CLINICAL ARTICLE

Total Hip Arthroplasty with Subtrochanteric Femoral Shortening Osteotomy for High Hip Dislocation

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Objective: To evaluate the outcomes of total hip arthroplasty (THA) with subtrochanteric femoral shortening osteotomy for high hip dislocation.

Methods: In this retrospective study, the results of 24 primary THAs with acetabular reconstruction and subtrochanteric femoral shortening osteotomy in 21 patients with high hip dislocation were evaluated. The acetabula were reconstructed with cemented or uncemented cups and bone grafting. Transverse subtrochanteric femoral shortening osteotomies were applied and the osteotomy sites treated by bone grafting and cable fixation. Assessment was by Hip Harris scores and radiographic evaluation.

Results: The mean follow-up time was 42 months (18–108 months), three cases being lost to follow-up 18–27 months postoperatively. The HHS improved from 47.5 ± 8.7 to 88.5 ± 3.1 . The mean length of femoral segments removed was 2.5 ± 0.8 cm (range, 1.0–4.5 cm) and mean acetabular inclination $43^\circ \pm 5^\circ$ (range, 31° – 54°). Caudalization of the femoral head center was 3.2 ± 3.0 mm (range, –3 to 12 mm) and lateralization 4.0 ± 4.0 mm (range, –9 to 11 mm). Mean greater trochanter height relative to theoretical hip center was 5.2 ± 1.0 cm (range, 3.5–7.1 cm) preoperatively and 0.2 ± 0.6 cm (range, –0.9 to 1.2 cm) postoperatively. Intraoperative trochanteric fractures occurred in three cases and sciatic nerve palsy in one.

Conclusion: THA with subtrochanteric femoral shortening osteotomy is an effective technique for treating high hip dislocation. Its advantages include improvement in limb imbalance and decreased risk of sciatic nerve injury.

Key words: High hip dislocation; Acetabular reconstruction; Subtrochanteric femoral shortening osteotomy; Total hip arthroplasty

Introduction

Developmental dysplasia of the hip (DDH) ranges from barely detectable acetabular dysplasia to severely malformed and high dislocation of the hip¹. The acetabulum is usually shallow and dysplastic, with increased acetabular anteversion, decreased anterosuperior bone stock, smaller femoral head, shorter neck and increased femoral anteversion^{2,3}. The greater trochanter is located posteriorly, and the femoral canal

is straight and narrow. Abnormal bony structures and the high hip center also cause changes in surrounding soft tissues, including abductor muscle insufficiency, capsular thickening and abnormal location of neurovascular structures.

Dysplasia of the hip has a common pathophysiological mechanism that leads to increased contact stress, changes in hip biomechanics, hip instability, and impact and labrum pathology. There are a variety of acetabular osteotomy styles to

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Fig. 1 Intraoperative photographs of THA in a 39-year-old woman with a high hip dislocation of the left hip. (A) Cancellous bone grafting. (B) Femoral head autograft.

choose from for early treatment of DDH; however, most patients with hip dysplasia secondary to osteoarthritis eventually require total hip arthroplasty (THA). There are many challenges when considering THA for patients with DDH, including patient factors such as young age, distorted anatomy and documented high failure and revision rates^{3–5}. As dysplastic hips are of narrow true acetabula and serious bone defect, acetabular reconstruction is very difficult. Proximal femoral osteotomies are a well-established means of restoring limb balance and decreasing the risk of nerve traction injury caused by distal migration of the femur during femoroacetabular reduction.

We here present a retrospective series evaluating the mid-term outcomes of cementless THA with a transverse femoral shortening osteotomy and implantation of a cylindrical, straight stem femoral component for high hip dislocation.

Patients and Methods

Patients

Between 2003 and 2012, 24 hip joints in 21 patients (three men with unilateral dislocation and 18 women with bilateral dislocation; mean age, 55 years; range, 36–71 years) with high hip dislocation were subjected to transverse femoral shortening osteotomy and cementless THA. Indications for this surgery were as follows: (i) severe hip pain and dysfunction; and (ii) severe acetabular deformities, bone defects and high hip dislocation. All bilateral cases were staged with an interval of at least 3 months. Systemic or local infection, any neuromuscular disease in the affected limb or some old patients with system diseases were considered as contraindications to surgery.

Six of the hips had been operated on during late adolescence; one had undergone a Salter osteotomy and the other five hip shelf arthroplasties.

Clinical evaluations and radiographic examinations were repeated after a mean period of 42 months (range, 18–108 months). The retrospective study design was approved by the institutional review board, who accordingly waived the requirement for informed consent.

Surgical Procedure

Preoperative planning was performed on anterior-posterior (AP) plain films of known magnification (1:1.2). Three-dimensional CT scans were used to evaluate the severity of acetabular bone defects.

All patients were operated on in a lateral decubitus position via a posterolateral approach to the hip. After adequate exposure of the acetabulum, the hypertrophic capsule was totally resected to reach the true acetabulum. Starting with 32 mm reamers, the acetabulum was then reamed gradually to reach the medial wall of the true acetabulum, which was prepared as described by Sener *et al.*⁶. The true acetabular fossa was deepened in a posterior and medial direction using reamers. Medialization allowed increased coverage of the acetabular shell. Despite this, superior-lateral coverage of the acetabular component of the true acetabular fossa was usually incomplete. The acetabulum was then reconstructed with an acetabular prosthesis.

Depending on the severity of acetabular deformity and bone defects, the acetabulum was reconstructed with cemented or uncemented cups. Depending on the severity of the acetabular deformity and bone defect, the acetabula were reconstructed with cemented or uncemented cups. Uncemented cups were used in six cases (six hips; Zimmer, Warsaw, IN, USA; Fig. 1) and cemented cups in the other 15 cases (18 hips; Link, Hamburg, Germany; Fig. 2). Trabecular metal acetabular components with dome screws were used in the uncemented hips (one to three screws). Primary stability was obtained by press-fitting the acetabular component. In contrast, the cemented hips were reconstructed with titanium-alloy (Ti-alloy) mesh (Link, Hamburg, Germany).

Ti-alloy mesh and impaction bone grafting are good treatments for patients with severe acetabular bone defects^{7,8}, which can be fixed by impaction or structural bone grafting. Autogenous or allogeneic cancellous bone allografts were used in nine patients (10 hips), whereas femoral head structural bone autografts were used in the other 12 patients (14 hips).

After the acetabular component had been implanted, the proximal femur was reamed with straight reamers. Sequential

Fig. 2 Intraoperative photographs of THA in 64-year-old woman with high hip dislocation of the left hip. (A) Acetabulum reconstructed with Ti-alloy mesh cup. (B) Polyethylene prosthesis fixation.

rasping was then carried out until the appropriate stem size was achieved, after which proximal transverse osteotomy was performed just beneath the lesser trochanter with a reciprocating saw (Fig. 3). To expose the subtrochanteric area for

osteotomy, the piriformis muscle and external rotators were disarticulated laterally. The final reamer was inserted into the proximal femur and rotated internally to achieve femoral anteversion of 10° to 15°. The proximal osteotomy was made

Fig. 3 Diagrams illustrating the transverse subtrochanteric femoral shortening osteotomy technique. (A) Proximal osteotomy line. (B) Proximal femur. (C) Distal osteotomy line. (D) Stabilization with cancellous bone, bone plate grafting and cables.

Fig. 4 Intraoperative photograph of THA in a 28-year-old woman with high hip dislocation of the right hip. Stabilization with cancellous bone, bone plate grafting and cables.

slightly distal to the minor trochanteric level in a superior lateral-to-inferior medial direction at a 90° angle relative to the longitudinal axis of the femur. The prosthesis template with proximal femur was reset to the acetabular prosthesis, and then the distal femur was pulled in the opposite direction to determine the extent of shortening and the distal transverse osteotomy line⁹ (Fig. 3).

After the osteotomy had been completed, a cylindrical, straight stem femoral component with porous coating and longitudinal wing processes (Wagner Cone; Zimmer) was implanted in all hips. After the prosthesis had been implanted, the osteotomy sites were grafted with semicircular resected segmental bone or bone plates with cable fixation (Figs 3, 4). If there were gaps between the osteotomy sites, cancellous bone allografts were necessary. Femoral head (Zimmer) size was 28 mm in all hips (Video S1).

Postoperative Functional Exercises

Limb training, including isometric exercises and active motion, were started immediately after surgery. Patients were encouraged to mobilize early with two crutches and toe-touch allowed seven days after surgery. Active-assisted range-of-motion exercises were started in the first week after surgery.

Clinical Evaluation

All patients were clinically rated at initial admission and final follow-up using Harris hip scores (HHS). Abduction strength was assessed by the Trendelenburg test. During follow-up, the patients were evaluated by assessment of daily activities, hip pain and gait.

Radiographic Evaluation

Routine clinical and radiologic postoperative assessments were performed at 6, 12, 24, and 52 weeks. Routine preoperative radiographic examinations included supine AP and lateral hip, standing knee AP, supine lumbosacral AP and lateral and supine full-length X-ray films of the lower limbs. Hip radiographs and supine full-length X-ray films of the lower limbs were repeated immediately postoperatively. Hip radiographs were repeated at each follow-up visit until solid union was

observed. Patients who had radiologic evidence of union at the osteotomy site were allowed to bear their full weight.

Statistical Analysis

Descriptive analysis of continuous and categorical data was performed using proportions, frequency distributions, means, and standard deviations. Student's *t*-test was used to compare pre- and post-treatment values. Statistical significance was set at $P < 0.05$.

Outcome Criteria

Harris hip scores were used for clinical evaluation. Presence of the Trendelenburg sign was recorded. Radiologic outcome criteria included caudal displacement of the greater trochanter and femoral head center, the position of the prosthetic femoral head center, union at the osteotomy site, type of osteo-integration of the femoral component with the femur, abduction angle of the acetabular component and loosening of prosthetic components. Medialization and verticalization of the acetabular component were measured by the methods described by Pagnano *et al.*¹⁰ and Stans *et al.*¹¹, which are based on calculations of the triangle of Ranawat *et al.*¹². Loosening was evaluated by radiographic analysis of the prosthesis as described by DeLee and Charnley¹³ for the acetabulum and by Gruen *et al.*¹⁴ for the femur. Cups with progressive radiolucencies in more than one zone or migration of more than 2 mm were classified as loose¹⁵. Osteo-integration of the stems was graded as showing stable bony ingrowth, stable fibrous ingrowth or loose according to the criteria of Engh *et al.*¹⁶. Subsidence of the femoral component into the femur was measured according to the method of Heekin *et al.*¹⁷; subsidence of 5 mm or greater was considered significant.

Results

Clinical Outcomes

In our cases, the mean operation time was 127 ± 18 min (range, 90–150 min) and the mean blood loss 1088 ± 219 mL (range, 600–1500 mL) (Table 1).

There were 21 cases (24 hips) in this study; three were lost to follow-up 18–27 months post operation. The mean follow-up time was 42 months (18–108 months) (Table 1). The mean HHS improved from 47.5 ± 8.7 to 88.5 ± 3.1 , which is a statistically significant difference ($t = 26.5$, $P = 0.000$) (Table 1). The mean length of femoral segments removed by subtrochanteric osteotomy was 2.5 ± 0.8 cm (range, 1.0–4.5 cm) (Table 1) and the mean leg-length discrepancy 0.5 cm (range, 0–3 cm) at the last visit.

During follow-up, the patients were evaluated by assessing daily activities, hip pain and gait. Severity of Trendelenburg gait decreased in all patients except one, who had a positive greater trochanter height (greater trochanter cranial to femoral head center) postoperatively.

Radiographic Assessment

Solid union at the osteotomy site was achieved at a mean of 4 months postoperatively (range, 3–6 months) (Fig. 5).

TABLE 1 Relevant patient characteristics and clinical and radiologic outcomes

Case	Sex	Age (years)	Operation time (min)	Blood loss (mL)	Preoperative HHS	Postoperative HHS	Femoral shortening (mm)	Preoperative greater trochanter height (cm)	Postoperative greater trochanter height	Acetabular inclination (°)	Caudalization of femoral head center (mm)	Lateralization of femoral head center (mm)	Follow-up (months)
1	Female	66	90	600	69	93	2	4.0	-0.7	43	4	2	21 (lost)
2	Female	53	120	1000	52	91	1.5	3.7	0.1	47	2	4	108
3	Female	67	150	1200	37	86	2	4.3	-0.1	41	3	4	27 (lost)
4	Female	44	130	1200	64	91	3.5	6.0	-0.3	37	3	-1	78
5	Female	55	100	800	51	89	3	5.7	-0.5	31	5	1	66
6	Female	49	110	750	54	83	1	3.8	0.4	43	3	-9	54
7	Female	41	135	1200	43	93	1.5	3.5	-0.6	45	2	7	54
8	Male	53	150	1000	39	87	3	5.9	0.8	41	12	5	54
9	Female	52	150	1200	39	87	3.5	6.3	1.0	38	3	5	48
10	Female	41	130	1200	39	87	2	5.5	1.2	49	7	4	48
	Female	41	120	1200	41	85	2	4.7	0.3	47	5	5	
11	Male	36	120	1200	57	89	2.5	5.3	0.6	45	3	11	42
12	Female	71	100	1000	53	91	3	5.1	-0.3	43	-3	6	42
13	Female	39	110	900	57	91	4	6.6	0.1	43	4	5	18 (lost)
14	Female	64	120	800	37	82	3	5.7	-0.9	54	2	6	36
15	Male	65	150	1200	43	85	3	5.3	-0.5	37	5	7	36
16	Female	51	150	1400	43	87	2	4.5	0	39	-3	9	36
	Female	51	135	1300	43	89	2	4.5	-0.1	37	-1	4	
17	Female	63	135	1200	43	92	3	6.5	0.7	45	5	7	27
18	Female	69	130	1000	47	91	2	4.6	0.5	51	3	6	24
19	Female	54	135	1400	51	87	2	6.9	1.2	41	4	5	24
	Female	54	120	1350	51	89	2	4.8	0.3	43	5	4	
20	Female	65	120	800	51	93	4.5	7.1	0	39	3	3	24
21	Female	28	150	1200	37	87	2	5.3	0.7	47	6	-3	18

Fig. 5 Radiographs of THA in a 28-year-old woman with high hip dislocation of the right hip. (A) Preoperative AP pelvic radiograph. (B) Early postoperative AP pelvic radiograph showing plate and screw fixation of the subtrochanteric shortening osteotomy with semicircular femoral graft.

According to the Engh classification, stem to bone healing was classified as stable bony ingrowth in 17 hips and stable fibrous ingrowth in seven hips 18 months post operation. None of the stems showed subsidence of more than 5 mm. At the final follow-up, all acetabular grafts had been remodeled, with stable acetabulum structure. The mean acetabular inclination was $43^\circ \pm 5^\circ$ (range, 31° – 54°) (Table 1).

The position of the femoral head center relative to the theoretical hip center of Ranawat *et al.*¹² was measured in each case. Caudalization of the femoral head center was 3.2 ± 3.0 mm (range, -3 to 12 mm), whereas lateralization was 4.0 ± 4.0 mm (range, -9 to 11 mm) (Table 1). Mean greater trochanter height relative to the theoretical hip center was 5.2 ± 1.0 cm (range, 3.5 – 7.1 cm) preoperatively and 0.2 ± 0.6 cm (range, -0.9 to 1.2 cm) postoperatively (Table 1).

Complications

Intraoperative trochanteric fracture occurred in three hips during reduction maneuvers; these were treated by cable or wire fixation. No dislocations occurred. Sciatic nerve damage occurred in only one case, resulting in numbness of the leg. Remission of the symptoms occurred in three months by persistent neurotropic therapy and flexion of knee and hip of the affected side. Bony union at osteotomy sites had occurred before 6 months in all cases. There were no infections.

Discussion

We here report our experience in treating high hip dislocation by THA with subtrochanteric femoral shortening osteotomy. The important findings of our study can be summarized as follows.

Depending on the severity of the acetabular deformity and bone defect, the acetabula were reconstructed by different means. Some research suggests that use of cemented cups for

acetabuloplasty or acetabular hip shift decreases the surgical failure rate¹⁸. Surgical failures are associated with age, severe acetabular dysplasia, high hip dislocation and failure to restore the anatomical location of the center of rotation of the acetabulum.

Our previous research has indicated that cemented cups should not be used for acetabuloplasty. Cemented cups and autogenous bone grafting achieve excellent early results; however, bone graft collapse and absorption and acetabular cup loosening are observed in long-term follow-up.

Cancellous bone grafting is an excellent means of increasing acetabular bone mass^{7,8}. Autologous bone grafting combined with allogeneic bone grafting has some advantages in facilitating bone reconstruction. Ti-alloy mesh cups have biomechanical benefits. Use of Ti-alloy mesh cups improves the stability of the acetabulum, preventing bone resorption and collapse.

Femoral shortening can be achieved through proximal, subtrochanteric or distal osteotomies^{15,19,20}. Restoration of the anatomical hip center creates the risk of nerve traction injury because the femur migrates distally during femoroacetabular reduction, increasing limb length by more than 4 cm^{21,22}. Shortening osteotomy of the femur reportedly minimizes imbalance of the legs, preventing nerve traction injury^{21,22}.

Subtrochanteric femoral shortening osteotomy is the optimal type of osteotomy; it improves the femoral anteversion angle, allowing resetting of the greater trochanter and thus restoring biomechanical abductor properties. Because the proximal femur metaphysis is retained, a cementless femoral stem prosthesis can be used¹⁵.

Consequently, in this study we performed subtrochanteric femoral shortening osteotomies and cementless femoral stem prostheses to treat high hip dislocation. The initial

stability of the osteotomy site depends mainly on the rotational stability and contact stress at the osteotomy site. Cylindrical, straight stem femoral components with porous coatings and longitudinal wing processes increase the rotational stability and contact stress at the osteotomy site, resulting in better initial stability of the osteotomy site. Good osteotomy bone healing occurred in all our cases.

This study has some limitations. There were relatively few patients and the mean duration of follow-up was relatively short. A control group for comparison would have strengthened our analysis and interpretation of findings. Additionally, several patients were lost to follow-up. Fixation of the subtrochanteric osteotomy sites with a bone plate and cables may be an appropriate alternative. In cases that need additional rotational stability, plate and screws should be kept in mind². Better methods and prostheses may be needed to reconstruct the acetabulum and achieve secure and stable fixation of the femoral stem after subtrochanteric osteotomy.

In conclusion, because of the abnormal anatomy of the proximal femur and acetabular structure, THA in patients with high hip dislocation is very difficult. In our opinion, rigorous preoperative assessment and prosthesis selection are very important. THA with subtrochanteric femoral shortening osteotomy is an effective technique for treating high hip dislocation. Transverse subtrochanteric femoral shortening osteotomy prevents distraction injury of the sciatic nerve. Further larger studies with a control group may provide more reliable and detailed knowledge about this subject.

Supporting Information

Additional Supporting Information may be found in the online version of this article on the publisher's web-site:

Video S1 Transverse subtrochanteric femoral shortening osteotomy technique.

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