperative body mass index, Harris hip score [11], and patient activity according to Devane et al [12] were available for all patients. The study was approved by the institutional review board (reference S-464/2012). In accordance with the ethics approval, informed consent did not have to be obtained.

Surgical Procedure and Implants

The procedures were performed by 6 surgeons in a university hospital setting (3 senior surgeons, 3 junior surgeons), all using a modified lateral transgluteal approach, according to Bauer and Russe [13], which was performed with the patient in the supine position. The standardized perioperative and postoperative protocol was identical in all groups. As implants, a cementless straight double-tapered nonmodular titanium stem with 3 different neck-shaft angles of 125°, 135°, and 145° and in 13 different sizes was used in group A (CLS Spotorno; Zimmer Inc, Warsaw, IN). In group B, a cementless straight double-tapered modular titanium stem in 10 different sizes was used in a standard or plus version (proximally 1 cm longer) (Profemur E/EHS implant system; European Hip System, Wright Medical Technology Inc, Arlington, TN). Eighteen neck options were available from 5 different neck designs in short and long versions. The 5 neck versions included a neutral neck, an 8° angled neck for varus or valgus, an 8° and 15° angled neck for anteversion or retroversion, and a neck with a combination of 4° for varus or valgus and 6° for anteversion or retroversion [14]. In group C, a short curved tapered nonmodular titanium stem with 4 different neck-shaft angles of 140°, 137°, 129°, and 127°, each in 14 different sizes was used (Fitmore; Zimmer Inc, Warsaw, IN). A 28-mm-diameter or 32-mm-diameter ceramic head with 3 neck length options (−4, 0, 4 mm) (BIOLOX forte; CeramTec, Plochingen, Germany) or a 32-mm CoCr femoral head with 1 neck length option (8 mm) articulated with a highly cross-linked polyethylene liner (Durasul; Zimmer, Warsaw, IN). A cementless titanium press-fit cup with or without screws (Allofit/Allofit-S; Zimmer Inc, Warsaw, IN) was used in all patients. In all 3 groups, surgeons aimed for secure acetabular press-fit fixation, secure endosteal femoral press-fit with the maximum possible canal fill, equal LL, reconstruction of the preoperative hip offset (HO), neutral stem alignment, cup inclination between 30° and 50° and cup anteversion between 10° and 30°. Preoperative planning of the prosthesis size and position was performed on AP radiographs of the pelvis in all cases. The stem design for implantation was selected independently by each surgeon based on best endosteal press-fit fixation in the proximal femur and most accurate hip geometry reconstruction for HO and LLD according to templating. The final femoral head and neck