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Instructional lecture

Temporary hemiepiphysiodesis with the eight-Plate for angular deformities: mid-term results

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Abstract
Background. Angular deformities can be treated with corrective osteotomies and application of internal or external fixation. In children, this major intervention can be avoided with temporary hemiepiphysiodesis (i.e., guided growth). Recently, a new device called the eight-Plate Guided Growth System, consisting of a two-hole plate and two screws, was presented as an alternative to the widely used Blount staple to perform temporary hemiepiphysiodesis in children.
Methods. Forty-three patients (54 physes, 51 limbs) underwent treatment between August 2004 and December 2005 with average follow-up after plate insertion of 2 years 2 months (range, 1 year 6 months to 2 years 6 months). Rate of correction and reversibility of this intervention were calculated.
Results. Average age at eight-Plate implantation was 9 years 7 months (age range, 4 years 0 months to 14 years 3 months). eight-Plates were inserted for an average 14.2 months (range, 5.0–27.4 months). No growth disturbance was observed. Mechanical lateral distal femoral angle changed an average 10.00 degrees (range, 1–18 degrees) or 0.65 degrees/month (range, 0.05–1.22 degrees/month). Medial proximal tibial angle changed an average 7.78 degrees (range, 0–14 degrees) or 0.58 degrees/month (range, 0.13–1.67 degrees/month). In the two distal tibial cases, lateral distal tibial angle improved 6 degrees and 10 degrees (average change, 0.44 degrees/month). Mechanical axis deviation improved an average 25.4 mm (range, 0–74 mm) or 1.73 mm/month (range, 0–6.4 mm/month). Ten patients (13 limbs) had more than 10 months of radiographic follow-up after plate removal; ten limbs showed average rebound of 15.7 mm or 1.0 mm/month, indicating the reversibility of this procedure. Four cases failed to achieve correction.
Conclusions. The eight-Plate effectively treats angular deformities in growing children and is less likely to extrude spontaneously than the Blount staple. We have not observed growth disturbance or other complications related to this device.

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Introduction

Hemiepiphysiodesis is an attractive alternative to osteotomies in immature patients with angular deformities. Since Blount and Clarke's 1949 report[1] describing a staple for hemiepiphyseal arrest, many other procedures attempting to guide epiphyseal growth have been discussed and published.[2–9] Staples can break or extrude.[1,10–13] The eight-Plate Guided Growth System (Orthofix, McKinney, TX, USA)[14,15] is attached to the bone with two screws, making it more stable. The eight-Plate may correct the deformity more quickly than the Blount staple. Stevens hypothesized that rebound is less likely with the eight-Plate; although his first case series had two patients who required bilateral repeat eight-Plate insertion after rebound.[14] We are now presenting the results of our first series of 51 limbs (43 patients) that were treated for angular deformities with 54 eight-Plates. The purpose of this study is to evaluate the effectiveness and reversibility of hemiepiphysiodesis with the eight-Plate.

Subjects, materials, and methods

Before beginning this study, approval was obtained from our institutional review board. From August 2004 to December 2005, 54 eight-Plates were inserted into the lower extremities of 43 children (51 limbs) at a single hospital. The first 11 of the 43 children were reported in a preliminary study about the eight-Plate.[16] The current study reports these patients with longer follow-up. The precise surgical technique has been previously described.[16] All patients had angular deformities about the knee or ankle and were skeletally immature. Two patients also underwent concurrent treatment of an ankle deformity. Erect long-standing, anteroposterior, and lateral view radiographs were obtained before deciding to perform hemiepiphysiodesis using the eight-Plate. The eight-Plates were inserted with the intent of removing them when the deformity correction was achieved.[14,15] The magnitude of the deformity was measured before surgery and at periodic follow-up visits.[17] Patients had an average follow-up of 2 years 2 months (range, 1 year 6 months to 2 years 6 months) after plate insertion.

If osteotomies were performed or external fixation was applied to one limb segment and the eight-Plate was inserted in the other limb segment of the same limb, the data from the limb were not included in the calculations for average mechanical axis deviation (MAD). However, the data from the limb were included in the calculations of the average joint orientation angles. The data from one patient were excluded from the MAD calculations because the patient had an eight-Plate inserted in both the distal femur and proximal tibia. The data from another patient were excluded from the calculations of joint orientation angles and MAD because an eight-Plate was inserted in the medial distal femur and the patient underwent surgery of the femoral neck.

To assess the reversibility of this intervention, we also analyzed cases with radiographic follow-up of more than 10 months after plate removal. The main focus was to determine whether there was rebound of the deformity or any growth disturbance.

Results

All 54 eight-Plates were removed without any complications. Thirty-nine patients (48 eight-Plates, 45 limbs) underwent treatment for genu valgum deformity and four patients (6 eight-Plates, 6 limbs) underwent treatment for genu varum deformity. The primary diagnoses are shown in Table 1. The average age at the time of eight-Plate implantation was 9 years 7 months (age range, 4 years 0 months to 14 years 3 months). The average time between insertion and removal of the eight-Plate was 14.2 months (range, 5.0–27.4 months). Of the 54 eight-Plates, 3 plates were inserted in the lateral distal femora and 32 in the medial distal femora. Three plates were inserted in lateral proximal tibiae and 14 in medial proximal tibiae. The remaining 2 eight-Plates were inserted in medial distal tibiae (Table 1).

There were no complications. One patient underwent an exchange for a longer metaphyseal screw (24 mm exchanged for 32 mm) because the original screw had become loose. Fifty of the 54 cases were successfully treated, reaching either full deformity correction or enough to avoid undergoing an osteotomy in the treated limb segment. In four cases, the treatment failed either because there was not enough growth remaining in the treated physis or because of the limited growth secondary to underlying bone illness. The results are presented in Table 1; the MAD improved in 44 cases by an average 25.4 mm (range, 0–74 mm) or 1.73 mm/month (range, 0–6.4 mm/month). The mechanical lateral distal femoral angle (mLDFA) improved in 33 cases by an average of 10.00 degrees (range, 1–18 degrees) or 0.65 degrees/month (range, 0.05–1.22 degrees/month). The medial proximal tibial angle (MPTA) improved in 18 cases an average 7.78 degrees (range, 0–14 degrees) or 0.58 degrees/month (range, 0.13–1.67 degrees/month). In the two distal tibial cases, the lateral distal tibial angle (LDTA) improved 6 degrees and 10 degrees in 24.4 and 12 months, respectively, resulting in an average change of 0.44 degrees/month.

The results of ten patients (13 limbs) were used to evaluate the reversibility of the intervention as well as the issue of rebound (Table 2). These patients had an average radiographic follow-up time after plate removal of 16 months (range, 10–24 months). The average rebound of the MAD was 15.7 mm or 1.0 mm/month. The average rebound of the joint orientation angles was 3.7 degrees or 0.23 degrees/month.

Discussion

Seven patients (10 eight-Plates) were excluded from the calculation of MAD, as they underwent osteotomies or had external fixation applied to one limb segment and the eight-Plate was inserted in the other limb segment of the same limb (see data in Table 1 that are highlighted in gray). Four of these seven patients had severe conditions such as fibular hemimelia and congenital femoral deficiency, and the eight-Plate was used as an adjuvant tool alongside the main procedures with external fixation. However, in six of the seven patients who were excluded from the average MAD calculation, the eight-Plate fully corrected the focal deformity.

Four cases failed to achieve correction. A 12-year-6-month-old girl with a diagnosis of fibular hemimelia

Table 1. Patient data

Diagnosis	Case number	Patient number	Gender	Age (years + months)	Side	Duration of insertion (months)	Location of insertion	Angle	Joint orientation angle measurements (degrees)				Mechanical axis deviation (mm)			
									Initial angle	Final angle	Change	Degrees/ month	Initial MAD	Final MAD	Change	mm/ month
Fibular hemimelia	1	1	♂	7 + 9	R	15.0	mdf	mLDFA	80	90	10	0.67	l 30	l 8	22	1.47
	2	2	♂	12 + 9	R	20.7	mdf	mLDFA	82	89	7	0.34	l 25	l 9	16	0.77
	3	3	♀	7 + 6	L	20.4	mdf	mLDFA	80	90	10	0.49	l 28	l 0	28	1.37
	4	4	♂	7 + 10	R	19.1	mdf	mLDFA	80	98	18	0.94	l 16	l 7	9	0.47
	5	5	♀	10 + 1	R	18.9	mdf	mLDFA	80	91	11	0.58	l 33	l 3	30	1.59
	6	6	♀	7 + 8	L	17.5	mpt	MPTA	96	84	12	0.69	l 32	l 2	30	1.71
	7	7	♀	10 + 11	L	18.9	mdf	mLDFA	82	94	12	0.64	l 21	m 2	23	1.22
	8	8	♀	6 + 10	R	18.3	mdf	mLDFA	84	98	14	0.77	*l 16*	*l 5*	*11*	*0.60*
	9	9	♀	12 + 6	R	15.0	mdf	mLDFA	77	80	3	0.20	*l 77*	*l 9*	*68*	*4.61*
	10	10	♂	8 + 9	L	7.0	mpt	MPTA	95	87	8	1.14	l 30	m 8	38	5.40
Idiopathic genu valgum	11	11	♂	7 + 1	R	6.2	mdf	mLDFA	82	88	6	0.97	l 17	l 0	17	2.74
	12				L	6.2	mdf	mLDFA	86	92	6	0.97	l 13	m 5	18	2.90
	13	12	♀	9 + 8	L	21.8	mdf	mLDFA	84	93	9	0.41	l 27	l 3	24	1.10
	14	13	♂	4 + 4	R	8.2	mpt	MPTA	106	93	13	1.59	l 42	l 17	25	3.05
	15	14	♀	8 + 7	L	16.6	mdf	mLDFA	95	89	6	0.36	*n.m.*	*n.m.*	*//*	*//*
	16	15	♂	10 + 4	R	9.6	mdf	mLDFA	*84*	*87*	*3*	*0.31*	*l 30*	*l 7*	*23*	*2.40*
	17	16	♂	10 + 2	R	24.4	mdf	mLDFA	84	92	8	0.33	l 24	m 2	26	1.07
	18				R	24.4	mdt	LDTA	76	82	6	0.25	*//*	*//*	*//*	*//*
	19	17	♂	13 + 6	L	21.9	mdf	mLDFA	86	88	22	0.09	l 17	l 3	14	0.64
	20	18	♂	13 + 8	R	6.0	mpt	MPTA	94	84	10	1.67	l 15	m 14	29	4.80
	21				L	6.0	mpt	MPTA	94	87	7	1.20	l 22	l 0	22	3.70
	22	19	♂	5 + 7	R	10.0	mdf	mLDFA	82	90	8	0.80	l 19	m 4	23	2.30
	23				L	10.0	mdf	mLDFA	83	94	11	1.10	l 20	m 4	24	2.40
Congenital femoral deficiency	24	20	♂	6 + 2	R	18.4	mdf	mLDFA	84	98	14	0.76	l 26	m 2	28	1.52
	25	21	♂	13 + 3	L	27.4	mpt	MPTA	96	86	10	0.37	l 40	m 3	43	1.57
	26	22	♀	10 + 11	L	11.3	mdf	mLDFA	85	90	5	0.44	l 35	l 28	7	0.62
	27	23	♀	10 + 11	L	12.6	mdf	mLDFA	90	100	10	0.79	*n.m.*	*n.m.*	*//*	*//*
	28	24	♂	10 + 1	L	23.0	mpt	MPTA	93	88	5	0.44	l 18	m 8	26	1.13
	29	25	♀	9 + 10	R	22.2	mdf	mLDFA	80	94	14	0.63	*l 30*	*l 13*	*17*	0.77
	30	26	♀	12 + 7	L	12.0	mdf	mLDFA	79	90	11	0.92	l 38	l 3	35	2.92

Table 1. Continued

Diagnosis	Case number	Patient number	Gender	Age (years + months)	Side	Duration of insertion (months)	Location of insertion	Angle	Joint orientation angle measurements (degrees): Initial angle	Final angle	Change	Degrees/month	Mechanical axis deviation (mm): Initial MAD	Final MAD	Change	mm/month
Blount disease	31	27	♂	4 + 7	L	42.1	mpt	MPTA	95	88	7	0.13	l 11	l 4	7	0.46
	32	28	♀	11 + 4	L	17.8	ldf	mLDFA	96	86	10	0.56	m 90	m 72	18	1.01
	33	29	♀	7 + 3	L	7.7	lpt	MPTA	86	94	8	1.04	m 28	m 3	25	3.25
Clubfoot	34	30	♂	12 + 5	L	13.0	mdf	mLDFA	81	91	10	0.77	l 30	m 8	38	2.92
	35	31	♂	4 + 11	R	12.0	mpt	MPTA	95	91	4	0.33	l 17	l 4	13	1.10
	36				R	12.0	mdt	LDTA	82	92	10	0.83	//	//	//	//
Multiple exostoses	37	32	♂	9 + 2	R	16.5	mdf	mLDFA	85	98	13	0.79	l 20	m 20	40	2.42
	38	33	♂	9 + 10	R	18.9	mdf	mLDFA	84	93	9	0.48	*l 31*	*m 4*	*35*	*1.85*
	39				R	18.9	mpt	MPTA	97	93	4	0.21	*l 31*	*m 4*	*35*	*1.85*
	40				L	18.9	mdf	mLDFA	84	95	11	0.58	l 11	m 8	19	1.00
	41	34	♂	14 + 3	R	19.6	mdf	mLDFA	80	81	1	0.05	l 42	l 32	10	0.51
Neurofibromatosis	42	35	♂	4 + 0	L	20.2	mpt	MPTA	102	88	14	0.69	l 20	l 12	8	0.40
	43	36	♂	10 + 0	L	14.2	mpt	MPTA	96	93	3	0.21	l 40	l 40	0	0.00
Multiple epiphyseal dysplasia	44	37	♀	5 + 5	R	15.1	mpt	MPTA	98	84	14	0.93	l 34	l 4	30	1.99
	45				L	15.1	mpt	MPTA	98	84	14	0.93	l 25	m 4	29	1.92
Marfan syndrome	46	38	♀	7 + 5	R	11.0	mdf	mLDFA	81	90	9	0.82	l 32	l 2	30	2.70
TAR syndrome	47	39	♂	8 + 9	R	12.0	ldf	mLDFA	90	100	10	0.83	m 52	l 22	74	6.20
	48				L	12.0	ldf	mLDFA	95	105	10	0.83	m 44	l 18	52	4.30
Perthes disease	49	40	♀	11 + 7	R	5.0	mdf	mLDFA	84	90	6	1.20	l 21	m 11	32	6.40
	50				L	5.0	mdf	mLDFA	84	89	5	1.00	l 22	m 7	29	5.80
Poliomyelitis	51	41	♀	10 + 7	R	12.3	mdf	mLDFA	82	92	10	0.81	l 19	m 3	22	1.79
Osteosarcoma	52	42	♂	13 + 8	R	10.0	lpt	MPTA	79	79	0	0.00	m 29	m 29	0	0.00
	53				L	10.0	lpt	MPTA	83	90	7	0.69	m 26	l 3	29	2.90
Delayed development	54	43	♀	13 + 0	R	9.0	mdf	mLDFA	79	90	11	1.22	l 49	m 6	55	6.10

Data highlighted in gray were excluded from the calculations of the average joint orientation angles or the average mechanical axis deviation

//, not applicable; L, left; ldf, lateral distal femur; l, lateral; LDTA, lateral distal tibial angle; lpt, lateral proximal tibia; m, medial; MAD, mechanical axis deviation; mdf, medial distal femur; mdt, medial distal tibia; mLDFA, mechanical lateral distal femoral angle; mpt, medial proximal tibia; MPTA, medial proximal tibial angle; n.m., not measurable; R, right; TAR, thrombocytopenia with absent radius

Table 2. Results of mid-term follow-up

Diagnosis	Case	Gender	Age (years + months)	Side	Follow-up after removal (months)	Location of insertion	Angle	Joint orientation angle measurements: Initial measurement (degrees)	Joint orientation angle measurements: Measurement before removal (degrees)	Joint orientation angle measurements: Measurement at latest follow-up (degrees)	Joint orientation angle measurements: Rebound (degrees)	Mechanical axis deviation: Initial measurement (mm)	Mechanical axis deviation: Measurement before removal (mm)	Mechanical axis deviation: Measurement at latest follow-up (mm)	Mechanical axis deviation: Rebound (mm)
Fibular	1	♂	7 + 9	R	12	mdf	mLDFA	80	90	88	2	lat 30	lat 8	lat 20	12
hemimelia	5	♀	10 + 1	R	14	mdf	mLDFA	80	91	88	3	lat 33	lat 3	lat 35	32
	8	♀	6 + 10	R	10	mdf	mLDFA	84	98	88	10	lat 16	lat 5	lat 28	23
Idiopathic	20	♂	13 + 8	R	17	mpt	MPTA	94	84	88	4	lat 15	med 14	med 9	5
genu valgum	21	♂	13 + 8	L	17	mpt	MPTA	94	87	90	3	lat 22	lat 0	lat 8	8
	22	♀	5 + 7	R	14	mdf	mLDFA	82	90	90	0	lat 19	med 4	lat 9	13
	23	♀	5 + 7	L	14	mdf	mLDFA	83	94	88	6	lat 20	med 4	lat 16	20
Blount disease	33	♂	7 + 3	L	10	lpt	MPTA	86	94	90	4	med 28	med 3	med 14	11
Clubfoot	34	♂	12 + 5	L	12	mdf	mLDFA	81	91	91	0	lat 30	med 8	med 5	3
	35	♀	4 + 11	R	22	mpt	MPTA	95	91	92	1	lat 17	lat 4	lat 10	6
	36	♀	4 + 11	R	22	mdt	LDTA	82	92	90	2	″	″	″	″
Marfan syndrome	46	♀	7 + 5	R	24	mdf	mLDFA	81	90	82	8	lat 32	lat 2	lat 29	27
Delayed development	54	♀	13 + 0	R	20	mdf	mLDFA	79	90	85	5	lat 49	med 6	lat 32	38

L, left; lat, lateral; LDTA, lateral distal tibial angle; lpt, lateral proximal tibia; mdf, medial distal femur; mdt, medial distal tibia; med, medial; mLDFA, mechanical lateral distal femoral angle; mpt, medial proximal tibia; MPTA, medial proximal tibial angle; R, right

did not achieve correction because the LDFA improved from only 77 to 80 degrees. The reason for this failure was lack of growth potential in the distal femoral physis. Another failure occurred in a 14-year-3-month-old boy with a diagnosis of multiple exostosis and enchondromatosis. We think this treatment failed because of the underlying illness of the bone combined with the lack of growth potential in this nearly skeletally mature male. The third failure occurred in a 10-year-old boy with severe neurofibromatosis who had the eight-Plate removed after 14 months. The MPTA in this case improved from 96 to 93 degrees. In the fourth failure case, the eight-Plate was used to correct a varus deformity in a patient who underwent resection of an osteosarcoma in the tibia. In this case, the proximal tibia experienced no further growth as the physis was permanently damaged from the treatment of the osteosarcoma. However, the MPTA of the healthy contralateral limb improved from 83 to 90 degrees.

One of the patients whose data was excluded from the MAD calculation had an eight-Plate inserted in the medial distal femur and Blount staples placed bilaterally in the medial proximal tibiae. In this case, we observed that the rigid staple produced more of a compressive effect after insertion and therefore corrected faster than the eight-Plate. In cases in which the remaining growth potential is limited, we prefer to use the Blount staple. However, Peter Stevens,[14,15] the inventor of the eight-Plate, believes the eight-Plate works faster than the Blount staple. The time for deformity correction is dependent on the width of the growth plate,[18] with narrow growth plates correcting faster than wide ones. The rigid Blount staple causes a technical narrowing of the growth plate, whereas the eight-Plate creates an angulation correction axis[17] outside the growth plate, thereby "widening" the physis.

A larger patient group should be followed until skeletal maturity to gather more data about the impact of rebound and how much overcorrection should be planned to compensate for rebound. The data should also be examined to determine whether there is a correlation between the pathology and the amount of rebound.

Because of the easy and precise technique of insertion, its reversibility, and the decreased risk of spontaneous extrusion, the eight-Plate has widely replaced the Blount staple in our center. We disagree with Stevens in matters of the rate of correction compared with the Blount staple and the problem of rebound. At our institution, the eight-Plate costs six times as much as a Blount staple, which is another area of concern.

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References

1. Blount WP, Clarke GR. Control of bone growth by epiphyseal stapling: a preliminary report. J Bone Joint Surg Am 1949;31: 464–78.
2. Eidelman M, D'Agostino P. Hemiepiphysiodesis around the knee by percutaneously guided and grooved staple. J Pediatr Orthop B 2005;14:434–5.
3. Haas SL. Retardation of bone growth by a wire loop. J Bone Joint Surg [Am] 1945;27:25–36.
4. Horton GA, Olney BW. Epiphysiodesis of the lower extremity: results of the percutaneous technique. J Pediatr Orthop 1996;16: 180–2.
5. 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; 27:623–8.
6. Métaizeau JP, Wong-Chung J, Bertrand H, Pasquier P. Percutaneous epiphysiodesis using transphyseal screws (PETS). J Pediatr Orthop 1998;18:363–9.
7. Nouth F, Kuo LA. Percutaneous epiphysiodesis using transphyseal screws (PETS): prospective case study and review. J Pediatr Orthop 2004;24:721–5.
8. Phemister DB. Operative arrestment of longitudinal growth of bones in the treatment of deformities. J Bone Joint Surg Am 1933;15:1–15.
9. Blount WP. A mature look at epiphyseal stapling. Clin Orthop Relat Res 1971;77:158–63.
10. Stevens PM, Maguire M, Dales MD, Robins AJ. Physeal stapling for idiopathic genu valgum. J Pediatr Orthop 1999;19:645–9.
11. Brockway A, Craig WA, Cockreli BR Jr. End-result study of 62 stapling operations. J Bone Joint Surg Am 1954;36:1063–70.
12. Frantz CH. Epiphyseal stapling: a comprehensive review. Clin Orthop Relat Res 1971;77:149–57.
13. Mielke CH, Stevens PM. Hemiepiphyseal stapling for knee deformities in children younger than 10 years: a preliminary report. J Pediatr Orthop 1996;16:423–9.
14. Stevens PM. Guided growth for angular correction: a preliminary series using a tension band plate. J Pediatr Orthop 2007;27:253–9.
15. Stevens PM, Klatt JB. Guided growth for pathological physis: radiographic improvement during realignment. J Pediatr Orthop 2008;28:632–9.
16. Burghardt RD, Herzenberg JE, Standard SC, Paley D. Temporary hemiepiphyseal arrest with a screw and plate device to treat knee and ankle deformities in children: a preliminary report. J Child Orthop 2008;2:187–97.
17. Paley D. Frontal plane mechanical and anatomic axis planning. In: Paley D. Principles of deformity correction. 1st ed, corrected 3rd printing. Berlin Tokyo Heidelberg New York: Springer-Verlag; 2005:61–97.
18. Bowen JR, Leahey JL, Zhang ZH, MacEwen GD. Partial epiphysiodesis at the knee to correct angular deformity. Clin Orthop Relat Res 1985;198:184–90.