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Overgrowth of the Lower Limb after Treatment of Developmental Dysplasia of the Hip

발달성 고관절 이형성증의 치료 후 발생하는 환측 하지의 과성장

2018년 2월

서울대학교 대학원

임상의과학과

윤 찬

A thesis of the Degree of Master of Science

발달성 고관절 이형성증의 치료 후 발생하는 환측 하지의 과성장

Overgrowth of the Lower Limb after Treatment of Developmental Dysplasia of the Hip

February, 2018

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Abstract

Overgrowth of the Lower Limb after Treatment of Developmental Dysplasia of the Hip

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Background: During treatment of developmental dysplasia of the hip (DDH), overgrowth of the affected leg can sometimes develop. However, little was studied about this phenomenon. The purpose of this study was to evaluate the incidence of leg length discrepancy by overgrowth and investigate the risk factors for overgrowth in patients treated for DDH.

Methods: One hundred and seven patients who were treated for unilateral DDH and reached skeletal maturity were included in this study. Overgrowth was assessed on standing anteroposterior radiographs of the hip by measuring the difference in the height of femoral heads. Significant overgrowth was defined when the affected femoral head was higher than the contralateral side by more than 10 mm. The associations among treatment modalities, age at treatment, radiologic parameters, and development of significant overgrowth were retrospectively analyzed.

Results: Significant overgrowth was found in 45 patients (42%). Binary logistic regression analysis revealed that anterolateral open reduction (OR) and femoral osteotomy were the significant and independent risk factors for overgrowth ($p = 0.032$ and $p = 0.011$, respectively). In the femoral osteotomy group, the incidence of overgrowth was higher in patients who underwent femoral osteotomy at the age of 2 to 4 years than those who underwent femoral osteotomy in other age range (87% and 13%, respectively; $p = 0.021$). In the non-femoral osteotomy group, anterolateral OR and center-head distance discrepancy (CHDD) over 7.4% around the age of 3 years were significant risk factors for overgrowth ($p = 0.024$ and $p = 0.002$, respectively).

Conclusion: Overgrowth of the affected leg is a commonly encountered problem during treatment of DDH. Patients who underwent femoral osteotomy, especially at the age of 2 to 4 years, as well as the patients who underwent anterolateral OR or who showed large CHDD around the age of 3 years may require careful follow-up for development of overgrowth.

Keywords: developmental dysplasia of the hip; leg length discrepancy; overgrowth; long leg dysplasia

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CONTENTS

List of Figures

List of Tables

List of Abbreviations

DDH -------------- developmental dysplasia of the hip

LLD -----------------------leg length discrepancy

FHHD ---------------- femoral head height difference

AI ----------------------------acetabular index

CHDD --------------center-head distance discrepancy

ICC -----------------intraclass correlation coefficient

ROC ----------------receiver operating characteristic

OR ---------------------------- open reduction

CR --------------------------- closed reduction

CI --------------------------- confidence interval

Introduction

During the follow-up period after treatment of developmental dysplasia of the hip (DDH), it has been noted that overgrowth of the affected leg can sometimes develop[1]. Overgrowth and consequent leg length discrepancy (LLD) results in hip adduction and decrease of lateral center-edge angle on the long limb side in the weight-bearing position. This may lead to excessive load on superolateral acetabular epiphysis and consequent compromised acetabular development, leaving so-called “long-leg dysplasia”[1]. Moreover, LLD can cause low back pain, gait disturbance, and difficulties in total hip arthroplasty which is a procedure commonly performed in patients with sequelae of DDH[2-7].

In patients with DDH, LLD may develop either from proximal femoral growth disturbance associated with treatment of DDH or from overgrowth of the affected leg. Most previous studies focused on LLD due to proximal femoral growth disturbance [8-10]. To the best of our knowledge, only one study reported the incidence of LLD by overgrowth in patients with DDH[1], and no study has evaluated risk factors for overgrowth in them.

The purposes of this study were to assess the incidence of LLD by overgrowth and to investigate the risk factors for development of overgrowth in patients who were treated for DDH.

Materials and Methods

Study subjects

Medical records and serial radiographs of patients with DDH who were treated in a tertiary-care children's hospital between April 1982 and December 2004 were reviewed. We collected dislocated-type DDH cases with unilateral involvement which had not received any prior treatment before referred to our hospital. Out of 202 consecutive patients meeting these inclusion criteria, patients who was not followed until skeletal maturity (n = 68), patients associated with neuromuscular disease (n = 10), one patient associated with other congenital anomaly, and 4 patients who had medical conditions affecting leg length such as septic arthritis of the hip or femoral shaft fracture were excluded. We also excluded 10 hips which had femoral shortening osteotomy concurrent with closed or open reduction and 2 hips with type 3 proximal femoral growth disturbance according to the criteria by Bucholz-Ogden[11]. On the basis of these criteria, 107 hips in 107 patients became the subjects of this study (Fig. 1).

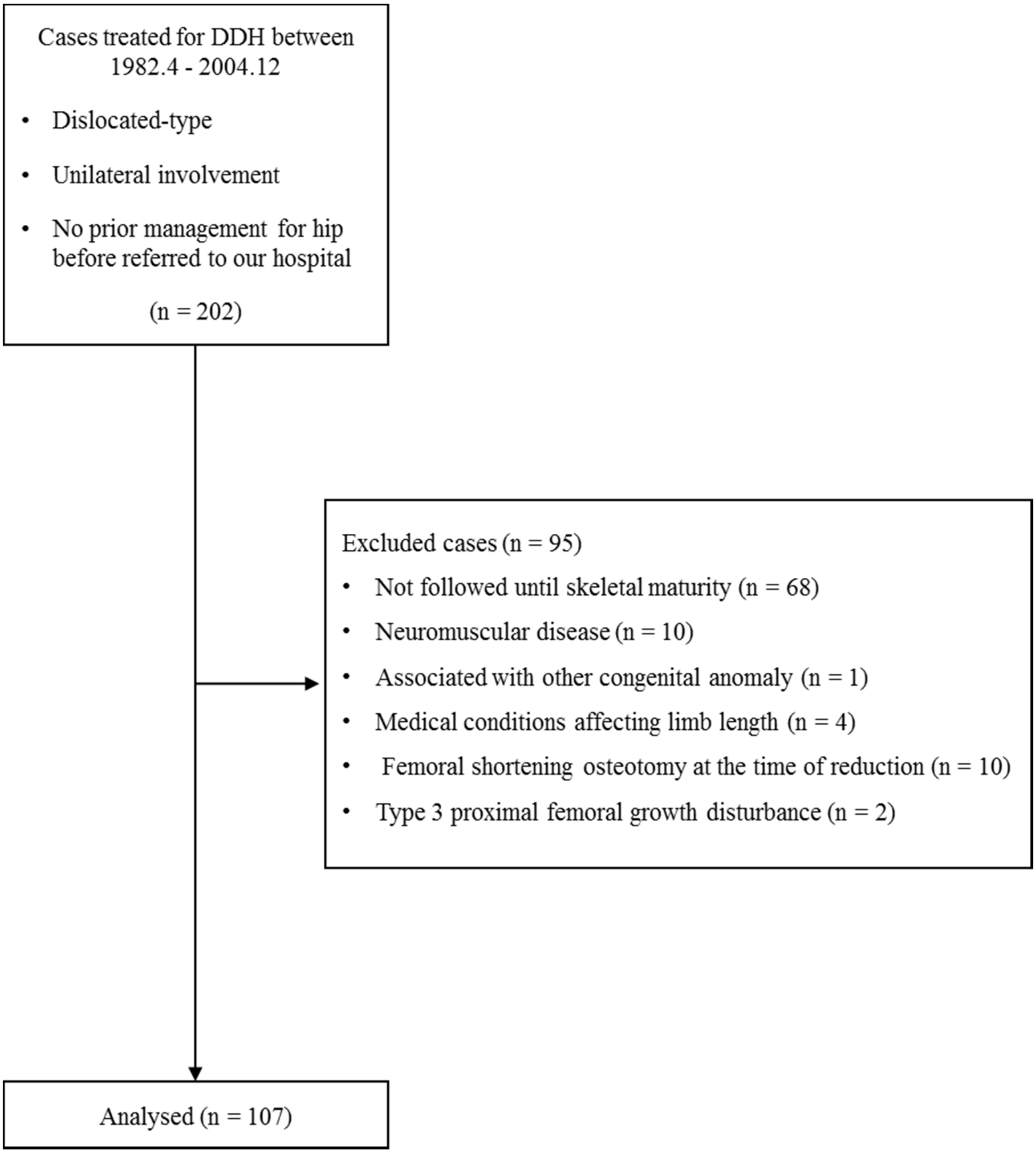

Fig. 1. Flow chart of study selection

There were 97 female (91%) and 10 male (9%) patients. Sixty-five hips (61%) were left side. Five hips (5%) had type 1, and 30 hips (28%) had type 2 proximal femoral growth disturbance according to Bucholz-Ogden classification[11]. Various treatment modalities were applied to the patients (Table 1).

Table 1. Treatment modalities applied to patients

Treatment modalities	N* = 107	Age at treatment†
CR under general anesthesia	35 (33%)	14 ± 16 months
CR with osteotomy	3(3%)	40 ± 34 months
Medial OR	10 (9%)	13 ± 5 months
Anterolateral OR	35 (33%)	16 ± 9 months
Anterolateral OR with osteotomy	24 (21%)	25 ± 13 months
Osteotomy for residual dysplasia		
Femoral osteotomy‡	24 (22%)	3.8 ± 2.3 yrs
Pelvic osteotomy‖	25 (23%)	4.6 ± 2.6 yrs

*The values are given as the number of hips.

† The values are given as the mean and the standard deviation.

‡ There were patients who had femoral osteotomy twice (n = 3) or three times (n = 2) before skeletal maturity.

‖ There were 4 patients who had pelvic osteotomy twice before skeletal maturity.

CR, closed reduction; OR, open reduction

Femoral osteotomies made the neck−shaft angles ranged from 100º to 125º using medial closing−wedge technique, depending on whether the procedure had been combined with a pelvic osteotomy, and made the femoral anteversion angles ranged from 10º to 20º. The mean age at the latest follow−up was 16.5 ± 3.4 years (range, 11.7 to 29.3 years), and the follow−up duration averaged 15.1 ± 3.4 years (range, 6.5 to 26.2 years).

Radiographic evaluation

On standing anteroposterior radiographs of the hip, femoral head height difference (FHHD) was measured at skeletal maturity or at intervention for overgrowth to determine LLD (Fig. 2)[4].

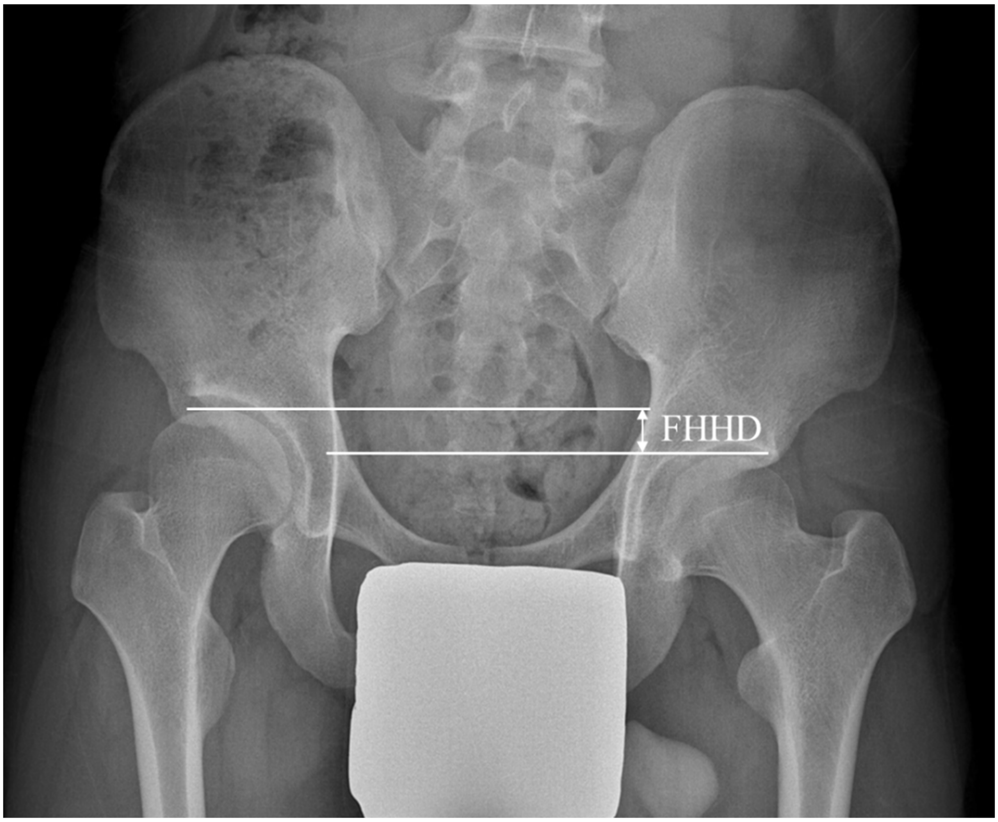

Fig. 2. Measurement of the femoral head height difference (FHHD) on standing anteroposterior radiograph of the hip

It was presented as a positive value when the affected side was longer than the unaffected, and as a negative value when the affected side shorter. Significant overgrowth was defined when the affected femoral head was higher than the contralateral side by more than 10 mm which could cause shift of center−of−pressure toward the longer leg[12−14]. In order to evaluate the association between radiologic parameters and incidence of overgrowth, the acetabular index (AI)[15] was measured at the time of reduction and around the age of 3 years (2 ~ 4 years), and the center−head distance discrepancy (CHDD)[16] around the age of 3 years. In the patients who underwent femoral osteotomy either at reduction or after reduction due to residual dysplasia, the AI and CHDD were also measured just before femoral osteotomy. The widest diameter of the femoral head was measured at skeletal maturity or just before the intervention for overgrowth. Femoral head diameter discrepancy was defined as the difference in the femoral head diameter between the affected and unaffected sides, and expressed as a percentage of the unaffected side measurement[17]. Coxa magna was categorized when the femoral head diameter discrepancy was 10% or more[17, 18]. Skeletal maturity was determined based on the closure of the proximal femoral growth plate and triradiate cartilage.

All radiographs were reviewed by the two orthopaedic surgeons. To determine intra-observer reliability, measurements were made by the author on two different days, 4 weeks apart. To determine the inter-observer reliability, the same measurements were made by another orthopaedic surgeon after a consensus building session to define the radiographic measurements. When measuring the AI, the lateral osseous margin of the acetabular roof was used as a reference point instead of the lateral end of the sourcil. Intra-observer and inter-observer reliability were evaluated by intraclass correlation coefficients (ICCs), which were calculated assuming absolute agreement and a single measurement with a 2-way-random-effects-model. In the intra-observer reliability test, ICCs were 0.998 (95% confidence interval [CI], 0.997 to 0.999) for FHHD, 0.885 (0.768 to 0.943) for AI, 0.963 (0.925 to 0.982) for CHDD, and 0.948 (0.914 to 0.969) for femoral head diameter and. In the inter-observer reliability test, ICCs were 0.996 (95% CI, 0.994 to 0.997) for FHHD, 0.826 (0.740 to 0.883) for AI, 0.918 (0.880 to 0.944) for CHDD, and 0.851 (0.746 to 0.913) for femoral head diameter.

Statistical analysis

A sample size of 50 participants was required to detect a difference of 19% between groups in the incidence rate of LLD by overgrowth, using a two-sided Z-test of the difference between proportions with a power of 80% at a level of significance of $p < 0.05$. This 19% difference represents the difference between a 35% LLD incidence rate in the DDH group and 16% rate in normal population[4].

Continuous data were statistically analyzed using the independent Student t test or Mann-Whitney U test, and categorical data were analyzed using the Fisher exact test. Binary logistic regression analysis with backward stepwise selection was used to identify factors independently associated with development of overgrowth. A receiver operating characteristic (ROC) curve was applied to determine cutoff values for the AI and CHDD at the age of 3 years which distinguished between the cases with and without overgrowth in the non-femoral osteotomy group. P values of < 0.05 were considered significant. We retrospectively analyzed the associations among treatment modalities, age at treatment, radiologic parameters, and development of significant overgrowth.

Results

Significant overgrowth of DDH-affected leg developed in 45 patients (42%). Twenty patients of them (44%) did not have surgical intervention for overgrowth, but showed FHHD larger than 10 mm at skeletal maturity. Sixteen patients of them had permanent epiphysiodesis or percutaneous epiphysiodesis using transphyseal screws in the distal femur at a mean age of 11.6 ± 0.6 years (range, 10.7 to 12.6 years), and 9 patients had femoral shortening combined with varization osteotomy at a mean age of 8.3 ± 2.9 years (range, 3.4 to 12.5 years). Their mean FHHD was 15.4 ± 3.3 mm (range, 10.2 to 20.7 mm) at the surgical intervention (Table 2) and −1.6 ± 7.2 mm (range, −14.6 to 12.8 mm) at the latest follow-up. In 82 patients who did not have any surgical intervention for overgrowth, 62 patients (76%) had FHHD less than 10 mm. When we change the cutoff value of FHHD for significant overgrowth from 10 mm to 15 mm, the incidence of overgrowth was 21%.

Table 2. Femoral head height difference in the patients who had surgical intervention for overgrowth

FHHD at intervention	N^{*} = 25
FHHD > 20 mm*	2 (8%)
20 mm ≥ FHHD > 15 mm*	12 (48%)
15 mm ≥ FHHD > 10 mm*	11 (44%)

*The values are given as the number of hips.

FHHD, femoral head height difference

Significant overgrowth developed more frequently in the patients who underwent anterolateral open reduction (OR) compared to those who underwent closed reduction (CR) or medial OR ($p = 0.019$). Age and the AI at reduction were not significantly different between the overgrowth and no overgrowth groups (Table 3). Although femoral head diameter discrepancy was slightly larger in the overgrowth group than the no overgrowth group, the incidence of coxa magna was not significantly different between the overgrowth (16 of 45 patients; 36%) and no-overgrowth groups (13 of 62 patients; 21%) ($p = 0.123$) (Table 3).

Table 3. Association between mode of reduction, age at reduction, acetabular index at reduction, diameter of femoral head, and development of overgrowth

	Overgrowth group (n = 45)	No overgrowth group (n = 62)	P Value
CR or medial OR *	14 (29%)	34 (71%)	0.019 ‡
Anterolateral OR *	31 (53%)	28 (47%)	
Age at reduction (month) †	18.0 ± 9.2	17.8 ± 12.8	0.699 §
AI at reduction (°) †	32.8 ± 6.0	33.3 ± 6.0	0.931 §
Femoral head diameter discrepancy (%) † ‖	7.8 ± 6.3	4.6 ± 6.2	0.010 §
Coxa magna*	16 (36%)	13 (21%)	0.123 ‡

*The values are given as the number of hips.

† The values are given as the mean and the standard deviation.

‡ Fisher exact test. § Student t test.

‖ (Diameter of affected femoral head – diameter of unaffected femoral head)/ diameter of unaffected femoral head x 100%

CR, closed reduction; OR, open reduction; AI, acetabular index.

The incidence of significant overgrowth was different depending on performance and site of osteotomy ($p = 0.036$) (Fig. 3). It was more commonly found in the patients who underwent femoral osteotomy only and in those who underwent pelvic and femoral osteotomies compared to those who did not undergo osteotomy ($p = 0.019$ and $p = 0.044$, respectively).

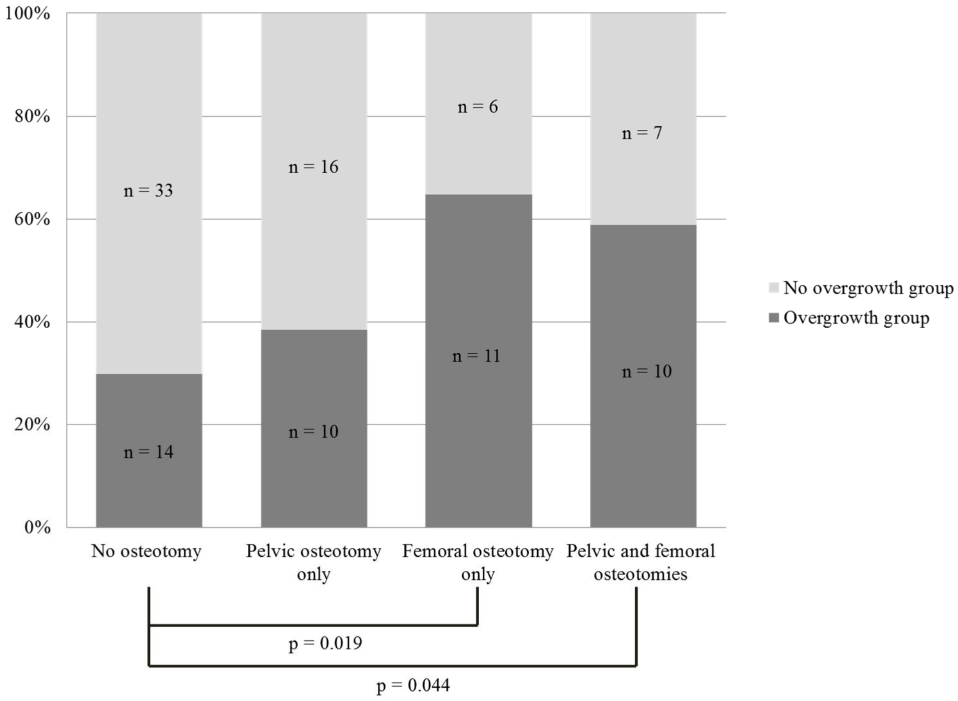

Fig. 3. Incidence of overgrowth by performance and site of osteotomy

Binary logistic regression analysis revealed that anterolateral OR and femoral osteotomy were significant and independent risk factors for development of significant overgrowth (Table 4). In the patients who underwent anterolateral OR, age and AI at the time of reduction were not significantly different between the overgrowth and no overgrowth groups (Table 5).

Table 4. Regression analysis of risk factors for overgrowth

Treatment Modalities	Odds Ratio (95% CI)	P Value*
Anterolateral OR	2.481 (1.081 to 5.695)	0.032
Femoral osteotomy	3.067 (1.289 to 7.294)	0.011

*Binary logistic regression test with backward stepwise selection.

CI, confidence interval; OR, open reduction.

Table 5. Comparison of age and acetabular index at reduction between the overgrowth and no overgrowth groups in the patients who underwent anterolateral open reduction

	Overgrowth group (n = 31)	No overgrowth group (n = 28)	P Value†
Age at reduction (months)*	19.8 ± 8.9	19.8 ± 13.8	0.998
AI at reduction (°)*	32.4 ± 6.2	32.3 ± 5.1	0.970

*The values are given as the mean and the standard deviation.

†Student t test

AI, acetabular index

In 29 patients who had femoral osteotomy once, the incidence of significant overgrowth was different depending on age at femoral osteotomy ($p = 0.05$) (Fig. 4). It developed much more frequently in the patients who underwent femoral osteotomy at the age of 2 to 4 years (87%) than those who underwent femoral osteotomy before age of 2 years (33%) or after age of 4 years (46%) ($p = 0.021$). However, the mode of reduction, the AI and CHDD at the time of femoral osteotomy were not significantly different between the overgrowth and no-overgrowth groups (Table 6).

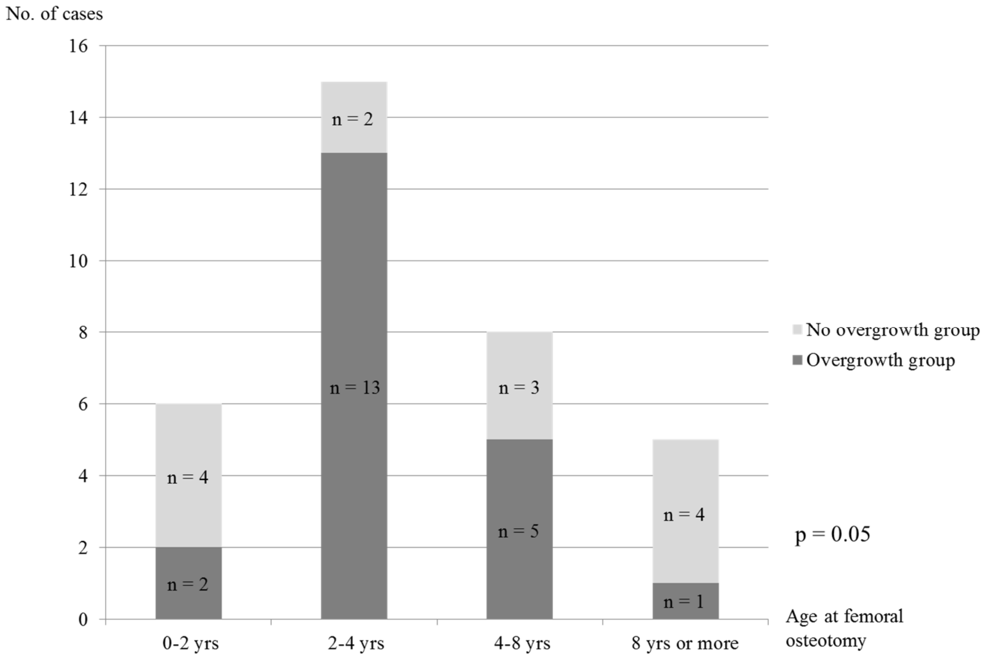

Fig. 4. Incidence of overgrowth by age at femoral osteotomy

Table 6. Comparison of acetabular index and center-head distance discrepancy at femoral osteotomy between the overgrowth and no overgrowth groups in the patients who underwent femoral osteotomy

Radiographic Parameters	Overgrowth group (n = 21)	No overgrowth group (n = 13)	P Value†
AI at femoral osteotomy (°)*	28.2 ± 6.7	30.0 ± 6.2	0.604
CHDD at femoral osteotomy (%)*	20.5 ± 14.8	19.1 ± 10.5	0.985

*The values are given as the mean and the standard deviation.

† Mann-Whitney U test

AI, acetabular index; CHDD, center head distance discrepancy.

In the non-femoral osteotomy group, the patients who underwent anterolateral OR showed higher incidence of significant overgrowth (17 of 37 patients; 46%) than those who underwent CR or medial OR (7 of 36 patients; 19%) ($p = 0.024$). The AI at the age of 3 years was not significantly different between the LLD and non-LLD groups ($p = 0.573$). On the other hand, CHDD at the age of 3 years was significantly larger in the LLD group than the non-LLD group ($p = 0.002$) (Table 7).

Table 7. Comparison of acetabular index and center-head distance discrepancy at the age of 3 years between overgrowth and no overgrowth groups in the patients who did not undergo femoral osteotomy

Radiographic Parameters	Overgrowth group (n = 24)	No overgrowth group (n = 49)	P Value†
AI at the age of 3 years (°)*	24.5 ± 6.7	25.5 ± 7.1	0.573
CHDD at the age of 3years (%)*	10.8 ± 6.7	6.2 ± 4.5	0.002

*The values are given as the mean and the standard deviation.

†Student t test

AI, acetabular index; CHDD, center head distance discrepancy.

An ROC curve showed the optimal cutoff value for significant overgrowth to be a CHDD of 7.4%, with 72.7% sensitivity and 69.8% specificity (area under the curve = 0.717, 95% CI = 0.578 to 0.856; $p = 0.004$). The incidence of significant overgrowth was higher in 29 patients with CHDD of ≥ 7.4% (55%) than 36 patients with CHDD of < 7.4% (17%) ($p = 0.002$). The patients who underwent pelvic osteotomy had larger CHDD (10%) than the others (7%) ($p = 0.026$), but the frequency of pelvic osteotomy was not significantly different between the overgrowth (10 of 24 patients; 42%) and no overgrowth groups (16 of 49 patients; 33%) ($p = 0.603$). Binary logistic regression analysis showed that anterolateral OR (odds ratio = 4.033, 95% CI = 1.203 to 13.520, $p = 0.024$) and CHDD of ≥ 7.4% (odds ratio = 6.684, 95% CI = 1.985 to 22.505, $p = 0.002$) increased the risk of overgrowth, independently.

Discussion

In this study, we investigated the incidence and risk factors of overgrowth of the lower extremity of the affected side in patients treated for DDH. There have been various studies about LLD in normal population[2, 4]. However, little has been reported on the incidence as well as risk factors of LLD by overgrowth in patients with DDH. In the current study, more than 40% patients had LLD exceeding 10 mm. LLD of 10 mm may not have large influence on normal hip[19]. Nevertheless, in patients with DDH, small amount of LLD can induce compromised acetabular development due to preexisting hip dysplasia, which may result in the vicious cycle of excessive load on superolateral acetabular margin and hip dysplasia.

In the current study, significant overgrowth developed in 42% when we set cutoff value of FHHD to 10mm and in 21% when 15mm. This incidence is much higher than that of the healthy cohort of Hellsing et al., who reported that 4% of 600 military recruits had LLD of more than 15 mm[20]. And it is similar to that of another study about DDH which reported an incidence of 17% of overgrowth more than 15 mm although this study did not mention whether cases with avascular necrosis were included in the analysis of overgrowth incidence or not[1]. They experienced recurrence of hip dysplasia in 4 of 12 hips with the increase in leg length.

Femoral osteotomy was found as the most significant risk factor for overgrowth of the affected leg in this study. It seems that mode of reduction and radiologic parameters does not affect overgrowth much in the femoral osteotomy group since the large influence of femoral osteotomy on overgrowth masks the effect of other factors with smaller effect. Similar to our results, in the study of Zadeh et al., all of the hips showing overgrowth of the affected leg had femoral osteotomy in conjunction with OR[1]. Geometrically, proximal femoral varus osteotomy using medial closing-wedge technique shortens the effective length of the femur[3, 21, 22]. In this study, serial standing hip radiographs were available in 5 patients. In all of them, the affected leg was shorter than the unaffected leg 6 months after femoral osteotomy. However, the affected leg overgrew afterwards and eventually became longer than the unaffected leg at skeletal maturity or at the time of intervention for overgrowth (Fig. 5).

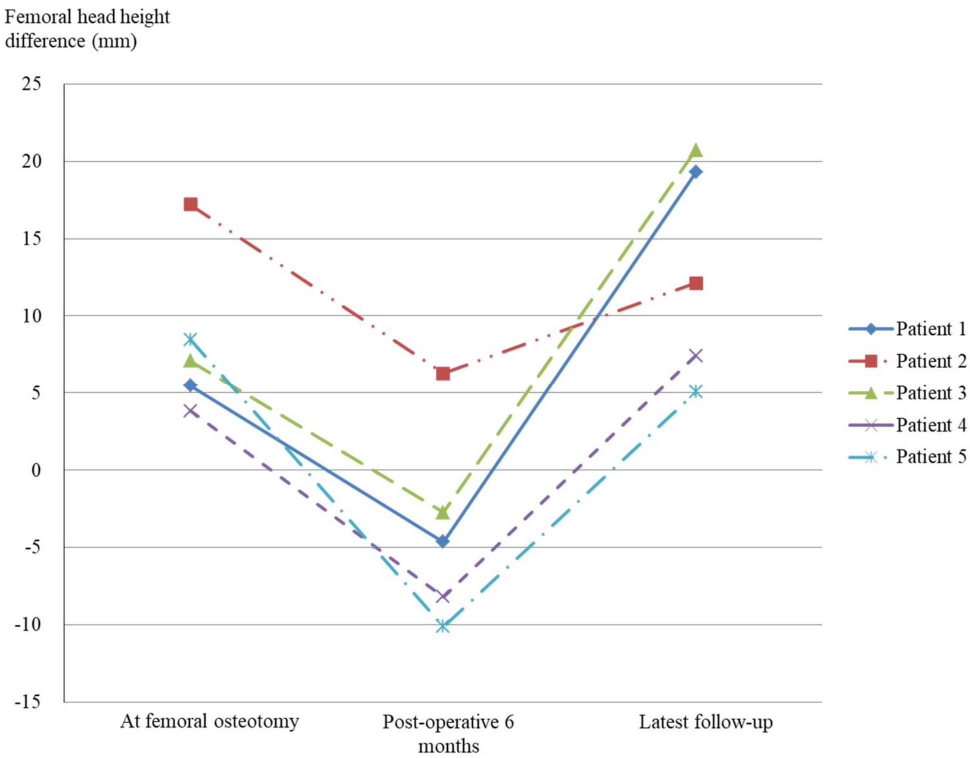

Fig. 5. Temporal change of femoral head height difference in five patients who underwent femoral varus osteotomy

This overgrowth phenomenon resembles femoral overgrowth following femoral shaft fracture[23-27]. Although some previous studies reported no association between overgrowth and age at fracture[28, 29], it occurred mainly in children over 2 years of age in many studies[23, 26, 30, 31]. In concordance with results of these studies, overgrowth occurred more often when femoral osteotomy was performed especially at the age of 2 to 4 years in this study. On the other hand, Suda et al.[22] reported no difference of femoral length between the affected and unaffected sides at skeletal maturity after femoral varus osteotomy in patients with DDH. However, they evaluated LLD in only 45% of subjects due to availability of radiograph and their mean age at femoral osteotomy was 4.7 years which was older than the most vulnerable age for overgrowth of our study. Risk of overgrowth could be a consideration when deciding between femoral and pelvic osteotomy, especially at the age of 2 to 4 years.

In the non-femoral osteotomy group, anterolateral OR and CHDD over 7.4% at the age of 3 years were associated with overgrowth of the affected side. This association has not been reported before to the best of our knowledge, and it is not easy to speculate its pathogenic mechanism. Anterolateral OR may cause more surgical insult and subsequent inflammatory reaction compared to those by CR or medial OR, and they may be one of reasons for overgrowth as in inflammatory arthritis[32]. However, because the incidence of coxa magna was not different between the overgrowth and no overgrowth groups, overgrowth may attribute to the physeal overgrowth rather than epiphyseal overgrowth.

The cause of overgrowth in the patients with large CHDD is also difficult to speculate. A study on adult hip dysplasia showed that 64% patients, who did not have any surgery at childhood, had the affected leg longer than the unaffected by more than 5mm[33]. Altered mechanical loading on the proximal femur by lateral subluxation which appeared as large CHDD might affect leg length through Hueter-Volkmann law[34]. We could not exclude possibility that LLD persisted in early childhood before measuring CHDD because the standing hip radiograph was not available in this age group.

This study has several limitations. First, because it was a retrospective study, there was no standardized indication for mode of reduction and osteotomy. Second, there were patients who were lost to follow up before skeletal maturity. And patients with overgrowth may have a higher follow-up rate than those without it. Theses may make the incidence of overgrowth overestimated. Third, because LLD by overgrowth was determined by FHHD, difference of pelvic height was not reflected in LLD.

Despite these limitations, we concluded that overgrowth is a commonly encountered problem after treatment of DDH. Femoral osteotomy significantly increases the risk of overgrowth especially when it is performed at the age of 2 to 4 years. Among the patients who did not undergo femoral osteotomy, those who underwent anterolateral OR and those with large CHDD at the age of 3 years have a higher risk for overgrowth; and require careful follow-up for LLD development because it may also jeopardize the normal development of acetabulum. Further studies are warranted to prove the association between overgrowth of the affected leg and recurrence of hip dysplasia.

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국문 초록

배 경: 발달성 고관절 이형성증의 치료 후 환측하지의 과성장은 드물지 않게 관찰되는 합병증이나 이에 대한 연구는 부족한 실정이다. 이에 본 연구는 발달성 고관절 이형성증 환자에서 과성장의 발생 빈도를 평가하고, 발생의 위험인자를 밝히고자 하였다.

대상 및 방법: 편측의 발달성 고관절 이형성증으로 치료받고 골 성숙시기까지 추시된 107명의 환자를 대상으로 하였다. 과성장은 기립 고관절 전후 방사선 영상을 사용하여 대퇴골두의 높이 차이로 측정하였고, 10mm 이상의 차이를 임상적으로 유의한 과성장으로 정의하였다. 발달성 고관절 이형성증의 치료방법, 치료시기 및 방사선학적 지표들이 과성장에 미치는 영향을 후향적으로 분석하였다.

결 과: 임상적으로 유의미한 과성장은 45명의 (42%) 환자에서 나타났다. 이변량 로지스틱 회기분석 결과 전외측 접근을 통한 관혈적 정복술 (p = 0.032) 및 근위 대퇴골 절골술이 (p = 0.011) 모두 독립적으로 유의한 과성장의 위험인자로 밝혀졌다. 대퇴골 절골술을 시행한 환자들 중 특히 2-4세에 절골술을 시행한 경우 87%에서 과성장이 나타난 반면, 타연령에 시행한 환자들의 경우 13%에서 과성장이 나타났다 (p = 0.021). 대퇴골 절골술을 시행하지 않은 환자군에서는 전외측 접근을 통한 관혈적 정복술을 시행한 경우 (p = 0.024), 그리고 3세 시점의 중심대퇴골 거리

차이 가 7.4% 이상일 경우 (p = 0.002)가 유의한 위험인자로 밝혀졌다.

결 론: 발달성 고관절 이형성증 환자에서 환측 하지의 과성장은 드물지 않게 발생할 수 있는 문제로 특히 2-4세의 나이에 대퇴골 절골술 치료를 받은 경우, 또는 대퇴골 절골술을 받지 않았더라도 전외측 접근을 통한 관혈적 정복술을 받았거나 3세 시점의 대퇴골 거리차이가 클 경우 과성장의 발생에 주의를 요한다.

색인 단어: 발달성 고관절 이형성증, 하지부동, 과성장

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