

# Correction of coronal plane deformities around the knee using a tension band plate in children younger than 10 years

Ruta M Kulkarni, Faizaan M Ilyas Rushnawala, GS Kulkarni, Rajiv Negandhi, Milind G Kulkarni, Sunil G Kulkarni

## ABSTRACT

**Background:** Guided growth through temporary hemiepiphysiodesis has gained acceptance as the preferred primary treatment in treating pediatric lower limb deformities as it is minimally invasive with a lesser morbidity than the traditional osteotomy. The tension band plate is the most recent development in implants used for temporary hemiepiphysiodesis. Our aim was to determine its safety and efficacy in correcting coronal plane deformities around the knee in children younger than 10 years.

**Materials and Methods:** A total of 24 children under the age of 10 were operated for coronal plane deformities around the knee with a single extra periosteal tension band plate and two nonlocking screws. All the children had a pathological deformity for which a detailed preoperative work-up was carried out to ascertain the cause of the deformity and rule out physiological ones. The average age at hemiepiphysiodesis was 5 years 3 months (range: 2 years to 9 years 1 month).

**Results:** The plates were inserted for an average of 15.625 months (range: 7 months to 29 months). All the patients showed improvement in the mechanical axis. Two patients showed partial correction. Two cases of screw loosening were observed. In the genu valgum group, the tibiofemoral angle improved from a preoperative mean of 19.89° valgus (range: 10° valgus to 40° valgus) to 5.72° valgus (range: 2° varus to 10° valgus). In patients with genu varum the tibiofemoral angle improved from a mean of 28.27° varus (range: 13° varus to 41° varus) to 1.59° valgus (range: 0-8° valgus).

**Conclusion:** Temporary hemiepiphysiodesis through the application of the tension band plate is an effective method to correct coronal plane deformities around the knee with minimal complications. Its ease and accuracy of insertion has extended the indication of temporary hemiepiphysiodesis to patients younger than 10 years and across a wide variety of diagnosis including pathological physis, which were traditionally out of the purview of guided growth.

**Key words:** Angular deformity, genu valgum, genu varum, hemiepiphysiodesis

**MeSH terms:** Paediatrics, epiphysis, knee, limb deformities

## INTRODUCTION

Pediatric deformity correction has been at the core of the foundation of Orthopedics since the publication of *L'Orthopedia* by Andry in 1741. Identifying these

pathologic deformities and their subsequent management forms an integral part of pediatric orthopedic surgery.

Presence of angular deformities around the knee in children is a common finding including genu valgum and genu varum.<sup>1</sup> However, a majority of these deformities are physiologic in nature corresponding to the normal physiologic changes in the alignment of mechanical axis from birth to adolescence.<sup>2,3</sup> Differentiating between these physiologic deformities from pathologic conditions such as Rickets, skeletal dysplasias, etc., is of paramount importance as the majority of the physiological ones correct themselves by adolescence requiring no treatment.<sup>4</sup> However, some of these physiologic deformities may persist beyond adolescence warranting orthopedic management. Thus, correct patient selection is important.

Osteotomies have traditionally been the mainstay of treating deformities not only in adults but also in children. These

Department of Orthopaedic Surgery, Post Graduate Institute of Swasthiyog Pratishtan, Miraj, Maharashtra, India

**Address for correspondence:** Dr. Faizaan M Ilyas Rushnawala, Department of Orthopaedic Surgery, Post Graduate Institute of Swasthiyog Pratishtan, Extension Area, Miraj - 416 410, Maharashtra, India. E-mail: faizaanr@gmail.com

Access this article online	
Quick Response Code:	Website: www.ijoonline.com
	DOI: 10.4103/0019-5413.152484

involve extensive soft-tissue dissection, complications of wound closure, infection, delayed union, malunion and prolonged immobilization which increases the morbidity of the patients.<sup>5-7</sup> Guided growth harnesses the plastic nature of the physis to bring about the desired correction required. Being minimally invasive technique with a lesser morbidity than osteotomy,<sup>8,9</sup> Guided growth is an alluring option and has gained acceptance as the preferred primary treatment in pediatric lower limb deformities. Conventionally, temporary hemiephysiodesis has been carried out after the physiologic remodeling of the knee has ended. However, neglecting the pathologic deformities at a younger age could worsen the deformity, lead to gait disturbances and affection of the surrounding joints in due course of growth. Early guided growth in pathologic knee deformities brings about a qualitative improvement in the physis of not only the knees but the hips and ankle as well.<sup>10</sup> Use of staples have a fear of permanent iatrogenic physeal arrest<sup>11-13</sup> preventing their use in under the age of eight by most authors.<sup>14</sup> Mielke and Stevens in 1996 reported good results with the use of staples in the under 10 age group with no report of a permanent physeal arrest.<sup>14</sup> Though several studies have reported application of the tension band plate in a few young patients, none have shown results exclusively in this age group.

We present outcome of the patients who underwent deformity correction through temporary hemiephysiodesis employing the tension band principle.

## MATERIALS AND METHODS

With prior institutional board review, 29 patients under the age of 10 with a coronal plane deformity around the knee were operated upon from July 2007 to August 2012 at our institute. Twenty four of them were completed plate removal with a followup of at least 1 year after plate removal. The results of three of these children were still pending at the time of data collection and thus were excluded from our

study. Two of them had inadequate followup data also warranting exclusion from this study.

All the children were operated with an extra periosteal tension band plate and two nonlocking screws and each deformity was treated with a single plate per physis. Patient selection was done meticulously to confirm the pathology and rule out physiological deformities based on the clinical history, metabolic work-up and radiographic assessment. Full length anterior posterior (AP) weight bearing radiographs of both limbs with the patella facing forwards were taken with a lateral view of the knees as well (preoperatively as well as on followups). Patients were examined for limb length discrepancies, ligamentous laxity and patellar tracking. Detailed visual gait analysis was performed. All the patients were ambulatory. None of the patients had patellar subluxation or dislocation.

We had seven cases of nutritional Rickets, five cases of vitamin D resistant Rickets, four cases of metaphyseal chondrodysplasia, two cases of posttraumatic tibia valga and one each of congenital short femur syndrome, idiopathic genu valgum, achondroplasia, distal femur valgus secondary to proximal tibia chronic osteomyelitis, arthrogyposis with bilateral genu valgum and developmental dysplasia of the hip (DDH) with a unilateral left genu valgum [Table 1].

After confirming the pathological nature of the deformity and ruling out a physiological deformity, the parents were counseled regarding the nature of the disease, its progression and the consequence of the deformity on the surrounding joints, ambulation, gait and further development. All these patients had a significant clinical deformity and after a written informed consent, surgical intervention was carried out. Counseling the parents regarding the gradual nature of deformity correction that temporary hemiephysiodesis employs is very important especially amongst the rural population.

**Table 1: Patient demographics and results**

Patient	Age at surgery (years+ months)	Diagnosis	Deformity	Duration to IR Years+months	F/U post IR	Previous treatment	Result	Other procedures	Complication
1	5+11	Metaphyseal chondrodysplasia	Genu varum	2+1	2+4	B/L proximal tibial osteotomy for bowing of the tibia	Corrected	None	None
2	8+6	Nutritional rickets	Genu valgum	2+5	1+2	Bracing	Partial correction	Bilateral tibial osteotomy after IR	None
3	3+3	Left hip DDH with left genu valgum	Genu valgum	1+4	3+1	OR of the hip done 1 year prior followed by salters innominate osteotomy	Corrected	None	None

*Contd...*

Table 1: Contd...

Patient	Age at surgery (years+months)	Diagnosis	Deformity	Duration	F/U	Previous treatment	Result	Other procedures	Complication
				to IR	post IR				
				Years+months					
4	8+1	Distal femur valgus secondary to proximal tibia chronic osteomyelitis	Genu valgum	1+8	4+0	Antibiotic therapy and bracing	Corrected	Tibial lengthening over Ilizarov construct simultaneously	None
5	6+2	Vit. D resistant rickets	Genu valgum	1+4	2+4	Bracing	Corrected	None	Loosening of the metaphyseal screw after 1 year 3 month
6	3+1	Nutritional rickets	Genu valgum	1+4	2+2	Bracing	Corrected	None	None
7	6+1	Achondroplasia	Genu varum	1+6	1+1	None	Corrected	None	None
8	2+0	Vit. D resistant rickets	Genu varum	1+0	1+4	Bracing	Corrected	None	None
9	3+1	Vit. D resistant rickets	Genu varum	1+0	1+0	Bracing	Corrected	None	None
10	9+1	Idiopathic genu valgum	Genu valgum	1+1	1+6	Bracing	Corrected	None	None
11	4+3	Nutritional rickets	Genu valgum	0+7	1+0	Bracing	Corrected	None	None
12	2+6	Nutritional rickets	Genu varum	1+2	1+3	Bracing	Corrected	None	None
13	8+2	Vit. D resistant rickets	Genu varum	1+0	1+1	Bracing	Partial Correction	B/L femoral osteotomy after IR	None
14	4+10	Posttraumatic tibia valga	Genu valgum	1+0	1+0	Closed reduction+cast	Corrected	None	None
15	3+2	Nutritional rickets	Genu varum	0+9	2+5	Bracing	Corrected	None	None
16	3+0	Nutritional rickets	Genu valgum	1+3	1+1	Bracing	Overcorrection	None	None
17	3+6	Arthrogryposis with B/L genu valgum	Genu valgum	2+1	2+11	Bilateral supracondylar femur osteotomy + lat. Closing wedge osteotomy for cavus foot	Corrected	None	None
18	4+0	Nutritional rickets	Genu valgum	1+5	1+2	Bracing	Corrected	Resurgery to replace the backed out plate at 9 month	Loosening of metaphyseal screw and backing out of plate after 9 month
19	3+8	Vit. D resistant rickets	Genu varum	1+2	1+4	Bracing	Corrected	None	None
20	6+1	Metaphyseal chondrodysplasia	Genu varum	1+9	2+4	None	Corrected	None	None
21	5+2	Metaphyseal chondrodysplasia	Genu varum	0+9	1+0	None	Corrected	None	None
22	7+9	Metaphyseal chondrodysplasia	Genu varum	1+4	1+3	None	Corrected	None	None
23	8+2	Congenital short femur syndrome	Genu valgum	1+2	1+9	Lengthening of femur over ilizarov construct 5 years prior	Corrected	None	None
24	6+3	Posttraumatic tibia valga	Genu valgum	1+1	2+2	Closed reduction+cast	Corrected	None	None

F/U=Followup, IR=Implant removal, OR=Open reduction, B/L=Bilateral, DDH=Developmental dysplasia of hip

## Operative procedure

A single plate was applied per physis. Under general anesthesia, tourniquet was applied and a 2 cm incision taken centering over the physis located under a C-arm. A 1.2 mm K wire now passed into the physis under fluoroscopic guidance. Care should be taken to avoid any damage to the physis. The tension band plate (2-hole 4.5 mm titanium plate) now placed extra periosteally and 1.6 mm guide wires introduced into the metaphyseal and the epiphyseal region with care to avoid damaging the periosteum. The plate placed flush to the bone and fixed with 4.5 mm fully threaded self-tapping cannulated screws over the guide wires into the metaphysis and the epiphysis after drilling with a 3.2 mm cannulated drill bit. A gap between the bone and the plate has been known to cause screw breakage.<sup>15</sup> The final placement of the plate and the screws is confirmed under the C-arm in AP and lateral views with the plate being in the center on the lateral view to avoid any iatrogenic sagittal plane deformities. Skin was sutured with nonabsorbable sutures.

Though many centers perform surgery on outpatient department basis, we advise admission to our patients for 1-2 days postoperatively for early ambulation and physiotherapy. On the postoperative day 1, mobilization of the knee was started. Early ambulation was encouraged with weight bearing and the child discharged after satisfactory physiotherapy. Full activity is usually gained in 3-4 weeks. These patients were followed every 3 months with full length standing AP and lateral radiographs. The radiographs were evaluated by measuring the lateral distal femoral angle (LDFA), medial proximal tibial angle (MPTA), mechanical axis deviation and the tibio-femoral angle. The mechanical axis ratio (MAR) was obtained by measuring the distance of the mechanical axis from the midpoint of the proximal tibial epiphysis and dividing it by the width of the proximal tibial epiphysis.<sup>14,16</sup> The MAR would eliminate any discrepancy of magnification on radiographs and aid in standardizing the result. Implant removal was carried out when there was no clinically visible deformity and the mechanical axis corrected to zone 1 or with mild overcorrection.<sup>14,17,18</sup> Statistical analysis employing the paired *t*-test was carried out to assess the MAR and the tibiofemoral angles.  $P < 0.01$  was considered to be significant.

The response of the physis varies with age, the nature of the disease, nutrition and is unpredictable. Following implant removal recurrence of the deformity as a result of the rebound phenomenon is very common and many studies do advocate a mild overcorrection into the opposite zone 1 to compensate for the impending rebound.<sup>9,11,14,16,19-23</sup> After removing the plate, 3 monthly followups were

carried out until 1 year followed by annual followups. If a rebound was detected, 3 months followups were continued until a decision of resurgery taken. We intend to followup these patients until maturity to determine the incidences of premature physeal closure, limb length discrepancy, rebound phenomenon and other complications.

## RESULTS

In all, a total of 24 patients were included in our study. Of which, 11 patients were males and 13 were females. Thirteen of them suffered from genu valgum while the remaining 11 had a genu varum deformity. Sixteen of the children had a bilateral presentation. In all, there were 63 deformities (Femur-34, Tibia-29) in 40 limbs that were operated upon.

The 12 children with Rickets were treated with prior bracing. All of them were given appropriate medical treatment for Rickets, which was continued after surgery. Of the four children with metaphyseal chondrodysplasia, one had undergone bilateral tibial osteotomy. The two cases of posttraumatic tibia valga had received treatment for the fracture in the form of closed reduction and casting. The patient with arthrogryposis had undergone bilateral supracondylar femoral osteotomies for knee fixed flexion deformity and a lateral closing wedge osteotomy for cavus foot. Open reduction of the hip was done for the child with DDH followed by Salter's innominate osteotomy. One patient with a congenital short femur syndrome had undergone lengthening of the femur over an Ilizarov construct 5 years prior.

The average age at surgery was 5 years 3 months (range: 2 years to 9 years 1 month) [Figure 1]. The postimplant removal followup of these patients ranged from 1 to 4 years (mean 21 months). Total followup ranged from 1 year 7 months to 5 years 8 months. The plates were removed after a mean of 15.625 months (range 7-29 months) [Figure 2]. In the genu valgum group, the anatomical tibiofemoral angle improved from a preoperative mean of 19.89° valgus (range 10°-40° valgus) to 5.72° valgus (range 2°-10° valgus) at plate removal. In patients with genu varum the anatomical tibiofemoral angle improved from a mean of 28.27° varus (range 13°-41° varus) to 1.59° valgus (range 0-8° valgus). The MAR improved from a preoperative mean of 0.902-0.177. In the genu valgum group, the MAR improved from 0.753 (range 0.35-1.67) to 0.14 (range 0.01-0.33), while in the genu varum group it changed from 1.02 (range 0.7-1.45) to 0.211 (range 0.05-0.72) both of which were highly significant with  $P < 0.001$  [Tables 2 and 3]. Overall rate of correction was 1.53°/month (below 5 years of age - 1.67°/month, above 5 years of age - 1.39°/month).

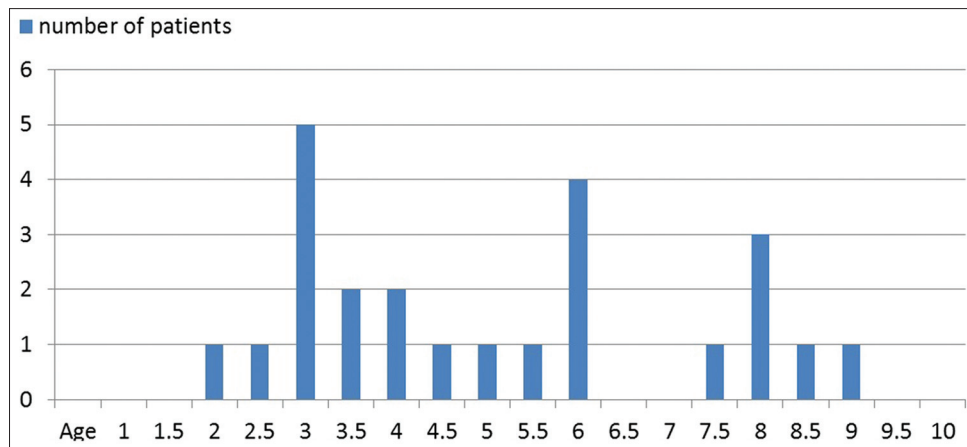


Figure 1: Distribution of age at surgery

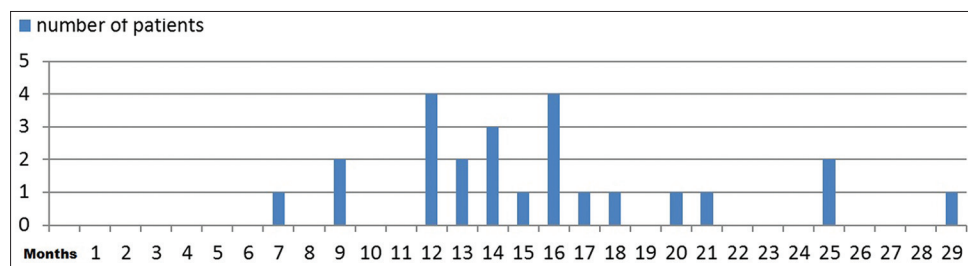


Figure 2: Duration of implantation of the plate to achieve a neutral mechanical axis, mean being 15.6 months

Table 2: Measurements-mechanical axis ratio and tibiofemoral angle

Patient	Mechanical axis ratio				Tibiofemoral angle			
	Right		Left		Right		Left	
	Preop	PostIR	Preop	PostIR	Preop	PostIR	Preop	PostIR
1	0.86	0.35	0.82	0.24	30 (varus)	6 (valgus)	30 (varus)	3 (valgus)
2	0.71	0.215	0.88	0.3	24 (valgus)	6 (valgus)	30 (valgus)	10 (valgus)
3	-	-	0.43	0.01	-	-	18 (valgus)	6 (valgus)
4	-	-	0.59	0.06	-	-	10 (valgus)	4 (valgus)
5	-	-	1.67	0.24	-	-	40 (valgus)	10 (valgus)
6	0.76	0.18	-	-	10 (valgus)	5 (valgus)	-	-
7	1.23	0.3	1.23	0.23	35 (varus)	2 (valgus)	41 (varus)	2 (valgus)
8	0.91	0.06	1.24	0.06	19 (varus)	1 (valgus)	25 (varus)	1 (valgus)
9	0.70	0.24	1.22	0.08	19 (varus)	0 (valgus)	40 (varus)	0
10	0.35	0.05	1.01	0.17	16 (valgus)	9 (valgus)	24 (valgus)	10 (valgus)
11	0.45	0.05	0.52	0.05	20 (valgus)	0 (valgus)	24 (valgus)	2 (valgus)
12	1.22	0.05	1.45	0.1	39 (varus)	2 (valgus)	41 (varus)	0
13	0.82	0.64	0.89	0.72	13 (varus)	0 (valgus)	18 (varus)	0
14	-	-	0.8	0.1	-	-	16 (valgus)	6 (valgus)
15	0.75	0.36	0.76	0.05	26 (varus)	8 (valgus)	24 (varus)	5 (valgus)
16	0.60	0.26 (varus)	0.69	0.33 (varus)	22 (valgus)	2 (varus)	21 (valgus)	2 (varus)
17	0.93	0.06	0.8	0.13	10 (valgus)	6 (valgus)	10 (valgus)	6 (valgus)
18	0.86	0.06	-	-	24 (valgus)	6 (valgus)	-	-
19	0.91	0.06	1.24	0.06	20 (varus)	0	24 (varus)	0
20	0.86	0.35	0.82	0.24	26 (varus)	2 (valgus)	30 (varus)	1 (valgus)
21	0.70	0.24	1.22	0.08	20 (varus)	0	20 (varus)	0
22	1.22	0.05	1.45	0.1	41 (varus)	0	41 (varus)	2 (valgus)
23	0.71	0.07	-	-	19 (valgus)	8 (valgus)	-	-
24	-	-	0.8	0.1	-	-	20 (valgus)	5 (valgus)

IR=Implant removal

All the patients showed improvement in the mechanical axis [Figures 3 and 4]. Twenty one of these patients showed complete correction with the mechanical axis returning into zone 1 or with slight over correction into the opposite zone 1 after a mean of 15.625 months. One case of nutritional Rickets, aged 3 years with a bilateral genu valgum deformity showed over correction to opposite zone 2 in both limbs 15 months after surgery. The preoperative tibiofemoral angle was 22° and 21° for the right and left limbs respectively which progressed to a varus of 2° in both limbs after 15 months. This child had good followup initially but missed followups after 9 months. He reported 6 months later with over correction. The child had no symptoms with

a mild clinical varus deformity and did not require further management.

Two patients showed partial correction. Patient no. 2 was a case of nutritional Rickets with bilateral genu valgum with the mechanical axis progressing to zone 2 bilaterally after a followup of 29 months. The other child, a case of vitamin D resistant Rickets and bilateral Genu varum showed partial correction at 12 months followup with the mechanical axis returning to zone 2 in both limbs with no correction seen in last 2 followups. Both these patients improved to normal values of LDFA and MPTA with the deformity at the knee corrected but with a residual bowing of the tibia and femur respectively, subsequently requiring osteotomies.

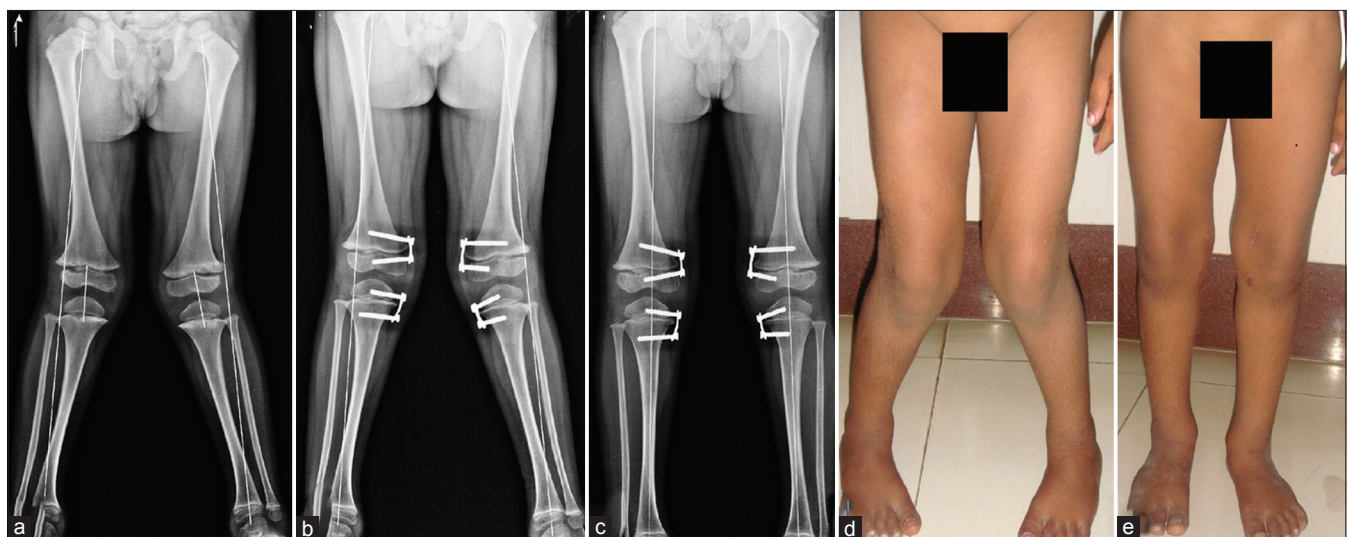
Two cases of screw loosening were observed. One of them developed loosening at the fifth followup at 15 months but had completed the desired correction and did not require further revision. The other child, a 4-year-old boy with vitamin D resistant Rickets and a unilateral valgus deformity developed loosening of the metaphyseal screw with backing out of the plate 9 months after plate insertion. This was revised with longer screws and the deformity corrected completely 8 months later.

No cases of limb length discrepancy were noted. One case of chronic osteomyelitis of the proximal tibia had developed a compensatory valgus deformity at the distal femur with the femoral physis being intact. The distal femur valgus was corrected by tension band plate application. We also carried out simultaneous lengthening and varus correction of the proximal tibia over an Ilizarov construct. The case of congenital short femur had a preoperative shortening

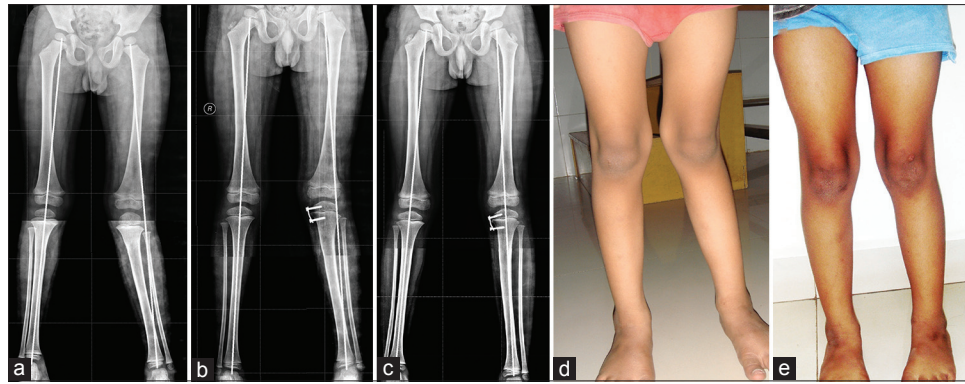
**Table 3: Statistical analysis**

Deformity	Mean	Standard deviation	t	P value	Significance
<b>Mechanical axis ratio</b>					
Varus (n=22)					
Preoperative	1.02	0.25	-9.83	<0.001	Highly significant
Postimplant removal	0.21	0.19			
Valgus (n=18)					
Preoperative	0.75	0.29	-9.40	<0.001	Highly significant
Postimplant removal	0.14	0.10			
<b>Tibiofemoral angle</b>					
Varus (n=22)					
Preoperative	28.27	9.07	-13.27	<0.001	Highly significant
Postimplant removal	1.59	2.20			
Valgus (n=18)					
Preoperative	19.89	7.69	-7.81	<0.001	Highly significant
Postimplant removal	5.72	2.97			

Statistical analysis=Paired t test was used to compare the means of preoperative and postimplant removal results



**Figure 3:** (a) Preoperative radiograph of a 4 year 3 months old case of nutritional rickets and bilateral genu valgum. (b) Postoperative radiograph with plates inserted in bilateral femur and tibia. (c) Neutral mechanical axis 7 months after insertion. (d) Clinical appearance before surgery. (e) Clinical appearance at 7 months after surgery



**Figure 4:** (a) A 4 year 10 months old boy with a posttraumatic tibia valga with mechanical axis in lateral zone 3. (b) Radiograph at 4 months after plate insertion shows the mechanical axis in lateral zone 2. (c) Radiograph at 12 months after plate insertion showing a neutral mechanical axis. (d) Clinical appearance before surgery. (e) Clinical appearance 12 months after surgery following which the plate was removed

of 3 cm which remained unchanged for 21 months after plate removal.

No cases of screw breakage were seen. None of the cases had any signs of infection postoperatively. During the followup, none of the physis suffered from permanent damage or premature physal arrest (longest total followup being 68 months). All the cases resumed growth after implant removal. Two patients (1 Rickets + 1 metaphyseal dysplasia) developed a rebound phenomenon and scheduled for resurgery. Mean time for the rebound was found to be 16.33 months after plate removal. However, a longer followup is required to ascertain the actual incidence of this recurrence. None of the 24 patients developed a sagittal plane deformity until last followup.

## DISCUSSION

From birth to adolescence, there is a continuous change in the tibiofemoral angle at the knee as part of the physiological evolution of limb alignment. A newborn present with a genu varum of up to  $15^\circ$  followed by a neutral mechanical axis by the age of 12-18 months. By the age of 3-4 years, a maximum genu valgum of up to  $12^\circ$  develops, which gradually settles to a  $4-7^\circ$  of valgus during adolescence corresponding to the adult values.<sup>2</sup> However, throughout childhood the mechanical axis remains in the central half of the knee joint (zones +1 and -1 around the midline) in normal subjects despite the above mentioned variations.<sup>24</sup> This evolution in limb alignment should always be borne in mind especially while treating deformities in the younger age group to prevent any inadvertent surgery on physiological deformities. Thus, patient selection should be carefully done during the physiologic remodeling phase and a physiologic deformity should be ruled out before a decision for surgery is taken. However, one should keep in mind the possibility of overlap of deformities due to the underlying pathology and the normal physiologic process.

As the deformities around the knee progress, gait disturbances arise which are noticed as soon as the child starts walking. A genu valgum of  $>10^\circ$ , leads to a circumducting gait and anterior knee pain.<sup>25</sup> A genu varum would cause a lateral thrust, ligamentous laxity and a waddling gait.<sup>26</sup> These deformities around the knee have been known to cause precocious osteoarthritis often requiring surgery.<sup>27</sup>

Apart from the clinical signs and symptoms, it is important to note the effect of these deformities on the malleable physis. Heuter and Volkmann independently studied the effect of compression and tension forces on the physis and the consequent bone remodeling and growth.<sup>28-30</sup> Excessive and sustained forces on the epiphysis, exert pressure on the mechanotransducer chondrocytes, inhibiting the growth of the physis. Thus, a deformity would undergo progression until the eccentric loading of weight exists on the physis further exacerbating the gait disturbance, pain and ultimately leading to functional disability. Going by the Heuter-Volkmann principle one should be correcting these deformities at the earliest.

However, traditionally, most authors advocate delaying surgery, i.e., temporary hemiepiphysiodesis until 8-10 years of age due to concerns of permanent physal damage.<sup>11-14,20,31,32</sup> The factors supporting this thought are a young malleable physis, a pathologically compromised physis and the implants used in hemiepiphysiodesis.

Patients with a pathologic physis (also known as sick physis) including conditions such as Rickets, skeletal dysplasias etc., were also until recently excluded from the purview of temporary hemiepiphysiodesis. The governing ideology was the already compromised physis may not tolerate direct surgical manipulation with the likelihood of a permanent physal arrest and irreversible damage.<sup>20</sup> In the year 2008 Stevens and Klatt published a retrospective review of 14 patients with a pathological physis undergoing temporary

hemiepiphyodesis.<sup>20</sup> They showed improvement in not only the limb alignment but also the pathological state of the physis. The explanation being, by eliminating the eccentric loading of the already compromised physis, the recovery occurs faster. They advocated that in due course of time, the pathology at the knees and the malaligned limbs would affect the hips and ankles as well. These patients would later need surgery for the consequent deformities at the ankle and hips as well.<sup>33</sup> As the mechanical axis corrected, there was an improvement in appearance and width of not only the physis at the knees but at the hip and ankle as well. Thus, the current trend is to perform a temporary hemiepiphyodesis at an early age to prevent deterioration of not only the knees but the surrounding joints as well. Studies by Novais and Stevens and Boero *et al.* show safe implementation of temporary hemiepiphyodesis in pathologic physis with the preferred implant being a tension band plate and screw construct.<sup>26,34</sup> However, the rate of correction seen in a pathologic physis would be slower than an idiopathic deformity owing to the slower growth rate in these physis.<sup>26</sup> Our cases corrected at an average rate of 1.53°/month.

Staples have been a popular implant in performing temporary hemiepiphyodesis around the knee since their introduction by Blount and Clarke in 1949.<sup>11,13,35-42</sup> Staples work by introducing a rigid fulcrum within the physis. This rigid fulcrum brings about compression of the physis and retards growth in that portion of the physis. Prolonged presence of such a rigid implant around the physis carried the concern of bringing about permanent physal closure.<sup>2,11-13,31</sup> In order to avoid such a permanent damage to the physis, temporary hemiepiphyodesis was not advocated in preadolescent children.

Studies regarding the mechanical and biological responses of the physis to compression, have shown chondrogenesis and provisional calcification to come to a standstill following staple insertion.<sup>43-47</sup> Biopsy specimens have shown disorganized cell columns and metaphyseal tongues of disorganized cartilage and biochemical alteration by radioimmunoassay in presence of staples.<sup>34</sup> However all these changes caused by stapling seem to be reversible in nature.<sup>12,43,45-47</sup> And most studies advocate removal of these staples within 24 months to resume growth of the physis.<sup>14,39,44</sup> Prolonged retention of these staples beyond the stipulated time would raise the chances of physal damage.

In an article in 1996, Mielke and Stevens have reported a series of 25 patients younger than 10 years who underwent temporary hemiepiphyodesis.<sup>14</sup> The mean age at time of surgery was 6 years and 4 months (ranging from 3 years 6 months to 9 years 11 months). They showed improvement in every case with no instances of a permanent physal closure or a limb length discrepancy. One staple backed

out and one broke while implant removal. However, staples though effective have a number of complications including breakage, extrusion, migration and malposition.<sup>20,35,48</sup> There have been reports of inadvertent permanent hemiepiphyodesis.<sup>49,50</sup> Migration of these staples increase the frequency of repeat surgery especially in younger patients.<sup>19</sup> The prongs of the staples being smooth allow easy extrusion and migration in a predominantly unossified bone in younger patients. In 1998, Métaizeau *et al.* introduced transphyseal screws to retard growth on one side of the physis.<sup>9</sup> This method however has concern of irreversible and complete growth arrest as the transphyseal screws traverse the physis.<sup>51</sup>

The concept of the tension band plate with two nonlocking screws to bring about temporary hemiepiphyodesis was introduced by Stevens in 2007 in lieu of the complications of staples. These plates have their center of rotation outside the physis and as the physis grows the screws toggle in the plate and pivot in the bone bringing about gradual correction.<sup>19,31</sup> Thus, unlike the staples which bracket the physis this system of plate and screws does not compress the physis<sup>52</sup> reducing the concern of permanent physal damage.<sup>14,20,34</sup> Stevens stated that this system brought about a more rapid correction than staples.<sup>19</sup> Stevens and Klatt in 2008 reported a lower complication rate than with staples.<sup>20</sup> Several studies have shown a favorable result with the use of this technique.<sup>19,20,31,52-54</sup>

In contrast, several comparative studies between hemiepiphyseal stapling and tension band plate hemiepiphyodesis have shown no significant difference in the rate of deformity correction.<sup>52,55-57</sup> The complication rates too have been reported to be the same.<sup>52,57</sup> A recent randomized clinical trial by Gottlieb *et al.* also found no difference in treatment times in patients inserted with either the tension band plate or the staple.<sup>58</sup> With regards to surgery time, Jelinek *et al.* noted that the time required for either insertion or removal of the tension band plate to be significantly shorter than staples.<sup>57</sup> Furthermore, the insertion of the tension band plate is far more precise and controlled preventing any accidental insertion of the screws in the physis.<sup>52</sup> This scenario is important in cases of skeletal dysplasias due to the altered anatomy in the epiphyseometaphyseal region. Several studies now advocate using this system safely in younger patients with a pathological physis.<sup>26,31,34</sup> In our study, we applied the tension band plate to patients as young as 2 years with no cases of a permanent physal closure or limb length discrepancy with improvement in every case. We had a success rate of 91.66%, similar to that of other studies.<sup>19,20,31,52</sup>

One concern of these plates is the breakage of the metaphyseal screw. Burghardt *et al.* reviewed 65 patients



with a mechanical failure of this system.<sup>15</sup> In all these cases, the screws had broken and not the plate. Nearly 93% of these patients were either obese, overweight or morbidly obese (according to NIH). Schroerlucke *et al.* in their study have reported breakage of the metaphyseal screws in 8 of the 31 patients operated upon all of which suffered from Blounts disease.<sup>54</sup> Until date, implant failure has only been reported in patients of Blounts which is rare in India.<sup>5</sup> None of the patients we operated upon were obese and none of them suffered from screw breakage or implant failure. We propose that this system is well suited for the Indian children. In cases of obesity, it is suggested to use two parallel such tension band plates with solid screws to minimize breakage.<sup>15</sup>

Cases of staple migration have been reported in the past but none for the tension band plate until Oda and Thacker in 2011 reported a case in which a tension band plate applied to the anterior distal tibia was pulled through the physis leading to the creation of an anterior physeal bar in a 9-year-old female.<sup>48</sup> However, this is an isolated case and no such other cases have been reported. Placing the screws equidistant from the physis would prevent such an occurrence.

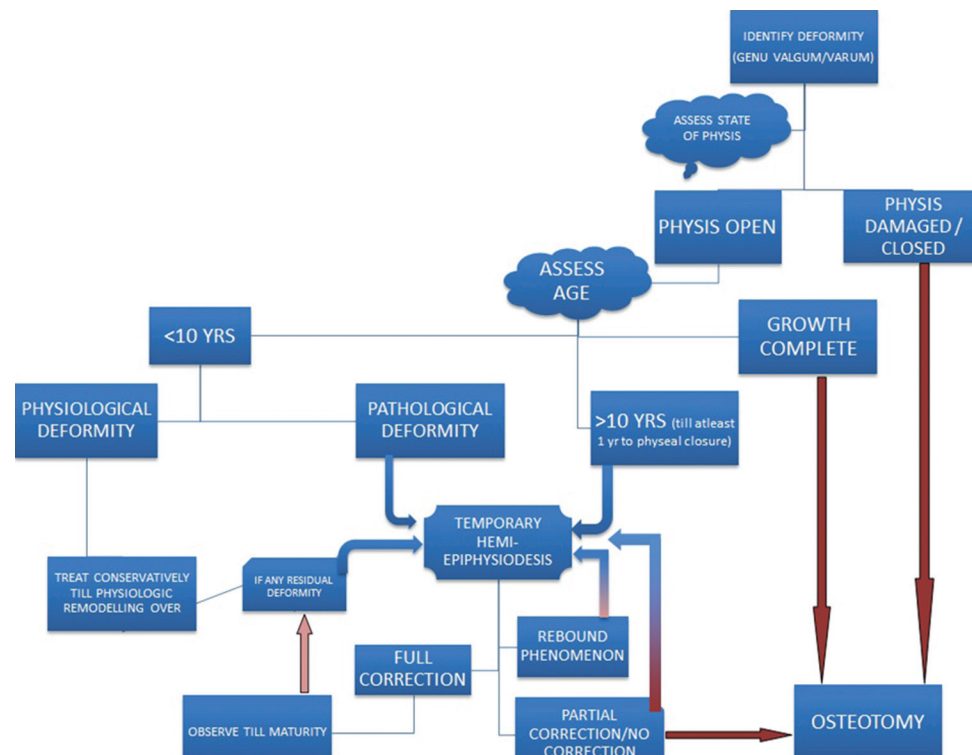
Ambiguity still persists regarding the timing of implant removal. Early removal would lead to undercorrection while delaying it would cause overcorrection. One should also bear in mind the rebound phenomenon seen following plate removal. Thus, most studies advocate an overcorrection

of 5° to take into account the rebound phenomenon. Two of our patients suffered the rebound phenomenon after an average of 16.33 months and required repeat surgery. Thus, the response of the physis may be unpredictable at times and with the possibility of under correction and rebound phenomenon, one may have to repeat this procedure multiple times to maintain a neutral mechanical axis in the growing child. Temporary hemiepiphysiodesis being minimally invasive, it is the least morbid option in correcting angular deformities around the knees and can be repeated as required. It has thus become safer to guide growth in younger preadolescent patients with the advent of the tension band plate [Figure 5].

Finally, an important aspect is counseling of the parents. Compliance may be a problem as no immediate result is obtained following surgery. Parents should be counseled regarding the gradual nature of deformity correction and that it may take as long as 1.5-2 years for the deformity to correct. Followup at regular intervals, preferably every 3 months is advised to prevent overcorrection and early detection of any complication.

### CONCLUSION

Temporary hemiepiphysiodesis through application of the tension band plate is an effective method to correct coronal plane deformities around the knee with minimal complications. Its ease and accuracy of insertion has



**Figure 5:** Guide to guided growth - flow chart depicting the guidelines for temporary hemiepiphysiodesis

extended the indication of temporary hemiepiphysiodesis to patients younger than 10 years and across a wide variety of diagnosis including pathological physis which were traditionally out of purview of guided growth. It carries a reduced risk of physeal damage when compared to other implants and the procedure can safely be repeated in cases of rebound with minimal morbidity.

## REFERENCES

1. Wilkins KE. Bowlegs. *Pediatr Clin North Am* 1986;33:1429-38.
2. Salenius P, Vankka E. The development of the tibiofemoral angle in children. *J Bone Joint Surg Am* 1975;57:259-61.
3. Heath CH, Staheli LT. Normal limits of knee angle in white children – Genu varum and genu valgum. *J Pediatr Orthop* 1993;13:259-62.
4. Kling TF Jr, Hensinger RN. Angular and torsional deformities of the lower limbs in children. *Clin Orthop Relat Res* 1983;176:136-47.
5. Kulkarni GS. Angular deformities in lower limb in children. In: Kulkarni GS, editor. *Text Book of Orthopedics and Trauma*. 2<sup>nd</sup> ed. New Delhi: Jaypee Publishers; 2008. p. 3650-7.
6. Mycoskie P. Complication of osteotomies about the knee in children. *Orthopedics* 1981;4:1005-15.
7. Steel HH, Sandrow RE, Sullivan PD. Complications of tibial osteotomy in children for genu varum or valgum. Evidence that neurological changes are due to ischemia. *J Bone Joint Surg Am* 1971;53:1629-35.
8. Masse P, Zreik H. Can one determine the age at which epiphysiodesis should be performed in the treatment of genu valgum in the adolescent? *Rev Chir Orthop Reparatrice Appar Mot* 1985;71:319-25.
9. Métaizeau JP, Wong-Chung J, Bertrand H, Pasquier P. Percutaneous epiphysiodesis using transphyseal screws (PETS). *J Pediatr Orthop* 1998;18:363-9.
10. Rubinovitch M, Said SE, Glorieux FH, Cruess RL, Rogala E. Principles and results of corrective lower limb osteotomies for patients with vitamin D-resistant hypophosphatemic rickets. *Clin Orthop Relat Res* 1988;237:264-70.
11. Zuege RC, Kempken TG, Blount WP. Epiphyseal stapling for angular deformity at the knee. *J Bone Joint Surg Am* 1979;61:320-9.
12. Bylski-Austrow DI, Wall EJ, Rupert MP, Roy DR, Crawford AH. Growth plate forces in the adolescent human knee: A radiographic and mechanical study of epiphyseal staples. *J Pediatr Orthop* 2001;21:817-23.
13. Frantz CH. Epiphyseal stapling: A comprehensive review. *Clin Orthop Relat Res* 1971;77:149-57.
14. 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.
15. Burghardt RD, Specht SC, Herzenberg JE. Mechanical failures of eight-plate-guided growth system for temporary hemiepiphysiodesis. *J Pediatr Orthop* 2010;30:594-7.
16. Cho TJ, Choi IH, Chung CY, Yoo WJ, Park MS, Lee DY. Hemiepiphyseal stapling for angular deformity correction around the knee joint in children with multiple epiphyseal dysplasia. *J Pediatr Orthop* 2009;29:52-6.
17. Stevens PM, Pease F. Hemiepiphysiodesis for posttraumatic tibial valgus. *J Pediatr Orthop* 2006;26:385-92.
18. Muller K, Muller-Farber J. Indications, localization and planning osteotomies about the knee. In: Hierholzer G, Muller K, editors. *Corrective Osteotomies of The Lower Extremity After Trauma*. Berlin: Springer-Verlag; 1984. p. 195-223.
19. Stevens PM. Guided growth for angular correction: A preliminary series using a tension band plate. *J Pediatr Orthop* 2007;27:253-9.
20. Stevens PM, Klatt JB. Guided growth for pathological physes: Radiographic improvement during realignment. *J Pediatr Orthop* 2008;28:632-9.
21. Inan M, Chan G, Bowen JR. Correction of angular deformities of the knee by percutaneous hemiepiphysiodesis. *Clin Orthop Relat Res* 2007;456:164-9.
22. Nouth F, Kuo LA. Percutaneous epiphysiodesis using transphyseal screws (PETS): Prospective case study and review. *J Pediatr Orthop* 2004;24:721-5.
23. Stevens PM, Maguire M, Dales MD, Robins AJ. Physeal stapling for idiopathic genu valgum. *J Pediatr Orthop* 1999;19:645-9.
24. Sabharwal S, Zhao C, Edgar M. Lower limb alignment in children: Reference values based on a full-length standing radiograph. *J Pediatr Orthop* 2008;28:740-6.
25. Fabry G, MacEwen GD, Shands AR Jr. Torsion of the femur. A followup study in normal and abnormal conditions. *J Bone Joint Surg Am* 1973;55:1726-38.
26. Boero S, Michelis MB, Riganti S. Use of the eight-Plate for angular correction of knee deformities due to idiopathic and pathologic physis: Initiating treatment according to etiology. *J Child Orthop* 2011;5:209-16.
27. Janakiraman N, Teichtahl AJ, Wluka AE, Ding C, Jones G, Davis SR, *et al.* Static knee alignment is associated with the risk of unicompartmental knee cartilage defects. *J Orthop Res* 2008;26:225-30.
28. Willy C, Schneider P, Engelhardt M, Hargens AR, Mubarak SJ, Richard von Volkmann: Surgeon and Renaissance man. *Clin Orthop Relat Res* 2008;466:500-6.
29. Heuter C. Anatomische studien an den extremitätengelenken neugeborener und erwachsener. *Virchows Arch* 1862;25:572-99.
30. Volkmann R. Die Krankheiten der Bewegungsorgane. In: Pitha, Billroth, editors. *Handbuch Der Allgemeinen Und Speziellen Chirurgie*. Bd 2. Abt A, S.694. Stuttgart: Ferdinand Enke; 1869.
31. Burghardt RD, Herzenberg JE, Standard SC, Paley D. Temporary hemiepiphyseal arrest using a screw and plate device to treat knee and ankle deformities in children: A preliminary report. *J Child Orthop* 2008;2:187-97.
32. Farnum CE, Nixon A, Lee AO, Kwan DT, Belanger L, Wilsman NJ. Quantitative three-dimensional analysis of chondrocytic kinetic responses to short-term stapling of the rat proximal tibial growth plate. *Cells Tissues Organs* 2000;167:247-58.
33. Carroll K, Coleman S, Stevens PM. Coxa vara: Surgical outcomes of valgus osteotomies. *J Pediatr Orthop* 1997;17:220-4.
34. Novais E, Stevens PM. Hypophosphatemic rickets: The role of hemiepiphysiodesis. *J Pediatr Orthop* 2006;26:238-44.
35. Blount WP, Clarke GR. Control of bone growth by epiphyseal stapling; A preliminary report. *J Bone Joint Surg Am* 1949;31A:464-78.
36. Blount WP. A mature look at epiphyseal stapling. *Clin Orthop Relat Res* 1971;77:158-63.
37. Blount WP, Clarke GR. The classic. Control of bone growth by epiphyseal stapling. A preliminary report. *Journal of Bone and Joint Surgery*, July, 1949. *Clin Orthop Relat Res* 1971;77:4-17.
38. Canale ST, Russell TA, Holcomb RL. Percutaneous epiphysiodesis: Experimental study and preliminary clinical results. *J Pediatr Orthop* 1986;6:150-6.

39. Goff CW. Histologic arrangements from biopsies of epiphyseal plates of children before and after stapling. Correlated with roentgenographic studies. *Am J Orthop* 1967;9:87-9.
40. Howorth B. Knock knees. With special reference to the stapling operation. *Clin Orthop Relat Res* 1971;77:233-46.
41. Piorier H. Epiphysial stapling and leg equalisation. *J Bone Joint Surg Br* 1968;50:61-9.
42. Stevens P. Double osteotomy for lower extremity alignment. *Surg Rounds Orthop* 1988;2:35-9.
43. Haas SL. Retardation of bone growth by a wire loop. *J Bone Joint Surg* 1945;27:25-36.
44. Christensen N. Growth arrest by stapling. *Acta Orthop Scand* 1973;151:1-75.
45. Ehrlich MG, Mankin HJ, Treadwell BV. Biochemical and physiological events during closure of the stapled distal femoral epiphyseal plate in rats. *J Bone Joint Surg Am* 1972;54:309-22.
46. Hall-Craggs EC, Lawrence CA. The effect of epiphysial stapling on growth in length of the rabbits tibia and femur. *J Bone Joint Surg Br* 1969;51:359-65.
47. Herwig J, Schmidt A, Matthiab HH, Kleemann H, Buddecke E. Biochemical events during stapling of the proximal tibial epiphyseal plate in pigs. *Clin Orthop Relat Res* 1987;218:283-9.
48. Oda JE, Thacker MM. Distal tibial physeal bridge: A complication from a tension band plate and screw construct. Report of a case. *J Pediatr Orthop B* 2013;22:259-63.
49. May VR Jr, Clements EL. Epiphyseal stapling: With special reference to complications. *South Med J* 1965;58:1203-7.
50. Skyttä E, Savolainen A, Kautiainen H, Lehtinen J, Belt EA. Treatment of leg length discrepancy with temporary epiphyseal stapling in children with juvenile idiopathic arthritis during 1957-99. *J Pediatr Orthop* 2003;23:378-80.
51. 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.
52. Wiemann JM 4<sup>th</sup>, Tryon C, Szalay EA. Physeal stapling versus 8-plate hemiepiphysiodesis for guided correction of angular deformity about the knee. *J Pediatr Orthop* 2009;29:481-5.
53. Ballal MS, Bruce CE, 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;92:273-6.
54. Schroerlucke S, Bertrand S, Clapp J, Bundy J, Gregg FO. Failure of Orthofix eight-Plate for the treatment of Blount disease. *J Pediatr Orthop* 2009;29:57-60.
55. Burghardt RD, Herzenberg JE. Temporary hemiepiphysiodesis with the eight-Plate for angular deformities: Midterm results. *J Orthop Sci* 2010;15:699-704.
56. Niethard M, Deja M, Rogalski M. Correction of angular deformity of the knee in growing children by temporary hemiepiphysiodesis using the eight-plate. *Z Orthop Unfall* 2010;148:215-21.
57. Jelinek EM, Bittersohl B, Martiny F, Scharfstädt A, Krauspe R, Westhoff B. The 8-plate versus physeal stapling for temporary hemiepiphysiodesis correcting genu valgum and genu varum: A retrospective analysis of thirty five patients. *Int Orthop* 2012;36:599-605.
58. Gottliebsen M, Rahbek O, Hvid I, Davidsen M, Hellfritzschi MB, Møller-Madsen B. Hemiepiphysiodesis: Similar treatment time for tension-band plating and for stapling: A randomized clinical trial on guided growth for idiopathic genu valgum. *Acta Orthop* 2013;84:202-6.

**How to cite this article:** Kulkarni RM, Ilyas Rushnawala FM, Kulkarni GS, Negandhi R, Kulkarni MG, Kulkarni SG. Correction of coronal plane deformities around the knee using a tension band plate in children younger than 10 years. *Indian J Orthop* 2015;49:208-18.

**Source of Support:** Nil, **Conflict of Interest:** None.