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ORIGINAL RESEARCH

Treatment of Osteoarthritis Secondary to Severe Coxa Vara with Modular Total Hip Arthroplasty

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Objective: We aimed to demonstrate the methods of treatment for coxa vara with modular total hip arthroplasty (THA) and evaluate clinical and radiographic outcomes, and further survivorship at the midterm follow-up.

Methods: We retrospectively reviewed 33 patients (42 hips) who underwent modular THA for coxa vara deformity from May 2008 to December 2019. The clinical and radiographic results, including Harris Hip Score (HHS), leg length discrepancy (LLD), greater trochanteric height, femoral offset, abductor lever arm, stem alignment and limp, and complications, were evaluated.

Results: The follow-up time was mean 69.9±43.7 months. Clinically, the HHS improved significantly (p<0.001) on average from 42.90±14.44 points to 89.54±4.75 points. The mean LLD decreased from 33.3±19.4 mm to 5.0±5.8 mm (p<0.001), and 27 patients (82%) thought that total equality of the lower limbs was obtained. Patients demonstrated diminished or no limping in 88% (29/33) of hips and a significant improvement of biomechanics. At the final follow-up, all stems of hips were in clinical neutral alignment and the prostheses survivorship rates for all-causes revisions was 97.6%.

Conclusion: Modular THA is a valuable alternative to render favorable outcomes for treatment of osteoarthritis secondary to severe coxa vara.

Keywords: osteoarthritis, coxa vara, modular, total hip arthroplasty

Introduction

Coxa vara is a hip disorder characterized by varus deformity of the proximal femur.[1–4] Congenital coxa vara is rare, with an estimated incidence of 1 in 25,000.[1] In addition, coxa vara could be a sequela resulting from avascular necrosis after the treatment of developmental hip dysplasia (DDH), Legg-Calve-Perthes (LCP) disease, previous femoral osteotomy, childhood septic arthritis or metabolic bone disease.[1–3,5,6] Coxa vara is commonly associated with a spectrum of pathologies that involve a short neck, relative overgrowth of the greater trochanter (GT), insufficiency of hip abductors and limb length discrepancy (LLD).[1,3,4,7] All these deformities in adult patients could lead to osteoarthritis of the hip and degenerations of the spinopelvic complex, which will eventually require total hip arthroplasty (THA).[2,6,7] On account of the native femoral proximal morphology of these patients, it is technically difficult to restore the normal structure.[1,3,6–9] A conventional cementless tapered stem tends to be inserted in a varus position,[4,10] which could lead to a higher distal strain distribution, femoral cortical hypertrophy, thigh pain and negative survivorship in the long term.[3,4,6,10] To maintain neutral stem alignment, it is recommended in some literatures performing the greater trochanteric osteotomy and trochantoplasty, while both have potential negative

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consequences.[1,3,5,6] In addition, monoblock stems with a varus neck, hip resurfacing or even customized implants have been given consideration.[2,11] However, all of the above methods have limited capacity in adjusting femoral offset (FO), anteversion and length of lower limbs. In contrast, the modular THA allows adjustment of the abnormal femoral anteversion and offset of coxa vara and versatility to optimize soft tissue tension to improve biomechanics, appropriately matching the differences of the medullary cavity to generate maximal stability and protecting the abductor tendon insertion.[2,12–14] To our knowledge, there has been no published study analyzing the results of modular THA in the treatment of deformities of coxa vara. Therefore, the aim of this study was to evaluate early- to mid-term postoperative outcomes of treating coxa vara, stem position, complications and further survivorship by modular THA.

Methods
Patients
We retrospectively reviewed 62 patients in our institution who underwent primary THA from May 2008 to December 2019 for the treatment of osteoarthritis secondary to coxa vara after the institutional review board of our hospital approval. The patients were diagnosed by the radiographic criterion of decreased neck-shaft angle (NSA).[1,3] The exclusion criteria were 1) THA without a modular cementless prosthesis, 2) previous greater trochanteric osteotomy or trochantoplasty, 3) follow-up time of less than one year, or 4) patients with inadequate clinical or radiographic data. Therefore, a total of 33 patients (42 hips) were ultimately included in this study. The demographics and clinical

information were based on the historical and clinical findings in medical records (Table 1). The reasons for coxa vara included DDH (n=20), osteonecrosis of the femoral head (n=6), septic arthritis (n=9), Legg-Calve-Perthes disease (n=3) and deformities after trauma (n=4). According to the Bucholz-Ogden (B-O) classification,[6,15] 21 hips were classified as B–O Type III, and 21 hips were classified as Type IV by preoperative radiographs.

Surgical Procedure
All operations were performed by one senior surgeon (YG Zhou) with a posterolateral approach using cementless modular femoral components (S-ROM, DePuy, Warsaw, IN, USA), which consisted of a fluted stem for rotational stability, a distal slot to prevent deformation, and a modular metaphyseal sleeve that adjusted the anteversion.[2,13] The cementless acetabular component (Pinnacle, DePuy, Warsaw, USA, n=30; Duraloc, DePuy, Warsaw, USA, n=9; Betacup, Link, Hamburg, Germany, n=3) was utilized. The detailed surgical procedure has been reported in our previous literature.[16,17] The fascia was divided along the line of the incision and the gluteus maximus was split. The short external rotators were divided close to their femoral attachment. Subsequently, the hip joint was dislocated, and the femoral head was resected. A ceramic-on-ceramic bearing was placed on the cup, which was implanted at the anatomic position. Next following prophylactic cerclage wiring of the femur in osteoporosis cases and reaming, proximal cone reaming of the femur canal was performed until the maximum cortical contact was reached. Then, based on the

Table 1 Patient Characteristics

	Total	B-O Type III	B-O Type IV	P-value
Number of hips (patients)	42(33)	21(16)	21(17)	
Age (years)*	42.3±13.1	45.2±14.6	39.4±10.8	0.253
Height (cm)*	160.5±8.9	161.8±9.1	158.2±9.2	0.298
BMI (kg/m2)*	22.26±3.37	24.5±5.4	22.4±3.3	0.196
Gender				
Male	11 (33%)	7(44%)	4 (24%)	
Female	22 (67%)	9 (56%)	13 (76%)	
Follow-up (months)*	69.9±43.7	63.7±42.6	76.2±45.0	0.360

Note: *The values are given as the mean and standard deviation.
Abbreviation: BMI, body mass index.

anatomical morphology of the metaphysis, appropriate conical or triangular reaming was performed again to match the sleeve and the metaphysis. With the trial seated in the femur, reduction was performed. A subtrochanteric transverse osteotomy might be performed for femoral shortening if reduction was impossible by measuring the vertical distance between the femoral head and the cup. Eight hips with Crowe IV DDH due to high dislocation underwent subtrochanteric osteotomy after removing the trial. The osteotomy position was planned to approximately 1–2 cm beneath the lesser trochanter. Prophylactic cerclage wires were placed proximally and distally around the planned fragment. Next a transverse osteotomy was performed and the length of the osteotomy was based on the distance measured before, leaving about 1–1.5 cm with surgeon's discretion. The wires were tightened and fixed to make the end achieve maximum contact. Then trial reduction was performed again. This step could be repeated until reduction was finished. After completion of trial reduction and the evaluation of stability, equal limb length and soft tissue tension by adjusting the head/neck length, the femoral component was implanted. Finally, femoral anteversion was modified with the advantages of a modular prosthesis to maintain the tension of the gluteus medius. All patients were advised to partial weight-bearing exercise and walk with the aid of two crutches for six weeks on the second day after the operation.

Clinical Evaluation

Routine follow-ups were scheduled at three, six, and twelve months and every year thereafter. Patients who had not returned for follow-up were contacted by telephone and were asked to return to the clinic. The final follow-up evaluation was performed at an average of 69.9 ±43.7 months (range, 15 to 153 months) postoperatively.

Clinical evaluation was performed using the Harris hip scoring (HHS),[18–20] leg length discrepancy (LLD), and limp preoperatively and at the final follow-up. The measurement of LLD is defined as the difference in vertical distance between the lower margin of the lesser trochanter and the line of connecting intertear drops.[8,9,21,22] All the patients were adults with no bony growth further and no differences in tibial length of lower limbs, which ensured that LLD just reflected the changes on hips. Any visual manifestation of lateral imbalance of the pelvic movement during gait was identified as the limp. Limp was categorized as none, slight, moderate, severe, or unable to walk.[2,3,11]

Radiographic Assessment

Anteroposterior (AP) radiographs of the pelvis preoperatively and at the final follow-up were analyzed, all of which were obtained in the supine position using a standardized instruments and procedures to achieve reproducible projection.

The following parameters were measured in AP radiographs (Figure 1): Greater trochanteric height (GTH) (mm):[1–4,7] the perpendicular distance between the center of rotation(COR) of hip and the tip of the trochanter; femoral offset (FO) (mm):[2,8,21] the perpendicular distance from the COR to the femoral medullary central axis; abductor lever arm (ALA) (mm):[2,3,21] the perpendicular distance between the COR and the abductor force vector; body weight lever arm (BWLA) (mm):[2,3,21] the perpendicular distance between the COR and the body weight vector. Femoral stem alignment was also evaluated, which was determined by measuring the angle between the longitudinal axis of the stem and the longitudinal axis of the femur. The stem alignment was classified as neutral, valgus (>3° of lateral deviation), or varus (>3° of medial deviation).[4,10,22]

Implant fixation and osteolysis around the acetabular component (according to Latimer and Lachiewicz[23]) and the femoral component (according to Engh et al[24]) were evaluated by comparing AP radiographs at the final follow-up to those at post-operation. The lesions were located according to the 3 zones on the acetabular side, which are described by DeLee and Charnley.[25] Heterotopic ossification was evaluated according to Brooker et al.[26] Complications, reoperation and implant survival rates were also evaluated.

All radiographic measurements and classification were made by two independent investigators using the digital technique of Digimizer v5.4 (MedCalcSoftware, Ostend, Belgium) to eliminate magnification error. All of the parameters were measured again four weeks later without knowledge of the previous results to assess the intraobserver reliability. These intraclass correlation coefficients (ICCs) for interobserver (0.82 to 0.91) and intraobserver (0.81 to 0.88) reliability indicated high reproducibility.

Statistical Analysis

The mean and standard deviation were calculated for continuous variables in each group. The normal distribution of all data was checked by the Shapiro-Wilk and Kolmogorov–Smirnov test. Student's *t*-test was used to
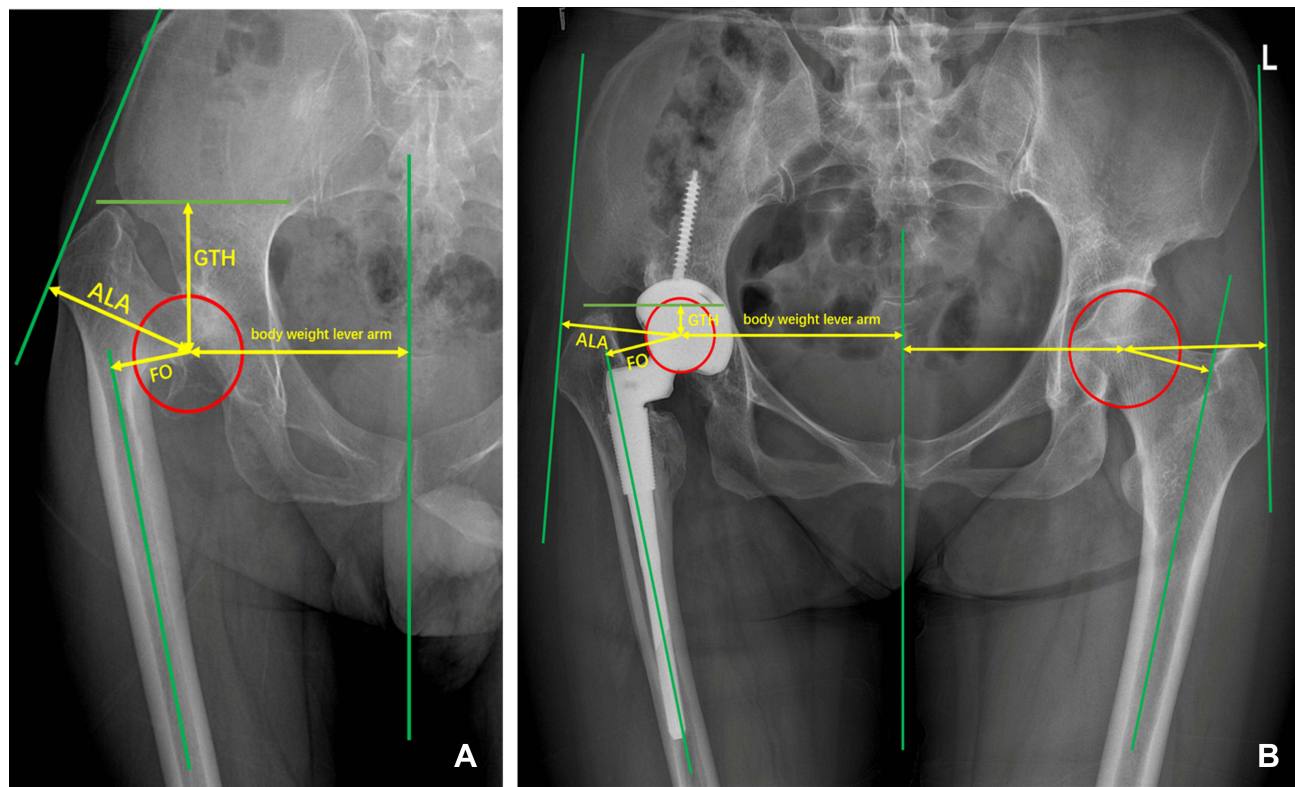
Figure 1 Diagrams for radiographic measurement of coxa vara (**A**) pre-operation; (**B**) the final follow-up.

assess the significance on mean parameter values. Kaplan–Meier analysis was performed to determine the probability of survivorship. A P-value of <0.05 was considered significant. All analyses were performed using SPSS version 26.0 (IBM, Armonk, NY, USA).

Results

The mean operation time was 3.47±1.51 hours (range, 1.58 to 7.67), and the mean amount of estimated blood loss was 542.42±467.89 mL (range, 100 to 2600) for all patients.

Clinical Evaluation

Clinically, HHS in pre-operation and final follow-up improved significantly (p<0.001) on average from 42.90 ±14.44 points to 89.54±4.75 points. Patients demonstrated diminished or no limping in 88% (29/33) of hips. In all patients, seven (21%) had slight limps, and six (18%) had moderate limps compared with all had moderate to severe limp preoperatively. Most of the limbs in the operation were prolonged, and the mean LLD decreased from 33.3 ±19.4 mm to 5.0±5.8 mm (p<0.001). Twenty-seven patients (82%) thought that total equality of the lower limbs was obtained compared to the preoperative state in their own perceptions. Six of the LLDs resulted from unrecovered

deformity of the spinopelvic oblique, and two explained that the LLDs resulted from insufficient exercise postoperatively, causing poor strength of muscle (Table 2).

Radiographic Assessment

For all radiographic parameters, the GTH and BWLA were significantly decreased compared to those preoperatively, and the FO and ALA were significantly increased (Table 3 and Figure 2). All stem of hips measured at the final follow-up were in clinical neutral alignment (varus 0.87 ±1.12° on average) between the longitudinal axis of the stem and the longitudinal axis of the femur.

Radiographic analysis at the final follow-up demonstrated that all prostheses were ingrown and were in stable positions. Two hips had a slight osteolysis in zone 1 and three hips had a slight osteolysis in zone 2 of the

Table 2 Long-Term Clinical Evaluation

	Pre-Operation	**Final Follow-Up**	**P-value**
HHS (points)	42.9±14.4	89.5±4.8	<0.001
LLD (mm)	33.3±19.4	5.0±5.8	<0.001

Note: The values are given as the mean and standard deviation.
Abbreviations: HHS, Harris hip score; LLD, limb length discrepancy.

Table 3 Radiographic Assessment

	Pre-Operation	Final Follow-Up	P-value
GTH (mm)	37.2±12.0	3.4±8.3	<0.001
FO (mm)	23.1±7.8	31.5±5.9	<0.001
Body weight lever arm (mm)	102.9±10.6	84.8±9.0	<0.001
ALA (mm)	48.8±9.7	53.1±9.8	0.014

Note: The values are given as the mean and standard deviation.
Abbreviations: GTH, great trochanteric height; FO, femoral offset; ALA, abductor lever arm.

acetabulum. No loosening or ossification was observed (Figure 3). Bony union was achieved for all patients undergoing subtrochanteric osteotomy in 6 months postoperatively.

Complications

Periprosthetic fracture of the distal femur occurred in one hip eight days after the operation owing to severe osteoporosis and excessive exercise, which was treated by open reduction with cable cerclage wiring immediately and healed in six months. One hip underwent revision because of loosening of the femoral component 5.2 years after the operation, which demonstrated a satisfactory outcome at the final follow-up. There were no other complications, such as nerve injury, dislocation or infection. With revision for any reason as the end point, the implant survival of 97.6% at the final follow-up was observed by Kaplan-Meier survival analysis (Figure 4).
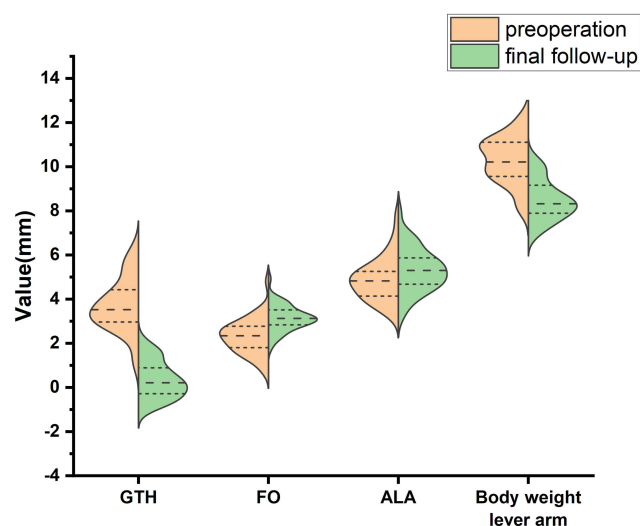

Figure 2 Scattergram showed there were significant differences in radiographic parameters (GTH, FO, ALA and Body weight lever arm) between the pre-operation and the final follow-up.

Discussion

The treatment of osteoarthritis secondary to coxa vara, which is associated with low NSA, overgrowth of the GT and limp, causing pelvic obliquity and degeneration of the lumbar spine, is challenging for surgeons.[3,8,11] Many methods have been proposed for the restoration of normal anatomic structure and improvement of biomechanics,[2,3,6,10,27] while little attention has been given to modular THA. We demonstrated that the outcomes of modular THA in patients with coxa vara who were followed up for more than 5 years were inspiring and positive, which achieved the expected satisfaction for all patients.

Customed cementless tapered stems have been utilized for years, but they may tend to varus on account of the native proximal morphology of the femur, for dictating the best fit of the prosthesis. For the Corail stem, mild varus alignment does not seem to have a negative effect, as Vidalain and Boldt reported.[4,10,28] However, techniques to maintain a neutral alignment, such as lowering the neck cut and lateralizing the entry point to the edge of GT, still risked damaging the abductor, altered the required offset or best fit of the prosthesis, and affected length of lower limbs and stability, meaning that varus alignments were not the original goal but were the result of compromise, let alone the disadvantages mentioned above.[4,28,29] A requirement for a more tailored prosthesis with either increased modularity or a custom-made prosthesis is feasible, while the latter is costly and involves a time-consuming process.[11]

Some scholars have suggested that greater trochanteric osteotomy or trochantoplasty is necessary for neutral alignment and avoiding obstruction of the GT, as Bartoníbek et al[6] and Yoo et al[3] reported. However, these techniques add to the complexity of the operation and the opportunity for infection owing to the increased blood loss, the higher frequency of taking intraoperative radiographs and the delay of rehabilitation, associated with femoral fracture and osteotomy nonunion.[2,3,6,11] Bartoníbek et al reported the result of only valgus intertrochanteric osteotomy in 15 patients with coxa vara, and 20% of patients had already undergone conversion to THA at the final follow-up because of the poor surgical technique. Refixation of osteotomies is also highly technically demanding. Although the procedure has been improved,[5] certain complications, high rates of dissatisfaction may be unavoidable.[1,5,6] Roberts et al[1] reported patients with congenital coxa vara by femoral valgus derotational osteotomy suggested 22% recurrence rate, resulting in residual deformity and progression to
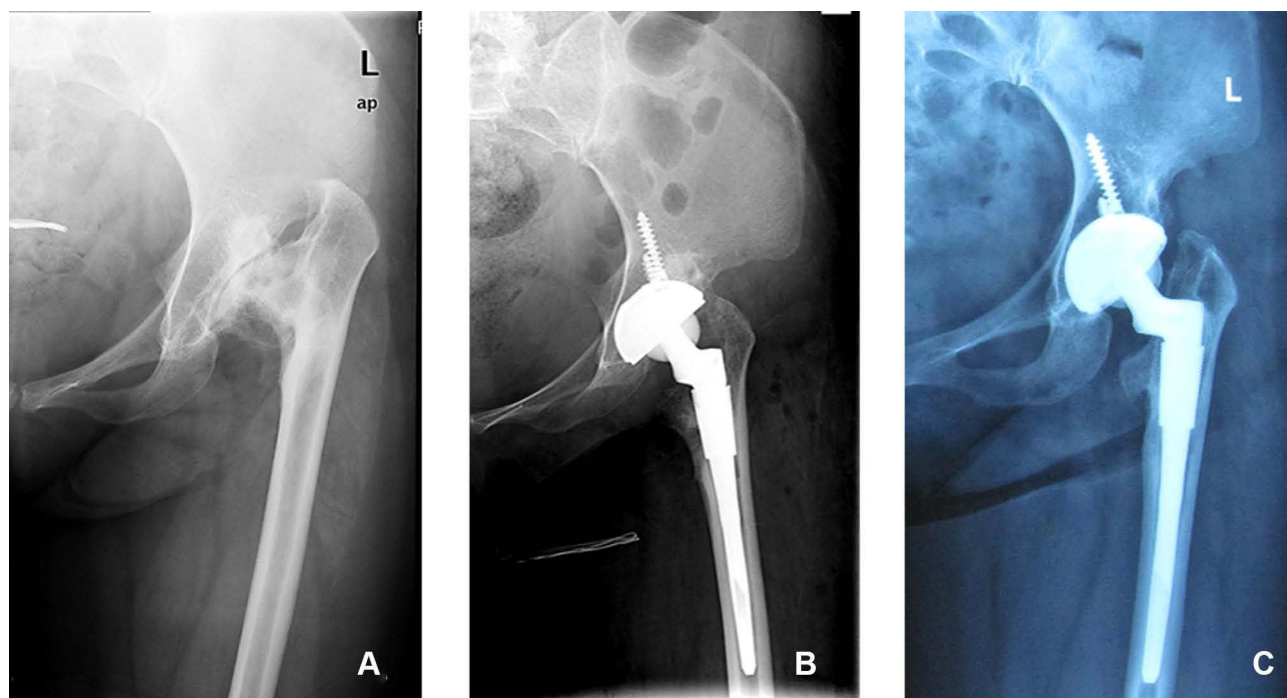
Figure 3 A 39-year-old woman with severe coxa vara. Preoperative (**A**) anteroposterior X-ray showed the severe deformity of the hip. Postoperative (**B**) anteroposterior X-ray showed normal anatomical structure and biomechanics were restored and the modular prosthesis achieved the initial stability.[37] (**C**) After 11.2 years it showed the optimal positions of the acetabular cup and femoral stem and the patient had no related symptoms.
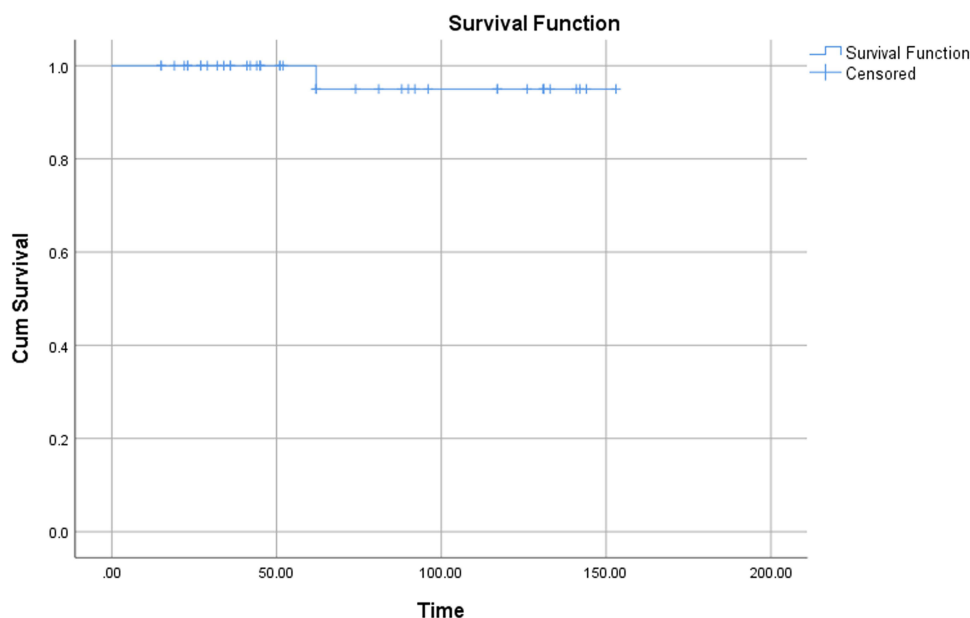

Figure 4 The Kaplan–Meier survival curve with revision for any reason as the end point was shown.

osteoarthritis over time, which indirectly reflected that severe osteoarthritis could be the final result regardless of whether the osteotomy was performed. In addition, THA performed after failed trochanteric osteotomies, including trochantoplasty, is also known to be of increased operating time and blood loss, more technical difficulties and higher complication rates (6%-31%).[30–33] Osawa et al[32] reported that the HHS after THA at the final follow-up was significantly poorer in the osteotomy group than in the primary group due to poor physical function caused by osteotomy,

and Carlile et al[27] suggested there were higher restrictions on patient selection and the surgical techniques for resurfacing arthroplasty in coxa vara. More complicated arthritic hips, such as hips with large cysts, osteopenia, LLD >1 cm or a diminished FO, that usually occurs in coxa vara, may be better served by a modular THA.[27,34,35]

Compared with the methods discussed above, the distinct advantages of modular THA depend on individualization for coxa vara. First, the modularity of the SROM allowed relatively free adjustment of the abnormal femoral anteversion by rotation between the stem and sleeve to avoid the obstruction of the overhanging greater trochanter, protecting the abductor tendon insertion and decreasing instability.[2,12,14] Second, different sizes of sleeves and stems could appropriately match the different morphologies of the medullary cavity to generate maximal contact, which decreased the occurrence of proximal bone loss due to stress shielding,[13,14] and alter the FO and length to achieve strong initial fixation. As a decrease in FO is common due to a stem NSA became greater than the native value after THA,[8,21] an increased offset is necessary during surgery to reduce the load of the abductor, which has been showed in our radiographic results, and it decreased the joint reaction force, improving limp and enhancing the survival of the artificial join. The significant decrease in the mean LLD represented not only that LLD was addressed but also that the effective ALA was increased by the lengthening of the affected limb with modular THA, which is beneficial to biomechanics.[2,21,36] In addition, the decrease in GTH manifested the COR was restored in normal morphology. All stems were in varus at an average of 0.87±1.12° but in clinical neutral alignment, meaning that a slight varus position (< 3°) was acceptable.

Another advantage not to be ignored is the use of conical sleeves to obtain stability due to the narrow and straight shape of the medullary cavity in coxa vara.[1,4,8] It is difficult for tapered stems to sink and stabilize deeply, which not only risks fracture of the metaphysis but also leads to the dilemma of reduction. The stem with conical sleeve could sink deeper and varus alignment is avoided. It has been reported that subtrochanteric osteotomy is usually necessary for some high dislocation hips such as Crowe type IV DDH.[13,16,37] However, in our study, some of these varus hips might avoid osteotomy by matching the metaphyseal with a conical sleeve, benefiting from the deeper implantation of stems, which is worthy of further study (Figure 5).

Kang et al[14] demonstrated similar good mid-term results in secondary coxarthrosis, including dysplastic hip or deformed femur, by the S-ROM prosthesis, which supported our results, while radiological parameters in this study were more specific and comprehensive. Seufert et al[2] also reported outcomes for the arthritis with LCP disease with modular THA. However, the author did not demonstrate signs of varus in their cases, and the sample size was small. Abouelela et al[38] and Talmo et al[12] studied modular THA after failed internal fixation of trochanteric fracture, 5% to 11% malunion of which caused varus deformity. Abouelela et al did not emphasize whether there was varus in their cases, and the study by Talmo et al is just case reports.
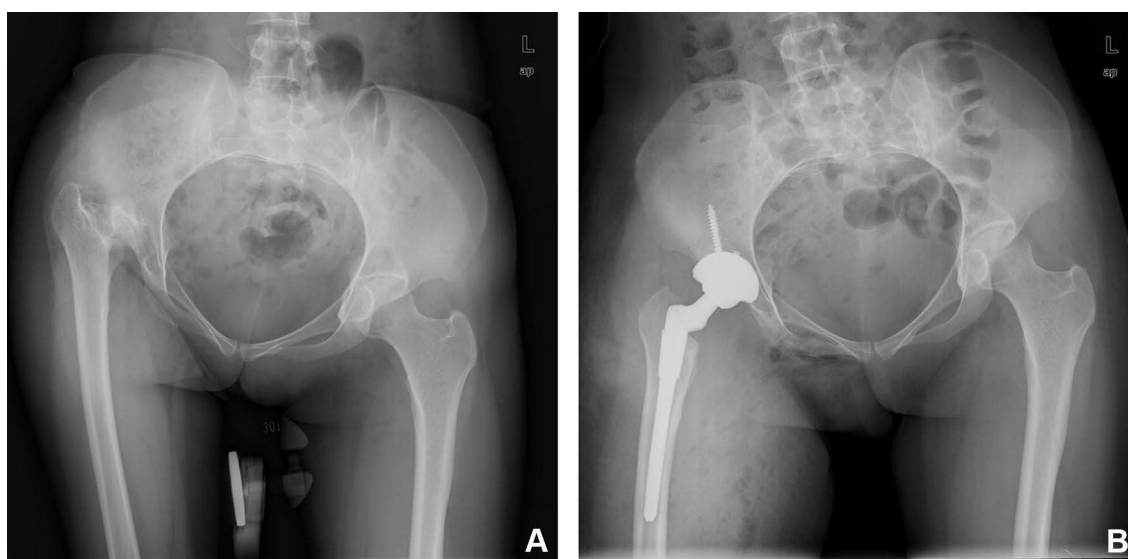

Figure 5 Preoperative (**A**) the deformity of coxa vara is associated with a high dislocation and a narrow and straight medullary cavity, which might be undergone the subtrochanteric osteotomy. Postoperative (**B**) the use of conical sleeve in SROM prosthesis made the stem sink deeper to avoid the osteotomy probably.

This study has several limitations. First, it is a retrospective, single-center review based on a relatively small sample size. However, coxa vara is a rare condition, and a large-cohort prospective study is hard to perform. Our patients were identified from a consecutive series, reducing the possibility of selection bias. Second, patients with bilateral coxa vara were not excluded and this could influence the results slightly. Moreover, we included patients affected by coxa vara due to different reasons, while all of hips had similar morphological features and solutions. Third, our study was performed in East Asia. Our results might not be generalizable to patients with a higher body mass index in western countries. Fourth, the measures of some parameters in this study were indirect, while we believe good medium-term outcomes lend credibility to modular THA and may serve as a basis for further research on more modular prostheses in longer-term follow-ups.

Conclusion

In conclusion, we believe that modular THA is effective and promising for osteoarthritis secondary to severe coxa vara caused by multiple primary diseases, which simplifies the operation, improves the deformity of hips, avoids unnecessary complications and achieves positive and satisfactory outcomes. However, larger comparative studies with more types of prostheses and longer follow-ups are required to validate this technique.

Ethical Approval

This retrospective review study involving human participants was in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. This study was approved by the medical ethics committee of Chinese PLA General Hospital.

Informed Consent

Prior to the study, the written informed consent was obtained from all patients for publication of this study and any accompanying images.

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Disclosure

The authors report no conflicts of interest in this work. Bohan Zhang and Jingyang Sun contributed equally to this work and are considered co-first authors for this study.

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