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Effect of greater trochanteric epiphysiodesis after femoral varus osteotomy for lateral pillar classification B and B/C border Legg–Calvé–Perthes disease

A retrospective observational study

Keun-Sang Kwon, MD, PhD[a], Sung Il Wang, MD, PhD[b], Ju-Hyung Lee, MD, PhD[a], Young Jae Moon, MD[b], Jung Ryul Kim, MD, PhD[b,*]

Abstract

This is a retrospective observational study. Greater trochanteric epiphysiodesis (GTE) has been recommended to prevent Trendelenburg gait and limitation of the hip joint motion due to trochanteric overgrowth after femoral varus osteotomy (FVO) in Legg–Calvé–Perthes disease (LCPD). However, capital femoral physeal arrest frequently occurs in patients with severe disease (lateral pillar C), so GTE might not be as effective in these patients. The aim of this study was to compare trochanteric growth inhibition due to GTE after FVO between 2 age groups (<8 or >8 years) in patients with lateral pillar B and B/C border LCPD and evaluate the effectiveness of GTE compared with the normal, unaffected hip.

This study included 19 children with lateral pillar B and B/C border LCPD in 1 leg who underwent FVO followed by GTE. Of the 19 children, 9 underwent GTE before the age of 8 years and 10 underwent GTE after 8 years of age. On radiographs taken at the immediate postoperative period and at skeletal maturity, the articulo-trochanteric distance (ATD), center-trochanteric distance (CTD), and neck-shaft angle (NSA) were compared between the 2 age groups. The amount of correction was compared between groups. The contralateral, unaffected hip was used as a control for trochanteric growth. The patients were clinically evaluated with Iowa hip score at the final follow-up.

There was no significant difference between the 2 age groups in terms of time to GTE, length of follow-up, or lateral pillar classification. In the affected hip, the amount of correction of the ATD, CTD, and NSA was significantly greater in patients < 8 years than in patients > 8 years. However, in the unaffected hip, the change in the ATD, CTD, and NSA did not differ significantly between the 2 groups.

We suggest that FVO followed by GTE for lateral pillar B and B/C border LCPD in patients under the age of 8 years can affect growth of the greater trochanter. However, effective growth inhibition due to GTE was not achieved after 8 years of age.

Abbreviations: ATD = articulotrochanteric distance, CTD = center-trochanteric distance, FVO = femoral varus osteotomy, GTE = greater trochanteric epiphysiodesis, LCPD = Legg-Calve-Perthes disease, NSA = neck-shaft angle.

Keywords: epiphysiodesis, femoral varus osteotomy, greater trochanter, growth inhibition, Legg–Calvé–Perthes disease

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KSK and SIW contributed equally to this work.

Authorship: KSK and JRK designed this paper. KSK, SIW, JHL, and YJM performed data collection and analysis. All authors have agreed to authorship and order of authorship for this manuscript. We confirm that all authors have the appropriate permissions and rights to the reported data.

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All the data needed to achieve the conclusion are presented in the paper. The raw data cannot be shared, as most patients do not want to share their individual data. In addition, we are preparing patent.

The authors report no conflicts of interest.

[a] Department of Preventive Medicine, Chonbuk National University Medical School, [b] Department of Orthopaedic Surgery, Chonbuk National University Medical School, Research Institute of Clinical Medicine of Chonbuk National University-Biomedical Research Institute of Chonbuk National University Hospital and Research Institute for Endocrine Sciences, Jeonju, Republic of Korea.

[*] Correspondence: Jung Ryul Kim, Department of Orthopaedic Surgery, Chonbuk National University Medical School, Research Institute of Clinical Medicine of Chonbuk National University-Biomedical Research Institute of Chonbuk National University Hospital and Research Institute for Endocrine Sciences, 567 Baekje-daero, Deokjin-gu, Jeonju 54896, Republic of Korea. (e-mail: jrkeem@chonbuk.ac.kr)

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1. Introduction

Legg–Calvé–Perthes disease (LCPD) is a condition in which an avascular event affects the capital epiphysis of the femur.[1] The vascular insult may damage the capital femoral growth plate, resulting in premature closure and subsequent shortening of the femoral neck.[2,3] Patients with a group B or B/C border lateral pillar classification in whom disease onset occurred after the age of 8 are treated by surgical containment. Femoral varus osteotomy (FVO) and Salter innominate osteotomy are commonly used to contain the femoral head in patients with LCPD and produce similar results, and each has its advantages and disadvantages.[4] By performing a pelvic osteotomy, less varus is needed from the femoral osteotomy theoretically decreasing the risk of abnormal hip mechanics. However, the Salter osteotomy is occasionally complicated by refractory hip stiffness. FVO can aggravate limping and reduce hip joint motion due to a decrease in the neck-shaft angle (NSA) and trochanteric overgrowth.[5–7] Shah et al[6] reported that concomitant trochanteric epiphysiodesis at the time of FVO during the active stage of LCPD minimizes trochanteric overgrowth and gait abnormalities. However, if growth arrest of the capital femoral physis occurs, greater trochanteric epiphysiodesis (GTE) could minimize trochanteric overgrowth. Moreover, growth arrest of the capital femoral physis frequently occurs in the severe type of the disease (lateral pillar C), but the effect of GTE in these cases remains unknown.

Some authors have reported that GTE has beneficial clinical effects[8,9] and that it should be performed in patients younger than 8 years old.[5] However, these studies did not consider the severity of the disease or the final outcomes. The proximal femoral physis of B and B/C border hips might be less damaged than that of lateral pillar C hips.[10] Therefore, we hypothesized that GTE would have beneficial clinical effects if cases of lateral pillar C were excluded. To our knowledge, no previous studies have reported the long-term outcomes of patients with lateral pillar B and B/C border LCPD who underwent prophylactic GTE after FVO. We compared trochanteric growth inhibition associated with GTE after FVO between 2 age groups (<8 or >8 years) with lateral pillar B and B/C border LCPD. We evaluated the effectiveness of GTE compared with the normal, unaffected hip, and we compared the amount of correction between the 2 groups in relation to treatment outcomes.

2. Methods

This was a retrospective study of children with unilateral LCPD who underwent FVO followed by GTE. The study was approved by the Institutional Review Board of Chonbuk National University Hospital (IRB No.: 2011-07-023-003). All patients provided written informed consent. Medical records and radiographs of 38 patients with LCPD who underwent surgical treatment between July 2006 and April 2013 were reviewed. Inclusion criteria were as follows: diagnosis of unilateral Perthes disease with no known disease affecting the contralateral hip; patients who had lateral pillar B or B/C border LCPD; children who underwent FVO followed by GTE; and patients who had anteroposterior (AP) hip radiographic follow-up until skeletal maturity (Risser 5). The exclusion criteria were patients who had inadequate radiographs or clinical records, patients who underwent pelvic osteotomy, and patients who not to be a skeletal maturity. According to these criteria, 19 patients met these criteria. All patients were male. In 12 patients (49%), the left hip was affected, and in 7 (51%) patients, the right hip was affected. In all cases, FVO was performed as a containment treatment in the early fragmentation stage. When the plate and screws were removed after osteotomy union, GTE was performed by drilling 5 to 6 holes across the greater trochanteric physis, followed by placement of 1 cannulated screw and washer. All hardwares for GTE were removed when sufficient closure was achieved on the radiologic findings. The radiographic amount of correction at skeletal maturity was measured (Fig. 1). All procedures were performed by a single surgeon (JRK). Growth of the greater trochanter was compared between the 9 patients who underwent GTE before the age of 8 years and the 10 patients who underwent GTE after the age of 8 years (Figs. 2 and 3). The contralateral, unaffected hip was used as a control. The mean age of patients under 8 years was 6.4 ± 0.7 years; the mean age of patients over 8 years was 8.5 ± 1.1 years. The AP view of the hip was used to measure growth of the greater trochanter in terms of the articulotrochanteric distance (ATD) and center-trochanteric distance (CTD). The ATD is the distance between the articular surface of the femoral head and the tip of the greater trochanter. The CTD is the distance between the center of the femoral head and the tip of the greater trochanter. The extent of remodeling of the varus femoral neck was measured with the NSA, which is the angle formed by the axis of the femoral shaft and the line drawn along the axis of the femoral neck through the center of the head of the femur (Fig. 4). The amount of correction for the ATD, CTD, and NSA measurements was calculated as the difference between the postoperative value and the last follow-up. The lateral pillar classification was determined from AP radiographs of the pelvis taken during the early fragmentation stage of the disease.[10] Treatment outcomes were evaluated according to the modified Stulberg classification of Herring et al.[11] To evaluate the clinical outcomes in 2 groups at the final follow-up, we administered the Iowa hip score, which considers function, pain, gait, absence of deformity, muscle strength, and the Trendelenburg sign.[12] Three orthopedic surgeons (SIW, HJK YJM) assessed the interobserver reliability of the radiographic measurements. Each examiner took the measurements independently, without knowledge of the patients' clinical information or the other orthopedic surgeons' measurements. All measurements were collected by a research assistant (LZ) who did not otherwise participate in the study.

2.1. Statistical analysis

The perioperative clinical outcomes in the same group were compared by paired *t* test. Unpaired *t* test was used for analysis of quantitative variables such as age at FVO, time to GTE, and follow-up period between the patients <8 and >8 years. Comparisons of categorical data were tested with use of the

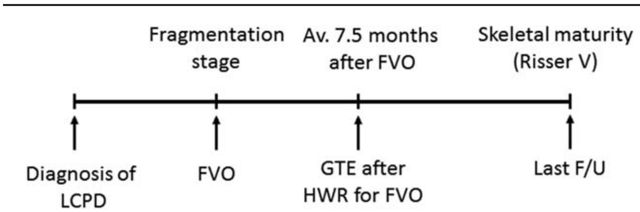

Figure 1. Study design. FVO was performed in the early fragmentation stage. GTE was performed at an average 7.5 months after FVO when the plate and screws were removed. The amount of correction for the ATD, CTD, and NSA at skeletal maturity was measured.

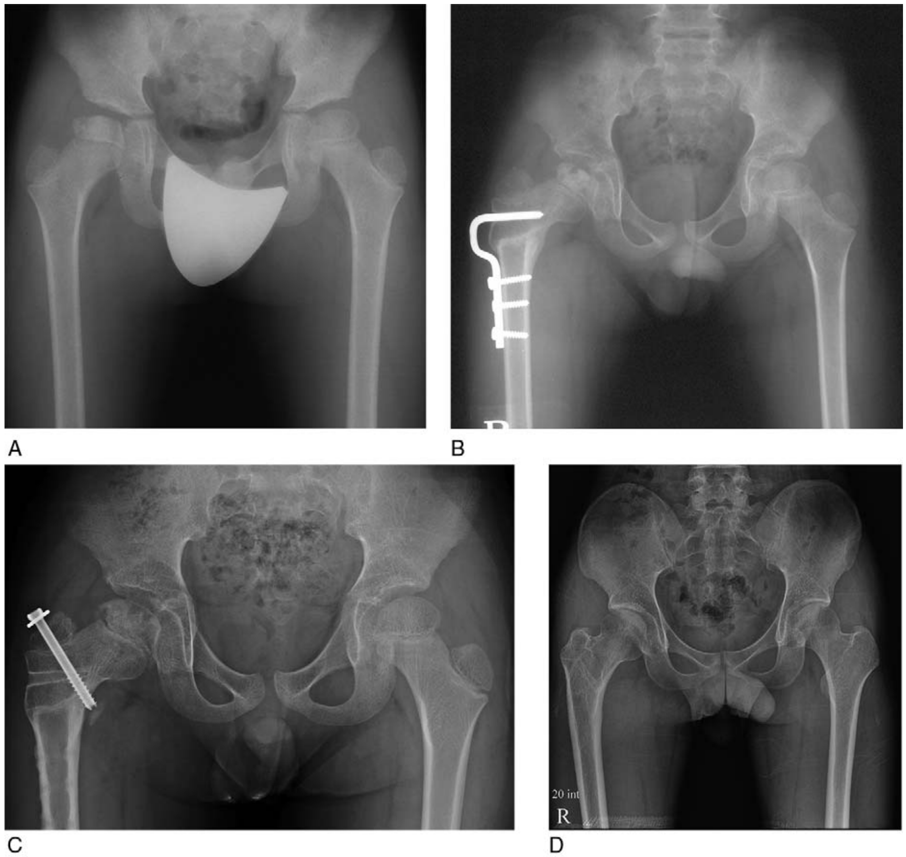

Figure 2. (A) Anteroposterior radiograph of the lateral pillar classification in a patient who was 7.1 years old at presentation. (B) Postoperative anteroposterior pelvic radiograph after FVO. (C) Postoperative anteroposterior pelvic radiograph after GTE and 6 months after FVO. The ATD was 6.5 mm for the affected hip and 38.5 mm for the normal hip. The CTD was −8.1 mm for the affected hip and 26.5 mm for the normal hip. The NSA was 113.5° for the affected hip and 146.1° for the normal hip. (D) Anteroposterior radiographs at skeletal maturity showing correction of trochanteric overgrowth of the right hip. The ATD was 15.8 mm for the affected hip and 18.2 mm for the normal hip. The CTD was −3.4 mm for the affected hip and 1.5 mm for the normal hip. The NSA was 128.5° for the affected hip and 138.3° for the unaffected hip.

Chi-square test. All analyses were performed with SPSS version 21.0 for Windows (SPSS, Inc., Chicago, IL). P values $<.05$ were considered statistically significant.

3. Results

The 2 age groups did not differ significantly in terms of time to GTE, length of follow-up, lateral pillar classification, or treatment outcomes (Table 1). All radiographic measurements showed good to excellent interobserver reliability (Table 2).

In the unaffected hip, the mean ATD, CTD, and NSA were lower at the last follow-up than at the immediate postoperative period in both groups. The amount of correction did not differ significantly between the 2 groups as measured by the change in the ATD ($P=.08$), CTD ($P=.68$), and NSA ($P=.72$) (Table 3).

In patients <8 years of age, the mean ATD of the affected hip was significantly increased at the last follow-up compared with the immediate postoperative period. In patients >8 years of age, the mean ATD of the affected hip was decreased at the last follow-up compared with the immediate postoperative period. The amount of correction of the ATD was significantly different between the 2 groups ($P=.001$), averaging $6.9\pm6.0°$ in patients aged <8 years and $-3.3\pm5.3°$ in patients aged >8 years. In patients <8 years of age, the mean CTD of the affected hip at the last follow-up was significantly increased compared with the immediate postoperative value. In patients >8 years of age, the mean CTD of the affected hip was decreased at the last follow-up compared with the immediate postoperative period. The amount of correction of the CTD was significantly different between the 2 groups ($P=.002$), averaging $4.9\pm1.8°$ in patients <8 years of age and $-3.3\pm9.3°$ in patients >8 years of age. In both groups, the mean NSA of the affected hip was increased at the last follow-up compared with the immediate postoperative period. However, the amount of correction of the NSA differed significantly between the 2 groups ($P=.012$). In the affected hip, the ATD at skeletal maturity was 85% of the value of the unaffected hip in patients <8 years of age and 53% of the value of the unaffected hip in patients >8 years of age. In the affected hip, the CTD at skeletal maturity was 71% of the value of the unaffected hip in patients <8 years of age and −104% of the value of the unaffected hip in patients >8 years of age. In the affected hip, the NSA at skeletal maturity was 95% of the value of the unaffected hip in patients <8 years and 91% of the value of the unaffected hip in patients >8 years (Table 4). The mean Iowa hip score was significantly improved from 78.5 ± 7.17, preoperatively to 92.6 ± 5.14 ($P<.01$) at the last follow-up in patients <8 years of age. However, there was no statistically significant improvement in comparison to the preoperative evaluation in patients >8 years of age (77.5 ± 6.25, preoperatively to 83.6 ± 8.14 at the last follow-up) ($P>.05$).

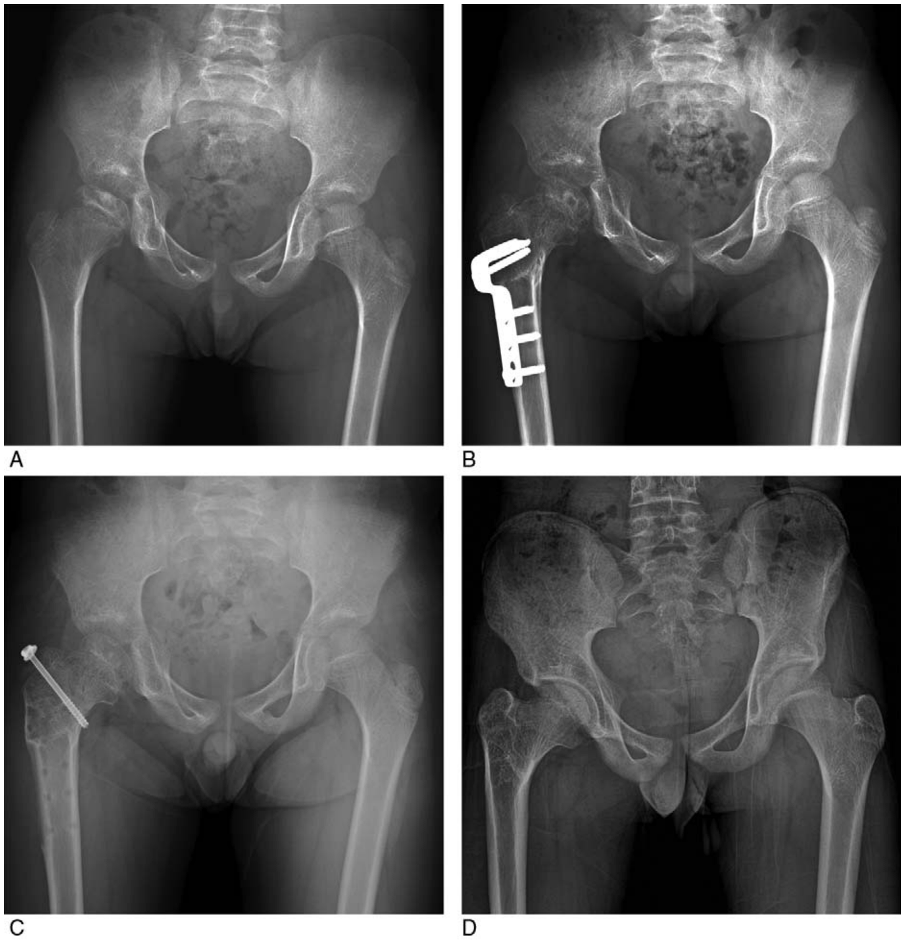

Figure 3. (A) Anteroposterior radiograph of the lateral pillar classification in a patient who was 8.5 years old at presentation. (B) Postoperative anteroposterior pelvic radiograph after FVO. (C) Postoperative anteroposterior pelvic radiograph after GTE and 6 months after FVO. The ATD was 11.2 mm for the affected hip and 26.1 mm for the normal hip. The CTD was −10.1 mm for the affected hip and 5.8 mm for the normal hip. The NSA was 111.1° for the affected hip and 141° for the normal hip. (D) Anteroposterior radiographs showing no improvement of the right hip. The ATD was 3.2 mm for the affected hip and 21.9 mm for the normal hip. The CTD was −20.6 mm for the affected hip and 1.2 mm for the normal hip. The NSA was 112.2° for the affected hip and 130.5° for the normal hip.

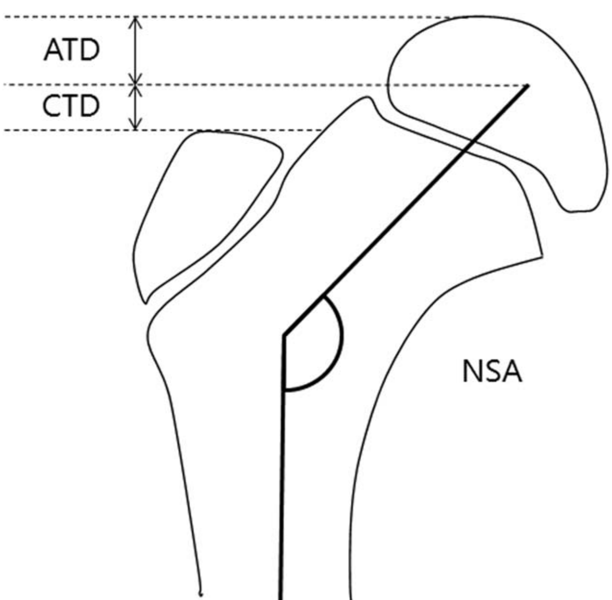

Figure 4. Radiographic measurements of the articulotrochanteric distance (ATD), center-trochanteric distance (CTD), and neck-shaft angle (NSA).

4. Discussion

FVO is a widely accepted operative treatment for LCPD. In cases of lateral pillar B and B/C border, the outcomes of FVO are significantly better than those of nonoperative treatment in children over the age of 8.0 years at the onset of the disease. However, variation of the femoral neck and trochanteric growth can aggravate Trendelenberg gait. For these reasons, prophylac-

Table 1

General characteristics of study population.

	Age at GTE, <8 y (n=9)	Age at GTE, ≥8 y (n=10)	*P*
Age at FVO, y	6.4±0.7	8.5±1.1	<.001[*]
Time to GTE, mo	7.3±1.6	7.6±1.1	.67[*]
Op day to last follow-up	8.4±1.1	7.6±1.8	.29[*]
Lat pillar, B	4	3	.65[†]
B/C	5	7	
Stulberg, I	4	1	.06[†]
II	5	5	
III	0	4	

FVO=femoral varus osteotomy, GTE=greater trochanteric epiphysiodesis.
[*] Unpaired *t* test.
[†] Chi-square test.

Table 2

Intraclass correlation.

	ICC	95% CI
Unaffected site, postop ATD	0.997	0.993–0.999
Affected site, postop ATD	0.984	0.965–0.993
Unaffected site, last ATD	0.996	0.992–0.999
Affected site, last ATD	0.998	0.996–0.999
Unaffected site, postop CTD	0.936	0.863–0.973
Affected site, postop CTD	0.998	0.996–0.999
Unaffected site, last CTD	0.960	0.915–0.983
Affected site, last CTD	1.000	0.999–1.000
Unaffected site, postop NSA	0.937	0.857–0.974
Affected site, postop NSA	0.950	0.892–0.979
Unaffected site, last NSA	0.955	0.899–0.981
Affected site, last NSA	0.987	0.973–0.995

ATD = articulotrochanteric distance; CI = confidence interval; CTD = center-trochanteric distance; ICC = intraclass correlation coefficient; NSA = neck-shaft angle.

Table 4

Comparisons of ATD, CTD, and NSA according to age at GTE in affected hip.

	Age at GTE, <8 y (n=9)	Age at GTE, ≥8 y (n=10)	*P*
Affected hip			
ATD, cm, at post-op (A)	17.4±6.5	16.4±5.6	.71*
At last follow-up (B)	24.3±4.4	13.1±4.7	<.001*
Difference (B-A)	6.9±6.0	−3.3±5.3	.001*
CTD, cm, at post-op (A)	−0.6±4.3	−2.1±4.7	.47*
At last follow-up (B)	4.3±3.2	−5.4±7.2	.002*
Difference (B-A)	4.9±1.8	−3.3±9.3	.002*
NSA, cm, at post-op (A)	119.1±5.3	117.4±5.0	.48*
At last follow-up (B)	129.7±6.1	120.7±5.4	.003*
Difference (B-A)	10.6±7.0	3.0±4.1	.012*

ATD = articulotrochanteric distance; CTD = center-trochanteric distance; GTE = greater trochanteric epiphysiodesis; NSA = neck-shaft angle.
* Unpaired *t* test.

tic GTE can be performed simultaneously at the time of FVO or at the time of hardware removal for FVO. Matan et al[13] described statistically significant improvements in pain, range of motion, abductor strength, and activity levels for patients with LCPD treated with intertrochanteric osteotomy and GTE compared with those treated with intertrochanteric osteotomy alone. Shah et al[6] found that prophylactic GTE minimized trochanteric overgrowth and the resultant Trendelenburg gait in an older child with LCPD. However, flattening of the femoral head due to damage of the proximal femoral physis can affect epiphyseal height.[9] In our study, we assumed that physeal damage of the femoral head would be lower in cases of lateral pillar B and B/C border than in cases of lateral pillar C. Therefore, we excluded cases of lateral pillar C to eliminate patient selection bias by flattening of the femoral head. As an additional safeguard against selection bias, a single surgeon performed intertrochanteric FVO, and epiphysiodesis was performed at the time of plate and screw removal after osteotomy union (postoperative 6–7 months) to ensure accurate cannulated screw placement for apophyseal growth inhibition.

Growth of the greater trochanter is divided equally between appositional growth in the superior portion of the greater trochanter and growth in the metaphysis.[13,14] McCarthy and Weiner[5] reported that 46% of appositional growth was arrested

Table 3

Comparisons of ATD, CTD, and NSA according to age at GTE in unaffected hip.

	Age at GTE, <8 y (n=9)	Age at GTE, ≥8 y (n=10)	*P*
Unaffected hip			
ATD, cm, at post-op (A)	31.4±3.8	29.4±5.7	.38*
At last follow-up (B)	28.7±5.1	24.6±6.0	.13*
Difference (B-A)	−2.8±2.4	−4.8±2.3	.08*
CTD, cm, at post-op (A)	12.4±2.8	10.5±4.3	.26*
At last follow-up (B)	6.1±4.8	5.2±3.2	.63*
Difference (B-A)	−6.3±6.0	−5.3±4.9	.68*
NSA, cm, at post-op (A)	144.0±4.9	139.2±7.6	.12*
At last follow-up (B)	137.1±4.2	133.0±4.2	.05*
Difference (B-A)	−6.9±3.6	−6.2±4.6	.72*

ATD = articulotrochanteric distance; CTD = center-trochanteric distance; GTE = greater trochanteric epiphysiodesis; NSA = neck-shaft angle.
* Unpaired *t* test.

by GTE and that bone peg epiphysiodesis tended to be more effective than screw epiphysiodesis. In our study, the ATD of the affected hip at skeletal maturity was 85% of the value of the normal hip in patients aged <8 years and 53% of the value of the normal hip in patients aged >8 years. The CTD of the affected hip at skeletal maturity was 71% of the value of the normal hip in patients <8 years of age and −104% of the value of the normal hip in patients >8 years of age. The NSA of the affected hip at skeletal maturity was 95% of the value of the normal hip in patients aged <8 years and 91% of the value of the normal hip in patients aged >8 years. We suggest that screw placement is a key factor in the effective inhibition of greater trochanteric growth. The starting point must be the center of the greater trochanter, with a 60° to 70° angle from the ground direction toward the lesser trochanter to purchase the opposite cortex. We performed GTE at the time of plate and screw removal after FVO for effective apophyseal growth inhibition because it is impossible to achieve accurate screw placement for GTE simultaneously at the time of FVO.

Previous studies have found that the strongest predictors of outcome are age and lateral pillar classification.[15–19] According to a previous study, two-thirds of patients with lateral pillar B hips had a good result, while half of patients with B/C-border hips had an intermediate result. Children presenting on or before their eighth birthday had a 59% rate of good results and only an 8% rate of poor results. In contrast, those presenting after their eighth birthday had a 39% rate of good outcomes and a 26% rate of poor outcomes.[11] Our outcome evaluation according to the Stulberg grade showed that all patients <8 years of age had a favorable result, and 4 of 10 patients >8 years of age group had a III result.

This study had several limitations.

The limitations of this study included the fact that it was retrospective design, small number of cases, although we followed them to skeletal maturity. Then, given our small sample size, there is a chance that we missed the difference in clinical outcomes among the groups. Adjusted analysis could also not be performed to examine interactions of the any factors. Second, we did not compare our results to those of patients treated with FVO alone as a comparison group for the effect of GTE. Third, we could not compare results between patients with lateral pillar B and B/C border because our sample size was too small.

5. Conclusion

The GTE led to a greater inhibition of growth in children less than 8 years of age than in children greater than 8 years of age. We suggest that FVO followed by GTE for lateral pillar classification B and B/C border LCPD epiphysiodesis in patients under the age of 8 years can affect growth of the greater trochanter. However, effective growth inhibition due to GTE did not occur after 8 years of age.

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