Excessive femoral offset does not affect the range of motion after total hip arthroplasty

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Abstract

Purpose Implant dislocations are often caused by implant or bone impingement, and less impingement is critical to prevent dislocations. The aim of this study was to clarify the effect of the femoral offset in avoiding component or bony impingement after total hip arthroplasty (THA).

Methods Seventy-eight patients underwent THA with a Pinnacle cup and Summit stem (DePuy). Intraoperative kinematic analysis was performed with a navigation system, which was used to obtain intraoperative range of motion (ROM) measurements during trial insertion of stems of two different offset lengths with the same head size. Further, ROM was also measured after actual component insertion.

Results Maximal ROM was independent of the femoral offset of the stem in each patient. However, the range of external rotation was significantly greater in patients with a greater femoral offset.

Conclusions The Summit stem has enough offset length to avoid implant/bone impingement, even when the standard offset stem is used. Nevertheless, selection of the offset stem should be performed carefully to prevent offset complications.

Introduction

Dislocation is one of the most frequent and critical complications after total hip arthroplasty (THA), and occurs in 1–4 %

of the patients undergoing this procedure [1–3]. Many factors have been suggested to be associated with implant dislocation following THA, including patient-related factors such as developmental dysplasia of the hip, high age, alcohol abuse, and obesity. Surgery-related factors include posterior approach and mal-orientation of the implant [4–7]. Further, characteristics of the prosthesis, such as implant design, head size, and head-neck ratio affect joint stability after THA [8–11]. In most cases, implant dislocations are caused by implant or bone impingement [12]. Therefore, reducing impingement is critical to prevent implant dislocations. Matsushita et al. reported that a greater femoral offset avoided bony impingement and led to an improved range of motion (ROM) after THA [13]. Therefore, an increase in the femoral offset may improve ROM and reduce implant dislocation.

Navigation systems have been developed to intraoperatively facilitate correct component positioning and provide anatomical hip angular information [14, 15]. These systems are also used for intraoperative kinematic analyses other than those performed for correct component positioning. We recently demonstrated that intraoperative ROM showed that obese patients had less ROM and tended to more soft tissue impingement [6].

The aim of this study was to clarify the effect of the femoral offset in avoiding component or bony impingement after THA. To investigate this aspect, we performed kinematic analysis by using a navigation system intraoperatively. The intraoperative ROM was measured using stems with two different offset lengths and the same head size. Measurements were made in extension, external rotation, flexion, internal rotation, and abduction.

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Materials and methods

Patients and surgery

Seventy-eight hips (11 male and 67 female subjects) were analysed in this study (Table 1). The mean age $\pm$ standard deviation of the patients at the time of surgery was 67.2 ± 10.4 years.

All patients underwent THA with a Pinnacle cup and Summit stem (DePuy, Warsaw, IN) (Fig. 1) via the anterolateral approach between January 2010 and May 2012 for osteoarthritis (65 patients) or idiopathic osteonecrosis of the femoral head (13 patients). There was no case of dislocation after THA in this study. The summit stem has two different high offset lengths (+6 mm and +8 mm). The offset length is defined as the distance between the centre of the femoral head and a line drawn through the centre of the stem. The selection of stem offset size is decided by adjustment for the offset length of the contra-lateral side pre-operatively; however, the offset size is finally selected by joint stability after stem trial insertion during THA.

A computed tomography (CT)-based fluoro-matched navigation system (VVHIP3.5; BrainLAB, Feldkirchen, Germany) was used in all cases during surgery. The surgeon followed the registration procedures, which were performed using fluoroscopic imaging with reference landmarks on the patient's anatomy relative to the tracked reference arrays.

The software associated the positions of the registered anatomical landmarks relative to the reference arrays, with the 3D representations of the patient's bones calculated from segmentation of the patient's CT scans. The software also provided the surgeon with real-time information on the location of surgical instruments relative to the patient's anatomy.

Preoperative planning was performed using the navigation system. The study protocol was approved by Kobe University Graduate School of Medicine Ethics Committee, and all patients provided informed consent.

Registration of navigation THA

The registration was performed using fluoroscopic imaging with reference landmarks on the patient's anatomy relative

Table 1 Demographic data of the study group

Total number		78 patients (78hips)
Sex	Male	11
	Female	37
Age		67.23
Preoperative diagnosis	Osteoarthritis	65
	Osteonecrosis	13

High offset

Standard

Fig. 1 Photographs of two different femoral offsets left: high offset stem, right: standard offset stem

to the tracked reference arrays. A pelvic tracker was percutaneously fixed to the iliac crest, and a femoral tracker was fixed to the anterolateral phase of the distal femur. Registration of the pelvis was performed by 2D–3D image matching. Fluoroscopic images of the pelvis, including the femoral head and pubic symphysis, were taken and matched with preoperative CT data. The matched image was confirmed by touching the anterior superior iliac spine with a pointer. Finally, the surface of the iliac crest was denoted to complete the process of verification. For the registration of the femur, fluoroscopic images of the proximal femur including the femoral head were taken first. Then, the medial and lateral epicondyle landmarks were recorded with a pointer. Subsequently, the fluoroscopic images were matched with preoperative CT images. Finally, the registration accuracy was verified by touching the proximal femur with a pointer. Registration was concluded prior to skin incision.

Fig. 2 Effect of the femoral offset in the ROM

Fig. 3 Effect of the femoral offset length in the ROM. **a** comparison with standard offset stem and +6 mm high offset stem in the ROM. **b** comparison with standard offset stem and +8 mm high offset stem in the ROM

Intraoperative measurement of ROM

The maximal ranges of hip extension, external rotation, flexion, internal rotation, and abduction were measured by the measuring tool of the navigation system after trial insertion of the prosthesis. Two different offset stems (standard and high offset) were tested for measurement of the maximal ROMs. The necks of the trial stems were changeable, and we tested two different offset necks for measuring ROMs during trial insertion. In order to analyse the effect of femoral offset length on ROM, we measured the intraoperative maximal ROM corresponding to high offset stems of two different lengths (stem sizes 1–3; +6 mm, patients No=54, stem sizes 4–9; +8 mm, patients No=24), and compared the maximal ROMs between the standard- and high-offset stems. The endpoint for the maximal ROM measurement was the point when the system detected a separation between the centre of rotation of the cup and centre of rotation of the femoral head.

The axes for postoperative ROM simulation were based on the mechanical axis of the femur and the anterior pelvic plane of the pelvis. The mechanical axis of the femur was estimated by determining the centre of the epicondyles of both femurs and the centre of the femoral head.

Statistical analysis

All data are expressed as the mean $\pm$ standard deviation (SD) values unless otherwise indicated. Statistical analysis was performed using one-way analysis of variance with

Tukey's post hoc test for multiple comparisons of paired samples. Correlations between the ROM and femoral offset length were examined by Pearson's chi-square test. In all cases, $p < 0.05$ was considered significant.

Results

Maximal ROM was not dependent on stem offset

In order to analyse the effect of femoral offset on the ROM, intraoperative maximal ROM was measured for both standard-offset and high-offset stems. Intraoperative maximal ROM was similar between the standard-offset and high-offset stems: maximal flexion was 86° (standard offset) and 88° (high offset) and maximal internal rotation was 86° (standard offset) and 86° (high offset) (Fig. 2). There were no statistically significant differences in any of the ROM values (Fig. 2). These results indicated that the maximal ROM was independent of the femoral offset of the stem, and the standard-offset stem may have enough femoral offset to avoid implant/bone impingement.

Femoral offset length did not affect range of motion

In the case of stem sizes 1–3 (+6 mm offset), maximal flexion was 86° (standard offset) and 88° (high offset) and maximal internal rotation was 42° (standard offset) and 42° (high offset) (Fig. 3a). There were no statistically significant differences between the values for the standard-offset and high-offset stems. Even in sizes 4–9 (+8 mm high offset), the

Table 2 Effect of the femoral offset length in the ROM

	Extension	External rotation	Flexion	Internal	Abduction
Correlation coefficient	0.02	0.36	0.14	0.02	0.16
P value	0.43	0.02	0.13	0.42	0.11

Bold emphasis means significant difference

maximal ROMs were similar to those in sizes 0–3 (+6 mm offset): maximal flexion was 88° (standard offset) and 88° (high offset) and maximal internal rotation was 40° (standard offset) and 38° (high offset) (Fig. 3b). There were no statistically significant differences. These results indicate that an excessive offset length of the stem may not affect ROM.

Range of external rotation was higher in patients with greater femoral offset length

We also analysed the correlation between femoral offset length and ROM, and found that the range of external rotation was significantly greater in patients with greater femoral offset (RR=0.36, $P=0.02$) (Table 2). However, we could not show any correlation for the ROM values in the other planes of motion.

Discussion

Increasing femoral offset might be expected to improve ROM. However, we did not notice any difference in ROM between standard-offset and high-offset stems. In a cadaver study, Matsushita et al. demonstrated that increasing the femoral offset resulted in a significantly improved ROM [13]. The discrepancies between those results and the results of our study can be explained as follows. Matsushita et al. used the PerFix stem (Kyocera Medical, Osaka, Japan), which is available in eight different sizes (standard offset lengths: 31.9–37.3 mm). In contrast, the Summit stem is available in nine different sizes, with standard offset lengths ranging from 36.0 mm to 44.0 mm. The average offset of Summit stem was larger than that of the PerFix stem. These differences in offset length could be the reason why the high offset stem did not change maximal ROM in our study. Further, the summit stem employs two different types of high offset lengths (+6 mm and +8 mm). We did not find any difference in maximal ROM, even after using the +8 mm high offset stem. Our results indicated that even the Summit standard offset stem might have enough femoral offset to avoid implant/bone impingement.

We also analysed the interaction between femoral offset and ROM, and showed the correlation between the range of external rotation and the femoral offset. However, we could not show any correlation with other planes of motion. Our result correlated with the results of previous reports [13, 16]. THA was performed via the anterolateral approach, and the anterolateral walls of soft tissue including muscle are relatively weak intraoperatively. The external rotation may be mostly affected by anterolateral. Therefore, the femoral offset may affect the external rotation by the effect of the soft tissue balance. We need to clarify the reason further.

Many studies have demonstrated that high femoral offset reduces the joint reactive force and may improve the polyethylene wear rate [17, 18]. Asayama et al. reported that increased femoral offset decreased the abductor force for walking and reduced the energy requirement for gait and the overall reactive force at the articulating surface of the femoral head [18]. Therefore, increased femoral offset can be expected to improve soft tissue tension and joint stability. In contrast, Little et al. reported that reproduction of reconstructed femoral offset to over 5 mm of the native femoral offset was associated with a 33 % increase in linear ultra high molecular weight polyethylene (UHMWPE) wear and 32 % increase in volumetric UHMWPE wear [19]. Further, Johnston et al. reported that increasing stem offset increased the bending moment on the prosthesis and increased the strain in the medial cortex, and may lead to early failure of the femoral component [20]. The selection of stem offset should be made carefully during THA.

In conclusion, even the standard offset Summit stem has sufficient offset length to avoid implant/bone impingement. Nevertheless, stem selection should be performed carefully to avoid any other complications related to stem offset.

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