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Original Research

Satisfactory Outcomes in Patients Operated With Primary Total Hip Arthroplasty for Perthes-like Deformities: Results From a Surgical Technique Utilizing a Conical Stem, an Elevated Hip Center, and No Shortening Femoral Osteotomy

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A B S T R A C T

Background: Total hip arthroplasty (THA) performed on patients with Perthes-like deformities are technically challenging because of the patient's abnormal hip anatomy. Patients with Perthes-like deformities are at a higher risk of revision, aseptic loosening, nerve injury, and intraoperative fracture after THA, especially if shortening osteotomies are performed. This analysis sought to examine the clinical and radiographic outcomes of a patient cohort with Perthes-like deformities receiving THA with a conical stem, an elevated hip center, and no shortening femoral osteotomy.
Methods: Twenty-six patients (27 hips) received THA with MODULUS femoral stems, ceramic or metal femoral heads, and highly cross-linked polyethylene liners between April 2011 and March 2016. All patients were treated at a single center by 4 participating surgeons. Patients completed 2 questionnaires preoperatively and at the final follow-up visit (between 1 and 5 years postoperatively): Harris Hip Score and Japanese Orthopaedic Association Hip-Disease Evaluation Questionnaire. Differences in patient-reported outcome measures (PROM) scores were measured by paired *t*-tests. Preoperative and postoperative anteroposterior radiographs were analyzed to monitor patient outcomes.
Results: Significant clinical improvements were observed in all individual subcategories of the Harris Hip Score and of the Japanese Orthopaedic Association Hip-Disease Evaluation Questionnaire; the largest magnitude improvements were observed in the subcategory of pain relief for both questionnaires. No complications, including intraoperative and postoperative femoral fractures, nerve palsy, dislocations, or deep venous thrombosis, were observed.
Conclusion: This study found that patients treated with an elevated hip center and low stem-positioning technique using a conical, modular implant system had good clinical outcomes and did not suffer complications at the mean follow-up from surgery of 2.8 years (range: 1-5 years).

Introduction

Perthes-like deformities (PLD) can present in patients who have been treated for or have a natural history of developmental dysplasia of the hip [1]. Affected patients suffer deformities such as the overgrowth of the greater trochanter, shortening of the femoral neck, acetabular dysplasia, and flattened femoral heads [1-6].

Total hip arthroplasty (THA) in patients with PLD and Legg-Calvé-Perthes disease (LCPD) can be technically challenging for many reasons. These include preexisting conditions such as (1) soft tissue contractures due to corrective osteotomies performed during childhood [7,8], (2) joint contracture, (3) proximal femural deformities (ie, short femoral necks, femoral metaphyseal-diaphyseal mismatch due to cortical hypertrophy [9], high riding trochanters, and coxa vara [8,10,11]), and (4) leg length inequality [12].

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Studies reviewing outcomes of THA in patients with PLD or LCPD found that though patient-reported improvements in satisfaction and postoperative function are similar to those of other patients who underwent THA [8,13], revision rates in patients with PLD and LCPD were slightly higher [8]. Three frequent complications are aseptic loosening, sciatic nerve injury, and intraoperative fracture. Moreover, these complications occur at higher rates in patients with PLD and LCPD than in other patients who underwent THA [8,14]. Although subtrochanteric shortening osteotomies can avoid sciatic nerve injury, these procedures increase a patient's risk of nonunion and femoral fracture [15].

The prevention of corrective osteotomies and use of modular implants in patients who underwent THA with PLD can mitigate the risk of the aforementioned complications. The primary aim of this prospective analysis was to assess the radiographic outcomes of primary THA performed for patients with PLD. These patients did not receive shortening femoral osteotomies and were treated with an elevated hip center and a conical modular stem positioned to lower into the femoral canal with time. The secondary aim of this study was to measure the clinical outcomes, as determined by changes in Patient-Reported Outcome Measures, in the same patient cohort.

The authors of this article hypothesize that THA performed as outlined in the primary aim for patients with PLD would result in the good radiographic and clinical outcomes.

Material and methods

Patients and data collection

Patients for the current analysis were selected from a prospective study evaluating the clinical and radiographic outcomes of dysplastic patients undergoing THA with MODULUS (Villanova di San Daniele del Friuli, Italy) femoral stems and an elevated hip center. Seventy-five patients treated between April 2011 and March 2016 at a single center by 4 surgeons were identified. Of this cohort, 26 patients (27 hips) presented with PLD and were included in this present analysis.

Six patients (23%) were male, and 20 patients (77%) were female. The average age at the time of surgery was 58 years (range: 41-78 years). Eleven (41%) were done on the right hip, and 16 (59%) on the left hip. The severity of dysplasia was evaluated based on the Crowe classification [16]: 17 (63%) hips were classified as Crowe I, 9 (33%) hips were Crowe II, and 1 (4%) hip was Crowe III. Patients returned for follow-up at 2 months, 6 months, and 1 year postoperatively. Annual visits beyond 1-year follow-up were also recommended.

Surgical technique

All patients were operated in a lateral decubitus position with a posterolateral approach. A femoral neck osteotomy was performed based on a preoperative plan at a level that minimized postoperative leg length discrepancy (LLD). Cementless acetabular cups were implanted using a line-to-line technique and screw fixation [17,18]. The femoral canal was reamed to the size that gave an option for having the femoral head at the same horizontal height as the tip of the greater trochanter.

Surgeons then attempted to reduce the femoral head into the acetabular cup. If this was not possible, the femoral neck was modified, a smaller stem size was selected, or soft tissue was released. If it was still impossible to reduce the hip, the cup orientation was modified facilitated by the line-to-line reaming technique. Shortening femoral osteotomies to alleviate excessive tension were not performed in any case. Adductor tenotomy was performed in 13 cases preoperatively because of a hip abduction of less than 20°. Iliopsoas tenotomy was performed in 2 cases because of extension contracture and inability to reposition the implant as a consequence of excessive tension.

Prosthetic material

All patients were treated only with a MODULUS implant system. One patient suffered an intraoperative fracture from another stem and was subsequently fitted with a MODULUS stem intraoperatively. This implant system is comprised of an uncemented conical tapered stem coupled axially with a Morse taper to a modular neck by a locking screw (Fig. 1). The stems have a rough blasted surface and radial fins. The medial or distal part of the stem is fixed to the femoral canal. This design allows for a stable cementless fixation in the femoral canal and a uniform stress distribution [19-22].

Four different models of modular necks were used in this study, with 2 options for length (short and long) about the cervical axis and 2 options for cervico-diaphyseal angles (125° and 135°). With equal lengths about the cervical axis, the 125° cervico-diaphyseal angle yields a 5-mm lateralization of the implant, as compared to the 135° angle (Fig. 2).

Six of the treated hips received cobalt-chromium femoral heads, 6 received alumina femoral heads, and 15 hips were treated with Delta ceramic femoral heads. Eighteen of the femoral heads were 28 mm in diameter, and 9 were 32 mm in diameter. All liners were highly cross-linked polyethylene.

Clinical outcomes (Patient-Reported Outcome Measures)

Patients were evaluated clinically by 2 patient-reported questionnaires preoperatively and at the final follow-up visit (between 1 and 5 years postoperatively): the Harris Hip Score (HHS, scored from 0 to 100, with 100 marking minimal pain and maximal function of the affected hip) [23] and the Japanese Orthopaedic Association Hip-Disease Evaluation Questionnaire (JHEQ, scored from 0 to 84, with 84 representing maximal mental health, pain relief, and activities of daily living) [24,25]. The visual analog scale of the JHEQ (VAS, scaled 0-100, with 0 marking complete satisfaction) was assessed separately [26,27].

Radiographic outcomes

Anteroposterior radiographs taken preoperatively, immediately postoperatively, and at the final follow-up visit were assessed by senior surgeons. In this analysis, surgeons noted the location of the hip center, identified osteolytic areas or radiolucent lines according to the zones defined by Gruen et al. [28], recorded signs of spot welds (bone ingrowth) according to Gruen zone [28], noted signs of shaft subsidence beyond 4-6 mm, logged signs of aseptic loosening, as previously defined [29], recorded stress shielding or cortical hypertrophy [30], and measured LLD (A positive LLD indicates that the patient's operated leg was longer than its nonoperated counterpart.).

Statistical methods

Differences between mean preoperative and postoperative PROM scores were measured by paired t-tests, with significance set at P values less than .05.

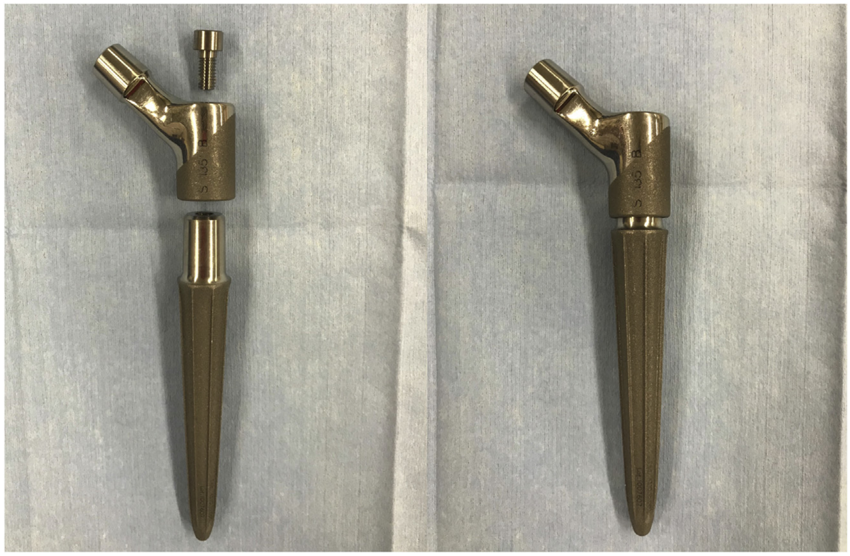

Figure 1. The MODULUS stem system. This stem system is comprised of a stem and a neck. The stem has a rough blasted surface and radial fins. The neck part can be inserted into the stem at any version and fixed by taper lock and screw.

Results

Clinical outcomes

Patient demographics are given in Table 1. The median follow-up duration was 2.1 years (interquartile range: 1.0-4.0 years). The mean preoperative HHS and JHEQ scores were 45 (range: 27-70) and 27 (range: 3-57), respectively. Mean HHS and JHEQ scores at the final follow-up visit were 93 (range: 78-100) and 64 (range: 31-84), respectively. Mean HHS ($P < .001$) and JHEQ ($P < .001$) scores were statistically significantly different preoperatively and at the final follow-up visit (Figs. 3 and 4, respectively). The mean preoperative VAS of 84 (range: 48-100) was statistically significantly different than the mean VAS of 5 at the final follow-up visit (range: 0-50).

Significant clinical improvements were observed in all individual subcategories of the HHS (pain, range of motion, gait, activities, deformity) and of the JHEQ (pain, movement, mental health), although the largest magnitude improvement was observed in the subcategory of pain relief for both questionnaires.

Radiographic outcomes

To identify the location of the hip center radiographically, an interteardrop line (horizontal line; Figs. 5 and 6) was drawn through the tip of the teardrop, and a vertical line was drawn perpendicular to the interteardrop line (vertical line; Figs. 5 and 6). The mean vertical distance (yellow arrow; Fig. 5) from the hip center to the interteardrop line was 21.9 mm (range: 12.0 to 33.6 mm). The mean horizontal distance (yellow arrow; Fig. 6) from the hip center to the tip of the teardrop was 29.3 (range: 16.3 to 36.4 mm). The mean postoperative vertical distance from the hip center to the tip of the greater trochanter (yellow arrow; Fig. 7) was 10 mm (range: 0 to 25.3 mm). Sample preoperative and postoperative radiographs have been included as Figures 8 and 9, respectively.

All stems were positioned in a neutral alignment, meaning that the stem was installed within 2° varus or valgus from the femoral axis. Radiolucent lines were observed in 6 (22%) cases; 1 case (4%) in Gruen zone 1 only, 1 case (4%) in Gruen zone 7 only, and 4 cases (15%) in both Gruen zones 1 and 7. None of the patients with radiolucent lines had clinical symptoms. No cases of osteolysis or implant loosening were observed. All cases were judged stable bone ingrowth state. Nine cases (33%) displayed bone ingrowth (Spot Welds) in the shaft-neck passage (Gruen zones 1 and 7); 1 case (3.7%) displayed bone ingrowth in the distal part of the stem (Gruen zones 3 and 5). There were 0 (0.0%) cases of shaft subsidence greater than 2 mm (Table 2).

Stress shielding was observed in 24 (89%) of the 27 hips: 10 cases (37%) as grade 1, 10 cases (37%) as grade 2, 4 cases (15%) as grade 3. Cortical hypertrophy was evident in 3 cases (11%): 1 case (4%) in Gruen zones 3, 1 case (4%) in Gruen zone 5, 1 case (4%) in both Gruen zones 3 and 5. The average preoperative LLD was −25.2 mm (range: −40 to 13 mm). The average LLD at the final follow-up visit was −4.6 mm (range: −21 to 22 mm). The LLD of all patients was improved at the time of the final follow-up visit.

No complications, including intraoperative and postoperative femoral fractures, nerve palsy, dislocations, and deep venous thrombosis, were observed.

Figure 2. Femoral neck variations. Four different femoral necks are available, with 2 options for angle version (125° and 135°) and 2 options for length (short and long).

Table 1
Patient demographics.

Parameter	Value
Number of patients	26
Number of hips	27
Patients by gender	
Male	6
Female	20
Patient age at procedure (y)[a]	58 (41-78)
Duration from surgery to latest follow up (y)[a]	2.8 (1-5)
Diagnosis	
Secondary osteoarthritis due to developmental dysplasia of the hip[b]	27 (100)
Crowe type [16]	
I[b]	17 (63.0)
II[b]	9 (33.3)
III[b]	1 (3.7)
IV[b]	0 (0)
Dorr type [31]	
A[a]	3 (11.1)
B[a]	17 (63.0)
C[a]	7 (25.9)

[a] Values are given as mean (range).
[b] Values are given as N (%).

Discussion

Patients with PLD or LCPD have severe anatomical deformities, including a shortened femoral neck, high riding trochanters, coxa vara, and leg length discrepancies. These abnormalities can make THA quite challenging, especially when considering the complications that may arise when trying to restore LLD.

Leg lengthening of the operated limb after THA can result in postoperative nerve injury. To prevent this complication, surgeons treating patients with PLD can either conduct shortening osteotomies on the operated limb or perform THA with a slightly elevated prosthetic hip center. Because patients with PLD are more prone than other patients to intraoperative fractures, postoperative sciatic nerve injury, and postoperative aseptic loosening, shortening osteotomies should be performed with discretion. With this consideration in mind, the authors of this manuscript sought to examine the clinical and radiographic outcomes of patients with PLD treated at a single center with an elevated hip center, no shortening osteotomies, and a sized-down femoral stem with a lower stem placement. This study found that patients treated with an elevated hip center and low stem-positioning technique using a conical, modular implant system had good clinical outcomes and did not suffer complications at the mean follow-up from surgery of 2.8 years (range: 1-5 years).

Various features of the conical modular implant systems facilitate the treatment of patients with PLD. In fact, surgeons using conical modular implant system can select the appropriate neck length and offset of the femoral stem based on intraoperative findings, thus reducing the risk of postoperative or intraoperative dislocations and avoiding leg lengthening caused by an incorrect stem size. In revision settings, studies have shown that modular and nonmodular stems yield similar postoperative HHS and satisfaction and long-term survival, although modular stems fracture more frequently, have less stem subsidence, and undergo more mechanical failures than their nonmodular counterpart [32].

Patients were allowed full weight-bearing as of the first postoperative day. It is common in Japanese culture to sit and lie on the floor, as well as to use a Japanese style toilet. These actions require a deep flexion of the hip joint. Although we recommended to the patients that it is suitable to avoid deep flexion of hip joint for 6 months postoperatively, we do not prohibit participation in the aforementioned activities, as we installed the particular stem according to the intraoperative findings.

However, the MODULUS stem is unique as is it more fitted to the femoral canal and fixes at the median/distal, rather than proximal, portion of the implant. This different load transferring might lead to more stress shielding in patients treated with MODULUS implants than those treated with other implant systems. Despite the short-term results of this previous study, radiographs of 88.9% of the patients followed in this analysis displayed stress shielding at 3 years of follow-up. As in previous studies, it is predicted that stress shielding in this patient cohort will increase with time. Because stress shielding can increase the risk of periprosthetic fracture, long-term observation of these patients is needed.

A retrospective review of clinical outcomes in patients with PLD revealed that osteotomies performed during THA to improve leg length discrepancies were associated with an increased risk of

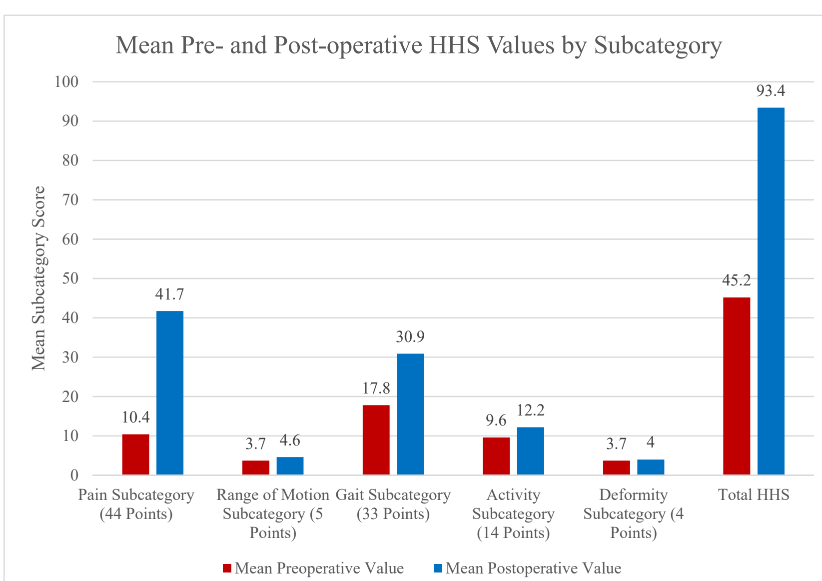

Figure 3. Mean preoperative and postoperative HHS values by subcategory. Mean preoperative values are represented by the red bars, whereas mean postoperative values are represented by blue bars.

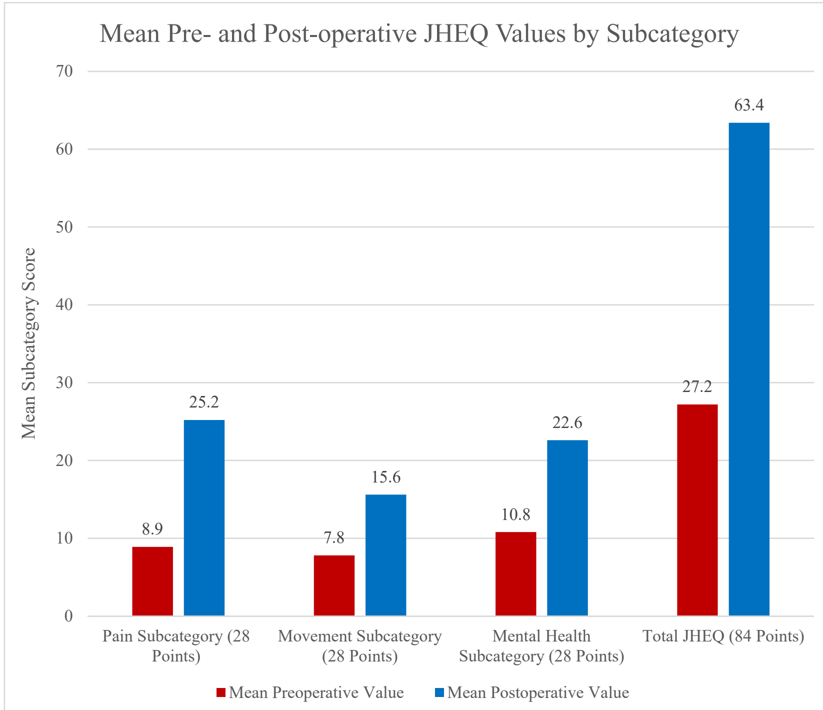

Figure 4. Mean preoperative and postoperative JHEQ values by subcategory. Mean preoperative values are represented by the red bars, whereas mean postoperative values are represented by blue bars.

sciatic nerve injury [8], fracture, and nonunion [33,34]. On the other hand, THA performed with an elevated hip center and modular hip implants is thought to reduce the risk of perioperative fractures in patients with PLD and has the added benefit of allowing for the adjustment of offset, version, neck length, and the metaphyseal-diaphyseal mismatch intraoperatively [9]. One study found that modular femoral implants used in patients with PLD undergoing THA restored anteversion of the femoral component and rectified LLD without causing tension in soft tissues or having neurological ramifications [9]. Moreover, modular femoral implants were associated with a lower risk of intraoperative fracture [8]. Another benefit to line-to-line reaming of the acetabular cup, as opposed to press-fitting implants, is that physicians can easily change cup alignment intraoperatively, if necessary, to accommodate for hip

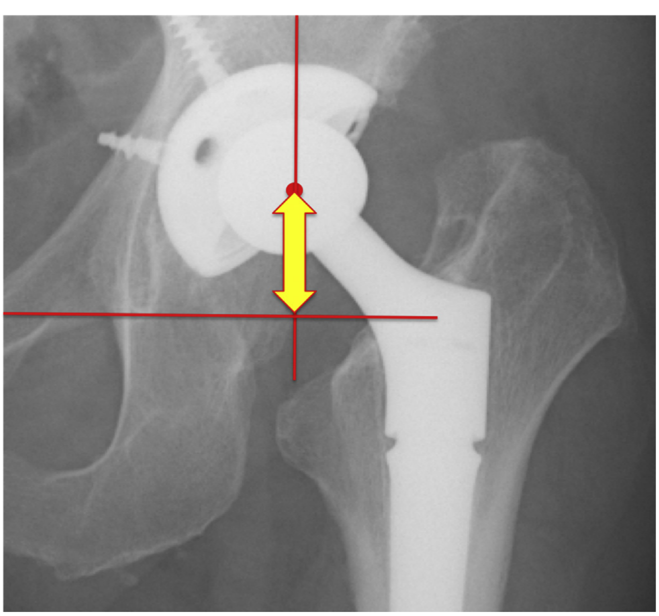

Figure 5. Vertical distance from hip center to interteardrop line. The horizontal red line in this radiograph is the interteardrop line; a vertical line has been drawn perpendicular to the interteardrop line. The vertical distance between the interteardrop line and the hip center is denoted by the yellow arrow.

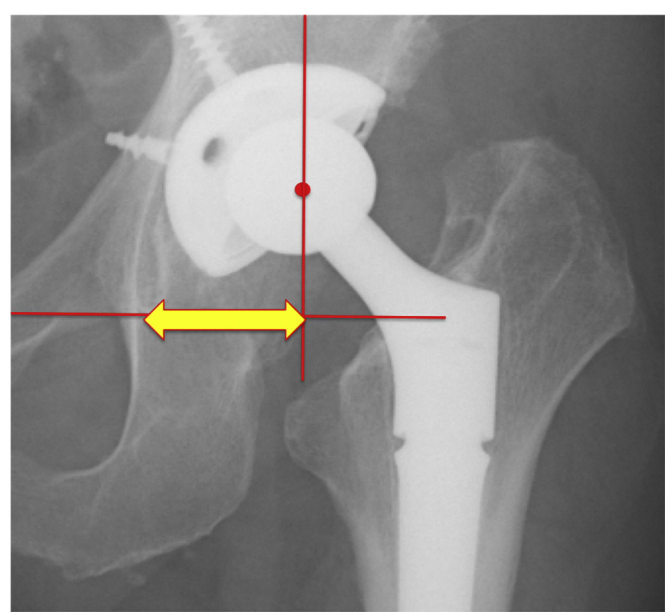

Figure 6. Horizontal distance from hip center to tip of teardrop. The horizontal red line in this radiograph is the interteardrop line; a vertical line has been drawn perpendicular to the interteardrop line. The horizontal distance between the tip of the teardrop and the hip center is denoted by the yellow arrow.

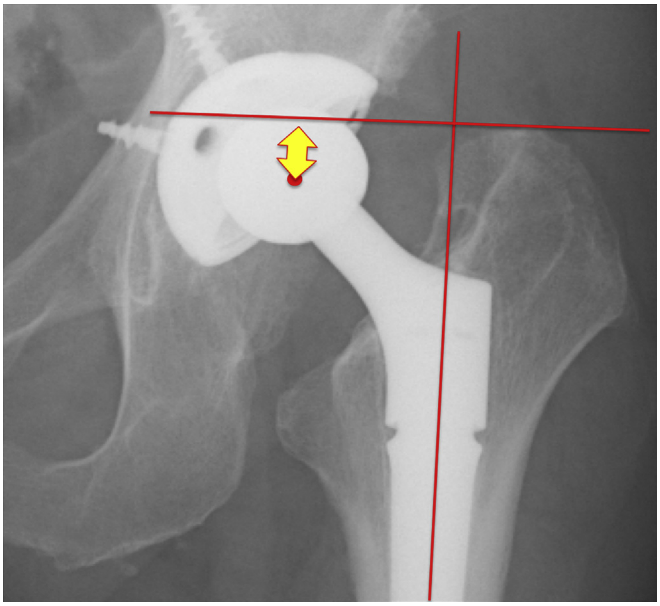

Figure 7. Postoperative vertical distance from hip center to tip of greater trochanter. The vertical red line in this radiograph has been drawn through the center of the femoral canal. The horizontal red line in this radiograph is drawn perpendicular to the vertical red line and passes through the tip of the greater trochanter. The vertical distance from the hip center to the tip of the greater trochanter is shown by the yellow arrow in this figure.

deformities in patients with PLD [35]. As such, surgeons can increase the height of the prosthetic hip center relative to the prior acetabular cup and bypass the need for a shortening osteotomy.

Previous studies have also adopted the elevated hip center technique and have reported positive long-term clinical and radiographic outcomes in patients with hip deformities. These studies have emphasized that elevation without lateralization of the hip center yields good clinical outcomes [36-38] and does not impact hip abduction so long as the length of the femoral neck is accordingly increased [39]. Nonetheless, it should be noted that with increasing hip center height comes a decreased range of motion in the operated hip, especially with hip centers located more than 35 mm above the interteardrop line, referred to as “high hip center” [40,41]. Accordingly, all patients in this study cohort

Figure 8. Preoperative radiograph. This preoperative radiograph of a 51-y-old female study patient shows a typical case of Perthes-like deformity. The proximal femur shows severe deformities, including a flattened femoral head, shortened femoral neck, high riding trochanters, and coxa vara.

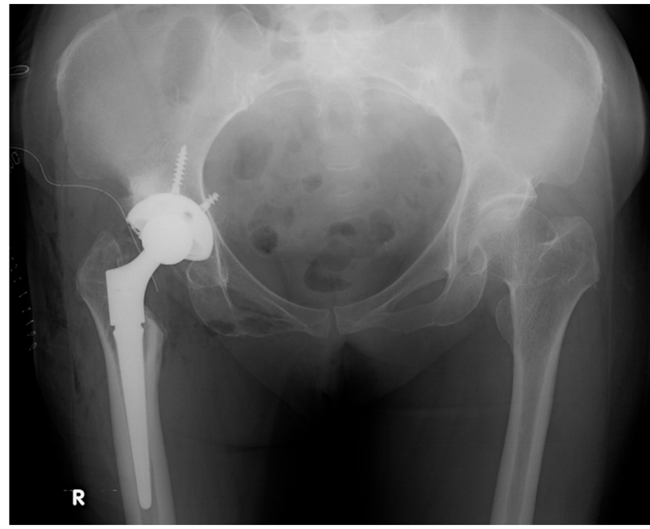

Figure 9. Postoperative radiograph. This postoperative radiograph of a 51-y-old female study patient shows a prosthetic hip center located at a higher point than the anatomical hip center and lower than the tip of great trochanter.

were treated with elevated hip centers under 34 mm above the interteardrop line. Moreover, the strong clinical and radiographic outcomes of the patients in our study cohort are consistent with reported outcomes of previous studies. A longitudinal follow-up study examining the outcomes of cementless elevated hip center reconstructions also reported excellent component fixation and attributed this finding to the higher bone coverage of the acetabular component in these patients [37,40,41].

The increase in PROM scores observed in this present study is consistent with the clinical observations of elevated hip center reconstructions [37,40]. The authors of this article believe that the high postoperative satisfaction of this patient cohort is due to finding the ideal postoperative leg length and none of the patients suffered postoperative dislocations. Before surgery, the muscles around the hip joint had been contracted because of leg shortness. After surgery, the length of the operated limb is increased to almost the length of the other leg, yielding improved range of motion without pain and thus increasing patient satisfaction. If the operated leg reaches the same length as its contralateral, it is possible that a patient can feel pain due to muscle contraction or can present with flexion contracture of the hip joint. By using an elevated hip center and a sunken stem technique, surgeons were also able to minimize the postoperative LLD in this patient cohort, a factor that the authors of this manuscript believe contributed to the high postoperative patient satisfaction.

However, it should be noted that a limitation of the present study is the lack of data on postoperative limping. Postoperative limps can be caused not only as a consequence of weak abductor muscles but also due to LLD over 15 mm. In this patient cohort, the mean postoperative LLD was 10 mm, not only to minimize the chance of developing postoperative limps and pain but also to reduce the chance of complications such as fracture and nerve injury. Subcategories of the HHS and JHEQ report on a patient’s gate. Mean HHS gait scores improved from 18 preoperatively to 31 postoperatively, a value close to the highest score of 33. This improvement in HHS gait scores is consistent with a lack of postoperative limp. As the movement subcomponent of the JHEQ relates to hip flexion, this PROM cannot be used to evaluate postoperative limps. A lack of limping in this patient cohort is consistent with the lack of postoperative limping observed in other patient cohorts treated with cementless implants using elevated

Table 2
Radiographic outcomes.

Radiographic findings	N (%)	Gruen zone 1, N (%)	Gruen zone 2, N (%)	Gruen zone 3, N (%)	Gruen zone 4, N (%)	Gruen zone 5, N (%)	Gruen zone 6, N (%)	Gruen zone 7, N (%)
Radiolucent lines	6 (22.2)	5 (18.5)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	5 (18.5)
Spot welds	13 (48.1)	9 (33.3)	3 (11.1)	2 (7.4)	0 (0)	1 (3.7)	2 (7.4)	7 (25.9)
Cortical hypertrophy	3 (11.1)	0 (0)	0 (0)	2 (7.4)	0 (0)	2 (7.4)	0 (0)	0 (0)
Osteolysis	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

hip center reconstructions [39]. The authors of this article theorized that postoperative satisfaction could also serve as a proxy for postoperative limping, as patients with severe limps would likely report elevated scores in the unsatisfactory VAS.

Despite the strong clinical and radiographic outcomes of the patients followed up in this study, the study cohort was relatively small, and the follow-up was only short term. Nonetheless, the follow-up period in this study spans the amount of time during which most of these complications are prone to occur. Future studies should focus on the long-term results of patients with PLD treated with elevated hip center reconstructions and sunken stems, paying particular attention to long-term loosening, the presence or absence of postoperative limping, and wear analysis and examining the prevalence of stress shielding with time.

Conclusion

THA performed with an elevated hip center and a conical modular stem (positioned to lower into the femoral canal) for patients with PLD has yielded good radiographic outcomes and highly satisfactory clinical outcomes in this study cohort, without any major complications. This technique is very useful, easy, and simple and can be an effective alternative method for challenging patients with PLD.

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Conflict of interests

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: H. Malchau received royalties from MAKO/Stryker and research support from Zimmer, Biomet, Smith & Nephew, MAKO, and DePuy and was a board member for RSA Biomedical. A. Kaneuji is a part of the speaker bureau of Zimmer, Biomet, and Johnson & Johnson; received research support from Johnson & Johnson; and is a board member of the Japanese Hip Society. N. Kawahara is a board member of the Japanese Orthopaedic Association.

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