The Reconstruction Accuracy of the Hip Center of Rotation After Cementless Total Hip Arthroplasty for Failed Treatment of Acetabular Fractures. Does It Matter?

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Research Article

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Abstract

Background

To assess the impaction of reconstruction accuracy of hip center of rotation (COR) on midterm clinical and radiographic results of cementless reconstruction of total hip arthroplasties (THAs) for patients after failed treatment of acetabular fractures.

Methods

One hundred and four patients (107 hips) who underwent THAs after failed treatment of acetabular fractures were retrospectively evaluated and cementless cups and stems were implanted in all hips. Clinical outcomes were assessed using the Harris hip score (HHS) and Western Ontario and McMaster Universities Arthritis Index (WOMAC) scoring system. Radiographic results were analyzed by serial perioperative x-rays.

Results

At the latest follow-up examination, the median HHS increased from 52 (42-65) before surgery to 93 (90-97) ($p < 0.001$) and the median WOMAC decreased from 52 (36-65) before surgery to 5.8 (1.5-8) ($p < 0.001$). Compared with normal contralateral hip, 79 cups migrated superiorly (0.2-33.6mm) and 22 cups migrated inferiorly (0.2-16.1mm). The distance of superior migration of reconstructed COR was correlated with positive Trendelenburg sign at the latest follow-up examination ($r=0.504$; $p < 0.001$). The percentage of postoperative Trendelenburg sign was significantly higher in superior migration subgroup than that in subgroup with anatomical restoration of COR ($P=0.015$).

Conclusions

Cementless THAs in patients after failed treatment for acetabular fractures achieved predictable clinical and radiographic outcomes. A superiorly migrated hip COR appeared to exert a negative effect on abductor muscle function.

Background

Optimal restoration of hip center of rotation (COR) is of great importance for implant longevity in total hip arthroplasty (THA). Any errors in reconstruction of hip COR can inevitably affect implant load, stability, wear rates and can eventually result in poor hip function with costly complications, including pain, loosening and dislocation [1, 2, 3, 4, 5].

Acetabular fractures may lead to late complications, including posttraumatic arthritis and avascular necrosis of femoral head with or without initial open reduction and internal fixation (ORIF) [6, 7]. THA has been utilized to treat patients with disabling pain and functional limitations after failed treatment of acetabular fractures. Previous literature has demonstrated encouraging outcomes with regard to cementless acetabular components [8, 9, 10, 11, 12, 13]. Among these, previous articles ever described the reconstructive accuracy of hip COR after THA, but failed to compare it with clinical results [8, 9, 10].

The purpose of this study was to retrospectively review a single center's experiences in treating failed acetabular fractures with THA by cementless components. An additional purpose was to assess whether the reconstructed hip COR affects clinical results and complication rate.

Methods

Between 2001 and 2017, 124 consecutive patients were treated at our institute with primary THAs after failed treatment of acetabular fractures. The median duration of follow-up was 93.0 months (47-151 months) in 104 patients (107 hips) (Table 1); 20 patients were lost to monitoring. Approval of the local institutional review board and informed consent from all participating patients were obtained.

Table 1
Comparison of Preoperative Demographic and Clinical Study Data

Variable	Data Group 1	Data Group 2	Total
Gender	78 men (75%)	26 women (25%)	104 patients
Cause of fracture	Motor vehicle accident in 83 hips (77.6%)	Weight-compression injuries in 5 hips (4.6%); fall from a height in 19 hips (17.8%)	107 hips in high-energy accidents
Treatment	ORIF in 67 hips (63%)	Conservative treatment in 40 hips (37%)	
BMI	25.8±3.7		
Average age at fracture (yr)	40 (range, 33-48.5)		
Average age at THA (yr)	50 (range, 43-47)		
Treatment interval between fracture and THA (mo)	47 (range, 18-156)		
Positive Thomas sign	68 hips (63.6%)		
Positive Trendelenburg sign	57 hips (53.3%)		

ORIF = open reduction and internal fixation; BMI=body mass index; THA= total hip arthroplasty.

The initial fracture pattern was classified according to Judet classification system (Table 2). We exposed all 107 hips through a posterolateral approach. Hardware was partially removed in 21 hips, entirely in 26 hips, and left in situ in 20 hips. We implanted tantalum trabecular metal (TM) (Zimmer, Warsaw) cups in 38 hips and titanium hemispheric cups in the other 69 hips. In 69 cases, the cups were supplemented with 2 to 5 screws and the initial stability and orientation of the cup was confirmed with intraoperative radiographs. Cementless stems were implanted in all hips. We used a ceramic-on-ceramic bearing surface in 38 hips (35.5%), a ceramic-on-polyethylene bearing surface in 45 hips (42.1%), and a cobalt–chrome head on a polyethylene bearing surface in 24 hips (22.4%).

Table 2
Initial fracture pattern according to Judet system[17]

Fracture pattern	N (%)
Simple fractures	69 (64.5%)
Posterior wall	59 (55.1%)
Posterior column	3 (2.8%)
Transverse	7 (6.5%)
Complex fractures	38 (35.5%)
Posterior column plus posterior wall	20 (18.7%)
Both columns	4 (3.7%)
Transverse plus posterior wall	12 (11.2%)
T-shaped	2 (1.9%)
Acetabular bone defects were classified according to the Paprosky criteria [14]. There were 22 grade I acetabular defects, 17 grade IIa defects, 15 grade IIb defects, 7 grade IIc defects, 3 grade IIIa defects and 1 grade IIIb defects. Thirty-six hips had acetabular bone autografts: 27 had morcelized autografts and 9 received bulk autografts.	

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Clinical And Radiographic Evaluation

All clinical evaluations were conducted by independent observers (C.M.X., L.W.Y.) who had not participated in the THAs. All patients were routinely examined at three months, six months, one year, yearly until 5 years after surgery and then every 5 years thereafter. For patients who did not comply with routine follow-up schedules, data collection was accomplished via telephone, E-mail, or WeChat software. Clinical outcomes were evaluated using the Harris hip score (HHS) and Western Ontario and McMaster Universities (WOMAC)Arthritis Index scoring system. Patient satisfaction was also evaluated using a self-administered four-category scale (very satisfied, somewhat satisfied, somewhat dissatisfied, and very dissatisfied).

Serial radiographs included anteroposterior (AP), lateral, and two 45° oblique views of the involved hip before THA and at the follow-up visit. Computed tomography scans of the involved pelvis were routinely reviewed preoperatively. Radiographic assessments of acetabular components were accomplished in three zones, as devised by DeLee and Charnley [15]. Radiographic failure was determined by >3 mm of vertical or horizontal migration, > 5° change in inclination angle and presence of fewer than two signs of osteo-integration according to Moore criteria [16]. Heterotopic ossification (HO) was categorized by the classification system of Brooker et al [17]. The acetabular inclination and anteversion angles were measured according to the method described by Widmer [18]. 40±10° for inclination and 15±10° for anteversion were regarded as the safe zone proposed by

Lewinnek et al [19]. Preoperative, postoperative, and the change in leg length discrepancy (LLD) were recorded. The LLD is measured from the inter-teardrop line to the midpoint of the lesser trochanter on both sides.

The vertical and horizontal locations of cups were documented according to the method described by Martel et al [20]. Patients who had undergone bilateral THA or who had abnormal contralateral hips were excluded. We calculated the difference between each horizontal and vertical distance in the reconstructed hip and in the contralateral hip. All radiographs reviewed were at the latest follow-up examination from the electronic picture archiving and communication system (PACS) in our institute and the magnification ratio was determined from the known diameter of implanted prosthetic head. Each parameter was measured twice with Mimics software (version 16.0) and averaged.

The statistical analysis was used by SPSS software (version 17.0). Descriptive analyses for categorical variables were based on percentages and frequencies and for continuous variables on mean and standard deviation (SD) or median and quartile (25-75%) if the data were skewed. The preoperative and final follow-up HHS and WOMAC were compared using the Wilcoxon signed rank test. The correlations between continuous variables and ordinal variables were determined using Pearson correlation analysis and Spearman rank correlation analysis by correlation coefficient (r), respectively.

The method for intergroup comparisons were as follows. 101 hips with unilateral hip replacement were classified into an inferior migration subgroup (inferior migration distance of the reconstructed COR >5mm), superior migration subgroup (superior migration distance>5mm) and subgroup with anatomical restoration (inferosuperior migration distance equal or less than 5mm). Similarly, these hips were classified into a medial migration subgroup (medial migration distance >5mm), lateral migration subgroup (lateral migration distance>5mm) and subgroup with anatomical restoration (mediolateral migration distance equal or less than 5mm). For the cases with superior migration of reconstructed COR, hips were classified into a subgroup with anatomical restoration (0-5mm), a subgroup with mild migration (5-10mm), a subgroup with moderate migration (10-20 mm) and a subgroup with severe migration (≥10-20 mm). The statistical analysis was used to examine the differences between the variables describing these subgroups, including patient demographics (gender, age at THA, BMI, treatment interval, preoperative HHS and WOMAC), trauma-related factors (fracture pattern, initial ORIF treatment, preoperative LLD) and surgery-related factors (acetabular inclination and anteversion angle, use of an elevated liner, cup diameter, and bulk autografts). We also analyzed the differences between these subgroups regarding postoperative outcomes including LLD, Trendelenburg sign, HHS and WOMAC, and complication rate. The intergroup differences were compared by using Kruskal-Wallis tests or Fisher exact tests for continuous variables and for dichotomous variables, respectively. Significance was set at $p<0.05$, and tests were 2-tailed.

Results

Clinical assessment

The average HHS increased from 52 (42-65, range, 20-81) before surgery to 93 (90-97, range 59-100) at the latest follow-up examination ($p < 0.001$). There were excellent results in 83 hips, good for 15, fair for 2 and poor for an additional 7. The average WOMAC decreased from 52(36-65, range, 8-93) before surgery to 5.8 (1.5-8, range, 0-36) at the latest follow-up examination ($p < 0.001$).

After THA, the Thomas and Trendelenburg signs were positive in 8 (7.5%) and 18 hips (16.8%), respectively. All but seven patients were very satisfied (75 patients) or satisfied (22 patients) with the results. Four patients who were very dissatisfied all developed periprosthetic infection. Three patients were somewhat dissatisfied. One of them had an iatrogenic sciatic nerve injury, one patient had perceived LLD and another one endorsed persistent thigh pain.

Radiographic results

The overall inclination and anteversion angles of cups were 38.0±7.5° (range, 13.5-58.3°) and 17.8±7.1° (range, 3.0-34.7°), respectively. Of the 107 hips, 20 (18.7%) were outside of Lewinnek acetabular anteversion safe zone (16 hips>25° and 4 hips<5°) and 17 (15.9%) were outside inclination safe zone (5 hips>50° and 12 hips<30°). Only 3 hips had an inclination angle of <30° and an anteversion angle of <5° simultaneously.

The mean x-ray measured LLD decreased from 16.4±13.6 mm (range, 0-50.0 mm) preoperatively to 7.4±6.3 mm (range, -13.97-26.48mm) postoperatively ($p < 0.001$).

Compared with the normal contralateral hip, 79 cups (81%) of 101 hips migrated superiorly (0.2-33.6mm, average 7.7mm) and 22 (19%) migrated inferiorly (0.2-16.1mm, average 4.3mm). 68 cups (67%) of 101 hips migrated medially (0.2-29.0mm, average 5.2mm) and 33 (33%) migrated laterally (0.2-25.7mm, average 5.4mm). Compared with the contralateral hip, the reconstructed COR was within 5 mm of vertical and horizontal symmetry (anatomical restoration of hip center) in 24 hips (24%) and was more than 20 mm beyond vertical symmetry, horizontal symmetry, or both (nonanatomical restoration of hip center) in 8 hips (8%). The distance of superior migration of reconstructed COR was associated with preoperative LLD ($r=0.311$; $P=0.004$), postoperative LLD ($r=0.396$; $p < 0.001$) and positive Trendelenburg sign at the latest follow-up ($r=0.504$; $p < 0.001$). However, the distance of superior migration of reconstructed COR was not found to be associated with HHS ($r=0.007$; $P=0.948$) or WOMAC ($r=-0.047$; $P=0.676$) at the latest follow-up examination.

101 hips with unilateral THA were classified into a superior migration subgroup (46 hips), inferior migration subgroup (6 hips) and normal subgroup (49 hips). The results of intergroup comparisons among these three subgroups were listed in **Table 3**. Similarly, these hips were classified into a medial migration subgroup (31 hips), lateral migration subgroup (55 hips) and subgroup with anatomical restoration of COR (15 hips). The results of intergroup comparisons were listed in **Table 4**. In 79 hips with superior migration of reconstructed COR, the results of intergroup comparisons among anatomical restoration subgroup (33 hips), mild migration subgroup (22 hips), moderate migration subgroup (17 hips) and severe migration subgroup (7 hips) were listed in **Table 5**.

Table 3 Comparisons of perioperative parameters among the subgroup with anatomical restoration, superior migration, and inferior migration

COR= center of rotation, THA= total hip arthroplasty, BMI= bone mass index, ORIF= open reduction and internal fixation, LLD= leg length discrepancy, HHS= Harris hip score, WOMAC= Western Ontario and McMaster Universities Arthritis Index, HO= heterotopic ossification

* Indicate the hips with grade 2 or 3 Paprosky acetabular bone defect

parameters	superior migration (n=46)	anatomical restoration (n=49)	inferior migration (n=6)	P value
Age at THA (year)#	50.5(43.00 to 58.00)	50.0(44.50 to 57.00)	39.0(32.50 to 58.00)	0.464
Treatment interval (month)#	42.0(21.00 to 146.25)	60.0(17.50 to178.00)	35.5(18.00 to 240.00)	0.987
BMI§	25.9(3.4)	25.7(4.0)	26.0(3.1)	0.973
Female¶	9(19.6%)	14(28.6%)	2(33.3%)	0.526
Preop. HHS#	52.5(41.75 to 63.25)	52.0(43.00 to 66.00)	43.0(33.00 to 53.25)	0.321
Preop. WOMAC#	52.5(34.75 to 62.25)	50.0(37.00 to 65.50)	56.0(35.00 to 74.75)	0.797
Preop. positive Trendelenburg sign¶	23(50.0%)	30(61.2%)	2(33.3%)	0.306
Preop. LLD (mm)#	15.7(10.00 to 27.00)	10.0(0 to 20.00)	37.5(11.25 to 46.25)	0.024
Complex fracture pattern¶	18(39.1%)	15(30.6%)	5(83.3%)	0.036
Initial ORIF treatment¶	28(60.9%)	32(65.3%)	5(83.3%)	0.601
Severe bone defect*¶	23(50.0%)	16(32.7%)	4(66.7%)	0.121
Diameter of cup(mm)#	54.0(50.00 to 56.00)	54.0(50.00 to 56.00)	54.0(50.50 to 57.00)	0.923
Use of an elevated liner¶	32(69.6%)	27(55.1%)	4(66.7%)	0.379
Acetabular inclination angle (°)§	38.7(6.9)	37.7(6.9)	33.6(15.4)	0.307
Acetabular anteversion angle (°)§	17.7(7.6)	18.6(6.8)	14.9(7.7)	0.456
Bulk autograft¶	4(8.7%)	4(8.2%)	1(16.7%)	0.610
Distance of horizontal migration(mm) #♮	3.0(-2.31 to 6.64)	1.4(-1.23 to 5.36)	1.6(-5.98 to 12.61)	0.726
Postop. Trendelenburg sign¶	13(28.3%)	4(8.2%)	1(16.7%)	0.032
Postop. HHS#	95.0(89.75 to 97.75)	93.0(90.00 to 98.50)	95.0(68.25 to 97.75)	0.956
Postop. WOMAC #	4.0(0.75 to 8.00)	6.0(1.00 to 9.00)	4.5(1.50 to 31.50)	0.623
Postop. HO¶	7(15.2%)	10(20.4%)	0(0%)	0.571

Postop. sciatic injury¶	1(2.2%)	6(12.2%)	0(0%)	0.189

§ The normally distributed data are expressed as mean and standard deviation

The non-normally distributed data are expressed as median and IQR.

¶ The qualitative data are expressed as numbers and percentages.

♮ The negative values represented lateral migration

Table 4 Comparisons of perioperative parameters among the subgroup with anatomical restoration, medial migration, and lateral migration

COR= center of rotation, THA=total hip arthroplasty, BMI=bone mass index, ORIF=open reduction and internal fixation, LLD=leg length discrepancy, HHS=Harris hip score, WOMAC= Western Ontario and McMaster Universities Arthritis Index, HO= heterotopic ossification

* Indicate the hips with grade 2 or 3 Paprosky acetabular bone defect

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The non-normally distributed data are expressed as median and IQR.

¶ The qualitative data are expressed as numbers and percentages.

♮ The negative values represented superior migration

Table 5 Comparison of perioperative parameters among the subgroup with anatomical restoration, mild, moderate and severe migration

parameters	medial migration (n=31)	anatomical restoration (n=55)	lateral migration (n=15)	P value
Age at THA (year)#	50.0(34.00 to 56.00)	50.0(43.00 to 58.00)	53.0(47.00 to 57.00)	0.376
Treatment interval (month)#	24.0(12.00 to 72.00)	47.0(23.00 to 204.00)	120.0(36.00 to 156.00)	0.015
BMI§	25.7(3.6)	25.9(3.5)	25.7(4.6)	0.954
Female¶	3(9.7%)	18(32.7%)	4(26.7%)	0.053
Preop. HHS#	63.0(41.00 to 73.00)	50.0(42.00 to 63.00)	57.0(45.00 to 63.00)	0.183
Preop. WOMAC#	50.0(29.00 to 70.00)	53.0(40.00 to 67.00)	52.0(36.00 to 58.00)	0.287
Preop. positive Trendelenburg sign¶	16(51.0%)	31(56.4%)	8(53.3%)	0.961
Preop. LLD (mm)#	15.0(9.30 to 25.10)	15.3(25.00 to 0)	16.0(7.80 to 30.00)	0.688
Complex fracture pattern¶	13(41.9%)	16(29.1%)	9(60.0%)	0.075
Initial ORIF treatment¶	21(67.7%)	36(65.5%)	8(53.3%)	0.655
Severe bone defect*¶	14(45.2%)	18(32.7%)	11(73.3%)	0.017
Diameter of cup(mm)#	54.0(54.00 to 50.00)	54.0(56.00 to 50.00)	56.0(52.00 to 60.00)	0.009
Use of an elevated liner¶	19(61.3%)	33(60.0%)	11(73.3%)	0.690
Acetabular inclination angle (°)§	39.6(7.2)	37.6(6.7)	35.5(10.7)	0.208
Acetabular anteversion angle (°)§	17.5(6.6)	19.0(7.5)	15.3(7.0)	0.182
Bulk autograft¶	5(16.1%)	3(5.5%)	1(6.7%)	0.229
Distance of vertical migration(mm)#♮	-6.8(-10.44 to -2.42)	-3.5(-8.31 to -0.18)	-3.1(-14.46 to 0.75)	0.513
Postop. Trendelenburg sign¶	5(16.1%)	7(12.7%)	6(40.0%)	0.062
Postop. HHS#	93.0(90.00 to 100.00)	93.0(89.00 to 97.00)	94.0(93.00 to 97.00)	0.696
Postop. WOMAC#	5.0(0 to 8.00)	5.0(2.00 to 10.00)	4.0(3.00 to 6.00)	0.813
Postop. HO¶	8(25.8%)	7(12.7%)	2(13.3%)	0.277

Postop. sciatic injury¶	3(9.7%)	4(7.3%)	0(0%)	0.571

parameters	anatomical restoration(n=33)	mild migration (n=22)	moderate migration(n=17)	severe migration(n=7)	P value
Age at THA (year)$^{\#}$	52.0(45.00 to 57.00)	52.0(43.75 to 60.25)	48.0(37.00 to 59.00)	51.0(50.00 to 55.00)	0.557
Treatment interval (month)$^{\#}$	60.0(16.50 to 198.00)	36.0(16.75 to 125.75)	48.0(15.00 to 216.00)	96.0(24.00 to 192.00)	0.808
BMI§	25.6(4.2)	26.3(3.3)	24.3(2.8)	28.4(3.7)	0.092
Female¶	6(18.2%)	4(18.2%)	4(23.5%)	1(14.3%)	0.947
Preop. HHS$^{\#}$	63(43.50 to 71.50)	56.5(40.75 to 65.25)	49.0(44.00 to 64.00)	49.0(21.00 to 63.00)	0.548
Preop. WOMAC$^{\#}$	51.0(29.00 to 62.50)	51.0(32.00 to 56.00)	55.0(41.00 to 70.50)	56.0(27.00 to 61.00)	0.426
Preop. positive Trendelenburg sign	19(57.6%)	8(36.4%)	10(58.8%)	5(71.4%)	0.285
Preop. LLD (mm)$^{\#}$	10.0(0.40 to 20.00)	12.5(8.75 to 20.53)	16.1(10.00 to 23.00)	35.0(24.00 to 40.00)	0.022
Complex fracture pattern¶	9(27.3%)	6(27.3%)	6(35.3%)	6(85.7%)	0.032
Initial ORIF treatment¶	21(63.6%)	14(63.6%)	9(52.9%)	5(71.4%)	0.849
Severe bone defect*	11(33.3%)	10(45.5%)	8(47.1%)	5(71.4%)	0.294
Diameter of cup(mm)$^{\#}$	54.0(50.00 to 55.00)	54.0(51.50 to 56.00)	50.0(50.00 to 55.00)	56.0(54.00 to 64.00)	0.081
Use of an elevated liner¶	17(51.5%)	15(68.2%)	12(70.6%)	5(71.4%)	0.459
Acetabular inclination angle (°)§	37.7(7.8)	37.3(6. 8)	38.9(7. 8)	42.2(4.3)	0.438
Acetabular anteversion angle (°)§	17.8(6.4)	16.8(8.1)	19.3(7. 9)	16.7(5.1)	0.728
Bulk autograft¶	3(9.1%)	0(0%)	3(17.6%)	1(14.3%)	0.139
Postop. LLD (mm)$^{\#}$	4.9(2.26 to 9.13)	4.0(2.90 to 9.70)	6.2(1.73 to 11.42)	17.5(9.21 to 20.25)	0.010
Postop.	2(6.1%)	1 (4.5%)	7(41.2%)	5(71.4%)	0.001

Trendelenburg sign¶					
Postop. HHS#	93.0(90.00 to 98.50)	97.0(89.00 to 100.00)	93.0(90.50 to 97.00)	94.0(83.00 to 97.00)	0.587
Postop. WOMAC#	6.0(1.00 to 9.00)	3.0(0 to 6.25)	5.0(2.00 to 8.00)	4.0(3.00 to 13.00)	0.424
Postop. HO¶	6(18.2%)	3(13.6%)	3(17.6%)	1(14.3%)	0.969
Postop. sciatic injury¶	5(15.2%)	0(0%)	1(5.9%)	0(0%)	0.193
Distance of vertical migration(mm)#♮	-2.4(-3.41 to -1.55)	-7.5(-8.34 to -6.77)	-11.0(-13.80 to -10.64)	-21.1(-28.41 to -20.24)	0.001
Distance of horizontal migration(mm)#♮	2.1(-0.01 to 6.02)	3.6(-1.50 to 6.07)	3.3(-0.24 to 8.37)	-2.3(-11.00 to 2.68)	0.232

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[#] The non-normally distributed data are expressed as median and IQR.

[¶] The qualitative data are expressed as numbers and percentages.

[♮] The negative values represented superior and lateral migration

Complications

Perioperative complications included iatrogenic sciatic nerve injury in 8 hips and periprosthetic infection in 4 hips. Six hips with initial ORIF treatment and three hips with non-ORIF treatment already had a sciatic nerve lesion before the THA and only one of them presented with a worsening of the previous nerve lesion. The additional 7 hips had a new-onset sciatic nerve injury after THA. Three patients had a full resolution within three months after THA, three patients had a full resolution of sensory disturbance, but partial resolution of foot drop one year after THA. Two patients did not reveal any improvement in sensory disturbance and foot drop.

In the 4 patients who developed periprosthetic infection, microbial culture tests were used to confirm this diagnosis. All patients had a history of ORIF. The four hips were treated with implant removal, debridement, and antibiotic-loaded articulating cement spacers. Three of them acquired an infection control and received a successful two-stage revision arthroplasty. The infection remained uncontrolled in another patient and he refused to receive any further surgery.

After surgery, 17 hips demonstrated HO with no adverse clinical effects. Five hips had Brooker class I HO, 7 hips had class II and 5 hips had class III. No patient required a further procedure for HO.

Discussion

Although THA after failed treatment of an acetabular fracture is a technically demanding procedure, reconstruction with cementless components can achieve satisfactory prosthesis survivorship and clinical results [8, 9, 10, 11, 12, 13]. Our clinical findings in this young, active patient population affected by high-energy trauma were encouraging with a mean HHS of 93 and WOMAC of 5.8 at the latest follow-up examination. Perioperative complications included iatrogenic sciatic nerve injury in 8 hips (7.5%), periprosthetic infection in 4 hips (3.7%), and HO in 17 hips (15.9%).

A series of published studies have discussed the significances of the precise location of the COR in THA performed for patients with developmental dysplasia of the hip (DDH) [21], rheumatoid arthritis (RA) [22] and in revision situations [23]. However, in the published studies focusing on cementless acetabular reconstruction for failed treatment of acetabular fractures, only a few discussed the association of reconstruction accuracy in terms of hip COR with clinical results. Ranawat et al [10] reported only in three hips (9%) that the position of the COR was greater than 20 mm beyond vertical symmetry, horizontal symmetry, or both when compared with the unaffected hip. They found that nonanatomic restoration of COR was ultimately associated with need for revision surgery and with intraoperative discovery of a segmental acetabular defect. However, this did not correlate with prior treatment and HHS or with polyethylene wear.

In the current series, we found that a wide range of distribution of the reconstructed COR. The reconstructed COR was within 5 mm of vertical and horizontal symmetry (anatomical restoration of COR) in 24 hips (24%) and was more than 20 mm beyond vertical symmetry, horizontal symmetry, or both (nonanatomical restoration of COR) in 8 hips (8%). This distribution model reflected the abnormal anatomy of the acetabulum after initial fractures and treatments, and was further affected by the hardware and bone defect during implantation of the cementless cups. Consequently, compared with THA reconstruction for DDH or RA, the implant reconstruction for acetabular fractures become more irregular and technically demanding, which is analogous with situations in revision THA.

The results of horizontal intergroup comparisons suggested that only some preoperative parameters, including treatment interval, grade of acetabular bone defect and diameter of cup, had significant differences. For vertical intergroup comparisons, only percentage of postoperative positive Trendelenburg sign was significantly higher in superior migration subgroup than that in subgroup with anatomical restoration of COR (28.3% vs 8.2%, $P=0.015$). Moreover, the distance of superior migration of reconstructed COR was associated with positive Trendelenburg sign at the latest follow-up ($r=0.504$; $p < 0.001$). We made further investigations for 79 hips with superior migration of reconstructed COR. The percentage of postoperative positive Trendelenburg sign were equally higher in severe migration subgroup than that in anatomical restoration subgroup and in mild migration subgroup. These results suggested that a superiorly migrated COR appeared to exert a negative effect on abductor muscle function by decreasing the abductor moment arm, but did not detect any significant correlations with worse clinical outcomes and higher complication rate. Consequently, the abductor muscle function should be emphasized in postoperative rehabilitation program for this special patient population.

The main strengths of our study included a relatively large sample size and a high follow-up rate. However, we acknowledge that our study was not without its limitations. First, as this was a retrospective study, there are associated inherent limitations, most importantly the absence of control cases with which to compare outcomes. Patient selection, measurement and interviewer bias may affect functional assessment outcomes. Second, although the cases enrolled in the study were exclusively from one single center, all THAs were performed by several senior surgeons, which may affect the validity of our findings. Third, the multiple cementless acetabular component designs and different interface selections were included in our series.

Conclusions

In conclusion, our study revealed that despite the technically demanding nature and a relatively high complication rate, cementless THA performed in patients with failed treatments for acetabular fractures achieved predictable clinical and radiographic outcomes. A superiorly migrated COR appeared to exert negative effect on abductor muscle function and surgeons should pay proper attention to the accuracy of hip COR reconstruction.

Abbreviations

COR: center of rotation

THAs: total hip arthroplasties

HHS: Harris hip score

WOMAC: Western Ontario and McMaster Universities Arthritis Index

ORIF: open reduction and internal fixation

TM: trabecular metal

AP: anteroposterior

HO: heterotopic ossification

LLD: leg length discrepancy

PACS: picture archiving and communication system

SD: standard deviation

DDH: developmental dysplasia of the hip

Declarations

Ethics approval: Implementation of this study was approved by the Institutional Review Board of Beijing Jishuitan Hospital, and all methods were performed in accordance with the Declaration of Helsinki.

Consent to participate: Informed consent from all participating patients were obtained.

Consent to publication: Not applicable

Availability of data and material: Not applicable

Competing interest: The authors declare that they have no competing interests.

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