Abstract

**Purpose** Little data is available on the efficiency of different implants for epiphysiodesis. The purpose of this study is to compare the efficacy between plates and staples in decreasing leg-length discrepancy.

**Methods** A retrospective review of 19 children who underwent temporary epiphysiodesis of the legs was conducted, with a minimum of two years of follow-up. The bone length and length ratio to the short side were measured at six months, one year and two years postoperatively. The change in discrepancy was compared between staples and plates by an independent *t*-test, and the shortest time to a significant decrease in discrepancy was determined using a paired *t*-test.

**Results** Ten patients underwent 13 staple procedures in nine femurs and four tibias for a 2.8-cm discrepancy at age 11.8 years, and nine patients underwent 14 plate procedures in seven femurs and seven tibias for a 3.1-cm discrepancy at age 12.4 years. Patients were followed up to skeletal maturity, except two. The use of staples decreased the discrepancy in the bone ratio from +4.8% to +1.2% in two years, and the use of plates decreased this ratio from +5.1% to +3.3% in two years. The change in the length ratio was significantly greater after stapling. Six months were required after stapling before the first significant decrease in discrepancy; it took two years after plating.

**Conclusions** This study showed a significantly lower efficacy for decreasing leg-length discrepancy by tension band plating. Orthopaedic surgeons should be aware of the limitations of using plates for suppressing bone growth.

**Level of Evidence:** III
who underwent plating. As age is an important factor in
growth potential and efficiency of growth tethering, we
conducted a study to test a null hypothesis that epiphys-
iodesis with plates had a comparable efficacy to that with
staples in patients of similar ages.

Materials and methods
Staples were the standard implants for epiphysiodesis in
the Chang Gung Memorial Hospital, Taiwan until 2010, as
the manufacturer no longer supplies staples. After 2010,
with tension band plates gaining popularity for modify-
ing skeletal growth, we used stainless steel plate-screw
constructs for temporary epiphysiodesis. This retrospec-
tive study reviewed children with LLD who were treated
by temporary epiphysiodesis using plates or staples. To
control the age at operation, we only included children
who underwent epiphysiodesis between the ages of ten
and 14 years and had more than two years of follow-up.
Children who had LLD from skeletal dysplasia or meta-
bolic diseases were excluded. The study was approved
by the institutional review board in the authors’ hospital.

Surgeries
The epiphysiodesis surgeries were performed at the dis-
tal femur or proximal tibia between 2008 and 2012. In
patients who underwent stapling, one to two staples were
used at the medial and lateral sides of a physis. We used
one to two staples in each condyle to fit the body sizes
of the Asian children. The staples were manufactured by
Smith-Nephew (Memphis, Tennessee) (Fig. 1). In patients
who underwent tension band plating, one stainless steel
plate and two screws were fixed at the medial and lateral
sides of a physis. The stainless steel plates were manufac-
tured by Synthes (West Chester, Pennsylvania) (Fig. 2). No
physis ablation, curettage or excision was done with the
implantation operation.

Outcome assessment
After surgery, patients were followed up at six months
and one year and then yearly. Leg length was assessed
by a scanogram, and images were measured using the
electronic picture archiving and communications system.
Films were calibrated for measurement of distances, and
measurements were performed with the built-in software.
The LLD was recorded as exact length and length ratio.
Length ratio was the bone length of the epiphysiodesis
side divided by the length of the other side. Length ratio
was 1.0 when the bone length was equal to the other. The
efficiency of epiphysiodesis was assessed by the decrease
of bone length and length ratio after the operation. The
use of length ratio was to prevent the confounding of dif-
f erent body heights and growth rates among patients.
PLATING LESS EFFECTIVE IN LLD MANAGEMENT

J Child Orthop 2018;12:629-634 631

Statistical analysis

For comparison between patients who underwent stapling and those who underwent plating, background data of age at operation, sex, side, location of epiphysiodesis, initial LLD, follow-up duration and latest LLD were compared using the independent t-test for continuous variables and chi-squared test for nominal variables. Efficacy of epiphysiodesis was assessed by the decrease in discrepancy in the operated femur or tibia, and the efficacy was compared between the stapling and plating groups at six months, one year and two years postoperatively using the independent t-test. In assessing the time when the first significant reduction in discrepancy occurred, the paired t-test was used to compare between preoperative and postoperative conditions. A p-value of less than 0.05 was defined as statistically significant.

Results

In all, 19 patients, six boys and 13 girls, underwent 27 temporary epiphysiodesis surgeries in the study period. Eight patients received simultaneous operations at the ipsilateral femur and tibia. The causes of LLD included congenital short femur, fibular hemimelia, osteonecrosis after surgery for developmental dysplasia of the hip, traumatic physis injury, neonatal osteomyelitis, hemihypertrophy, idiopathy, radiation therapy for rhabdomyosarcoma and Legg-Calvé-Perthes disease (Table 1). They had operations at a mean age of 12.1 years (10.0 to 13.8 years) for an LLD of 2.9 cm and were followed up for 4.1 years on average. Physis closure occurred in all except two patients at the latest follow-up.

Ten patients underwent stapling in nine femurs and four tibias at the age of 11.8 years for LLD 2.8 cm. Three patients had simultaneous stapling in the femur and tibia. The other nine patients underwent plating in seven femurs and seven tibias at the age of 12.4 years for LLD 3.1 cm. Five patients had simultaneous plating in the femur and tibia. The age at operation, location of epiphysiodesis and initial LLD were comparable between the two groups of children (Table 2).

In the assessment of therapeutic efficacy between stapling and plating, the following analysis was conducted by length ratio of the operated femur or tibia rather than the whole leg length. The 13 staplings in nine femurs and four tibias decreased the bone length discrepancy from +1.72 cm (+4.8%) to +0.49 cm (+1.2%) in two years. The 14 platings in seven femurs and seven tibias decreased the bone length discrepancy from +1.90 cm (+5.1%) to +1.26 cm (+3.3%) in two years. The change of length ratio was significantly greater in the stapling group at two years (-3.6% by stapling versus -1.8% by plating, p < 0.05) (Fig. 3). The paired t-test between preoperative and postoperative length discrepancy showed that stapling produced the first significant decrease of discrepancy at postoperative six months (p = 0.036) and plating required two years to produce a significant decrease of discrepancy (p = 0.008) (Table 3).

Fig. 2 Temporary epiphysiodesis using plates.
With regard to the complications associated with the implants, no wound infection, implant loosening, limited knee movement or knee pain was noted in either group. Varus knee deformity occurred in two patients after femoral stapling and one patient after femoral plating. The problem was relieved by removing the implants from the medial femoral condyle. One patient with the sequel of septic hip underwent femoral plating for a 3.0-cm discrepancy at the age of 11.5 years. The discrepancy increased to 3.3 cm two years after plating, and the patient underwent lesion side femoral lengthening at the age of 14 years.

**Discussion**

The study results disproved the hypothesis that plating had the same efficacy in decreasing LLD as stapling. Stapling offered greater reduction of bone length and a quicker response to achieve a significant change. The implant-related complications were similar between staples and plates. With regard to the therapeutic efficacy and safety in temporary epiphysiodesis, staples were superior to plates.

Staples and plates shared a similar structure, which fixed the distance between the two anchors in the metaphysis and epiphysis. Cellular activity of the physis was suppressed by the two fixed-distance anchors, and skeletal growth was changed. The guided growth plates were designed to act as a ‘tension band’ that placed the centre of rotation outside the bone. Therefore, plates provided a faster angular deformation with less inhibition of bone growth at the central part of a physis. The advantage of greater angular correction became a less favoured feature in reducing longitudinal bone growth. An inferior efficacy of plating in epiphysiodesis was reported when compared to physis ablation.

A previous study reported comparable effectiveness in correcting LLD with plates, staples and transphyseal screws. This study showed different results between plates and staples. The two papers are retrospective reviews of patients with LLD from a variety of aetiologies. Lykissas et al measured whole leg length after epiphysiodesis at the femur and the tibia simultaneously, and therapeutic efficacy was evaluated by the change in leg length per year. This study measured isolated bone length of the femur or tibia because epiphysiodesis was performed as per the individual patient requirements. Age might be the underlying factor for the differences in results between the two studies. Epiphysiodesis at an age before the adolescent growth spur can achieve a greater correction. For the patients of the age of 13.4 years who underwent stapling in Lykissas’s study, the efficacy of stapling could be reduced by a lower growth potential compared to physis ablation. We completely agree with the report and want to offer further evidence from a comparative study that reported against using plates in treating LLDs.

Some complications associated with the implants used in growth tethering surgery have been reported, including stress fractures, infection, changes in alignment, implant fracture, iatrogenic permanent physeal arrest, rebound overgrowth and intraarticular migration. In our series, the most common complication was varus deformity after epiphysiodesis at the distal femur. In the stapling group, two cases of varus knee deformity were observed after nine femoral staplings, whereas in the plating group, one varus deformity was noted after seven femoral platings. The knee alignment could be restored to neutral after removing the medial implants without further osteotomy. Proximal migration of the implants was more common in the plating group and may have led to cutting through the growth plate and asymmetric growth inhibition. This is one of the weaknesses of temporary epiphysiodesis via plating and can lead to asymmetric growth tethering and premature closure of the physis. A rebound phenomenon was observed in a few patients after staple removal, and

![Table 1 Demographic data of patients](image)

| No. | Sex | Age at surgery | Diagnosis                  | LLD (cm) | Operation | Implant site |
|-----|-----|----------------|----------------------------|----------|-----------|--------------|
| 1   | F   | 12.9           | Tibia osteomyelitis        | 3.2      | F+T       | Staple       |
| 2   | F   | 12.8           | Idiopathic                 | 2.5      | F         | Staple       |
| 3   | F   | 10.1           | Congenital short femur     | 2.7      | F         | Staple       |
| 4   | M   | 13.5           | Traumatic physis injury    | 3.0      | F         | Staple       |
| 5   | M   | 12.8           | Hemihypertrophy            | 3.7      | F         | Staple       |
| 6   | F   | 10.0           | DDH                        | 2.1      | F         | Staple       |
| 7   | M   | 12.0           | Idiopathic                 | 2.8      | F+T       | Staple       |
| 8   | F   | 10.3           | DDH                        | 1.6      | F         | Staple       |
| 9   | F   | 12.0           | Idiopathic                 | 4.0      | F+T       | Staple       |
| 10  | M   | 11.3           | Idiopathic                 | 2.7      | T         | Staple       |

DDH: previous surgery for developmental dysplasia of the hip; LLD: leg-length discrepancy; F: distal femur surgery; T: proximal tibia surgery

![Table 2 Comparison of the patients treated with staples and those treated with plates. Data are presented as mean (so)](image)

| Patients (n) | Stapling | Plating | p-value (Independent t-test) |
|--------------|----------|---------|----------------------------|
| Sex (M/F)    | (4/6)    | (2/7)   |                            |
| Age (yrs)    | 11.8 (1.2) | 12.4 (1.0) | 0.26                    |
| Preoperative LLD (cm) | 2.8 (0.7) | 3.1 (0.9) | 0.57                |
| Follow-up LLD (cm) | 3.6 (1.1) | 4.7 (1.2) | 0.05                |
| Latest follow-up LLD (cm) | 1.3 (1.0) | 2.5 (1.5) | 0.08                |
| LLD improvement (cm) | 1.5 (0.8) | 0.6 (1.4) | 0.13                |

LDL: leg-length discrepancy

J Child Orthop 2018;12:629-634
premature physis closure did not occur in this case series. Subsequent growth after removing implants is unpredictable in the temporary epiphysiodesis. Besides, relative central overgrowth of the physis after using tension band plates, the so-called ‘volcano-effect’, was observed in this case series, especially in the young children. Although no knee pain or ambulation problems were reported by the patients or their parents, the long-term effects of this phenomenon will require further follow-up.

There were several limitations in evaluating the efficacy of epiphysiodesis in this study. The variety in the aetiologies of LLDs produced different rates of increase in discrepancy. This factor confounded the efficacy of epiphysiodesis that was evaluated by the decrease in discrepancy. This study combined epiphysiodesis at the distal femur and the proximal tibia, which have different growth rates. The case number was not sufficient for further splitting to the femur and tibia. Although the chronological age was comparable between the two groups, the skeletal age was not available for all patients. However, during the two-year postoperative follow-up period, the physis was still open in all cases. Besides the above factors, growth rate could be different among patients with different body lengths, parental factor and sex. For a clinical study, it is not easy to control for the velocity of skeletal growth since it is multi-factorial.

Since Blount and Clarke\textsuperscript{13} presented their early results with epiphyseal stapling in 1949, this method of epiphysiodesis has remained popular in treating LLD. We used staples and plates for temporary epiphysiodesis before and after 2010. This retrospective review showed longer latency and lower efficacy in decreasing LLD on using tension band plating. Orthopaedic surgeons should be aware of the limitations of a tension band plate in decreasing bone growth. A new generation of staples or plates with fixed angle screws are expected to help children with minor LLD.

Received 04 January 2018; accepted after revision 21 September 2018.

**COMPLIANCE WITH ETHICAL STANDARDS**

**FUNDING STATEMENT**

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.
PLATING LESS EFFECTIVE IN LLD MANAGEMENT

This article is distributed under the terms of the Creative Commons Attribution-Non Commercial 4.0 International (CC BY-NC 4.0) licence (https://creativecommons.org/licenses/by-nc/4.0/) which permits non-commercial use, reproduction and distribution of the work without further permission provided the original work is attributed.

ETHICAL STATEMENT

Ethical approval: Institutional review board approval was obtained before initiation of this retrospective study. 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.

Informed consent: No consent was required. Only general non-identifiable data on a series of patients is included.

ICMJE CONFLICT OF INTEREST STATEMENT

The authors declare no potential conflicts of interest.

REFERENCES

1. Gurney B. Leg length discrepancy. Gait Posture 2002;15:195-206.
2. Tjernström B, Olerud S, Rehnberg L. Limb lengthening by callus distraction. Complications in 53 cases operated 1986-1991. Acta Orthop Scand 1994;65: 447-455.
3. Campens C, Mousny M, Docquier PL. Comparison of three surgical epiphysiodesis techniques for the treatment of lower limb length discrepancy. Acta Orthop Belg 2010;76:226-232.
4. Heeg M, Visser JD, Drayer NM, Rouvé C. The treatment of leg length discrepancy using Phemister’s method of epiphysiodesis. Ned Tijdschr Geneeskd 1992;136:1599-1602.
5. Dewaele J, Fabry G. The timing of epiphysiodesis. A comparative study between the use of the method of Anderson and Green and the Moseley chart. Acta Orthop Belg 1992;58:41-47.
6. Little DG, Nigo L, Aiona MD. Deficiencies of current methods for the timing of epiphysiodesis. J Pediatr Orthop 1996;16:173-179.
7. Kemnitz S, Moens P, Fabry G. Percutaneous epiphysiodesis for leg length discrepancy. J Pediatr Orthop B 2003;12:69-71.
8. Aguilar JA, Paley D, Paley J, et al. Clinical validation of the multiplier method for predicting limb length discrepancy and outcome of epiphysiodesis, part II. J Pediatr Orthop 2005;25:192-196.
9. Lee SC, Shim JS, Seo SW, Lim KS, Ko KR. The accuracy of current methods in determining the timing of epiphysiodesis. Bone Joint J 2013;95-B:893-1000.
10. Gottliebsen M, Møller-Madsen B, Stokdille-Jørgensen H, Rahbek O. Controlled longitudinal bone growth by temporary tension band plating: an experimental study. Bone Joint J 2013;95-B:855-860.
11. Nouth F, Kuo LA. Percutaneous epiphysiodesis using transphyseal screws (PETS): prospective case study and review. J Pediatr Orthop 2004;24:721-725.
12. 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:270-275.
13. Blount WP, Clarke GR. Control of bone growth by epiphyseal stapling; a preliminary report. J Bone Joint Surg [Am] 1949;31-A:464-478.
14. Gorman TM, Vanderwerff R, Pond M, MacWilliams B, Santora SD. Mechanical axis following staple epiphysiodesis for limb-length inequality. J Bone Joint Surg [Am] 2009;91-A:2430-2439.
15. Khoury JG, Tavares JO, McConnell S, Zeiders G, Sanders JO. Results of screw epiphysiodesis for the treatment of limb length discrepancy and angular deformity. J Pediatr Orthop 2007;27:623-628.
16. Song MH, Choi ES, Park MS, et al. Percutaneous epiphysiodesis using transphyseal screws in the management of leg length discrepancy: optimal operation timing and techniques to avoid complications. J Pediatr Orthop 2015;35:89-93.
17. Gaumétou E, Mallet C, Souchet P, Mazda K, Ilharreborde B. Poor efficiency of eight-plates in the treatment of lower limb discrepancy. J Pediatr Orthop 2016;36:715-719.
18. Lykissas MG, Jain VV, Manickam V, et al. Guided growth for the treatment of limb length discrepancy: a comparative study of the three most commonly used surgical techniques. J Pediatr Orthop B 2013;22:311-317.
19. Lin TY, Kao HK, Li WC, Yang WE, Chang CH. Guided growth by a stainless-steel tubular plate. J Pediatr Orthop B 2013;22:306-310.
20. Akyut US, Yazici M, Kandemir U, et al. The effect of temporary hemiepiphysiostomy stapling on the growth plate: a radiologic and immunohistochemical study in rabbits. J Pediatr Orthop 2005;25:336-341.
21. Stevens PM. Guided growth for angular correction: a preliminary series using a tension band plate. J Pediatr Orthop 2007;27:253-259.
22. Burghardt RD, Herzenberg JE, Standard SC, Paley D. Temporary hemiepiphysial arrest using a screw and plate device to treat knee and ankle deformities in children: a preliminary report. J Child Orthop 2008;2:187-197.
23. Kanellopoulos AD, Mavrogenis AF, Dovris D, et al. Temporary hemiepiphysiodesis with blount staples and eight-plates in pigs. Orthopedics 2011;34:263.
24. Goyeneche RA, Primomo CE, Lambert N, Miscione H. Correction of bone angular deformities: experimental analysis of staples versus 8-plate. J Pediatr Orthop 2009;29:736-740.
25. Stewart D, Cheema A, Szalay EA. Dual 8-plate technique is not as effective as ablation for epiphysiodesis about the knee. J Pediatr Orthop 2013;33:843-846.
26. Lauge-Pedersen H, Hägglund G. Eight plate should not be used for treating leg length discrepancy. J Child Orthop 2013;7:285-288.
27. Al-Aubaidi Z, Engell V, Lundgaard B. Stress fracture following femoral epiphysiodesis. Ugeskr Laeger 2010;172:2847-2848.
28. Bach BR Jr, DaSilva J. Arthroscopic-assisted removal of a migrated intra-articular distal femoral epiphysiodesis staple. J Knee Surg 2009;22:272-275.