

Radiological and Clinical Results of Rotational Acetabular Osteotomy Combined with Femoral Intertrochanteric Osteotomy for Avascular Necrosis Following Treatment for Developmental Dysplasia of the Hip

Hiroshi Minagawa^a, Ayako Aiga^b, Hirosuke Endo^{a*}, Shigeru Mitani^a,
Tomonori Tetsunaga^a, and Toshifumi Ozaki^a

^aDepartment of Orthopaedic Surgery, Okayama University Hospital, Okayama 700-8558, Japan, and

^bDepartment of Orthopaedic Surgery, Okayama Rousai Hospital, Okayama 702-8055, Japan

This retrospective study assessed the radiographic results of 16 patients with avascular necrosis following treatment for developmental dislocation of the hip (DDH) who were subsequently treated between 1991 and 2005 by rotation acetabular osteotomy (RAO) combined with femoral intertrochanteric osteotomy (FIO). Initial treatment was by Pavlik harness, cast fixation, or overhead traction. The parameters that showed consistent improvement were the index of centralization, the index of acetabular coverage, adequate reduction of the greater trochanter, and abductor sufficiency. The combined procedure appears to be effective in cases in which preoperative planning shows a reasonable expectation of congruency and osteoarthritis is limited to the early stages.

Key words: rotation acetabular osteotomy, femoral intertrochanteric osteotomy, combined procedure, developmental dysplasia of hip, avascular necrosis

Most patients with developmental dysplasia of the hip (DDH) are diagnosed early via neonatal screening and are treated successfully with a Pavlik harness and splinting. However, 1% to 47% of patients [1-3] were reported to have avascular necrosis of the femoral head, which is a serious complication of the treatment for DDH that causes instability or incongruency of the hip and results in secondary osteoarthritis. In our hospital, 12% of patients with DDH treated by Pavlik harness developed avascular necrosis of the femoral head after treatment. Avascular necrosis of the hip is associated with sev-

eral deformities: coxa vara, flattening of the femoral head with relative overgrowth of the greater trochanter, and subluxation of the hip. The goals of our operative treatment for such patients are to improve antero-lateral acetabular coverage, to transform the weight-bearing surface horizontally, to decrease the shearing force, to medialize the center of rotation of the hip joint, and to improve the congruency of the hip joint. Rotation acetabular osteotomy (RAO) [4] is a circumferential periacetabular osteotomy, and it can restore the position and acetabular coverage of the dysplastic hip to nearly normal. Ninomiya and Tagawa [4] indicated this procedure for cases without deformation of the femoral head. We previously reported 34 patients without avascular necrosis who underwent only RAO following treatment for DDH [5]. In many

Received October 29, 2008; accepted March 4, 2009.

*Corresponding author. Phone:+81-86-235-7273; Fax:+81-86-223-9727
E-mail:hirosuke@md.okayama-u.ac.jp (H. Endo)

cases with femoral head deformity, performing only RAO causes incongruity of the hip joint. Chiari [6] recommended both pelvic and femoral osteotomy in cases with severe deformity of the femoral head. Because congruity will worsen upon improvement of roof obliqueness, a valgus osteotomy is performed initially to make the weight-bearing surface of the femoral head more horizontal, and RAO is done to attain acetabular coverage.

The purpose of the current study was to review the radiological and clinical records of 16 patients with avascular necrosis following treatment for DDH who were subsequently treated by RAO combined with femoral intertrochanteric osteotomy (FIO).

Patients and Methods

From 1991 to 2005, we performed RAO combined with FIO on 16 patients with avascular necrosis of the femoral head (Kalamchi & MacEwen classification [7] group III or IV) following treatment for DDH. Written informed consent was obtained for each of the patients. Central closure of the physis of the femoral head had caused a short femoral neck and relative overgrowth of the greater trochanter, but the femoral head was usually spherical and contained within the

acetabulum in the group III cases. Damage to the head and the physis had caused early joint incongruity, femoral head flattening, and coxa vara in the group IV cases.

There were 15 females and 1 male, and 9 right and 7 left hips were treated (Table 1). All patients happened to have unilateral DDH. Bilateral DDH was not a condition of exclusion. Patients were excluded from the study if they had multiple congenital abnormalities or showed teratological comorbidities. The latter were defined as fixed dislocation of the hip in association with either a recognized syndrome or a neurological disorder. We performed RAO combined with FIO on patients with hip instability, coxalgia, or limping due to acetabular dysplasia and a deformed femoral head. Patients who had severe osteoarthritis (Tönnis's Grade III [8]) or presented after menopause were excluded from operative indication and from the current study.

The initial reductions of 13 of the 16 hips were by Pavlik harness, 2 were by cast fixation, and 1 was by overhead traction. The average age at surgery was 23 years (13 to 41 years), and the average follow-up period was 39 months (11 to 97 months). The severity of osteoarthritis based on Tönnis's classification [7] was as follows: 14 hips were Grade I, and 2 hips

Table 1 Details of 15 patients with avascular necrosis following treatment of developmental dysplasia of the hip

Case	Grade (K&M) ⁵	Grade of OA (Tönnis) ⁶	Age (yrs)	Follow-up Period (months)	Sex	Method of Primary Treatment	Age at Reduction (months)	Period of Primary Treatment (months)
1	III	1	23	27	F	PH	3	1
2	III	1	26	28	F	PH	4	4
3	III	1	25	19	F	PH	4	3
4	III	1	21	58	F	CF	3	1
5	III	1	21	26	F	PH	3	3
6	III	1	34	26	F	PH	3	3
7	III	1	24	10	F	PH	4	3
8	III	1	15	11	F	PH	3	3
9	IV	1	15	64	F	PH	5	4
10	IV	1	24	56	F	PH	3	3
11	IV	1	23	24	F	PH	3	4
12	IV	1	14	14	F	PH	3	3
13	IV	1	13	21	F	PH	4	3
14	IV	2	41	59	M	CF	3	3
15	IV	2	35	68	F	OT	3	2
16	IV	1	19	50	F	PH	3	3
Ave.			23	39				

PH, Pavlik harness; CF, cast fixation; OT, overhead traction.

were Grade II.

The ordinary radiographic parameters included the following: center-edge angle (CEA) [9] as an index of centralization and acetabular coverage, acetabular ridge angle (ARA) [10] (as an index of the acetabular coverage), articular-trochanteric distance (ATD) [11] (as an assessment of the elevation of the greater trochanter and abductor insufficiency), and joint space. We also measured the obturator foramen-head distance (OFHD), which is the distance from the lateral side of the obturator foramen to the medial side of the femoral head, at preoperative and final evaluations, and defined it as an index of centralization of the hip. All of the parameters were measured on preoperative,

postoperative and final AP view radiographs. For the purposes of our treatment strategy, we defined centralization of the femoral head as a CEA of 20 degrees or more and adequate acetabular coverage as 0 degrees or less. We regarded a positive ATD as adequate reduction of the greater trochanter.

Clinical assessments analyzed in the current retrospective study included those made before the surgery and at the final examination using Harris Hip Score (HHS) [12] and leg length discrepancy (LLD). In addition, we conducted an investigation into whether additional hip reconstruction surgery (for example, hip arthroplasty, arthrodesis) was performed or not.

The two-tailed Student *t* test was used to compare

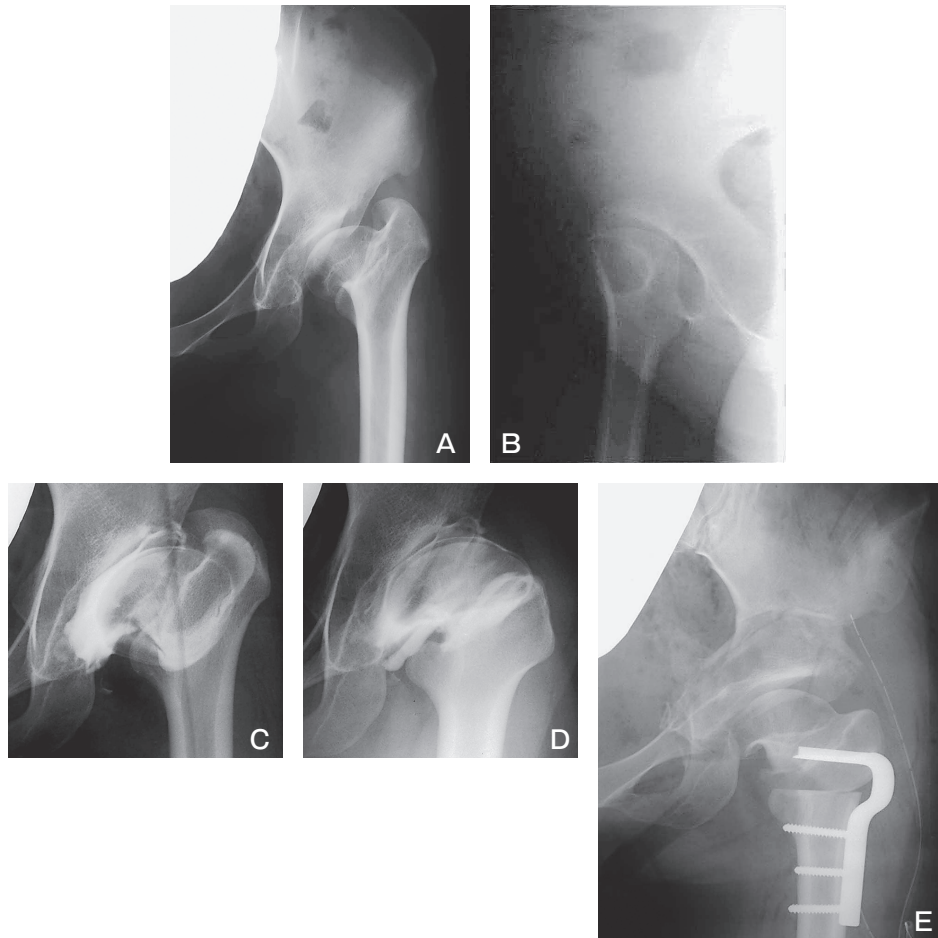


Fig. 1 The radiographs of case 6 (Group III). A and B are preoperative radiographs. C and D are the preoperative radiographs of arthrography. E is a postoperative radiograph. **A**, AP view. ARA was -38 degrees; **B**, False profile view. VCA 15 degrees. We planned to transfer the position of the acetabulum to 35 degrees lateral and 10 degrees anterior; **C**, AP view of arthrogram; **D**, Best-fit position was flexion 30 degrees and abduction 5 degrees. The planned femoral intertrochanteric osteotomy was valgus 30 degrees and extension 20 degrees.

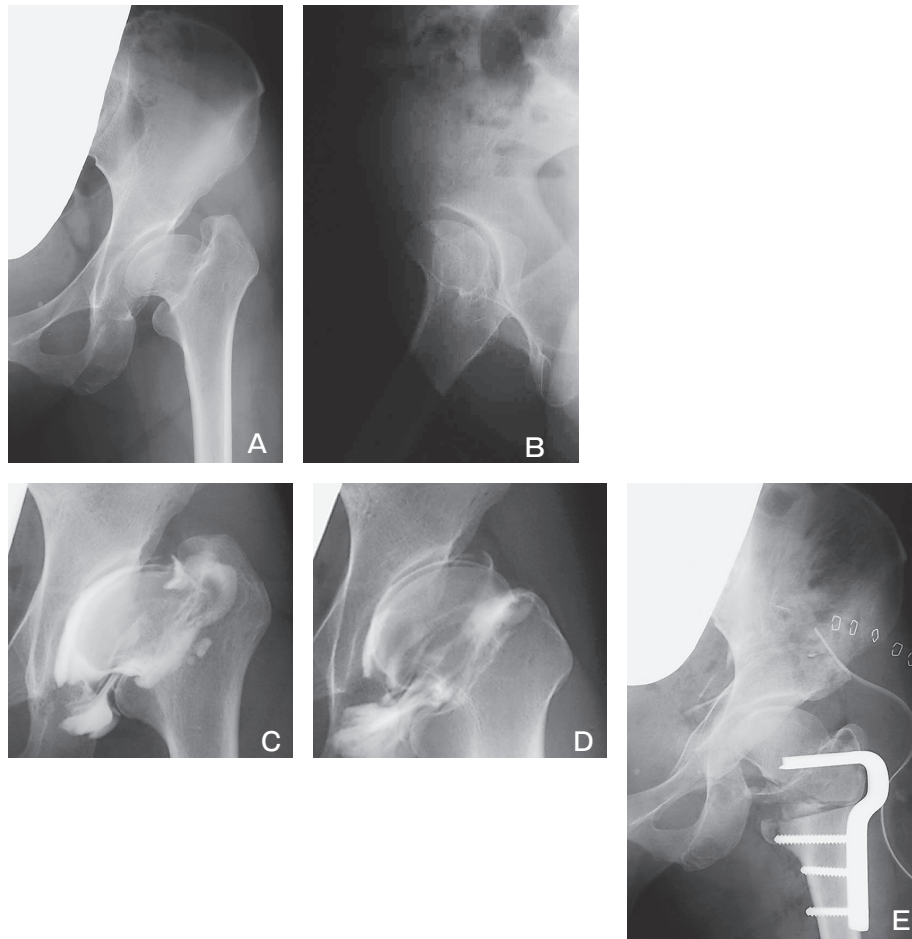


Fig. 2 The radiographs of case 10 (Group IV). A and B are preoperative radiographs. C and D are the preoperative radiographs of arthrography. E is a postoperative radiograph. **A**, AP view. ARA was -39 degrees; **B**, False profile view. VCA was 10 degrees. We planned to transfer the position of the acetabulum to 20 degrees lateral and 15 degrees anterior; **C**, AP view of arthrogram; **D**, Best-fit position was flexion 30 degrees and abduction 10 degrees. The planned femoral intertrochanteric osteotomy was valgus 30 degrees and extension 10 degrees.

all the radiographic evaluations and clinical assessments from before the surgery to the final examination. $P=0.05$ was selected to indicate statistically significant results.

Pre-operative planning. The ARAs in the neutral position and the vertical-center-anterior margin (VCA) angle [13] (as the assessment of the anterior cover of the femoral head) in false profile views were measured on the pre-operative radiographs (Figs. 1 and 2). The position of the acetabulum (traced en bloc) was represented by the position in which ARA was 0 degrees and VCA was 25 degrees. Congruency was confirmed by dynamic arthrography under an image intensifier. According to Catterall *et*

al. [14], we defined the best-fit position as that in which contrast medium pooled least at the medial side, and we planned each FIO to permit a neutral best-fit position. Briefly, the angle of the femoral valgus osteotomy was determined by subtracting the best-fit angle of abduction from the rotational angle of the lateral side of the acetabulum. The angle of the femoral extension osteotomy was determined by subtracting the rotational angle of the anterior side of the acetabulum from the best-fit angle of flexion.

Results

The average CEA changed from 4.4° (range: -15

Table 2 Radiological parameters and clinical findings

Case	CEA (deg)		ARA (mm)		ATD (mm)		Joint Space (mm)		OFHD (mm)		HHS (possible)		Limb Length Discrepancy (mm)	
	Pr	Final	Pr	Final	Pr	Final	Pr	Final	Pr	Final	Pr	Final	Pr	Final
1	17	43	-24	0	0	15	4	6	15	16	71	100	15	10
2	8	40	-24	-3	-8	15	3	4	22	15	77	96	20	5
3	24	48	-23	8	3	14	3	3	18	9	81	96	5	5
4	8	48	-38	-3	6	15	4	5	18	17	81	100	20	15
5	13	29	-23	-13	16	40	3	3	17	2	74	89	10	0
6	0	33	-38	-22	-9	6	3	3	7	6	55	100	20	10
7	23	26	-19	-3	4	41	3	4	14	17	66	95	10	0
8	5	40	-20	0	-16	10	4	4	17	10	91	100	30	0
9	20	28	-28	-14	-16	10	4	4	16	19	71	98	15	0
10	0	42	-39	5	-32	5	4	4	26	19	86	98	25	10
11	6	43	-45	-7	-19	8	4	2	17	19	80	95	20	20
12	-15	5	-39	-37	-23	22	4	2	22	19	88	97	25	10
13	-2	46	-27	6	-14	15	8	8	27	20	74	100	40	15
14	-11	20	-39	-33	-22	-10	9	4	23	14	77	93	30	20
15	-15	27	-50	-30	-18	-14	3	4	14	20	57	91	20	20
16	-11	50	-43	3	-30	6	3	2	20	12	78	95	20	15
Ave.	4.4	35.5	-32.4	-8.9	-11.1	12.4	4.1	3.9	18.3	14.6	75.4	96.4	20.3	9.7

Pr, preoperation; Final, final examination.

~24°) preoperatively to 35.5° (range: 5~50°) at the final examination. The average ARA changed from -32.4° (range: -50~-19°) to -8.9° (range: -37~8°). The average ATD changed from -11.1mm (range: -32~16mm) to 12.4mm (range: -14~41mm). The average joint space changed from 4.1mm (range: 3~9mm) to 3.9mm (range: 2~8mm), and the average OFHD from 18.3mm (range: 7~27mm) to 14.6mm (range: 2~20mm). The average HHS changed from 75.4 points (range: 55~91 points) preoperatively to 96.4 points (range: 89~100 points) at the final examination. Coxalgia decreased markedly in HHS. The average limb length discrepancy decreased from 20.3mm (range: 5~40mm) to 9.7mm (range: 0~20mm) (Figs. 1E and 2E) (Table 2). Additional surgery was not needed in any of the cases during the investigation periods.

Discussion

To our knowledge, there are few reports that describe the clinical results of operative treatment for severe avascular necrosis after treatment for DDH. Higashi *et al.* [15] reported an investigation of the treatment results of femoral lengthening with elongation of the femoral neck and distal transfer of the greater trochanter; they found that 4 of 6 cases

tended to subluxation postoperatively and 2 cases underwent RAO as additional surgery. In addition, Noguchi *et al.* [16] reported treatment results for intertrochanteric double osteotomy in 13 cases involving 14 hips. They described a case with dysplasia preoperatively that resulted in progression of subluxation and osteoarthritis. Trousdale *et al.* [17] reported the treatment results for periacetabular osteotomy in 32 cases and for combined periacetabular osteotomy and intertrochanteric osteotomy in 10 cases. They reported that 9 cases (21%) needed additional surgeries (additional intertrochanteric osteotomy in 3 cases, total hip arthroplasty in 3 cases) over 3 years postoperatively. No standard treatment has been established for severe deformity of dysplastic hip, and the previous reports have indicated relatively poor results.

In considering the principle of the treatment for severe avascular necrosis after the treatment for DDH, we can classify the patients into 3 groups. Patients in the first group are younger than 6 years old, which is younger than the minimum age in the Kalamchi & MacEwen evaluation system. All patients in the current study were 3-5 months old at the initial reduction. Because the possibility that the hip may adapt during this period exists, surgical treatment for this age group is not indicated.

Patients in the second group are 6–12 years old or school age. Affected hips in this group can be classified by Kalamchi & MacEwen's evaluation. However, these patients are skeletally immature, and we cannot predict the alterability of the deformity during the remainder of the growth period. The authors of the current study believe that surgical treatment is not indicated for this age group either. Wada *et al.* [18] performed the Pemberton osteotomy on 5 patients aged 7 to 11 years old with avascular necrosis in Kalamchi & MacEwen groups III or IV. At the end of their study, 3 hips were found to be in excellent condition and 2 hips in fair condition by McKay's evaluation. However, performing only a pelvic operation by a Pemberton osteotomy results in imperfect results, especially in group IV hips. The authors of the current study believe that it is important to consider the acetabular roof as well as the head-acetabular relationship.

Patients in the third group are older than 12 years and can be expected to show bony maturation, and hips in this group can be classified by the Kalamchi & MacEwen evaluation. While spontaneous correction of the deformity is not expected, surgical treatment can give adequate or nearly anatomical correction. Haverkamp [19] performed an FIO combined with acetabular shelf plasty in 8 cases of femoral head deformity following DDH. Four of these cases required total hip arthroplasty between 9 and 17 years later. The other 4 cases had good to excellent results on HHS, but an acetabular shelf plasty cannot alter the roof of the primary acetabulum or obtain cartilaginous cover. In contrast, RAO shifts the position of the acetabular surface and does not require remodeling of the joint if hip congruency is achieved at operation. For these reasons the authors consider that RAO achieves better biomechanical results than shelf plasty over time.

In a biomechanical study, Maquet [20] discussed how lateral displacement of the femoral head decreases the effective weight-bearing surface of the joint, which, in turn, provokes uneven distribution and increased articular compressive stresses and extended osteoarthritis. The aims of treatment for the prevention of secondary osteoarthritis are to stabilize the hip joint and avoid abnormally concentrated stress. For this reason, we regard the repositioning of the articular surface horizontally to obtain acetabular

coverage, centering the femoral head, and improving the congruency of the hip joint to be important.

The report by Endo [21] on three-dimensional gait analysis before and after RAO indicated that the hip extension motion angle on the treated side increased significantly, as reflected in the increased gait velocity and stride length, thus improving gait function. Their findings are consonant with Pauwel's earlier observation [22] that valgus osteotomy of the femur extends the leverage of abductor muscular strength and results in decreased joint pressure. The larger ATD values at final follow-up examinations in the current study reflect such decreased pressure (Table 2). Furthermore, an adequate femoral osteotomy can improve the congruency of the hip joint and increase the weight-bearing surface by decreasing the abnormal stress concentration.

In general, the radiographic and clinical results were satisfactory for the cases in the current study. The parameters that showed consistent improvement were the index of centralization, the index of the acetabular coverage, adequate reduction of the greater trochanter, and abductor sufficiency. However, in 4 cases in group IV, the joint space became narrowed. The patient in case 14 obtained a normal hip joint post-surgically because the limbus inverted spontaneously prior to the operation. Severe deformity of the femoral head in cases 11, 12, and 16 made it difficult to obtain good congruency of the hip (Table 2).

The findings suggest that this combined procedure appears to be effective in the early stage of osteoarthritis and in cases where there is a reasonable expectation during pre-operative planning that good congruency can be obtained. Our treatment results are good generally because there are no cases in which subluxation progressed and which required additional surgery. This procedure provided anatomical correction and the short-term radiographic and clinical improvements were gained. Detailed, individualized planning and long-term management are essential for these patients.

References

1. Brougham DI, Broughton NS, Cole WG and Menelaus MB: Avascular necrosis following closed reduction of congenital dislocation of the hip. Review of influencing factors and long-term

- follow-up. *J Bone Joint Surg Br* (1990) 72: 557–562.
2. Cashman JP, Round J, Taylor G and Clarke NM: The natural history of developmental dysplasia of the hip after early supervised treatment in the Pavlik harness. A prospective, longitudinal follow-up. *J Bone Joint Surg Br* (2002) 84: 418–425.
 3. Segal LS, Boal DK, Borthwick L, Clark MW, Localio AR and Schwentker EP: Avascular necrosis after treatment of DDH: the protective influence of the ossific nucleus. *J Pediatr Orthop* (1999) 19: 177–184.
 4. Ninomiya S and Tagawa H: Rotational acetabular osteotomy for the dysplastic hip. *J Bone Joint Surg Am* (1984) 66: 430–436.
 5. Endo H, Mitani S, Kadota H, Miyake A and Inoue H: Preoperative assessment of rotational acetabular osteotomy by arthrography. *Chubunihonseikeigekasaigaigekagakkaisassi* (The Central Japan Journal of Orthopaedic Surgery & Traumatology) (2002) 45: 507–508 (in Japanese).
 6. Chiari K: Iliac Osteotomy in Young Adults. *The Hip: Proceedings of the Seventh Open Scientific Meeting of The Hip Society*. (1979) 7: 260–277.
 7. Kalamchi A and MacEwen GD: Avascular Necrosis following Treatment of Congenital Dislocation of the Hip. *J Bone Joint Surg Am* (1980) 62: 876–888.
 8. Tönnis D: Clinical and Radiographic Schemes for Evaluating Therapeutic Results; in *Congenital dysplasia and dislocation of the hip in children and adults*, Tönnis D ed, Springer-Verlag, Berlin, Heidelberg, New York, London, Paris and Tokyo (1987) pp 165–171.
 9. Wiberg G: The anatomy and roentgenographic appearance of a normal hip joint. *Acta Chir Scand* (1939) 83: 7–38.
 10. Minobe Y, Kadowaki T, Inoue A, Takaoka K, Saito S, Sakai M, Shimizu N, Hosoya T and Kaga K: Long-term results of treatment in Perthes' disease. *Nihonseikeigekagakkaisassi* (J Jpn Orthop Ass) (1983) 57: 1367–1368 (in Japanese).
 11. Edgren W: Coxa Plana. A clinical and radiological investigation with particular reference to the importance of the metaphyseal changes for the final shape of the proximal part of the femur. *Acta Orthop Scand Suppl* (1965) 84: 1–129.
 12. Harris WH: Traumatic Arthritis of the Hip after Dislocation and Acetabular Fractures: Treatment by Mold Arthroplasty. *J Bone Joint Surg Am* (1969) 51: 737–755.
 13. Lequesne M and de Séze S: Le faux profil du bassin: nouvelle incidence radiographique pour l'étude de la hanche. Son utilité dans les dysplasies et les différentes coxopathies. *Rev Rhum Mal Osteoartic* (1961) 28: 643–652 (in French).
 14. Catterall A: Assessment of adolescent acetabular dysplasia; in *Recent advances in Orthopaedics*, Catterall A ed, 6th Ed, Churchill Livingstone, Edinburgh, London, Melbourne, New York and Tokyo (1992) pp 103–118.
 15. Higashi H and Hotta Y: Treatment of coxa vara deformities with leg length discrepancies; a study of femoral lengthening with elongation of the femoral neck and distal transfer of the greater trochanter. *Seikeigeka* (Orthopedic Surgery) (1985) 36: 1679–1686 (in Japanese).
 16. Noguchi Y, Oishi T, Miura Y, Sugioka Y, Matsumoto S and Fujii T: Intertrochanteric double osteotomy for coxa plana after treatment of congenital dislocation of the hip: A long-term result. *Rinsyoseikeigeka* (Clinical Orthopaedic Surgery) (1992) 27: 41–47 (in Japanese).
 17. Trousdale RT, Ekkernkamp A, Ganz R and Wallrichs SL: Periacetabular and intertrochanteric osteotomy for the treatment of osteoarthritis in dysplastic hips. *J Bone Joint Surg Am* (1995) 77: 73–85.
 18. Wada A, Fujii T, Takamura K, Yanagida H, Taketa M and Nakamura T: Pemberton Osteotomy for Developmental Dysplasia of the Hip in Older Children. *J Pediatr Orthop* (2003) 23: 508–513.
 19. Haverkamp D and Marti RK: Intertrochanteric osteotomy combined with acetabular shelfplasty in young patients with severe deformity of the femoral head and secondary osteoarthritis. *J Bone Joint Surg Br* (2005) 87: 25–31.
 20. Maquet P: Osteotomies of the proximal femur; in *Osteoarthritis in the young adult hip: options for surgical management*, Reynolds D, Freeman M eds, London, Churchill Livingstone (1989) pp 24–35.
 21. Endo H, Mitani S, Senda M, Kawai A, McCown C, Umeda M and Inoue H: Three-dimensional gait analysis of adults with hip dysplasia after rotational acetabular osteotomy. *J Orthop Sci* (2003) 8: 762–771.
 22. Pauwels F: Biomechanics of the normal and diseased hip; in *Theoretical foundation, technique and results of treatment*, Springer-Verlag, Berlin, Heidelberg and New York (1976) pp 8–29.

