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Effectiveness comparison of tension band plate and percutaneous transphyseal screw for knee deformity correction in children: A systematic review

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Abstract

Leg length discrepancy (LLD) and angular deformities due to premature physeal closure are common pediatric orthopedic issues. Growth modulation using Tension-Band Plates (TBP) and Percutaneous Transphyseal Screws (PETS) provides minimally invasive alternatives to permanent epiphysiodesis. However, evidence comparing their correction rates, alignment accuracy, and complications remains limited. This review compares the clinical outcomes of TBP and PETS in managing LLD in skeletally immature patients.This review followed PRISMA 2020 guidelines. Electronic databases (PubMed, SpringerLink, ScienceDirect, and Cochrane Library) were searched for clinical studies comparing TBP and PETS in children with open physes. Extracted outcomes included correction rate per year (cm/year), delta LLD (cm), Mechanical Axis Deviation (MAD), operative time, and length of stay. The Cochrane Risk of Bias tool was used for quality assessment. A total of 1,727 records were identified, and three studies (Bayhan et al., 2015; Cheng et al., 2021; Younis et al., 2022) involving 204 patients met inclusion criteria. Both TBP and PETS effectively corrected LLD. PETS showed faster correction rates (up to 0.83 ± 0.8 cm/year vs. 0.26 ± 0.4 cm/year, $p < 0.05$) and shorter operative time and hospital stay. TBP demonstrated superior control of mechanical axis deviation (−4.2 ± 14.9% vs. +7.1 ± 13.1%) and fewer alignment deviations. No major implant-related complications were reported. PETS achieves quicker correction through direct physeal compression but carries a higher risk of alignment variability, especially in the tibia. TBP modulates growth more gradually and predictably, making it preferable for younger patients with greater growth potential. Accurate implant positioning and skeletal maturity assessment remain crucial to optimize outcomes and minimize rebound deformity.Both TBP and PETS are effective for temporary epiphysiodesis in children with LLD. PETS is suitable for rapid correction in older patients, while TBP offers controlled, reversible correction in younger children.

Keywords: Tension Band Plate, Percutaneous transphyseal screw, Children, Knee deformity, Leg length discrepancy

Introduction

Physeal injuries represent a significant subset of pediatric fractures, accounting for approximately 18–30% of all cases. Among these, growth arrest develops in 5–10% of instances, often influenced by the location of the physis, the type of trauma, and the adequacy of management provided.[1,2] Although trauma remains the most common etiology, growth disturbances may also result from congenital conditions such as Blount's disease, infections, neoplasms, radiation exposure, metabolic or hematologic disorders, ischemia, dysfunction, or iatrogenic injury.[3]

Premature physeal closure is defined as the untimely cessation of longitudinal and/or appositional bone growth due to an insult to the growth plate prior to skeletal maturity.[3] The clinical consequences depend on the patient's skeletal age, the physeal location, and the size and position of the resulting physeal bar.

Central physeal bars commonly result in longitudinal growth arrest, leading to limb length discrepancies (LLD), while peripheral bars may cause both LLD and angular deformities.[4,27]

Multiple treatment strategies have been proposed to restore growth potential or mitigate complications from growth arrest, including surgical excision of the physeal bar with or without interpositional materials, and corrective procedures for angular deformities. The overarching goal of treatment is to restore limb length and mechanical alignment, preserve adjacent joint mobility, and prevent both functional and cosmetic disability. Commonly utilized approaches include physeal bar resection, epiphysiodesis, chondrodiastasis, and limb lengthening or deformity correction using circular fixators often in combination.[4]

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Growth modulation using tension-band plates (TBP) has gained global popularity over the past decade as a minimally invasive and effective approach to angular correction in skeletally immature patients.[5] Introduced in 2007 by Stevens, the TBP system involves a two-hole plate secured with two screws, offering secure fixation across the physis without exerting direct compressive forces, in contrast to conventional staples.[6]

An alternative technique, percutaneous transphyseal screw (PETS), has also been employed for growth modulation and angular correction. However, comparative data regarding the efficacy, correction rate, rebound tendency, and complication profiles between TBP and PETS remain varied. Therefore, the aim of this systematic review is to evaluate and compare the effectiveness of tension-band plates (eight-plate technique) and percutaneous transphyseal screws in the correction of knee deformities in children.

Methods

This systematic review followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) 2020 guidelines to address the review protocol.[7]

Search methods for Identification of studies

Potential studies were identified through a comprehensive search of electronic databases, including PubMed, SpringerLink, ScienceDirect, and Cochrane Library. The search was conducted without restrictions on publication date. Keywords and Medical Subject Headings (MeSH) terms were applied according to the PICO framework, which is, population (growth arrest, knee deformity, angular deformity, leg length discrepancy), intervention (epiphysiodesis), comparison (tension band plate [TBP], percutaneous transphyseal screws [PETS]), and outcomes (changes in leg length discrepancy [LLD in cm], correction rate per year [cm/year], and mechanical axis deviation [MAD in mm]). Boolean operators ("AND"/"OR") were used to combine terms, and the search strategy was refined in consultation with a methodological expert. The study selection process followed the PRISMA flow diagram.[7]

Type of studies and intervention

Only clinical studies comparing TBP and PETS for temporary epiphysiodesis in pediatric knee deformities with open growth plates were included. Temporary epiphysiodesis was defined as the surgical correction of knee deformity by partial physeal growth modulation using either TBP or PETS.

Eligibility assessment and data extraction

Two reviewers independently screened titles and abstracts, assessed full texts for eligibility, and all reviewers independently extracted data using a standardized form. Extracted information included study design, sample size, patient demographics, intervention details, follow-up duration, and reported outcomes (LLD, correction rate/year, MAD).

Risk of bias assessment

The risk of bias of the eligible studies was assessed using the Cochrane Risk of Bias Tool, which assesses 7 domains of bias.

Results

The PRISMA flow diagram was used to assess the eligibility criteria (Figure 1). A total of 1,727 records were identified from the databases, and eligibility was assessed for only 19 full-text articles. Of these, 16 were excluded and Ultimately, 3 studies fulfilled the eligibility criteria and were included in this review.

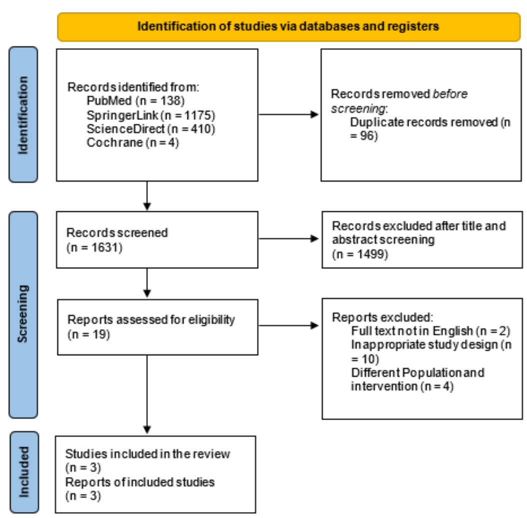

Figure 1. Flow diagram of assessing eligible studies according to PRISMA

Baihan et al. (2015) conducted a study involving 72 patients with an LLD between 2.5 and 5 cm who underwent either eight-plate epiphysiodesis or percutaneous epiphysiodesis (PE) of the distal femur and proximal tibia. The mean age at surgery was 12 years for the TBP group and 13 years for the PETS group, with follow-up durations of 26 ± 15 months and 34 ± 18.5 months, respectively. The annual distal femur correction rate was 0.37 and 0.41 cm for TBP and 0.41 cm for PETS, respectively, whereas the proximal tibia correction rate per year was 0.4 and 0.43 cm for TBP and 0.43 cm for PETS. These findings suggest relatively similar correction rates between the two techniques in both anatomical locations.[8]

Cheng et al. (2021) examined 60 patients with an LLD of 2–5 cm and adequate remaining growth who underwent temporary epiphysiodesis using either TBP or PETS at the distal femur or proximal tibia. The average age at surgery was 11.1 and 12.2 years in the TBP group and 12.2 years in the PETS group, respectively, with a follow-up period of 24 months (NR for PETS). Outcomes showed a delta LLD of 0.88 ± 0.78 cm for TBP and 1.16 ± 0.94 cm for PETS. The mechanical axis deviation was −4.2 ± 14.9% for TBP and +7.1 ± 13.1% for PETS, indicating slight differences in alignment outcomes between the two groups.[9]

Younis et al. (2022) studied 12 patients who had open physes at the time of surgery and received either TBP or PETS for LLD correction at the distal femur and proximal tibia. The mean age at surgery was 11.0 years for TBP and 13.1 years for PETS, with follow-up durations of 5.4 ± 2.9 months and 2.5 ± 1.1 months, respectively. The operative time was significantly longer for TBP (84.9 ± 32 minutes) than with PETS (62.9 ± 26 minutes, $p < 0.05$), while the length of hospital stay was also longer for TBP (2.04 ± 1.1 days vs. 1.07 ± 0.9 days, $p < 0.05$). The delta LLD was 1.42 ± 1.3 cm for TBP and 1.68 ± 1.34 cm for PETS, with correction rates per year of 0.26 ± 0.4 cm for TBP and 0.83 ± 0.8 cm for PETS. The mechanical axis deviation was 10.6 ± 16.5% for TBP and 15 ± 15.8% for PETS.[10]

Table 1 summarizes the characteristics and outcomes of three eligible studies comparing TBP and PETS for temporary epiphysiodesis in children with leg length discrepancy (LLD)

Table 1. Summary of eligible study

Study (year)	Sample Size	TBP Age (SD)	PETS Age (SD)	Inclusion Criteria	Follow-up TBP vs PETS (mo)	Outcome (TBP vs PETS)
Bayhan et al. (2015)[8]	72	12 (2)	13 (1.5)	All patients with an LLD between 2.5 and 5cm who underwent either eight-plate epiphysiodesis or PE of the distal femur and/ or proximal tibia for correction at our hospital were included	26 ± 15 vs 34 ± 18.5	Distal Femur Correction Rate per year (cm) # 0.37 (0.0 – 2.0) vs 0.41 (0.1 – 1.6) Proximal Tibia Correction Rate per year (cm) # 0.4 (0.19 – 0.65) vs 0.43 (0.1 – 2.8)
Cheng et al. (2021)[9]	120	11.1 (2.6)	12.2 (1.4)	patients with LLD of 2 cm to 5 cm with adequate growth remaining, who underwent temporary epiphysiodesis using TBP or PETS at the distal femur or proximal tibia	24 (NR)	Delta of LLD 0.88 ± 0.78 vs 1.16 ± 0.94 Mechanical Axis Deviation (%): -4.2 ± 14.9 vs +7.1 ± 13.1
Younis et al. (2022)[10]	12	11.0 (1.7)	13.1 (1.3)	Patients who had open physes at the	5.4 ± 2.9 vs 2.5 ± 1.1	Operative time (min) 84.9 ± 32 vs 62.9 ± 26*

				time of surgery and received TBP or PETS of the distal femur and/or proximal tibia for the treatment of LLD		Length of Stay (days) 2.04 ± 1.1 vs 1.07 ± 0.9* Delta of LLD 1.42 ± 1.8 vs 1.68 ± 1.34 Correction Rate per year (cm): 0.26 ± 0.4 vs 0.83 ± 0.8* Mechanical Axis Deviation: 10.6 ± 16.5 vs 1.5 ± 15.8

Table 1. Summary of Eligible Study. TBP = Tension Band Plates; PETS = Percutaneous Transphyseal Screws; LLD = Leg Length Discrepancy; SD = Standard Deviation; NR = Not Reported. *p<0.05; # data is presented in n (range)

Discussion

This systematic review aimed to compare the clinical effectiveness of tension-band plates (TBP) and percutaneous transphyseal screws (PETS) in correcting leg length discrepancy (LLD) in skeletally immature patients. Based on the findings from Bayhan et al., Cheng et al., and Younis et al., both TBP and PETS are viable techniques for temporary epiphysiodesis. The mean age at surgery for each procedure in the examined studies yielded comparable results, aligning with the findings of other research, which reported an average age of approximately 11-13 years for patients undergoing TBP or PETS.[11–14,26] However, differences were observed in the correction rates, alignment outcomes, and perioperative characteristics.[8–10]

Across two out of three studies, PETS exhibited a trend toward faster annual correction rates. For instance, Younis et al. reported a significantly higher correction rate with PETS (0.83 ± 0.8 cm/year) than with TBP (0.26 ± 0.4 cm/year). This can be attributed to the biomechanical principle behind PETS, which applies direct compression across the physis, leading to more rapid inhibition of growth. Conversely, TBP works via extraperiosteal tethering, which modulates growth more gradually and safely over time—particularly suitable for patients with greater remaining growth potential.[5,15]

Ilharreborde et al. (2012) found that while PETS is effective, particularly in the femur, its application in the tibia often results in complications, including valgus deformity in 20% of patients and a revision rate of 18%.[16] Consequently, the authors advise against using this technique in the tibia. In contrast, TBP tends to be more forgiving of technical errors and offers the advantage of reversibility, although the risk of rebound following implant removal remains a consideration.[17,18]

While PETS offers advantages in terms of operative time and hospital stay, as reported by Younis et al., this benefit may come at the cost of greater variability in mechanical axis deviation (MAD). Cheng et al. and Younis et al. both found that the PETS group had higher MAD values than TBP. This variability can increase the risk of malalignment due to asymmetric growth inhibition, especially in the presence of technical errors during implant placement. By preserving the integrity of the physis and allowing gradual correction, TBP has been shown to provide more predictable alignment outcomes.[15,19,25]

Suboptimal placement of TBP can lead to significant alterations in tibial slope, as documented in a study by Yıldız and Çullu (2022). Specifically, anterior placement of the 8-plate on the tibia has been shown to increase the posterior tibial slope, whereas midline placement is associated with a lower risk.[20] Consequently, accurate implant placement in the sagittal plane is essential to prevent mechanical disturbances in the knee. Notably, research has also demonstrated the effectiveness of 8-plates in addressing residual deformities, such as clubfoot, and complex cases, including melorheostosis with leg length discrepancy, without significant complications.[21,22] This expanded application of TBPs in pediatric orthopedic practice underscores their versatility in treating various conditions.

Age and skeletal maturity are also important considerations in choosing the modality. In the studies reviewed, patients receiving PETS were generally older, likely due to the need for quicker correction before physeal closure. TBP is often preferred in younger children with more growth remaining, as it allows reversible and titratable correction with a lower risk of premature closure or rebound. The rebound phenomenon after TBP removal, particularly in younger patients, has been well documented in the literature.[15,23]

Notably, none of the three included studies reported implant-related complications such as hardware failure, infection, or overcorrection. While this may reflect low complication rates, previous research has described issues such as screw loosening in TBP and asymmetric physeal closure in PETS.[5,19] These risks underscore the need for adequate surgical technique and regular follow-up.

From a clinical and logistical standpoint, PETS may be advantageous in resource-limited settings due to its simpler surgical technique, lower implant cost, and reduced operative time. However, TBP provides a controlled and gradual correction method, particularly beneficial in managing multiplanar deformities and cases where long-term modulation is necessary. [5,15,24]

This study has several limitations, including the relatively small number of studies analyzed and the majority being retrospective observational studies without randomized controls, which may introduce selection bias and reduce the reliability of the inferences drawn. The studies also exhibited clinical heterogeneity due to variations in patient characteristics, deformity location, and measurement methods, which could not be fully accounted for. Additionally, the differing follow-up durations and limited reporting of long-term complications restrict our understanding of the therapy's effects over an extended time period.

Conclusion

Both Tension-Band Plates (TBP) and percutaneous transphyseal screws (PETS) are effective modalities for temporary epiphysiodesis in the management of leg length discrepancy in skeletally immature patients. PETS appear to offer faster correction rates and shorter operative times, making it a suitable option for older children with limited remaining growth or in resource-constrained settings. On the other hand, TBP provides more gradual and controlled modulation of growth with better predictability of mechanical axis alignment, making it preferable in younger patients with significant growth potential. Given the differences in correction dynamics, alignment control, and technical profiles, the choice between TBP and PETS should be tailored to patient age, remaining growth, surgeon experience, and available resources. Further high-quality randomized studies with standardized outcome reporting are warranted to establish long-term effectiveness, complication rates, and optimal indications for each technique.

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