Hemiepiphysiodesis for Idiopathic Genu Valgum: Percutaneous Transphyseal Screw Versus Tension-band Plate

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Background: The aim of this study was to compare the outcomes of angular deformity correction by percutaneous hemiepiphysiodesis using transphyseal screw (PETS) or tension-band plating (TBP) in growing children with idiopathic genu valgum with emphasis on the rate of deformity correction.

Methods: We retrospectively reviewed cases of hemiepiphysiodesis for angular deformity in lower extremities between 2009 and 2014. A total of 90 limbs in 33 patients received PETS and 60 limbs in 24 patients received TBP. Angular measurements were compared preoperatively and at the time of hardware removal. The amount and rate of angular deformity correction were compared between the 2 groups. Potential factors affecting correction velocity were investigated using multivariate analysis.

Results: Angular correction was achieved in all patients. The mean rate of correction was more rapid with PETS than with TBP at both the distal femur (0.92 vs. 0.64 deg./mo, respectively; $P < 0.001$) and proximal tibia (0.72 vs. 0.55 deg./mo, respectively; $P = 0.019$). Multivariate analysis showed that the used implant significantly affected the rate of correction: PETS demonstrated faster correction velocity than TBP (-0.26, 95% confidence interval, -0.35 to -0.17, $P < 0.001$).

Conclusions: Both PETS and TBP techniques result in satisfactory correction of coronal angular deformity in patients with idiopathic genu valgum. However, the observed rate of correction was faster with PETS than TBP. Correction with PETS, rather than TBP, may better serve patients near skeletal maturity.

Level of Evidence: Level III—retrospective comparative series.

Key Words: hemiepiphysiodesis, transphyseal screw, tension-band plate, genu valgum

(*J Pediatr Orthop* 2016;00:000–000)

Coronal angular deformity of the knee is a not uncommon in pediatric orthopaedics and may lead to patella tracking problems, joint arthrosis of the lateral compartment, and cosmetic problems in adults.[1,2] Although there are several operative options for angular deformity, temporary hemiepiphysiodesis is a well-accepted method for children with significant growth remaining. Staples,[3] percutaneous transphyseal screws,[4] or tension-band plates[5] are routinely used in temporary hemiepiphysiodesis.

Stapling was first used to correct leg length discrepancy.[3] Many orthopaedic surgeons also use stapling in temporary hemiepiphysiodesis.[6–8] However, some studies report complications after stapling including epiphyseal arrest, breakage, and back-out.[8–10] In contrast, surgical outcomes of percutaneous epiphysiodesis using a transphyseal screw (PETS) or tension-band plating (TBP) are equally effective as stapling.[1,11–13] Although some papers reported complications of PETS, such as soft tissue swelling, overcorrection, and hardware irritation, PETS is a minimally invasive procedure that causes cosmetic scars and allow early rehabilitation.[1,4,14,15] In addition, even if there were reports of implant failure, ease of application and removal has led to widespread use of TBP.[12,16] Therefore, it seems that PETS and TBP are preferable to stapling.

Although PETS and TBP are both effective methods, it is unknown which facilitates a faster rate of coronal angular deformity correction. Although a percutaneous transphyseal screw imposes a rigid fulcrum within the physis, the tension-band plate places the center of rotation on the outside of the physis creating a longer moment arm for physeal growth, theoretically allowing for more rapid correction.[5,17] Therefore, the purpose of this study was to compare the radiologic outcomes of PETS with those of TBP for treatment of idiopathic genu

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The authors did not receive grants or outside funding in support of this research or for preparation of this manuscript. The authors did not receive payments or other benefits or a commitment or agreement to provide such benefits from a commercial entity. No commercial entity paid or directed, or agreed to pay or direct, any benefits to any research fund, foundation, educational institution, or other charitable or nonprofit organization with which the authors are affiliated or associated.

The authors declare no conflicts of interest.

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valgum with emphasis on the rate of deformity correction. We hypothesized that TBP would result in a more rapid correction of coronal angular deformity than PETS.

METHODS

The Institutional Review Board at our institution approved this retrospective study. We identified 65 patients who underwent PETS or TBP between January 2009 and March 2014 for idiopathic genu valgum. The inclusion criteria were (1) a valgus angular deformity around the knee on the coronal plane without any other cause for deformity such as trauma, or any kind of neuromuscular diseases, (2) radiologic follow-up until hardware removal, and (3) the absence of any other bony procedure. Patients were excluded from the study if there were inadequate preoperative or follow-up radiographs available for review or if hardware failure such as screw breakage or plate migration occurred. We excluded 4 patients with inadequate preoperative or follow-up radiographs and 1 patient with screws backing out after TBP.

A total of 57 patients (150 limbs) fulfilled the criteria. Data collected for this study included patient age at the time of surgery, sex, body mass index (BMI), the type of implant used, and the site of operation. Patients in the study were divided into 2 groups based on implant type. The surgeon switched the implant during study period. PETS was performed from January 2009 to February 2012. TBP was done between March 2012 and March 2014. Group 1 consisted of 33 patients treated with PETS. Group 2 consisted of 24 patients treated with TBP. The demographic data for each group are provided in Table 1.

Surgical Technique

A single surgeon (H.W.K.) performed all surgeries. In group 1, PETS was performed as described by Metaizeau et al[4] A stab incision over the distal femoral or proximal tibial diaphysis is made. A guide wire was inserted obliquely across the metaphysis and into the epiphysis so that the physis was crossed a zone of one third to one fourth of physeal width. On the lateral, care was taken to ensure that the guide wire crossed the center of the physis. A retrograde guide pin insertion technique was used at the distal femur.[11] After confirmed the position of the guide wire under image intensifier, partially threaded 7.0 mm (AO Cannulated Screw, Synthes, West Chester, PA) cannulated screws were inserted percutaneously. The screw length was selected to adequately purchase the epiphysis by at least 3 threads while ensuring that the screw head would not bury within the periosteum, as visualized by an image intensifier.

In group 2, a plate with 2 cannulated screws was placed spanning the growth plate (Orthofix, McKinney, TX). Through a 3- to 4-cm incision, each plate was placed in a submuscular or subfacial position, with care taken to preserve the periosteum. Fluoroscopy was used to verify satisfactory plate placement. The wound was closed in layers and a dressing applied. All patients in the 2 groups were allowed to bear full weight on operated limbs as soon as tolerated. Patients were discharged when they were able to ambulate with or without crutches.

The patients were followed quarterly, with comparison standing full-leg radiographs as needed. Considering rebound phenomenon, the implant was maintained until the mechanical axis was neutral. Once the axis was in slight varus, we removed the implant.[18–20]

TABLE 1. Patients Characteristics

	All	Group 1 (PETS)	Group 2 (TBP)	*P*
Patients (N)	57	33	24	
Physes (N)	150	90	60	
Distal femur	96	56	40	
Proximal tibia	54	34	20	
Age [mean (range) (y)]	11.9 (8.2-14.4)	12.1 (9.4-14.4)	11.7 (8.2-14.4)	NS (0.35)
Sex [n (%)]				NS (0.56)
Male	32 (56.1)	19 (57.5)	13 (54.2)	
Female	25 (43.9)	14 (42.5)	11 (45.8)	
Body mass index [mean (SD) (kg/m^2)]	21 (3.8)	21.3 (4.0)	20.7 (3.5)	NS (0.48)

NS indicates not significant, $P > 0.05$; PETS, percutaneous epiphysiodesis using a transphyseal screw; TBP, tension-band plating.

Radiographic Analyses

Standard, standing full-leg radiographs (patella pointing forward) were performed regularly, every 3 to 6 months. Radiologic analyses included measurements of mechanical lateral distal femoral angle (mLDFA) and medial proximal tibial angle (MPTA) as described by Paley and Tetsworth.[21] The measurements were taken immediately before surgery and at treatment completion (defined as hardware removal). All radiologic measurements were performed by 2 orthopaedic residents who were blinded to the study. The residents performed measurements independently, twice for each radiograph with at least 1 month between measurements. We converted the measured mLDFA and MPTA to valgus angle (the deviation angle from its normal value) for analyses, assuming a normal value of 88 degrees for mLDFA and 87 degrees for MPTA.[22]

The following variables were also calculated: amount of correction, duration of correction, and rate of correction. The duration of correction refers to the time between surgery and implant removal. The rate of correction was defined as the amount of angular correction divided by the time in months that lapsed from surgery to hardware removal.

Pairwise comparisons were made to see if there was a significant difference in the rate of correction between the 2 groups. Several demographic and surgical variables were considered as possible factors that could be related to rate of correction. These factors included (1) age, (2)

TABLE 2. Comparison of Postoperative Variables Between 2 Groups

	Group 1 (PETS)	Group 2 (TBP)	P
Distal femur			
Age (y)	12.0 ± 1.3	11.8 ± 1.7	NS (0.53)
Initial mLDFA (deg.)	83.3 ± 2.1	83.4 ± 2.2	NS (0.80)
Final mLDFA (deg.)	89.0 ± 2.0	89.3 ± 2.5	NS (0.51)
Amount of correction (deg.)	5.7 ± 1.8	5.9 ± 2.3	NS (0.64)
Duration of correction (mo)	6.6 ± 2.2	9.5 ± 2.8	< 0.001
Rate of correction, (deg./mo)	0.92 ± 0.31	0.64 ± 0.22	< 0.001
Proximal tibia			
Age (y)	12.2 ± 1.2	11.9 ± 1.4	NS (0.54)
Initial MPTA (deg.)	91.2 ± 1.3	90.9 ± 1.2	NS (0.42)
Final MPTA (deg.)	87.1 ± 1.5	86.5 ± 1.9	NS (0.24)
Amount of correction (deg.)	4.1 ± 1.1	4.4 ± 1.6	NS (0.51)
Duration of correction (mo)	6.2 ± 2.1	8.1 ± 2.8	0.016
Rate of correction (deg./mo)	0.72 ± 0.29	0.55 ± 0.15	0.019

All values are expressed as the means ± SD.
mLDFA indicates mechanical lateral distal femoral angle; MPTA, medial proximal tibial angle; NS, not significant, $P > 0.05$; PETS, percutaneous epiphysiodesis using a transphyseal screw; TBP, tension-band plating.

sex, (3) BMI, (4) surgical site, (5) implant type, and (6) valgus angle. A correlation analysis was performed to determine if the rate of correction significantly correlated with all possible factors mentioned above.

Interobserver and Intraobserver Repeatability

Bland and Altman plots and repeatability coefficients were used as measures of interobserver and intraobserver repeatability for all evaluations. The 95% limits of agreement represent a visual determination of the correspondence between reviewer measurements. By definition, the measurement error was smaller than the repeatability coefficient for 95% of the observations.

Statistical Analyses

Statistical analyses were performed using SPSS software (version 19.0, SPSS, Chicago, IL). Data were assessed for normality on plots and by the Shapiro-Wilks test. At the beginning of the study, we performed an a power analysis for mLDFA and MPTA and found that a minimum sample size of 20 limbs was required to achieve a statistical significance of 0.05 with 80% power and an effect size of 0.8, meaning it could detect a 80% of difference between PETS and TBP. We had 20 proximal tibias in TBP group, which was equal to the minimum sample size. To compare the 2 groups in regard to clinical characteristics and radiologic measurements, a 2-sample t test was used for continuous variables and a χ^2 test was used to compare categorical variables. Comparisons between preoperative and postoperative values in the same group were performed using a paired t test for continuous numerical data. Association between the rate of correction and all possible factors was analyzed by linear regression. In this multivariate model, duration of correction and amount of correction were excluded due to their theoretical interference with the outcomes. Multivariate analysis was performed with the explanatory variables, which were found to be significant in univariate analyses. In all analyses, a P-value of <0.05 was considered significant.

RESULTS

The results of angular deformity correction are presented in Table 2. All patients achieved full correction of genu valgum deformity in both groups (Fig. 1). No statistically significant differences were found between groups for the mean age at the time of surgery, measured radiographic values (the mean mLDFA and MPTA) on long standing radiographs taken at baseline and treatment completion, and the mean amount of correction. However, the mean duration of correction was shorter in group 1 on both the distal femur ($P < 0.001$) and proximal tibia ($P < 0.001$). The mean rate of correction was faster in group 1 on both the distal femur ($P = 0.016$) and the proximal tibia ($P = 0.019$).

The results of multivariate analysis of the rate of correction using a linear regression model are presented in Table 3. Unsurprisingly, the younger the age at the time of surgery, male sex, and distal femur were factors associated with an increase in the rate of correction. The implant type significantly affected the rate of correction; PETS resulted in faster correction than TBP. BMI and initial valgus angle had no effect on the rate of correction.

Interobserver and Intraobserver Repeatability

All measurements demonstrated excellent intraobserver and interoberver reliability. Correlation coefficients ranged from 0.83 to 0.94.

DISCUSSION

PETS and TBP possess several advantages for treatment of coronal angular deformity by temporary hemiepiphysiodesis compared with stapling. These methods have gained widespread popularity because they are safe, minimally invasive, and simple. However, to the best of our knowledge, there have been no studies comparing

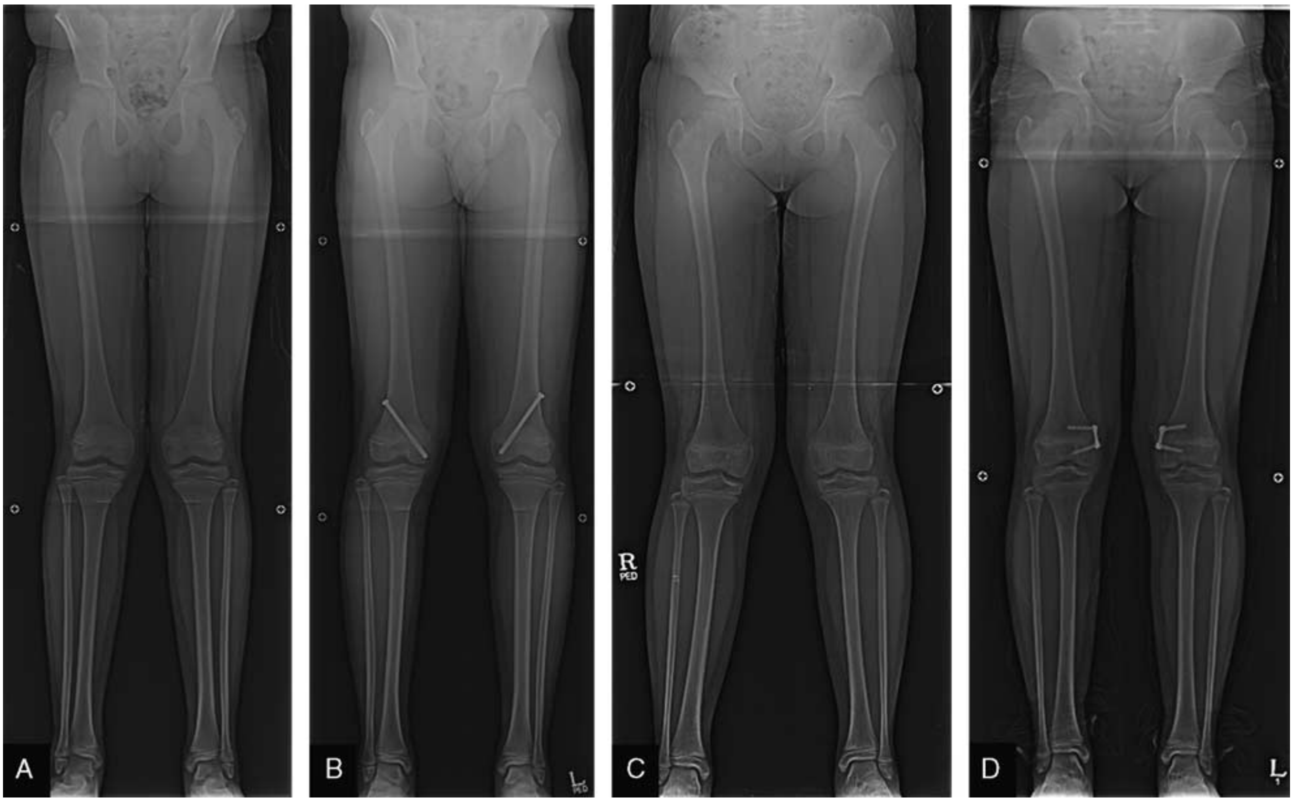

FIGURE 1. Examples of percutaneous hemiepiphysiodesis using transphyseal screw and tension-band plating deformity corrections. A, A 12.8-year-old boy is shown with idiopathic genu valgum. B, Percutaneous hemiepiphysiodesis using transphyseal screw treatment resulted in correction to satisfactory alignment at 6 months postoperative. C, A 10.2-year-old girl with idiopathic genu valgum is shown. D, Tension-band plating was performed at the distal femur. Perfect alignment was achieved at 9 months postoperative.

the efficacy of PETS and TBP and this is the first comparative study of these techniques in patients with idiopathic genu valgum. We found there were significant differences in the rate of correction between the techniques. Although both PETS and TBP are capable of gradually correcting genu valgum deformity in skeletally immature patients, PETS may lead to faster deformity correction with differences approaching statistical significance.

We hypothesized that TBP would correct deformities faster than PETS, because the tension-band plate has a longer lever arm. However, our study shows the opposite result. This may be because it takes a longer time for the tension-band plate to function as a hinge. Specifically, the screw holds the growth plate immediately after operation by means of mechanical compression, but the plate may not instantly restrain the physis, which requires tension to act as a tension-band plate.

Previous studies have reported the rate of correction for angular deformity using PETS and TBP. In our study, in group 1 (PETS), the rate of correction at the distal femur averaged 0.92 degrees per month and at the proximal tibia averaged 0.72 degrees per month. These results are comparable with a study by Shin et al[11] (0.92 deg./mo at distal femur, 0.52 deg./mo at proximal tibia). In group 2 (TBP), the rate of correction at the distal femur averaged 0.64 degrees per month and at the proximal tibia averaged 0.55 degrees per month. Although our results were also similar with those presented by Gottliebsen et al[12] (0.58 deg./mo at distal femur), some authors report faster correction rate using TBP (1 deg./mo at both the distal femur and proximal tibia).[23] However, it is difficult to compare our results with those of previous studies because most studies include patients with idiopathic angular deformity, neuromuscular disease, skeletal dysplasia, and metabolic diseases. In fact, only 1 article reports the outcomes of TBP in patients with idiopathic genu valgum.[12] Therefore, we believe that our results are more reliable than previous studies because all included patients had idiopathic genu valgum without underlying diseases.

Surgical results of TBP have been compared with those of stapling. Most papers report that the time to correction of the deformity is equal.[12,13,23–25] Several papers also compare PETS versus stapling; these papers describe no significant difference in the rate of correction.[1,11] On the basis of these papers, one might postulate that there is no difference between correction rates of PETS and TBP. However, our results showed a significant difference in correction velocity. In another type

TABLE 3. Multivariate Results for the Rate of Correction Using Linear Regression Model

Factors	Coefficient	95% CI	P
Sex			
Male vs. female	−0.16	−0.28 to −0.04	0.008
Age at surgery	−0.1	−0.15 to −0.06	< 0.001
Body mass index	0.02	−0.01 to 0.04	NS (0.39)
Site			
Distal femur vs. proximal tibia	−0.16	−0.26 to −0.07	0.001
Implant			
Screw vs. plate	−0.26	−0.35 to −0.17	< 0.001
Valgus angle at the surgery	−0.01	−0.03 to 0.02	NS (0.49)

CI indicates confidence interval; NS, not significant, $P > 0.05$.

of coronal deformity—ankle deformity, good results have been documented with PETS and TBP.[26–28] One study determined that the rate of correction was faster when PETS than with TBP.[29] We believe that the correction rate of angular deformity around the knee joint would be similar to that of the ankle joint.

Although the rate of correction using PETS is faster, we cannot conclude that PETS is superior to TBP. In fact, each technique has advantages and disadvantages, which have been investigated in previous studies[1,11–13,16]; however, our study is useful for understanding the differences between correction velocity of the 2 techniques. Here we focused only on the rate of deformity correction, which is unrelated to other factors including surgical complication, postoperative pain, follow-up periods, and rebound phenomenon. The long-term effects of hemiepiphysiodesis were not studied because all patients could not be followed until maturity. Therefore, we cannot draw conclusions about surgical complications related to PETS or TBP or about rebound phenomenon after hardware removal only to the rate of correction induced by the implant types.

Although we observed a faster correction rate with PETS versus TBP in our study, there was little difference between the 2 techniques. However, we think that even minimal differences may affect surgical results of angular correction in some patients. Considering our results, the preferred implant for hemiepiphysiodesis for angular deformity may depend on the relative importance of accelerated deformity correction. In other words, a patient with angular deformity near skeletal maturity may be better served with PETS to achieve maximum deformity correction.

There are several limitations to our study. First, it is based on a retrospective review. The relatively small number of cases may have decreased the power for statistical analysis. Second, our results may have been affected by our choice to include multiple surgical sites in 1 patient for statistical analysis. However, the 2 groups were well matched with regard to age, sex, and most importantly, etiology. Further studies with a larger cohort are needed to fully elucidate differences between the 2 implants. Third, it is known that the effect of PETS is related to angulation of the screw to physis and to its distance from the center of the knee. The mean angle between the physes and screws was 52.4 ± 5.9 degrees at the distal femurs and 58.8 ± 5.1 degrees at the proximal tibiae. These values were comparable with a previous study.[11] In addition, we positioned all screws in a zone at one third to one fourth of the growth plate width.

In conclusion, both PETS and TBP techniques can lead to successful correction of coronal angular deformity in patients with idiopathic genu valgum. The rate of correction was faster with PETS than with TBP. We recommend the use of PETS for angular correction in nearly skeletally mature patients.

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