The goal of this study was to investigate the treatment methods and surgical indications of distal tibial epiphyseal fractures in children. Two hundred eighty-six children with distal tibial epiphyseal fractures were included in the study. Among these patients, 202 were male and 84 were female. Mean age was 11.7 years. A retrospective study on the postoperative long-term complications and related risk factors was performed. Treatment methods were determined according to the distance of fracture displacement. A long-leg cast was applied after closed reduction for patients with primary fracture displacement less than 2 mm. For cases with more than 2 mm of fracture displacement, K-wire or screw fixation was performed. For patients with less than 2 mm of fracture displacement, closed reduction and internal fixation was performed. Open reduction was performed in patients with more than 2 mm of fracture displacement, even after closed reduction. Mean follow-up was 6.4 years. Premature physeal closure occurred in 42 patients, and, among them, varus and valgus ankle deformities occurred in 16 patients. Associated fibular fractures and cast immobilization after closed reduction for Salter-Harris type III and IV fractures were risk factors for premature physeal closure. It is not effective to determine the surgical procedure according to the distance of preoperative fracture displacement for improving the prognosis of distal tibial epiphyseal fractures in children. Conservative treatment should be performed for patients with Salter-Harris type I and II distal tibial epiphyseal fractures, and surgery should be performed in patients with Salter-Harris type III and IV distal tibial epiphyseal fractures to reduce the incidence of premature physeal closure. [Orthopedics. 2015; 38(3):e189-e195.]

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Surgical Indications for Distal Tibial Epiphyseal Fractures in Children

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The distal tibial epiphysis is the third most vulnerable epiphysis, and distal tibial epiphyseal injuries account for 11% of all epiphyseal injuries. The main complications of distal tibial epiphyseal injuries include premature physeal closure and joint deformity. The incidence of premature physeal closure after fracture in this site has been reported to be 17% to 60%. In addition, distal tibial epiphyseal fractures are the most common cause of deformity after fracture in children. The treatment strategy and surgical indication are still controversial.

The authors performed a retrospective study on the postoperative long-term complications and related risk factors for 286 patients with distal tibial epiphyseal fractures who were treated in the authors’ institution during the past 10 years to investigate the treatment strategy and surgical indication for this kind of fracture.

**Materials and Methods**

**Inclusion Criteria**

Two hundred eighty-six patients with distal tibial epiphyseal fractures were included in the current study. Patients with open fractures, patients who were treated 5 days after fracture, and patients with less than 6 months of follow-up were excluded.

**Conservative Treatment**

Conservative treatment was determined according to the distance of fracture displacement on preoperative anteroposterior radiographs or computed tomography (CT) images. If the distance was less than 2 mm, a long-leg cast was applied for 6 weeks after manual reduction. Anteroposterior radiographs of the ankle were taken 5, 10, and 15 days after cast immobilization. If the fracture displacement was more than 2 mm, surgery was performed.

**Surgical Indication**

If the preoperative fracture displacement was less than 2 mm, closed reduction was performed after anesthesia. If the fracture displacement was more than 2 mm after reduction and the articular surface was even, then K-wire fixation or screw fixation was performed. If the fracture displacement was still more than 2 mm after reduction, open reduction and internal fixation (ORIF) was performed. A long-leg, non-weight-bearing cast was applied for 4 weeks postoperatively and was changed into a short-leg, weight-bearing cast for 2 weeks. If the K-wire was used for internal fixation, it was removed 6 weeks postoperatively. If a screw was used for fixation, it was removed 2 to 6 months postoperatively.

**Long-term Follow-up**

Anteroposterior radiographs of the ankle were taken 5, 10, and 15 days after fracture. Computed tomography was not obtained as a routine examination but after the appearance of premature physeal closure on radiographs to identify the range of the bony bridge. Magnetic resonance imaging (MRI) was performed as needed.

**Data Collection**

The collected data included sex, age, age of contralateral physeal closure, injury mechanism, state of the fibula, distance of the primary fracture displacement, distance of the fracture displacement after closed reduction, surgical method, long-term complications, and secondary surgery.

**Statistical Analysis**

The authors analyzed the following possible risk factors for premature physeal closure: age, sex, side of injury, primary fracture displacement, fracture displacement after closed reduction, associated distal fibular fractures, and ORIFs. These analyses were performed using the t test (for measurement data) and Fisher’s exact probability test (for numeration data). A P value less than .05 was considered statistically significant. SPSS version 16.0 statistical software (SPSS Inc, Chicago, Illinois) was used for all analyses.

**Results**

Among 286 patients, 202 were males and 84 were females. Mean age was 11.7 years. Mean follow-up was 6.4 years.
Surgical Procedures

Surgery was performed if the preoperative fracture displacement was more than 2 mm. Closed reduction and internal fixation (CRIF) was performed for 4 patients with Salter-Harris type I fractures. Among 191 patients with Salter-Harris type II fractures, 70 underwent cast immobilization, 73 underwent CRIF, and 48 underwent ORIF. Among 53 patients with Salter-Harris type III fractures, 9 underwent cast immobilization, 12 underwent CRIF, and 32 underwent ORIF. Among 38 patients with Salter-Harris type IV fractures, 8 underwent cast immobilization, 9 underwent CRIF, and 21 underwent ORIF (Figure 1).

Treatment Outcomes and Postoperative Complications

Premature physeal closure was observed in 42 of 286 patients. Varus and valgus ankle deformities were observed in 16 patients.

Further Surgery

Bony bridge resection was performed in 24 of 42 patients with premature physeal closure. Supramalleolar osteotomy was performed in 5 patients, and epiphyseal arrest was performed in 2 patients.

Statistical Analysis

Two hundred eighty-six patients were divided into 2 groups based on whether there was postoperative premature physeal closure. There were no significant differences between the 2 groups with respect to sex, injury side, age, distance of primary fracture displacement, and distance of fracture displacement after closed reduction. However, fibular fracture was a risk factor for premature physeal closure (Figure 2; Table 1).

A patient with preoperative fracture displacement less than 2 mm underwent CRIF; the premature physeal closure was observed during follow-up (Figure 3). In other children with preoperative fracture displacement of more than 2 mm, the premature physeal closure occurred despite active open anatomic reduction (Patients 2 and 3; Figures 4-5).

The authors’ data showed that premature physeal closure may be related to the Salter-Harris classification. When the cases were divided into 2 groups according to the Salter-Harris classification (type I/II fractures vs type III/IV fractures) and the cases in each group were further divided into 2 subgroups based on premature physeal closure, the authors observed significantly different results. There were no significant differences between the 2 groups with respect to age, sex, injury side, and distance of preoperative fracture displacement. However, the incidence of premature physeal closure in the group of Salter-Harris type I/II fractures was significantly higher than that in the group of Salter-Harris type III/IV fractures. In addition, there were no significant differences be-

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**Figure 2:** The correlation between the incidence of premature physeal closure and the distance of primary fracture displacement.

**Table 1**

<table>
<thead>
<tr>
<th>Variable</th>
<th>No Premature Epiphysis Closure (n=244)</th>
<th>Premature Physeal Closure (n=42)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean±SD, y</td>
<td>11.7±3.3</td>
<td>11.9±3.7</td>
<td>NS</td>
</tr>
<tr>
<td>Male, No.</td>
<td>172</td>
<td>30</td>
<td>NS</td>
</tr>
<tr>
<td>Right-sided injuries, No.</td>
<td>138</td>
<td>26</td>
<td>NS</td>
</tr>
<tr>
<td>Primary fracture displacement, mean±SD, mm</td>
<td>7.3±2.3</td>
<td>8.2±3.8</td>
<td>NS</td>
</tr>
<tr>
<td>Fracture displacement after closed reduction, mean±SD, mm</td>
<td>3.1±2.7</td>
<td>3.8±3.6</td>
<td>NS</td>
</tr>
<tr>
<td>Associated distal fibular fractures, No.</td>
<td>56</td>
<td>23</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>ORIFs, No.</td>
<td>89</td>
<td>12</td>
<td>NS</td>
</tr>
</tbody>
</table>

Abbreviations: NS, not significant; ORIFs, open reduction and internal fixations.
between the 2 subgroups in the Salter-Harris type I/II group with respect to age, sex, injury side, and distance of preoperative fracture displacement, and the surgical procedure did not significantly affect the incidence of premature physeal closure. There were no significant differences between the 2 subgroups in the Salter-Harris type III/IV group with respect to age, sex, injury side, and distance of preoperative fracture displacement; however, the surgical procedure significantly affected the incidence of premature physeal closure. Open reduction significantly reduced the incidence of premature physeal closure, whereas cast immobilization after closed reduction was a risk factor for premature physeal closure (Tables 2-3; Figure 6).

**Discussion**

The growth plate of the distal tibia consists of the proliferative and hypertrophic layers, which are located at the articular surface of the metaphysis (Figure 7A). Premature physeal closure largely occurs due to the infiltration of bone marrow cells, osteoblasts, and osteoclasts from the epiphysis or metaphysis to the vertical cavity, which is formed due to the damage in the proliferative layer of the growth plate. There are 2 causes of vertical cavity formation. One cause is the death of proliferating cells caused by violent forces, including squeezing, torsion, and grinding at the time of injury; this cause cannot be improved, even after

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**Table 2**

<table>
<thead>
<tr>
<th>Variable</th>
<th>No Premature Physeal Closure (n=163)</th>
<th>Premature Physeal Closure (n=32)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean±SD, y</td>
<td>11.3±2.3</td>
<td>11.8±1.7</td>
<td>NS</td>
</tr>
<tr>
<td>Male, No.</td>
<td>119</td>
<td>23</td>
<td>NS</td>
</tr>
<tr>
<td>Right-sided injuries, No.</td>
<td>88</td>
<td>20</td>
<td>NS</td>
</tr>
<tr>
<td>Primary fracture displacement, mean±SD, mm</td>
<td>7.3±2.3</td>
<td>8.2±3.8</td>
<td>NS</td>
</tr>
<tr>
<td>Fracture displacement after closed reduction, mean±SD, mm</td>
<td>3.1±2.7</td>
<td>3.8±3.6</td>
<td>NS</td>
</tr>
<tr>
<td>Associated distal fibular fractures, No.</td>
<td>37</td>
<td>15</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>ORIFs, No.</td>
<td>40</td>
<td>8</td>
<td>NS</td>
</tr>
</tbody>
</table>

**Abbreviations:** NS, not significant; ORIFs, open reduction and internal fixations.
treatment. Aitken concluded that the impact on the growth plate at the time of injury is the main cause of growth disorders and that any subsequent treatments cannot completely resolve this type of growth disorder. Another cause of vertical cavity formation is displacement of the proliferative layer due to the fracture crossing the entire growth plate, which directly forms a vertical cavity in the fracture gap. At this time, it is important to perform anatomic reduction of the growth plate, especially the proliferative layer, to prevent premature physeal closure.

Type I/II fractures are limited in the deep hypertrophic layer and metaphysis and do not invade the proliferative layer (Figure 7B). In 2003, Barmada et al reported that the incidence of premature physeal closure was 36% to 40% in patients with Salter-Harris type II distal tibial epiphyseal fractures. In patients with Salter-Harris type II distal tibial epiphyseal fractures with more than 2 years of growth potential, surgical ORIF is recommended if the fracture displacement is more than 3 mm to reduce the incidence of premature physeal closure. The goal of surgery is to remove the periosteum embedded in the fracture gap to obtain anatomic reduction and reduce the incidence of premature physeal closure. However, Russo et al reported that although open reduction could remove the periosteum embedded in the fracture gap and obtain anatomic reduction for displaced Salter-Harris type II distal tibial epiphyseal fractures, open reduction cannot reduce the incidence of premature physeal closure. In contrast, the procedure may increase the chance of secondary and tertiary surgeries and the incidence of surgery-related complications.

One possible reason why open reduction cannot reduce the incidence of premature physeal closure is that the Salter-Harris type II fracture line transversely crosses the hypertrophic layer and extends to the metaphysis; the proliferative layer is not involved. No significant displacement of the proliferative layer may exist, although the proliferative layer is damaged at the time of injury. The formation of the vertical cavity within the proliferative layer of the growth plate is mainly caused by the death of proliferating cells caused by violent forces at the moment of injury, but not by fracture displacement. Therefore, anatomic reduction cannot avoid formation of the vertical cavity. Moreover, Gruber et al confirmed that bony bridge formation is not affected by periosteum embedding. Open reduction has a limited effect on type I/II fractures in preventing premature physeal closure. Therefore, it is recommended that surgery not be performed based on preoperative fracture displacement of more than 2 mm. With the exception of extremely serious deformities, conservative treatments, such as closed reduction and cast immobilization, should be used; however, all patients should be closely followed for at least 12 months. If bony bridges are observed on radiographs or CT scans, surgery should be performed to maintain normal anatomy of the ankle joint.

Table 3: Characteristics of Salter-Harris Type III/IV Subgroup (n=91)

<table>
<thead>
<tr>
<th>Variable</th>
<th>No Premature Physeal Closure (n=81)</th>
<th>Premature Physeal Closure (n=10)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean±SD, y</td>
<td>12.4±2.1</td>
<td>12.1±3.2</td>
<td>NS</td>
</tr>
<tr>
<td>Male, No.</td>
<td>53</td>
<td>7</td>
<td>NS</td>
</tr>
<tr>
<td>Right-sided injuries, No.</td>
<td>50</td>
<td>6</td>
<td>NS</td>
</tr>
<tr>
<td>Primary fracture displacement, mean±SD, mm</td>
<td>8.3±2.8</td>
<td>9.7±4.1</td>
<td>NS</td>
</tr>
<tr>
<td>Fracture displacement after closed reduction, mean±SD, mm</td>
<td>3.5±3.7</td>
<td>4.3±5.1</td>
<td>NS</td>
</tr>
<tr>
<td>Associated distal fibular fractures, No.</td>
<td>19</td>
<td>8</td>
<td>.01</td>
</tr>
<tr>
<td>ORIFs, No.</td>
<td>49</td>
<td>4</td>
<td>&lt;.01</td>
</tr>
</tbody>
</table>

Abbreviations: NS, not significant; ORIFs, open reduction and internal fixations.
In type III/IV fractures, the fracture line crosses the proliferative layer and there is displacement of the proliferative layer, which directly forms the vertical cavity (Figure 7C). For type III/IV fractures, anatomic reduction should be performed. Reduction of the proliferative layer is important for preventing premature physeal closure in patients with type III/IV fractures. If surgery is performed in patients with preoperative fracture displacement more than 2 mm, the prognosis may be poor because 2 mm of thickness exceeds the thickness of the growth plate. Displacement in the proliferative layer of more than 1 mm is sufficient for vertical cavity formation. Therefore, surgery should be performed on patients with type III/IV fractures. Seel et al. performed anatomic ORIF for patients with primary displacement of more than 2 mm or even less than 1 mm. The incidences of premature physeal closure were 7.4% and 8.7% in patients with type III and IV fractures, respectively, which is significantly less than in other reports (38% and 50%).

Based on the better results of Seel et al. and the theory of anatomical reduction with displacement less than 2 mm decreasing the risk of epiphysiodesis and preventing degenerative joint disease, the current authors took displacement of 2 mm as the cutoff. In addition, if a stable internal fixation is not performed after reduction, fracture displacement may occur due to the subsidence of swelling, poor patient compliance, and occasional weight bearing. Although the current authors conducted radiographic examinations 5, 10, and 15 days after cast immobilization, a simple radiographic examination could not show minimal displacements, and the timing of treatment might be delayed. Kling et al. also demonstrated that closed reduction and cast immobilization is a risk factor for growth disorders following type III/IV fractures.

In a study by De Sanctis et al., 72 patients with distal tibial epiphyseal fractures underwent conservative treatment (n=64) or surgical treatment (n=8). Sixty (83%) of 72 patients had good results. Good results were achieved in 8 of 11 (73%) type III fractures, 7 of 10 (70%) type IV fractures, 7 of 7 (100%) type I fractures, and 38 of 39 (97%) type II fractures. Another study of 59 patients included 4 with type I fractures, 22 with type II fractures, 29 with type III fractures, and 4 with type IV fractures. All 4 (100%) patients with type I fractures underwent closed reduction. Of the 22 patients with type II fractures, 4 (18%) underwent ORIF and 18 (82%) underwent closed reduction. Twenty-two (76%) of the 29 patients with type III fractures underwent ORIF. One (25%) of the 4 patients with type IV fractures underwent closed reduction. Mean American Orthopaedic Foot and Ankle Society score was 86.6 (range, 65-100) at last follow-up. In the current study, 195 patients had type I/II fractures and 91 patients had type III/IV fractures. Open reduction and internal fixation was performed in 101 patients, including 48 with type I/II fractures and 53 with type III/IV fractures.

The current authors suggest that surgery be performed on patients with Salter-Harris type III/IV distal tibial epiphyseal fractures to obtain anatomic reduction; specifically, alignment of the proliferative layer should be restored, and stable internal fixation should be applied subsequently.

**Conclusion**

If the surgical indication is based on the distance of the preoperative fracture displacement, the prognosis of the distal tibial epiphyseal fracture cannot improve significantly. Conservative treatment should be used for cases with Salter-Harris type I/II distal tibial epiphyseal fractures, and patients should be followed closely. Surgeries such as bony bridge resection, osteotomy, and epiphyseal arrest should be performed in patients with bony bridge or ankle deformities. Surgical treatment should be used for patients with Salter-Harris type III/IV distal tibial epiphyseal fractures to obtain anatomic reduction and rigid internal fixation and further reduce the incidence of premature physeal closure.

**References**


