Original Clinical Article

JOURNAL OF CHILDREN'S ORTHOPAEDICS

Journal of Children's Orthopaedics
2022, Vol. 16(6) 505–511

DOI: 10.1177/18632521221135192
journals.sagepub.com/home/cho

Effects of tension band plating on coronal plane alignment of lower extremities in children treated for idiopathic limb length discrepancy

Ozan A Erdal[1], Baris Gorgun[1], Ozan Razi[2], Ilker A Sarikaya[1], and Muharrem Inan[1]

Abstract

Purpose: One of the most common treatment methods for moderate limb length discrepancy in children is growth modulation using tension band plating. Coronal plane deformities after tension band plating for limb length discrepancy have been documented as an important complication in articles involving heterogeneous groups consisted of both idiopathic cases and patients with pathological physes. The aim of the study was to determine the rate of coronal plane deformities after treatment of a homogeneous group of idiopathic limb length discrepancy cases with tension band plating and to compare screw constructs of medial and lateral plates.

Methods: Patient files were retrospectively reviewed for amount of limb length discrepancy, anatomical femorotibial angle, mechanical lateral distal femoral angle, mechanical medial proximal tibial angle, and inter-screw angles of each plate on both sides of the tibiae and femora. Measurements at each follow-up period were compared to each other.

Results: A total of 26 patient files (37 bones) were included to the study. The mean age was 10.5 years. The mean limb length discrepancy was 27.5 mm. Implants were removed after mean 34.5 months. The mean follow-up period was 58.5 months. There was no significant difference in inter-screw angle on each side of the bones at the time of implantation and in lower limb alignments during follow-up.

Conclusion: Treatment of mild-to-moderate idiopathic limb length discrepancy with tension band plating in children was found to be safe against any coronal plane deformity during follow-up until skeletal maturity.

Level of evidence: Level IV.

Keywords: Tension band plate, limb length discrepancy, deformity, growth modulation

Introduction

Limb length discrepancy (LLD) of lower extremities more than 2 cm before or at skeletal maturity is an important cause of morbidity. It may cause gait abnormalities, chronic hip, knee or back pain, and osteoarthritis.[1,2] In children with more than 2 years of growth remaining, different growth modulation techniques have been defined as major treatment methods for moderate LLD.[3–7] Although its efficacy compared with other growth modulation methods has still been under debate, tension band plating (TBP) has been a common treatment option for LLD.[8–15]

Several complications related to TBP have been reported, including inadvertent coronal plane deformity of the lower extremity.[2,7,9,10,14,16–18] The rate of this complication and suggested reasons were reported in articles involving heterogeneous patient groups including both idiopathic cases and cases with pathological physes.[7,9,10,14,18,19] In

[1]Ortopediatri Istanbul, Academy of Pediatric Orthopaedics, Istanbul, Turkey
[2]Ministry of Health, Burhan Nalbantoglu State Hospital, Lefkosa, Cyprus

Date received: 15 May 2022; accepted: 5 October 2022

Corresponding Author:
Ozan A Erdal, Ortopediatri Istanbul, Academy of Pediatric Orthopaedics, Dikilitas Mah. Hakki Yeten Cad. No 10/D 34365 Besiktas, Istanbul, Turkey.
Email: ozanaerdal@yahoo.com

some studies, coronal plane deformities were attributed to poor surgical technique, proximal tibial anatomical features, younger age, larger LLD, or congenital physeal pathologies.[18–20] Another possible underlying mechanism might be the phenomenon involving that a TBP with a maximally divergent screws might affect earlier and more than another plate with less divergent screws.[10,21]

The aim of the study was to determine the rate of coronal plane deformities after treatment with TBP of a homogeneous group of children with idiopathic LLD. We also aimed to study whether there was any significant difference in inter-screw angles (ISA) between plates on each side of a bone, and relation of the change in limb alignment, if any, with difference of ISA.

Materials and methods

After receiving institutional review board approval, the files of patients operated for LLD with TBP between years 2013 and 2019 were retrospectively reviewed. Cases with idiopathic LLD were included to the study. Idiopathic term was used for cases without any known history of disease or trauma affecting the physeal growth. Non-idiopathic cases (e.g. skeletal dysplasias, Marfan's syndrome, and endocrine diseases), patients lost during follow-up, revision of cases from another institution, cases with previous lower extremity deformity, and those that required concomitant osteotomy or TBP at a level other than the knee were excluded from the study.

In addition to demographic data of the patients, initial limb measurement difference, the timing of the operation, operated bones, time of implant removal, and total follow-up duration were recorded. Each full-length leg X-ray of both lower extremities before the operation, at the time of the implant removal, and at final follow-up were measured for LLD, anatomical femorotibial angle (aFTA), mechanical lateral distal femoral angle (mLDFA), and mechanical medial proximal tibial angle (MPTA) according to previous reports.[20] The early postoperative anteroposterior knee X-rays and radiographies at the time of implant removal were evaluated for ISA. ISA was defined as the angle between screws on each plate (Figure 1). All measurements were made by the same author. The preoperative measurements were compared to the X-rays at the time of implant removal or final follow-up. The ISA on medial and lateral sides of each bone were also compared to each other.

The surgical procedure was performed under general anesthesia by authors. A 2- to 3-cm-long skin incision was done on each side of the focused growth plate (distal femur or proximal tibia). After exposing the deep fascia, it is cut and a K-wire is inserted into the physis under fluoroscopy. The periosteum was not cut or dissected. When the position of the wire was confirmed to be in the middle of the growth plate on lateral views, a titanium TBP (TST

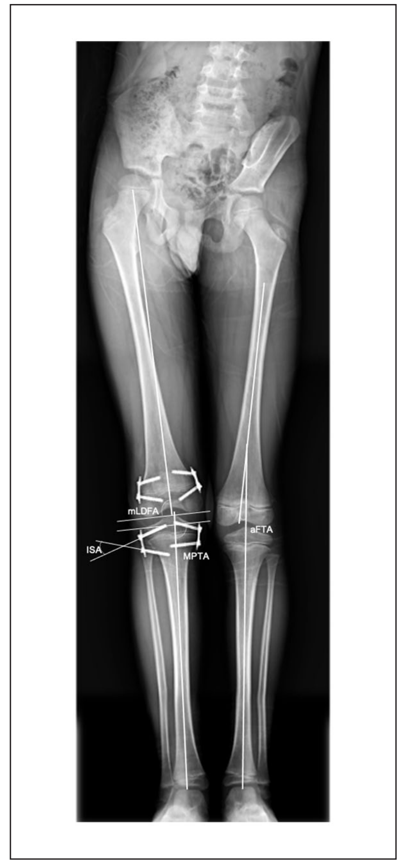

Figure 1. Preoperative X-ray of a male patient with 29 mm leg length discrepancy. Lower extremity alignment measurements and inter-screw angle (ISA) measurements are shown.
mLDFA: mechanical lateral distal femoral angle; aFTA: anatomical femorotibial angle; MPTA: medial proximal tibial angle.

Medical Devices, TR) with two holes was inserted over the wire and fixed with two cannulated screws in epiphysis and metaphysis, under fluoroscopic control.

Follow-up controls were made every 3 months until implant removal. Plates were removed when LLD was eliminated. After implant removal, all patients were followed until skeletal maturity with clinical examination and finally with X-ray around the time of maturity.

Statistical analyses were performed using NCSS program (Number Cruncher Statistical System) 2007 (Kaysville, Utah, USA). In addition to descriptive statistical methods, data distribution was evaluated with Shapiro–Wilk test. Two-group comparison of quantitative data was done by Mann–Whitney U test. Data of two periods of follow-up were compared using Wilcoxon test while data comparisons of three or more follow-up periods were performed using Friedman test. Significance was evaluated at $p < 0.05$.

Results

We retrospectively reviewed files of 35 patients who had undergone TBP for idiopathic LLD. After application of

Table 1. Demographic data of patients.

Demographic data	Mean ± SD	Min-max (median)
Age (years)	10.5 ± 2.14	6–14 (11)
Duration of plating (months)	34.54 ± 9.69	14–58 (34.5)
Follow-up (months)	58.46 ± 17.99	25–94 (61.5)
Initial LLD (mm)	24.3 ± 5.8	17–36 (24)

LLD: limb length discrepancy; SD: standard deviation.
N: 26—16 male, 10 female.

Table 2. Measurements of limb alignment and inter-screw angles.

	Early postop	Time of removal	Final follow-up	p
LLD	24.3 ± 5.8 17–36 (24)	3.19 ± 4.45 0–21 (2.5)	3.21 ± 4.23 0–21 (2.5)	0.001**
aFTA	3.62 ± 1.7 2–7 (3)	3.85 ± 2.13 1–10 (4)	3.85 ± 2.13 1–10 (4)	0.949
mLDFA	89.52 ± 3.7 82–101 (89)	89.13 ± 2.83 85–95 (89)	88.96 ± 2.4 85–94 (89)	0.895
MPTA	87.29 ± 3.07 83–93 (87)	88.57 ± 2.03 86–92 (88)	89.14 ± 2.11 86–93 (89)	0.069
LAT ISA	24.14 ± 8.57 2–45 (25)	34.38 ± 10.65 15–55 (38)	N/A	0.001**
MED ISA	22.84 ± 10.71 0–49 (23)	30.32 ± 11.37 10–52 (32)	N/A	0.001**

LLD: leg length discrepancy; aFTA: anatomical femorotibial angle; mLDFA: mechanical lateral distal femoral angle; MPTA: medial proximal tibial angle; ISA: inter-screw angle; LAT: lateral; MED: medial; N/A: not applicable.
Given as mean ± SD and min-max (median).
Friedman test: $^{**}p < 0.01$.

exclusion criteria, we included files of 26 patients. A total of 37 bones (23 femora; 14 tibiae) were operated for LLD with TBP between 2014 and 2018. The mean age of the patients was 10.5 years (range, 6–14; SD, 2.1), with at least 2 years of growth remaining according to the skeletal age, at the time of TBP application. The initial LLD was mean 24.3 mm (range, 17–36; SD, 5.8). Both tibiae and femora were operated in 11 children while 3 patients were operated only for tibia and 12 for only femur. All patients, except one, returned to their previous level of physical activity in 3–4 weeks. One case experienced joint limitation for more than 1 month and returned to previous activity level in 2 months only after receiving physical therapy. There was no other complication early after the procedure or throughout the follow-ups. The plates were removed at a mean of 34.5 months (range, 14–58; SD, 9.7), and each patient was followed for a mean of 58.5 months (range, 25–94; SD, 18) (Table 1). All except three patients reached skeletal maturity at the end of follow-up period. Implants were completely removed in all cases except five cases whose metaphyseal screws were removed first. The mean age of the patients at the time of implant removal was 13.4 years (range, 8–18). The final LLD measurements were mean of 3.2 mm (range, 0–21; SD, 4.7). The mean correction was 20.8 mm (range, 12–33; SD, 11.1), and the correction rate was 0.6 mm/month (range, 0.3–1.2; SD, 0.2). The mean correction rate in cases operated for only the femora or the tibiae were 0.6 mm/month (range, 0.3–1; SD, 0.2) and 0.9 mm/month (range, 0.6–1.2), respectively. Only one case, who was the oldest one in our cohort (14-year-old male) ended up with a more than 2 cm difference (21 mm), which required femoral lengthening surgery 2 years after skeletal maturity. In total, 24 out of 26 patients had less than 1 cm LLD at the final follow-up (mean, 2 mm; range, 0–6). The initial LLD were 24 and 36 mm in those two cases who ended up with 12 and 21 mm length difference, respectively. None of the patients experienced a rebound LLD and received a repeat TBP during follow-up.

The limb alignment measurements are given in Table 2. The difference of each measurement during follow-up was detected as insignificant. The final limb alignment measurements at the end of follow-up did not show any significant difference with the measurement at the time of implant removal (Figure 2). Also, there was no significant difference between measurements of both lower extremities during follow-up. There was a significant difference between early postoperative and implant removal time

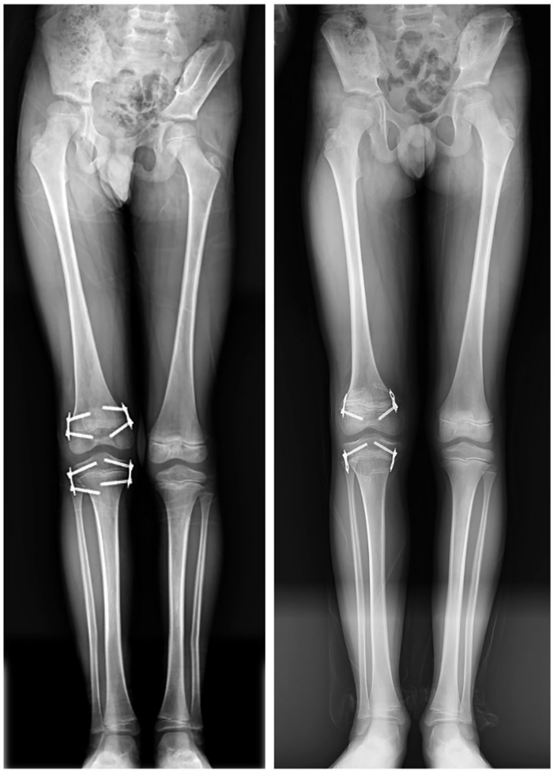

Figure 2. Full-length X-rays of a 10-year-old male patient at the time of tension band plate implantation and just after removal of the metaphyseal screws, 26 months after the first operation.

ISA, which showed divergence of the screws (Figure 3). ISA measurements showed no significant difference between medial and lateral plates at early postoperative and implant removal time, with p values 0.42 and 0.107, respectively. Additionally, any correlation or effect of ISA on coronal plane alignment was not suitable for statistical analysis, because there was no change on coronal alignment of the limbs. Therefore, the difference of medial and lateral ISA measurements on the coronal plane, which was about a mean of 4 degrees, was considered both statistically and clinically insignificant.

Discussion

TBP is a valuable alternative for the treatment of LLD in children with longer than 2 years of growth remaining. There has been significant controversy about its effectiveness and possible complications.[9] One of the possible important complications was coronal plane deformity at the end of treatment. In this study, we searched for it and the potential effect of ISA differences on coronal plane alignment due to potentially different hinge effects on each side of the physis.

More than 2 cm LLD at maturity is related to future morbidities due to gait deviation, hip pain, osteoarthritis, and lumbar pain.[1,17,22] Any LLD in children is evaluated if the difference increases to or beyond 2 cm in maturity, with the help of several prediction tools.[23] Cases with predicted discrepancy > 2 cm are indicated for appropriate treatment based on the remaining growth potential and predicted final height. For moderate LLD with 2–5 cm projected difference in patients with more than 2 years of growth remaining, growth modulation methods have attracted interest because of their minimally invasive applications and reversibility of some.[14] The first application was permanent epiphysiodesis with the help of a drill or curette.[6,18,24] Because of its irreversible effect, the technique required accurate prediction of remaining growth and predicted LLD.[6,10,16,18,21,23,25] However, accuracy of the prediction methods was reported to be moderate, with a mean prediction error of about 1 cm.[10,23] Therefore, the efficacy of permanent methods was under debate. They were predominantly recommended for older children with around 2 years of growth remaining.[7] Later, temporary epiphysiodesis or growth modulation methods were developed and gained popularity. Staples, percutaneous epiphysiodesis using trans-physeal screws (PETS), and TBP or 8-plates have been the major implants used for temporary growth modulation for deformity correction or treatment of LLD.[3,6–10,14,16,25]

TBP were introduced by Stevens.[8] The main characteristics of a TBP were peripheral location of its hinge apex from the physis, a longer lever arm compared to other implants, angular movement of screws on the plates, and inconstant compression force on the growth plate.[4,8,11,16,19,21] With the help of the movement of screw heads on the plate, it acts as a tether or a flexible hinge as the screws get more divergent and plate bends. With TBP, inconstant growth plate compression prevents physeal arrest, provides high reversibility, while the gap period of plate bending and screw divergence causes a delay in beginning of its effect.[4,8,10,11,13,19,21] Owing to its reversibility, TBP can be applied at earlier ages, treatment can be repeated as long as growth continues and accurate deformity or LLD prediction would not be required.[2,25] The implants can be removed, completely or partially depending on the age, and normal growth resumes.[7,10,16,21,22,26] Also, metaphyseal screws can be reinserted in cases with recurrent LLD or coronal plane malalignment during follow-up after removal of them, especially in younger children.[7,21] The effect of TBP on physeal growth was shown to be variable depending on the age of the patient, presence of underlying physeal pathology, and compliance to the standard surgical technique.[16]

TBPs were mainly used for the treatment of coronal plane deformities around the knee.[9,11,13,16,27] Following

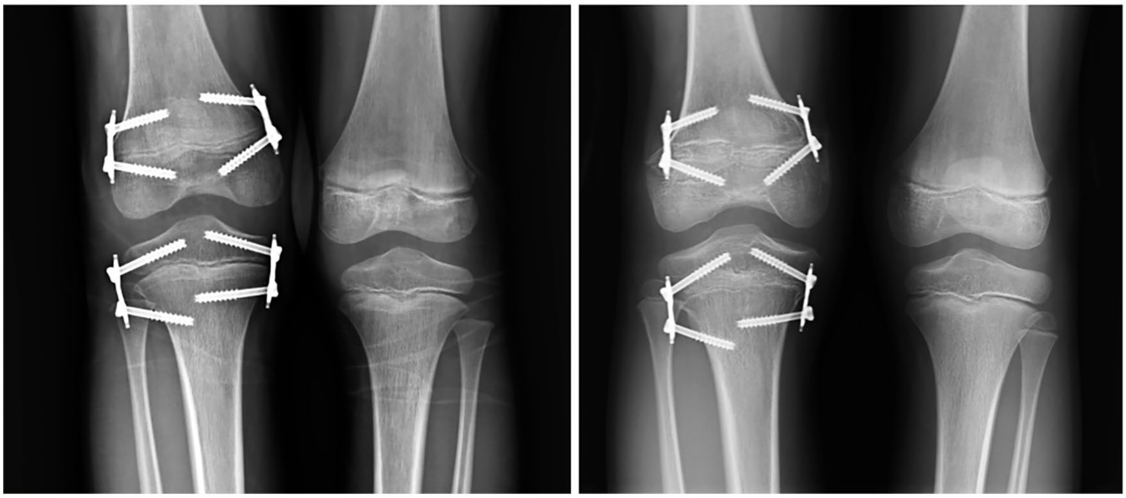

Figure 3. X-rays of a patient at the time of TBP implantation and at the time of removal, which show significant change in ISA during follow-up.
ISA: inter-screw angle.

reports on their effectiveness and reversibility, they were also used for sagittal plane corrections in children with knee flexion contractures.[4,12] Other studies evaluated their potential effect on rotational malalignment, as well.[8,28] After studies on the use of TBP in deformity correction, recent studies reported their results after using them for LLD in children with more than 2 years of growth remaining.[1,4,5,7,10,13,22,26,29] Although widely used because of reversibility of growth modulation and ability to apply at earlier ages without calculating remaining growth, there is still controversy about its efficacy in LLD. The first report on the effectiveness of TBP on LLD was from Lauge-Pedersen and Hägglund.[10] After TBP of proximal tibiae of 10 patients and follow-up of only 1.5 years, they concluded that the technique did not show significant effect on LLD. They commented that after maximal divergence, 18–24 months later, the plates might act like a rigid construct. Stevens[21] reported an important detail with the use of TBP, which was the fact that TBP required about 1 year more than standard methods considering the lag period, unless screws were all applied maximally divergent. Borbas et al.[7] and Bayhan et al.[15] found that the efficacy of TBP was similar to that of permanent epiphysiodesis. Lykissas et al.[13] found comparable results after TBP, PETS, and staple applications for LLD.

After increased number of studies about growth modulation with TBP, several complications were reported as well. Most of them were related to local wound complications and implant irritation, while some were more serious, like plate or screw breakage, permanent epiphysiodesis, under- or over-correction, physeal bone bridge formation, and iatrogenic bone deformity.[3,4,14,16–18,24] Complication rates were reported to be higher among patients with pathological physes.[2,9,16,18]

Coronal plane deformities after growth modulation with TBP for LLD have been of significant concern.[27–29] The deformities after growth modulation may be insignificant in some cases, but it may require surgical correction or partial removal of plates in cases with significant deformity. The rates of this complication were variable among articles. An article by Sinha et al.[4] reported change of morphology of the tibial plateau after TBP in eight patients with idiopathic LLD hemihypertrophy. Change in the tibial morphology was found to be correlated with change in ISA. Borbas et al.[7] reported 11.7% rate of varus/valgus deformity after TBP for LLD, among a heterogeneous patient group. Those patients required secondary TBP for the coronal plane deformities. However, Pendleton et al.[29] reported only one case with coronal plane deformity out of 34, after TBP for LLD. Nine patients were idiopathic. They concluded that femoral application was more predictable than tibial TBP. Gaumétou et al.[26] and Lykissas et al.[13] reported no coronal plane deformity in their cohorts. A recent article by Cheng et al.[14] reported 18/38 rate of varus/valgus deformities after TBP compared to 12/15 after percutaneous screws. Only 10 patients in all cohorts were idiopathic. The rate and comparison of complications in the idiopathic group were lacking. They also observed a tendency toward varus with TBP and valgus with screws.

The causes of varus/valgus deformities after TBP remain unclear. Problem with the surgical technique or unpredicted behavior of pathological growth plates might play a role. But other causes especially in cases with healthy growth plates or idiopathic cases have not been clarified, yet. An article by Lauge-Pedersen and Hägglund[10] suggested that the effect of TBP started only after maximal divergence of the screws and the screws of both plate on each side of the bone must have reached highest divergence at the same time against any asymmetrical growth retardation. As mentioned before by Stevens, TBP requires a gap time before bending of the plate and full divergence of the screws.[2,8,21] They also reported that for an early effect the screws might be applied divergent instead of parallel to the physeal line, which was presumed to shorten the initial gap time.[21] However, Gaumétou et al.[26] reported no increased effect with divergent screws. Based on these views, we searched for any coronal plane deformity after TBP for LLD and its relation with the asymmetry of the ISA on both sides of the tibia or the femur.

In our retrospective study of a patient group with idiopathic LLD, the rate of correction was 0.6 mm/month, which was similar to the wide range of reported rates in previous articles. The correction rate was 0.9 mm/month (1.11 cm/year) in a comparative study by Lykissas et al.[13] The reported correction rates (mm/month) in other studies were 0.51 (12.2 mm in 2 years) in the study by Borbas et al.;[7] 0.5 in another study;[14] and 0.37–0.41 in a study by Bayhan et al.[15] However, the timing of plate removal was later in our series, which was a mean of 3 years, compared to previously reported duration of plating which was a mean of 2 years.[2,19] We did not observe a clinically or statistically significant deformity. Therefore, idiopathic cases in our cohort seemed to be safe from any inadvertent coronal plane deformity after TBP. Additionally, the difference of the screw angles at the time of TBP between medial and lateral plates was statistically insignificant. The differences of mean ISA change during follow-up were also clinically low and insignificant, considering lack of any inadvertent deformity. Considering that none of the patients developed any coronal plane deformity, almost symmetrical application of plates was considered safe enough against any inadvertent coronal plane deformity in the treatment of idiopathic LLD with TBP. Our study was the first research that studied coronal plane alignment of the limbs after TBP for LLD in a homogeneous patient group without any growth plate affecting disease and also to evaluate ISA of the plates and their effect on limb alignment.

The results should be interpreted with limitations of this study. First, retrospective design of the study is a limitation. Also, the study lacks a comparison group such as permanent epiphysiodesis or other implants for growth modulation. That is because the TBP method has been the dominant technique for the treatment of LLD at our clinic. The number of cases was another limitation. However, the fact that the selected patient group comprised only idiopathic cases could be considered as a strength of the study. Another strength of the study was that almost all patients (23/26) were followed up until skeletal maturity, which may answer the question whether a coronal plane deformity occurs after implant removal due to long-term effect of a possible physeal damage. A similar but prospective comparative study on a larger cohort involving patients with normal growth plates and those with pathological physes would give more convincing results. Because there was no significant difference between the early postoperative ISA measurements or comparison group with different early ISA, it is not possible to conclude the parallel-placed screws as the key factor to avoid the complication of subsequent angular deformity. Another limitation could be the definition of ISA. It was only measured on the coronal plane. So, any divergence on the other planes and anatomical differences between both sides of the femur and the tibia were not considered in this study.

Conclusion

Treatment of children with mild-to-moderate idiopathic LLD with TBP applied almost symmetrically on the coronal plane was found to be safe against any inadvertent coronal plane deformity during follow-up until skeletal maturity. The ISA differences between medial and lateral sides of the bones were found to be statistically insignificant. Therefore, the study cannot draw any conclusion regarding the effect of significant ISA difference or different screw constructs on coronal plane alignment of the lower limbs.

Author contributions

Ozan A Erdal: Conception and design, data acquisition, analysis and interpretation of the data, production of the manuscript, drafting and critical revision of the manuscript, final approval of the manuscript.
Baris Gorgun: Conception and design, data acquisition, drafting and critical revision of the manuscript, final approval of the manuscript.
Ozan Razi: Conception and design, drafting and critical revision of the manuscript, final approval of the manuscript.
Ilker A Sarikaya: Conception and design, drafting and critical revision of the manuscript, final approval of the manuscript.
Muharrem Inan: Conception and design, data acquisition, analysis and interpretation of the data, drafting and critical revision of the manuscript, final approval of the manuscript.

Compliance with ethical standards

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The study was approved by institutional Ethical Committee of Scientific Research.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Informed consent

All subjects were given informed consent and agreed to participate in the project.

ORCID iDs

Ozan A Erdal https://orcid.org/0000-0002-8557-4016
Baris Gorgun https://orcid.org/0000-0003-4536-4070
Ilker A Sarikaya https://orcid.org/0000-0002-2659-173X

References

1. Schneider M, Buschbaum J, Joeris A, et al. Biomechanical investigation of two long bone growth modulation techniques by finite element simulations. *J Orthop Res* 2018; 36(5): 1398–1405.
2. Shabtai L and Herzenberg JE. Limits of growth modulation using tension band plates in the lower extremities. *J Am Acad Orthop Surg* 2016; 24(10): 691–701.
3. Troy M, Shore B, Miller P, et al. A comparison of screw versus drill and curettage epiphysiodesis to correct leg-length discrepancy. *J Child Orthop* 2018; 12: 509–514.
4. Sinha R, Weigl D, Mercado E, et al. Eight-plate epiphysiodesis. *Bone Joint J* 2018; 100-B: 1112–1116.
5. Frommer A, Niemann M, Gosheger G, et al. Temporary proximal tibial epiphysiodesis for correction of leg length discrepancy in children—should proximal fibular epiphysiodesis be performed concomitantly? *J Clin Med* 2021; 10: 1245.
6. Babu LV, Evans O, Sankar A, et al. Epiphysiodesis for limb length discrepancy: a comparison of two methods. *Strategies Trauma Limb Reconstr* 2014; 9(1): 1–3.
7. Borbas P, Agten CA, Rosskopf AB, et al. Guided growth with tension band plate or definitive epiphysiodesis for treatment of limb length discrepancy? *J Orthop Surg Res* 2019; 14: 99.
8. Stevens PM. Guided growth for angular correction: a preliminary series using a tension band plate. *J Pediatr Orthop* 2007; 27: 253–259.
9. Ballhause TM, Stiel N, Breyer S, et al. Does eight-plate epiphysiodesis of the proximal tibia in treating angular deformity create intra-articular deformity? *Bone Joint J* 2020; 102-B(10): 1412–1418.
10. Lauge-Pedersen H and Hägglund G. Eight plate should not be used for treating leg length discrepancy. *J Child Orthop* 2013; 7: 285–288.
11. Ballal MS, Bruce CE and Nayagam S. Correcting genu varum and genu valgum in children by guided growth: temporary hemiepiphysiodesis using tension band plates. *J Bone Joint Surg Br* 2010; 92(2): 273–276.
12. Klatt J and Stevens PM. Guided growth for fixed knee flexion deformity. *J Pediatr Orthop* 2008; 28(6): 626–631.
13. Lykissas MG, Jain VV, Manickam V, et al. Guided growth for the treatment of limb length discrepancy. *J Pediatr Orthop B* 2013; 22: 311–317.
14. Cheng YH, Lee WC, Tsai YF, et al. Tension band plates have greater risks of complications in temporary epiphysiodesis. *J Child Orthop* 2021; 15: 106–113.
15. Bayhan IA, Karatas AF, Rogers KJ, et al. Comparing percutaneous physeal epiphysiodesis and eight-plate epiphysiodesis for the treatment of limb length discrepancy. *J Pediatr Orthop* 2017; 37(5): 323–327.
16. Wiemann JM 4th, Tryon C and Szalay EA. Physeal stapling versus 8-plate hemiepiphysiodesis for guided correction of angular deformity about the knee. *J Pediatr Orthop* 2009; 29(5): 481–485.
17. Furuhashi H, Kaneko H, Iwata K, et al. Sagittal plane deformity after temporary epiphysiodesis of the distal femur for correcting limb length discrepancy. *J Orthop Sci* 2020; 25(3): 472–476.
18. Makarov MR, Dunn SH, Singer DE, et al. Complications associated with epiphysiodesis for management of leg length discrepancy. *J Pediatr Orthop* 2018; 38(7): 370–374.
19. Gottliebsen M, Shiguetomi-Medina JM, Rahbek O, et al. Guided growth: mechanism and reversibility of modulation. *J Child Orthop* 2016; 10(6): 471–477.
20. Gorman TM, Vanderwerff R, Pond M, et al. Mechanical axis following staple epiphysiodesis for limb-length inequality. *J Bone Joint Surg Am* 2009; 91(10): 2430–2439.
21. Stevens PM. Invalid comparison between methods of epiphysiodesis. *J Pediatr Orthop* 2018; 38(1): e29–e30.
22. Stewart D, Cheema A and Szalay EA. Dual 8-plate technique is not as effective as ablation for epiphysiodesis about the knee. *J Pediatr Orthop* 2013; 33: 843–846.
23. Makarov MR, Jackson TJ, Smith CM, et al. Timing of epiphysiodesis to correct leg-length discrepancy: a comparison of prediction methods. *J Bone Joint Surg Am* 2018; 100: 1217–1222.
24. Surdam JW, Morris CD, DeWeese JD, et al. Leg length inequality and epiphysiodesis: review of 96 cases. *J Pediatr Orthop* 2003; 23(3): 381–384.
25. Ilharreborde B, Gaumetou E, Souchet P, et al. Efficacy and late complications of percutaneous epiphysiodesis with transphyseal screws. *J Bone Joint Surg Br* 2012; 94-B(2): 270–275.
26. Gaumétou E, Mallet C, Souchet P, et al. Poor efficiency of eight-plates in the treatment of lower limb discrepancy. *J Pediatr Orthop* 2016; 36(7): 715–719.
27. Vaishya R, Shah M, Agarwal AK, et al. Growth modulation by hemi epiphysiodesis using eight-plate in Genu valgum in Paediatric population. *J Clin Orthop Trauma* 2018; 9(4): 327–333.
28. Arami A, Bar-On E, Herman A, et al. Guiding femoral rotational growth in an animal model. *J Bone Joint Surg Am* 2013; 95: 2022–2027.
29. Pendleton AM, Stevens PM and Hung M. Guided growth for the treatment of moderate leg-length discrepancy. *Orthopedics* 2013; 36(5): e575–e580.