A comparison of seven stems in restoring femoral offset and leg length using three-dimensional templating

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Introduction: A proper restoration of biomechanical parameters of the hip joint is fundamental to achieve satisfactory outcomes in terms of hip functionality after total hip arthroplasty (THA) [1]. The femoral offset and leg length were identified as relevant predictors of clinical function, and adverse outcomes are a result of inaccurate hip geometry restoration [2]. Preoperative templating in THA can help achieve appropriate femoral offset and leg length [3]. Today, a wide range of femoral implants with varying neck-shaft angles is available, and lateralized variants allow for the restoration of the femoral offset without influencing leg length [4]. Few analyses have addressed restoration of individual hip geometry with regard to differences in the restorative potential of femoral implant concepts [3, 5]. In this study, we investigated how closely anatomical femoral offset and leg length could be restored using three-dimensional (3D) templates for 6 femoral cementless nonmodular stems in common use in the Australia and 1 femoral cementless modular stem [6].

Materials and methods: The study was approved by the institutional review board. We retrospectively compared preoperative templating data in all 144 primary THAs. Between May 2017 and December 2020, 72 consecutive hips (45 patients 14 men and 56 women) with unilateral osteoarthritis (OA) including all hips with developmental dysplasia of the hip (DDH) were measured using computed tomography (CT) scanning with images processed using ZedHip software [7, 8]. Between January 2015 and December 2020, 72 consecutive hips (37 men and 35 women) with unilateral osteoarthritis of the femoral head (ONFH) have been analyzed using ZedHip software as a control group. CT-based simulation software was used to create three-dimensional 3D bone models and to perform computational simulations of the femoral cut and implant setting using the preoperative THA planning mode. The pelvic coordinate system was the functional pelvic plane, and the femoral coordinate system was defined by the center of the femoral head, the knee center, and both femoral condyles. All templating was performed on CT-based simulation software. The hip disease side was used for the templating and the contralateral hip reflected the geometry we wished to restore when performing THA. The simulated acetabular implant was the Continuum Acetabular System (Zimmer) with a polyethylene liner in all cases. The cup size was chosen so as to fill the anterior and posterior acetabular walls at the previously determined acetabular implant site. The cup implantation site was determined as the site where original acetabular contact-loaded the lateral wall of the teardrop. The template angle of the neck implant was chosen to restore a cap inclination of 40° and a cap anteversion of 20° in a radiographic manner [7]. The stems in the Australian implants in the 2015 were identified by reference to the national registry and 3D templates for these designs were obtained from this software [6]. We included one stem (Kinetic; Zimmer) which has been a commonly used modular stem in Japan [8]. As femoral implants, first, a stem with five different offset choices with two different neck-shaft angles (125°, 135°) was used (Corail; Depuy). Second, a stem with two different offset choices with two different neck-shaft angles (125°, 135°) was used (QUADRA-H; Medacta SA). Third, a stem with three different offset choices with three different neck-shaft angles (126°, 135°, 145°) was used (Polarstem; Smith & Nephew). Fourth, a stem with two different offset choices with two different neck-shaft angles (127°, 132°) was used (Accolade II; Stryker). Fifth, a stem with three different offset choices with two different neck-shaft angles (123°, 133°) was used (Taperloc; Zimmer). Sixth, a stem with two different offset choices with one neck-shaft angle (131°) was used (ANTHOLOGY; Smith & Nephew). The Kinetic has five offset choices and anteverted, neutral, or retroverted neck options. The stem was planned and positioned in the anatomical femur. The neck anteversion [7] of the stem selected was chosen for each femur to maximize both fit and fill in the femoral metaphysis [8]. The neck osteophyte plane was selected in order to restore the complete leg length. To be completely restored, the templating had to result in less than 1 mm of complete correction of femoral offset, similar to Archibeck et al. [3]. In the present comparative study, we questioned whether there is a difference in the restoration of femoral offset between 7 different stems. Additionally, the restoration of femoral offset between different stems was compared with diagnosis (OA and ONFH). P-values of <0.05 were considered significant.

Results: The mean patient age was 64.8 ± 12.2 years. The mean height and weight were 156.6 ± 9.8 cm and 60.2 ± 12.1 kg. The mean stem anteversion was 26.2° ± 10.0°. The mean amount of contralateral anatomical femoral offset was 33.9 ± 5.7 mm. The mean stem anteversion in the OA was 29.3° ± 10.3°, whereas it was 23.2° ± 8.7° in ONFH. The mean amount of contralateral anatomical femoral offset was 33.2 ± 6.2 mm, whereas it was 34.6 ± 5.0 mm in the ONFH. Femoral offset was restored to within 1 mm in 95% of cases with the Corail, 84% of cases with the QUADRA-H, 76% of cases with the Polarstem, 84% of cases with the Taperloc, 79% of cases with the ANTHOLOGY, and 95% of cases with the Kinetic. The use of the Corail, the Polastem and the Taperloc resulted in more frequent ability to restore within 1 mm of femoral offset than the QUADRA-H (p=0.001, p<0.001, p=0.005), and the ANTHOLOGY (p=0.000, p=0.000, p=0.003) and the use of the Corail resulted in more frequent ability to restore within 1 mm of femoral offset than the Polastem (p=0.023 and the Taperloc (p=0.032). The use of the Accolade II resulted in more frequent ability to restore within 1 mm of femoral offset than the QUADRA-H (p=0.003 and the ANTHOLOGY) (p=0.003). The use of the Kinetic resulted in more frequent ability to restore within 1 mm of femoral offset than Corail, the QUADRA-H, the Polastem, the Accolade II, the Taperloc and the ANTHOLOGY (p=0.001, p<0.000, p=0.000, p=0.000, p=0.000, p=0.000). Femoral offset was restored within 1 mm in 49% of cases with the stems with two offset options, 77% of cases with the stems with three offset options and 95% of cases with the stem with five offset options. The stems with three offset options resulted in more frequent ability to restore within 1 mm of femoral offset than the stems with two offset options (p=0.005) and the stems with three offset options (p=0.025). Femoral offset was restored to within 1 mm in 64% of cases in the OA and 73% of cases in the ONFH. The stems in the OA resulted in more frequent ability to restore femoral offset than the stems in the OA (p=0.012).

Discussion: We investigated how closely anatomical femoral offset and leg length could be restored using 3D templates for 6 femoral nonmodular stems and 1 femoral cementless modular stem in Asian patients. In our study, femoral offset was restored to within 1 mm in 43-86% of cases with the nonmodular stems and 95% cases with the modular stem. The use of the modular stem resulted in more frequent ability to restore within 1 mm of femoral offset than the nonmodular stems. The larger number of multiple offset options resulted in more frequent ability to restore within 1 mm of femoral offset. The stems in the OA resulted in more frequent ability to restore within 1 mm of femoral offset than the stems in the OA. Accurate restoration of femoral offset and leg length has an important influence on clinical outcomes, including hip function, abductor muscle strength, and femoral offset [2]. In our knowledge, few analyses have addressed restoration of individual hip geometry with regard to differences in the restorative potential of femoral implant concepts [3, 5]. Assessment of femoral offset is an important part of THA planning. Measurement of femoral offset by 3D analysis is more accurate than with 2D analysis [4]. In general, femurs in patients with DDH have a shorter, narrow canal, less femoral offset and a short excessively anteverted neck [8]. In our study, OA had less femoral offset in comparison with ONFH. The stems in the ONFH resulted in more frequent ability to restore femoral offset than the stems in the OA. Our results suggest that the larger number of multiple offset options of nonmodular stems or the modular stem can provide better femoral offset restoration. The present findings are of clinical importance because suboptimal hip geometry reconstruction can be associated with postoperative abductor weakness, limping, pain, impingement, dislocation, increased joint reaction force, and implant loosening.