The Accuracy of Current Methods in Deciding the Timing of Epiphysiodesis

Soon Chul Lee MD¹, Sung Wook Seo MD², Kyung Sup Lim MD², Jong Sup Shim MD²

Department of Orthopaedic Surgery,
¹Bundang CHA Medical Center, CHA Medical University School of Medicine,
²Samsung Medical Center, Sungkyunkwan University School of Medicine
Introduction

- **Leg Length Discrepancy (LLD)**

1. Common problem for growing children

2. Treatment

   Epiphysiodesis (LLD 2 - 5 cm)
Introduction

- For the Successful Epiphysiodesis

1. Accurate prediction of LLD at skeletal maturity

2. 4 methods of anticipating LLD
   a. Arithmetic method
   b. Growth remaining method
   c. Straight-line graph method
   d. Multiplier method
Introduction

- For the Successful Epiphysiolysis

3. Shapiro type: 5 patterns of LLD development

- Type 1: Upward slope pattern
- Type 2: Upward slope - deceleration pattern
- Type 3: Upward slope - plateau pattern
  - Type 3A: Downward slope - plateau pattern
  - Type 3B: Plateau pattern
- Type 4: Upward slope - plateau - upward slope pattern
- Type 5: Upward slope - plateau - downward slope pattern
Deficiencies of current methods for the timing of epiphysiodesis.


- Compared the accuracy of Arithmetic, Growth remaining, Straight-line graph method
- Differing the methodology did not have a meaningful effect on their similar but limited accuracy.
Deficiencies of current methods for the timing of epiphysiodesis.


3. Advocated the use of the Menelaus arithmetic method because of simplicity

4. Weak point of his study
   a. Didn’t consider Shapiro type
   b. Didn’t include the multiplier method
Purpose

- To analyze the result of epiphysiodesis using “Author’s modified growth remaining method” (Method 1)

- To compare the accuracy of Method 1 with 1. Variants of Growth remaining method (Method 2, 3)
  2. Variants of Multiplier method (Method 4, 5)
  3. Straight-line graph method (Method 6)
96 patients of all Korean patients treated with percutaneous epiphysiodesis due to LLD between 2 to 5 cm

- Lost follow-up: 24 excluded
- Not grown up until last follow-up: 15 excluded
- Insufficient data for analysis: 5 excluded
- Fractures of contralateral lower extremity: 2 excluded
- Growth hormone treatment: 3 excluded
- Additional surgery before maturity affecting the outcome: 3 excluded

Finally 44 patients were included
### Demographic data of patients

<table>
<thead>
<tr>
<th>Period</th>
<th>June. 1999 ~ Present</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>44 patients</td>
</tr>
<tr>
<td>M : F</td>
<td>27 boys and 17 girls</td>
</tr>
<tr>
<td>Chronologic age</td>
<td>Boys : mean, 13.8 years</td>
</tr>
<tr>
<td>at operation</td>
<td>Girls : mean, 12.4 years</td>
</tr>
<tr>
<td>F / U</td>
<td>3.7 years</td>
</tr>
</tbody>
</table>
## Etiologies of LLD

<table>
<thead>
<tr>
<th>Cause</th>
<th>Number (%)</th>
<th>Shapiro type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Congenital</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Idiopathic hemihypertrophy or hemihypotrophy</td>
<td>15 (34.1)</td>
<td>I : 11, II : 4</td>
</tr>
<tr>
<td>2. Klippel Trenaunauy Weber syndrome</td>
<td>1 (2.3)</td>
<td>I</td>
</tr>
<tr>
<td>3. Venous malformation</td>
<td>2 (4.5)</td>
<td>I : 2</td>
</tr>
<tr>
<td>4. Congenital multiple anomaly</td>
<td>1 (2.3)</td>
<td>I</td>
</tr>
<tr>
<td><strong>Developmental</strong></td>
<td>25 (56.8)</td>
<td></td>
</tr>
<tr>
<td>1. Fracture of long bone</td>
<td>6 (13.6)</td>
<td>II : 1, III : 5</td>
</tr>
<tr>
<td>2. Physis injury</td>
<td>2 (4.5)</td>
<td>I : 2</td>
</tr>
<tr>
<td>3. Tumorous condition</td>
<td>6 (13.6)</td>
<td></td>
</tr>
<tr>
<td>a. Polyostotic fibrous dysplasia</td>
<td>1</td>
<td>II</td>
</tr>
<tr>
<td>b. Ollier’s disease</td>
<td>1</td>
<td>I</td>
</tr>
<tr>
<td>c. Osteofibrous dysplasia</td>
<td>1</td>
<td>II</td>
</tr>
<tr>
<td>d. Osteochondromatosis</td>
<td>2</td>
<td>I : 1 II : 1</td>
</tr>
<tr>
<td>e. Histiocytosis X</td>
<td>1</td>
<td>II</td>
</tr>
<tr>
<td>4. Legg Perthes disease</td>
<td>8 (18.2)</td>
<td>I : 2, II : 2, III : 4</td>
</tr>
<tr>
<td>5. Slipped capital femoral epiphysis</td>
<td>1 (2.3)</td>
<td>II</td>
</tr>
<tr>
<td>6. Septic hip sequaleae</td>
<td>2 (4.5)</td>
<td>I : 1, II : 1</td>
</tr>
</tbody>
</table>
Methods

- Decide the Timing of Epiphysiodesis

  “Author’s modified growth remaining method”

1. No growth inhibition rate (GIR) & standard deviation (SD) of height

2. LLD measured in out patient clinic

   = Predicted LLD at grown up without operation

3. Effect of epiphysiodesis : Green & Anderson growth remaining chart

4. The timing of operation was appropriate if “Predicted LLD” within ±1 cm.
Example

Female / 12 (Skeletal age)

LLD 3 cm

Distal femur 2 cm

Proximal tibia 1 cm

→ 2 + 1 = 3 cm

→ Epiphysiodesis !!
Methods

- Operative technique

1. Percutaneous epiphysiodesis

2. Epiphysiodesis of proximal tibia

   → Always epiphysiodesis of proximal fibula

3. Immobilized with long leg splint for 3 weeks
Methods

Various Methods (in deciding the timing of epiphysiodesis)

<table>
<thead>
<tr>
<th>Method</th>
<th>Basically applied method</th>
<th>SD of height</th>
<th>Growth remaining of long leg</th>
<th>Age</th>
<th>Shapiro type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>Not applied</td>
<td>Not applied</td>
<td>Bone age</td>
<td>Not applied</td>
</tr>
<tr>
<td>2</td>
<td>Growth remaining method by Green and Anderson</td>
<td>Applied and estimated by Specific chart for Korean</td>
<td>Calculated by specific chart for Korean and considered SD of leg</td>
<td>Bone age</td>
<td>Applied</td>
</tr>
<tr>
<td>3</td>
<td>Effect of epiphysiodesis was calculated by Green and Anderson chart</td>
<td>Applied and estimated by Green and Anderson chart</td>
<td>Calculated by Green and Anderson chart and considered SD of leg</td>
<td>Bone age</td>
<td>Applied</td>
</tr>
<tr>
<td>4</td>
<td>Paley’s multiplier method</td>
<td>Unnecessary</td>
<td>Unnecessary</td>
<td>Bone age</td>
<td>Applied</td>
</tr>
<tr>
<td>5</td>
<td>Mosley’s straight-line graph</td>
<td>Unnecessary</td>
<td>Unnecessary</td>
<td>Chronologic age</td>
<td>Applied</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>Unnecessary</td>
<td>Unnecessary</td>
<td>Bone age</td>
<td>Applied</td>
</tr>
</tbody>
</table>
Methods

- Assumed that preoperatively we used these 5 methods.
- Compared “Predicted LLD” and “Final LLD”.

→ Determine their accuracy in predicting the actual effect of the epiphysiodesis

“Predicted LLD”: Calculated LLD preoperatively when we assumed that the epiphysiodesis had been performed.

“Final LLD”: LLD measured at grown up after operation
Methods

- Statistical analysis

1. Paired T-test
   “Predicted LLD” VS “Final LLD”

2. Correlation test
   Find the correlation between “Predicted LLD” VS “Final LLD”
Results

- **Closure of the Physis**
  
  In all patients, within 12 months after operation.

- **Distribution of “Final LLD”**

<table>
<thead>
<tr>
<th>LLD</th>
<th>Number of patient</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 &lt; &lt; 1 cm</td>
<td>21</td>
</tr>
<tr>
<td>1.1 &lt; &lt; 2 cm</td>
<td>18</td>
</tr>
<tr>
<td>&gt; 2 cm</td>
<td>5 (1 case was operated too lately)</td>
</tr>
<tr>
<td>Average</td>
<td>10.4 mm (-1 – 25)</td>
</tr>
</tbody>
</table>
# Results

## Summary of Statistical Analysis

<table>
<thead>
<tr>
<th>Method</th>
<th>Paired t-test</th>
<th>Pearson’s correlation analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Statistical significance</td>
<td>t-value</td>
</tr>
<tr>
<td>1</td>
<td>&lt;0.0001</td>
<td>-5.766</td>
</tr>
<tr>
<td>2</td>
<td>&lt;0.0001</td>
<td>-6.293</td>
</tr>
<tr>
<td>3</td>
<td>&lt;0.0001</td>
<td>-4.813</td>
</tr>
<tr>
<td>4</td>
<td>&lt;0.0001</td>
<td>-5.842</td>
</tr>
<tr>
<td>5</td>
<td>&lt;0.0001</td>
<td>-7.148</td>
</tr>
<tr>
<td>6</td>
<td>&lt;0.0001</td>
<td>-5.183</td>
</tr>
</tbody>
</table>
Results

Method 1

Method 2

Overcorrected value
results

method 3

predicted lld

final lld

method 4

predicted lld

final lld
Results

Method 5

Method 6
Discussion

- Causes of Error

1. Growth Remaining Method (Method 1, 2, 3)
   - Uses only the most recent bone age
   - GIR discrepancy: Which 2 points?
     
     Ex)

     | Leg length | 55.0 | 59.4 | 64.0 |
     |           | 52.6 | 57.5 | 61.3 |

     GIR = 0.033
     GIR = 0.174
Distribution of Lengths of the Normal Femur and Tibia in Korean Children from Three to Sixteen Years of Age

To develop a standard growth curve of the lower extremity in Korean children from 3 to 16 yr of age, the lengths from a total of 2087 normal bone segments (962 femurs and 645 tibias in boys, and 417 femurs and 443 tibias in girls) were measured. Children were grouped by years of bone age, which was determined by using the Korean specific bone age standard, TW2-20 method. The growth spurt occurred in girls from eight to eleven years by bone age, and in boys from eleven to thirteen years. The mean final length relative to the mean femoral length was 0.79 in boys and 0.76 in girls. The overall growth pattern was similar to that observed in American children in the 1960s. Korean children and adolescents appear to have a different tempo of growth.


Not available: Growth remaining chart of specific for distal femur & proximal tibia which gives the information about the effect of epiphysiodesis.
Discussion

- **Causes of Error**

  2. Mosley’s straight-line graph (Method 6)
     
     a. Assumes that the growth inhibition is linear
     
     b. But growth of leg was not always depicted as the straight line.

  3. Paley introduced the multiplier method (Method 4, 5)
     
     a. GIR discrepancy
     
     b. Bone age VS Chronologic age → Which is more accurate?
We compared the 6 methods and considered Shapiro type.

Clinically

Epiphysiodesis is effective because it reduced the LLD within 2 cm. (39/44, 88.6%)

Statistically

All the current methods are not accurate in predicting “Final LLD”.
**The Original Green & Anderson Growth Remaining Method** (Method 3)

Relatively more accurate than any other 5 methods

“Predicted LLD” calculated by all 6 methods have significant correlation with “Final LLD”.

But generally they afforded the overcorrected values.
1. No method give birth to exact “Predicted LLD”

2. More data and analysis !!!
   These are important in predicting “exact final LLD”.

3. New method would be necessary.