Postoperative Improvement of Femoroacetabular Impingement After Intertrochanteric Flexion Osteotomy for SCFE

Takashi Saisu MD, PhD, Makoto Kamegaya MD, PhD,
Yuko Segawa MD, PhD, Jun Kakizaki MD,
Kazuhisa Takahashi MD, PhD

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Abstract

Background Patients with slipped capital femoral epiphysis (SCFE) may develop cam-type femoroacetabular impingement (FAI). Early management of FAI has been advocated for patients with symptomatic FAI. The various treatment options, including reorientation surgeries, realignment procedures, and osteoplasty, remain controversial.

Questions/purposes We asked whether an intertrochanteric flexion osteotomy improved the clinical symptoms of FAI in patients with SCFE and confirmed whether the

radiographic signs were compatible with the clinical signs of FAI.

Methods We retrospectively reviewed 32 symptomatic patients who underwent 32 intertrochanteric flexion osteotomies for severe SCFE. FAI was diagnosed clinically with a positive impingement sign. The osteotomies were designed preoperatively using CT. Cam-type FAI was evaluated with the modified α angle (β angle) on a Lauenstein view, measured between the proximal femoral shaft axis and the line from the center of the femoral head to the anterior point where the distance of the head center exceeded the femoral head radius. The minimum followup was 2 years (mean, 5 years; range, 2–9 years).

Results At last followup, only two patients complained of pain or inconvenience in daily life; the impingement sign was negative in 24 hips (75%). The β angles at last followup were reduced on average by 39°. The postoperative β angle was higher in hips with positive clinical signs of FAI than in those with negative signs.

Conclusions Intertrochanteric flexion osteotomy for SCFE improved the clinical and radiographic signs of FAI. The β angle and clinical findings showed compatible improvement. We believe our intertrochanteric flexion osteotomy is a viable option for treating severe SCFE.

Level of Evidence Level IV, therapeutic study. See Instructions for Authors for a complete description of levels of evidence.

Each author certifies that he or she, or a member of his or her immediate family, has no funding or commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.

All ICMJE Conflict of Interest Forms for authors and *Clinical Orthopaedics and Related Research* editors and board members are on file with the publication and can be viewed on request. Each author certifies that the institution in which this study was conducted approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

This work was performed at the Chiba Children's Hospital, Chiba, Japan.

T. Saisu (✉), Y. Segawa, J. Kakizaki
Division of Orthopaedic Surgery, Chiba Children's Hospital,
579-1 Heta-Chou, Midori-ku, Chiba 266-0007, Japan
e-mail: h-saisu@dc4.so-net.ne.jp

M. Kamegaya
Chiba Child and Adult Orthopaedic Clinic, 3-24-2 Oyumino
Minami, Midori-ku, Chiba 266-0033, Japan

K. Takahashi
Department of Orthopaedic Surgery, Graduate School of
Medicine, Chiba University, 1-8-1 Inohana, Chuo-ku,
Chiba 260-8670, Japan

Introduction

Slipped capital femoral epiphysis (SCFE) is reportedly one of the major causes of osteoarthritis of the hip in human skeleton studies [9]. Boyer et al. [1] recommended in situ pinning alone because the group without realignment of the

slip had a lower rate of osteoarthritis after long-term (21–47 years) followup. Their recommendation has been widely accepted. However, only one patient treated with pinning for severe slip ($> 50^\circ$) was included in their study. Carney et al. [3] also recommended in situ pinning alone. In their long-term (mean, 41 years) study, the radiographic grade was better in 11 hips treated with in situ pinning for slips of more than 30° than in 26 hips treated with femoral neck or peritrochanteric osteotomies, a procedure not described in detail by the authors. Jerre et al. [11] reported “satisfactory” results (defined as a Harris hip score ≥ 80 , superior joint space height ≥ 2.0 mm, and anterior/posterior joint space height ≥ 1.5 mm) were achieved in only four of 11 patients more than 30 years after intertrochanteric osteotomies and discouraged the use of intertrochanteric osteotomy. Diab et al. [4] also reported no difference in the Harris hip score between in situ screw fixation alone and staged flexion intertrochanteric osteotomy, while the osteotomy improved hip ROM. On the other hand, early osteoarthritic change after in situ fixation reportedly occurs in approximately 92% of patients at 3.6 to 19.5 years of followup [27]. We believe at least in situ pinning alone is not the final answer for the best treatment of patients with severe SCFE.

Femoroacetabular impingement (FAI) in patients with SCFE has been pointed out in several papers [7, 13, 16, 18, 21, 22, 27]. The decision of whether or not FAI should be resolved surgically when diagnosed remains controversial. Recently, some surgeons have recommended treatment of symptomatic cam-type FAI to prevent subsequent osteoarthritis [7, 16, 21]. Although minimally invasive treatments such as arthroscopic osteoplasty may be appropriate to resolve FAI in mild slip cases [18], we believe realignment procedures such as intertrochanteric osteotomies or capital reorientation surgery should be considered in severe slip cases so that the weightbearing part of the femoral head will be covered by hyaline cartilage. Although remodeling after in situ pinning is expected in more than $\frac{1}{2}$ of the patients [12, 13], acetabular labrum damage and osteochondral damage due to FAI during a period of remodeling have been reported in some patients [17, 18]. For unstable SCFE, some surgeons recommend acute open reduction surgery that can resolve FAI [23]; however, there is a serious risk of avascular necrosis (AVN) from this surgical procedure. Recently, a modified Dunn procedure has been reported [26] as a successful treatment without any AVN, although this procedure is technically demanding and one study reported two of 23 patients developed severe osteoarthritis or osteonecrosis [24]. Among the various realignment osteotomy procedures [6, 10, 14, 25], we have preferred intertrochanteric flexion osteotomy for patients with symptomatic FAI because of the low risk of AVN. Our recent method

(preoperative CT-assisting intertrochanteric flexion osteotomy [POTOF]) is technically simple and more accurate than conventional intertrochanteric osteotomies, such as the methods of Southwick [25] and Imhäuser [10]. Since 1990, we have employed intertrochanteric flexion osteotomies for treating severe SCFE with a posterior tilting angle (PTA) of 40° or greater. However, it is unclear whether intertrochanteric flexion osteotomies relieve the clinical and radiographic signs of FAI.

We therefore determined whether (1) intertrochanteric flexion osteotomy can resolve the clinical symptoms, (2) radiographic indicators of the Nötzli α angle [7, 13, 27] or a modified α angle (β angle) [13] on a Lauenstein view can be reduced after intertrochanteric flexion osteotomy, (3) these radiographic indicators are compatible with the clinical signs of FAI, and (4) early osteoarthritic change, AVN, or chondrolysis develops after the osteotomy.

Patients and Methods

We retrospectively reviewed 34 patients who underwent 34 intertrochanteric flexion osteotomies for SCFE with severe slip during the period from 1990 to 2009. The indications for these osteotomies were (1) a PTA of 40° or more and (2) a positive hip impingement sign [2], which induces groin pain at adduction and internal rotation with hip flexion. Actually, in patients with positive hip impingement sign, either obligatory hip external rotation and abduction with hip flexion (Drehmann’s sign [5]) or limitation of hip flexion ($< 90^\circ$) was seen before inducing pain. Drehmann’s sign is reportedly useful for evaluating the presence of FAI [13]. The presence of this sign is associated with functional disability in daily living, including inability of Japanese-style sitting. The contraindications were (1) unstable epiphysis, which was assessed on the radiographic image intensifier under general anesthesia, or (2) the new weightbearing part of the femoral epiphysis after osteotomy could not be covered by viable bone in case of AVN. During the study period, we treated a total of 121 patients (136 hips), including 64 severe slip (PTA $\geq 40^\circ$) with SCFE. Of these, 76 patients (91 hips) were treated with in situ pinning, 34 patients (34 hips) with intertrochanteric flexion osteotomy, five patients (five hips) with manual reduction followed by pinning, four patients (four hips) with Dunn osteotomy, and two patients (two hips) with Southwick osteotomy. Until 2003, we performed intertrochanteric flexion osteotomy for the primary treatment, while we gradually changed our strategy to employ the staged flexion intertrochanteric osteotomy after 2004. In 34 patients treated with intertrochanteric osteotomy, two patients were lost to followup, leaving 32 patients (32 hips) for study: 24 boys and eight girls (Table 1). The mean age

Table 1. Patient demographics and operative data

Patient	Sex	Side	PTA (°)	Type*	Stability†	BMI (kg/m ²)	Age at onset (years)	Preceding pinning	Age at osteotomy (years)	AVN before osteotomy
1	Female	Right	55	AOC	Stable	24.3	11.3	No	11.6	No
2	Female	Left	65	AOC	Stable	24.4	11.4	No	12.0	No
3	Female	Left	50	C	Stable	29.7	11.9	No	12.2	No
4	Male	Left	58	C	Stable	24.9	11.6	No	11.7	No
5	Male	Left	42	AOC	Stable	23.0	11.5	No	11.8	No
6	Male	Left	48	AOC	Stable	23.5	11.0	No	11.8	No
7	Male	Right	45	C	Stable	25.0	12.0	No	12.6	No
8	Male	Right	54	C	Stable	26.0	12.1	No	12.7	No
9	Male	Left	76	C	Stable	25.2	12.1	No	12.4	No
10	Male	Left	90	C	Stable	30.2	12.9	No	15.1	No
11	Male	Left	60	C	Stable	31.9	13.4	No	13.8	No
12	Male	Left	52	C	Stable	25.1	13.3	No	13.5	No
13	Male	Left	55	C	Stable	24.6	13.5	No	14.2	No
14	Male	Left	50	C	Unstable	22.2	13.1	No	13.6	No
15	Male	Right	65	AOC	Stable	16.0	14.6	No	15.0	No
16	Male	Right	58	C	Stable	23.3	12.8	No	13.5	No
17	Female	Right	57	C	Stable	19.0	13.0	No	13.9	No
18	Male	Left	52	C	Stable	26.8	11.3	No	12.5	No
19	Male	Left	57	AOC	Stable	25.5	14.0	No	14.9	Yes
20	Male	Left	52	C	Stable	31.1	11.8	No	12.1	No
21	Female	Right	65	C	Stable	26.6	11.8	No	12.5	No
22	Male	Right	63	A	Stable	20.8	11.9	No	12.0	No
23	Female	Left	55	C	Stable	22.0	10.7	No	11.7	No
24	Male	Left	80	C	Stable	25.4	13.3	No	14.3	No
25	Male	Right	80	AOC	Unstable	18.9	12.9	Yes	14.3	No
26	Male	Left	64	AOC	Stable	22.1	12.8	No	14.5	No
27	Female	Right	75	AOC	Unstable	22.8	13.4	Yes	14.2	No
28	Male	Right	70	C	Stable	26.7	13.2	No	14.8	No
29	Male	Left	45	A	Unstable	24.6	11.0	Yes	12.4	Yes
30	Male	Right	54	C	Stable	27.8	10.2	Yes	13.0	No
31	Female	Right	85	C	Stable	37.1	13.2	No	16.9	Yes
32	Male	Left	48	AOC	Unstable	23.0	11.2	Yes	13.3	Yes

* Onset types: A = acute; AOC = acute on chronic; C = chronic; †classification of Loder et al. [19]; PTA = posterior tilting angle; AVN = avascular necrosis.

was 12 years (range, 10–15 years) at first onset, 13 years (range, 12–17 years) at the time of osteotomy, and 19 years (range, 16–24 years) at latest followup. The mean BMI at the time of osteotomy was 25 kg/m² (range, 16–37 kg/m²). The left hip was involved in 19 patients and the right hip in 13 patients. The mean PTA of all 32 hips was 60° (range, 40°–90°) just before osteotomy. According to types of onset, two hips were classified as acute, 10 as acute on chronic, and 20 as chronic. In the classification of Loder et al. [19], 27 hips were classified as stable type and the remaining five hips were classified as unstable type. In four patients, SCFE was noted in the contralateral hip. For these patients, in situ pinning alone was performed in three

patients with a mild slip and a Dunn osteotomy was performed in the remaining patient with a severe slip of 75° PTA. The minimum followup was 2 years (mean, 5 years; range, 2–9 years) after the osteotomies. No patients were recalled specifically for this study; all data were obtained from medical records and radiographs. The study was approved by the institutional review board.

Since 2003, we performed an in situ fixation first on five hips before intertrochanteric flexion osteotomy; this was the primary treatment with either single (three hips) or double (two hips) screws. As the physes were still open at the time of osteotomy, transphyseal K-wires were substituted for the screws to avoid a further slip and leave room

for the blade of the fixation plate. The mean interval between the in situ fixation and the following osteotomy was 16 months (range, 4–33 months). The remaining 27 hips primarily underwent an intertrochanteric flexion osteotomy at an average of 10 months (range, 1–45 months) after onset and an average of 1 month (range, 0.2–4 months) after the first visit to our hospital. AVN of the femoral head with obvious collapse was radiographically found in four hips before the osteotomies. In these patients, we confirmed preoperatively the viable posterior epiphysis could be located under the weightbearing portion of the acetabulum by osteotomy using three-dimensional CT simulation.

The POTO procedures were described in a previous report [14]. The osteotomy was performed at the middle level of lesser trochanter. We determined the appropriate axis for the correction using both preoperative plain and three-dimensional CT images and then, based on preoperative assessment, selected one of the following three osteotomy patterns: a simple flexion, a flexion with varus osteotomy, or a flexion with valgus osteotomy. These can be performed in the same fashion using a different type of angle plate: a 90°, 80°, or 100° angle plate, respectively. This made the procedure simpler and more accurate. Care was taken to obtain equal internal and external rotation of the hip at the time of provisional plate fixation by rotating the distal fragment. Two types of plate were used in this series: (1) Adolescents-Osteotomy Plate™ (Osteo, Selzach, Switzerland), which we used before 2003, and (2) K-Angle Plate™ (Nakashima Medical Co, Ltd, Okayama, Japan).

After surgery, the ipsilateral lower extremity was held in approximately a 45° hip flexion position to avoid acute stretching of a nutrient vessel. It was gradually extended to the neutral position over the course of a week. Skin traction was applied for another week. We allowed the patients nonweightbearing walking with crutches at 6 weeks after surgery. Partial weightbearing was started at 8 weeks after surgery.

After surgery, we routinely checked radiographs (AP and Lauenstein views) of both hips and hip ROM and questioned patients about the presence of pain and any inconvenience in daily life at 1-month intervals until 6 months postoperatively, 3-month intervals until 1 year, and 6-month intervals after 1 year.

We investigated cam-type FAI both preoperatively and postoperatively with a Nötzli α angle [7, 22, 27] on a Lauenstein view and a modified α angle (β angle) on a Lauenstein view [13]. The β angle measured the angle between a line parallel to the proximal long axis of the femoral shaft and a line from the center of the femoral head to the anterior point where the distance from the head center exceeded the radius of the subchondral surface of

the femoral head. Two of us (TS, treating surgeon; YS, staff surgeon) evaluated all radiographs and mean values were used for this study. Interobserver intraclass correlation coefficients were 0.97 for the preoperative α angles, 0.98 for the postoperative α angles, 0.96 for the preoperative β angles, and 0.98 for the postoperative β angles. Since α and β angles were measured retrospectively, they did not influence preoperative decision making. FAI was clinically evaluated with a hip impingement sign [2]. Since Drehmann's sign [5] or limitation of hip flexion was seen before inducing pain during the maneuver of the hip impingement sign, Drehmann's sign and maximum angle of hip flexion were also evaluated. In addition, we evaluated early osteoarthritic changes on the most recent AP radiographs according to the Kellgren-Lawrence classification system [8, 15].

We determined the changes in α and β angles using Wilcoxon signed-rank tests and the differences in α and β angles between positive and negative FAI clinical signs using Mann-Whitney U tests. We used StatView® Version 5.0 (SAS Institute Japan, Inc, Tokyo, Japan) for all analyses.

Results

At last followup, only two patients complained of pain or inconvenience in daily life. One patient with permanent chondrolysis complained of a slight limp with limitation of motion in the affected hip. Another patient with AVN, which was identified before osteotomy, complained of pain on flexion of the affected hip.

The mean corrected flexion angle was 44° (range, 40°–55°). Valgus realignment was simultaneously added in nine hips, with a mean angle of 13° (range, 5°–20°), and varus realignment was added in four hips, with a mean correction angle of 11° (range, 10°–15°). The mean neck-shaft angle at latest followup was 139° (range, 126°–156°). The hip impingement sign was positive in all hips preoperatively and became negative in 24 of the 32 hips (75%) postoperatively. Drehmann's sign was observed in all eight hips with positive hip impingement sign postoperatively (Table 2). Postoperative α angles (average, 76°; range, 43°–107°) did not decrease ($p = 0.11$) compared with preoperative α angles (average, 82°; range, 52°–119°). Postoperative β angles (average, 81°; range, 38°–124°) decreased ($p < 0.001$) on average by 39° compared with preoperative β angles (average, 119°; range, 93°–141°) (Table 3).

The postoperative α angle was higher ($p = 0.003$) in hips with positive FAI clinical signs (average, 91°) than in those with negative clinical signs (average, 71°). The postoperative β angle was higher ($p = 0.002$) in hips with positive clinical signs of FAI (average, 100°) than in those with negative clinical signs of FAI (average, 74°) (Table 4).

Table 2. Patient preoperative and postoperative clinical and radiographic data

Patient	Flexion angle (°)	Valgus or varus correction (°)*	Followup (years)	Postoperative maximum hip flexion angle (°)	Postoperative Drehmann's sign	α angle (°)		β angle (°)		NSA (°)	K-L grade	Complications
						Preoperative	Postoperative	Preoperative	Postoperative			
1	45	15	8.6	110	Positive	96	91	123	104	147	1	No
2	50	5	7.8	120	Negative	119	43	130	41	142	1	No
3	40	0	5.2	110	Negative	85	58	113	50	142	1	Temporary CL
4	50	0	4.5	110	Negative	96	63	127	77	154	1	No
5	40	0	6.5	120	Negative	100	62	121	63	129	1	No
6	40	0	6.7	120	Negative	71	60	115	70	140	1	No
7	40	0	7.8	100	Negative	80	60	112	57	141	1	No
8	45	0	6.1	120	Negative	85	71	115	63	135	1	No
9	45	0	5.3	100	Negative	64	56	128	69	138	1	No
10	45	0	8.4	95	Negative	58	86	134	124	133	3	No
11	45	0	1.9	110	Negative	76	78	117	73	135	1	No
12	40	0	3.9	100	Negative	73	65	117	85	145	1	No
13	45	0	6.2	120	Negative	83	83	111	70	141	2	No
14	45	20	8.9	120	Negative	110	83	133	62	134	1	No
15	45	0	6.5	60	Positive	106	103	130	112	126	4	Permanent CL
16	45	0	5.5	100	Positive	100	92	121	81	156	1	No
17	45	0	6.2	120	Negative	97	94	119	100	134	1	No
18	40	0	4.1	110	Negative	84	86	126	88	136	1	No
19	40	0	7.2	40	Positive	73	103	108	109	147	3	No
20	45	20	5.1	110	Negative	52	51	104	38	140	1	No
21	55	0	5.4	120	Negative	86	71	112	77	135	1	No
22	40	0	6.3	120	Negative	81	52	93	39	135	1	No
23	45	10	6.6	110	Negative	75	77	113	96	141	1	No
24	45	0	4.2	120	Positive	68	84	129	99	145	1	No
25	45	10	2.4	120	Negative	77	107	132	111	129	2	No
26	45	10	3.6	120	Negative	66	75	122	71	146	1	No
27	45	-10	5.5	110	Negative	94	81	141	81	128	2	No
28	45	-10	3.2	95	Negative	62	87	93	81	133	1	No
29	45	10	3.1	110	Positive	97	99	127	111	140	1	No
30	45	-15	5.1	110	Negative	61	48	114	89	137	1	No
31	45	20	2.2	120	Positive	77	78	134	88	128	2	No
32	45	-10	2.3	90	Positive	73	81	104	98	140	2	No

* Plus values indicate valgus correction and minus values indicate varus correction; NSA = neck-shaft angle; K-L grade = Kellgren-Lawrence classification [8, 15]; CL = chondrolysis.

Table 3. Changes in the α and β angles after intertrochanteric flexion osteotomy

Angle	Preoperative value (°)	Postoperative value (°)	p value*
α	82.0 $\pm$ 16.1	75.9 $\pm$ 17.2	0.11
β	119.3 $\pm$ 11.6	80.5 $\pm$ 22.5	< 0.001

Values are expressed as mean $\pm$ SD; * Wilcoxon signed-rank test

Table 4. Clinical signs of FAI and the postoperative α and β angles

Angle	Value (°)		p value*
	FAI [†] positive	FAI [†] negative	
α	91.4 $\pm$ 9.8	70.7 $\pm$ 16.0	0.003
β	100.3 $\pm$ 11.2	74.0 $\pm$ 21.5	0.002

Values are expressed as mean $\pm$ SD; * Mann-Whitney U test;

[†]clinical signs of FAI were judged positive when Drehmann's sign was positive or maximum flexion was less than 90°; FAI = femoro-acetabular impingement.

At last followup, 24 hips (75%) had Kellgren-Lawrence Grade 1 osteoarthritis (Fig. 1), five hips Grade 2, two hips Grade 3, and one hip Grade 4. There were no cases of newly identified AVN of the femoral head after osteotomy; chondrolysis was identified in two hips, one temporary and one permanent. In the latter, femoral lengthening was performed for correction of leg length discrepancy 16 months after osteotomy.

Discussion

Patients with SCFE may develop cam-type FAI. Early management of FAI has been advocated if the patients complain of symptoms based on FAI. The various treatment options, still controversial, include reorientation surgeries, realignment procedures, and osteoplasty. We determined whether (1) intertrochanteric flexion osteotomy can resolve the clinical signs of FAI, (2) radiographic indicators of the Nötzli α angle or the β angle on a Lauenstein view can be reduced after intertrochanteric flexion osteotomy, (3) these radiographic indicators are compatible with the clinical signs of FAI, and (4) early osteoarthritic change, AVN, or chondrolysis develops after the osteotomy.

There are some limitations evident in this study. First, we could not confirm FAI with dynamic imaging study using CT or MRI, which were unavailable in this retrospective study. Second, we measured the α angle, which was originally measured on MRI, on plain radiographs. Since the β angle on a Lauenstein view was compatible with the clinical signs of FAI, we suspect the original α

angle is not essential. Third, we did not analyze particular clinical scores, such as Harris hip score and Oxford hip score, at latest followup. Therefore, our study cannot be compared with other studies using these scores and we draw no conclusions about patient function. Fourth, the postoperative followup time is not long enough to confirm the consequences of intertrochanteric flexion osteotomy. Thus, additional followup is recommended to investigate and answer these issues.

We found the hip impingement sign resolved in 24 of 32 hips (75%) after osteotomy. Drehmann's sign [5], which is a characteristic feature in SCFE, remained positive in eight patients. This sign is judged positive when obligatory hip external rotation and abduction are induced with hip flexion and it reflects anterior impingement avoidance [13]. However, it resulted in some disabilities in the patients' daily living, including inability to perform Japanese-style sitting. Although torsional deformity resulting from epiphyseal slip exists in the proximal femur, we believe it was not the cause of Drehmann's sign because torsional deformity was limited inside the capsule. An intertrochanteric osteotomy did not change the morphology of the head-neck junction, but only the relationship of the head, neck, and trochanter with the diaphysis; however, FAI was resolved in 75% of hips in this study. This fact suggests we should only consider bone-to-bone contact due to the residual deformity of the proximal femur to improve FAI. Mamisch et al. [20] simulated postoperative ROM after osteotomies using three-dimensional CT and reported virtually measured ranges of hip flexion as determined by bone-to-bone contact of 61° and 63° after multiplanar osteotomy and uniplanar flexion osteotomy, respectively. They concluded the improvement in flexion is not adequate for the requirements of normal everyday life. Diab et al. [4] also reported the improvement of hip motion after staged flexion intertrochanteric osteotomy was not associated with better functional outcome as measured by Harris hip score. In contrast, both clinical and radiographic signs related to FAI were improved in our study. Naturally, even our treatment strategy will neither perfectly meet the requirements of normal life nor guarantee a good functional prognosis in the patients' life times. At the very least, the risk factors for poor prognosis in the future, such as a limited hip ROM and abnormal configuration of the proximal femur, should be eliminated and prevent or delay coxarthroses in adulthood. Realignment and remodeling of the proximal femur after the osteotomy would contribute to those improvements. In addition, our procedure was designed based on three-dimensional analysis using preoperative CT and then provided a simpler and more accurate correction, compared with conventional osteotomies, such as Southwick [25] and Imhäuser [10] methods, in which only two-dimensional analysis using plain

Fig. 1A–F (A) An AP radiograph of a patient with left chronic SCFE at the age of 12 years (Patient 20) is shown. (B) The preoperative PTA, α angle, and β angle were 52°, 52°, and 104°, respectively, on a Lauenstein view. (C) AP and (D) Lauenstein views taken 2 weeks after osteotomy of 45° flexion and 20° valgus are shown. (E) An AP

radiograph 5 years after osteotomy at the age of 17 years is shown. The Kellgren-Lawrence classification was Grade 1. (F) The postoperative α and β angles were 51° and 38°, respectively. The maximum range of hip flexion was 110°, with a negative Drehmann's sign.

radiographs had been available. However, FAI was not resolved in 25% of our patients with our protocol. We will consider additional procedures such as osteoplasty for patients with insufficient improvement of FAI in the future.

Postoperative α angles did not decrease much postoperatively (6°). On the other hand, the β angles decreased an average of 39°, which coincided with a mean flexion angle of 44° that was surgically corrected. Despite many reports regarding intertrochanteric osteotomies, there has been a lack of the analysis of the postoperative improvement of FAI after

the osteotomies. Many authors used the Nötzli α angle [22] for radiographic evaluation of FAI. While this angle was originally measured on MRI, it was measured on plain radiographs in some subsequent reports [7, 13, 27]. We found the α angle measured on a Lauenstein view was not useful for evaluating the postoperative changes after surgical realignment in FAI because the proximal femur was surgically flexed anteriorly with the femoral neck. Thus, the original α angle basically did not change after the surgery because the relationship between the femoral neck and head stayed the same. Therefore, we

employed the β angle, which was the angle measured between a line parallel to the proximal long axis of the femoral shaft and a line from the center of the femoral head to the anterior point where the distance from the head center exceeded the radius. Some remodeling around the head-neck junction seemed to result in a slight reduction of the α angle and the correction angle of the flexion osteotomy directly reflected the reduction of the β angle.

When evaluating FAI, β angles showed greater differences than α angles among hips with positive and negative clinical signs of FAI. We believe the β angle reflects the maximum flexion angle as determined by bone-to-bone contact. Therefore, the reduction of the β angle was consistent with improvement of the clinical signs, as reported in a previous study [13].

We detected early osteoarthritic changes in eight of the 32 hips (25%). Among these patients, AVN was detected before osteotomy in three hips, and the cause of SCFE was postulated as radiation therapy for a primitive neuroectodermal groin tumor in one hip. In the remaining four of 27 patients (15%) with neither AVN before osteotomy nor radiation therapy, the adverse effect of realignment operations could not be denied in view of severe slip angles (PTA: 55°, 65°, 80°, and 90°). However, only two of the 32 patients complained of inconvenience in daily life activities. Since Kellgren-Lawrence classification was designed for idiopathic arthrosis, it may not be appropriate for evaluation of arthrosis due to residual deformity after SCFE. Distal osteotomy at the trochanteric level reportedly results in a low incidence of AVN but a high incidence of chondrolysis compared with proximal osteotomy at the level of neck or growth plate [6]. The incidence of persistent chondrolysis (3%) in this study was compatible with those (4%–10%) in the past reports [3, 6, 11, 25].

We conclude intertrochanteric flexion osteotomy improved clinical signs of FAI in 75% of hips. The Nötzli α angle on the radiographs was not useful in evaluating FAI before and after intertrochanteric osteotomy. In addition, the modified α angle [13] (β angle) on a Lauenstein view was compatible with the clinical signs of FAI. Based on our data, we believe our intertrochanteric flexion osteotomy is a reasonable option for treating severe SCFE.

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