OUTCOME OF GROWTH MODULATION USING THE TENSION BAND PRINCIPLE OF 8 PLATE FOR PAEDIATRIC GENU VALGUM DEFORMITY

Ravi Teja Boddapalli[1], Mahendra Solanki[2], Anand Ajmera[3]

[1]Junior Resident, Department of Orthopaedics, MGM Medical College and MY Hospital, Indore, Madhya Pradesh.
[2]Associate Professor, Department of Orthopaedics, MGM Medical College and MY Hospital, Indore, Madhya Pradesh.
[3]Professor, Department of Orthopaedics, MGM Medical College and MY Hospital, Indore, Madhya Pradesh.

ABSTRACT

BACKGROUND

Osteotomies have traditionally been the mainstay of treating deformities not only in adults but also in children. Osteotomies involve extensive soft tissue dissection, complications of wound closure, infection, delayed union, malunion, and prolonged immobilization, which increase the morbidity of the patients. Depending upon the aetiology, recurrent deformity may lead to need for repeat osteotomy. While osteotomy is necessary for rotational correction and limb lengthening, angular correction may be achieved by other means. Several techniques of epiphyseal growth modulation have evolved, enabling gradual correction of angular deformities and/or length equalization through guided growth. Dallas Phemister introduced the concept of open epiphysiodesis which had the risk of permanent arrest of the physis. Walter Blount gave the idea of staples, but were susceptible to migration, bending and loosening. Permanent physeal closure might ensue with staples. Transphyseal screws by Metaizeau had a major risk of intra-articular perforation and also violated the physis. The 8-plate method of guided growth provides a tension band that expedites angular correction compared to stapling and transphyseal screws which rely upon the principle of compression.

METHODS

The study design was prospective and interventional. The parameters measured and documented were:

1. Tibio femoral angle
2. Lateral distal femoral angle
3. Medial proximal tibial angle
4. Mechanical axis zone

These parameters were collected at each follow up until the deformity was corrected. Data was analysed statistically. A paired t-test was applied to compare the pre-operative tibio-femoral angles, and the tibio-femoral angles at various durations of follow-up.

RESULTS

Eighteen patients were included in the study. They were evaluated by the alignment of tibio-femoral axis at each post-operative visit. The mean pre-operative and the mean post-operative tibio-femoral axes alignment was subjected to a paired t-test**.** The final outcome was taken at an angle of zero degrees between both axes. We observed a t-value of 7.23, which corresponds to a p-value of 0.02 which is significant i.e., less than 0.05.

CONCLUSION

8-plate hemi-epiphysiodesis is an effective means for correcting genu valgum deformities in skeletally immature patients. It is minimally invasive, and there is no permanent damage to the bone. It is a modular, diverse and a reversible procedure which accommodates the dynamic and ever-changing physis while promoting angular correction. The outlook for guided growth looks very promising, but as with all the new techniques, the results have to be evaluated carefully and the indications refined.

HOW TO CITE THIS ARTICLE: Boddapalli RT, Solanki M, Ajmera A. Outcome of growth modulation using the tension band principle of 8 plate for paediatric genu valgum deformity. J. Evid. Based Med. Healthc. 2019; 6(15), 1198-1202. DOI: 10.18410/jebmh/2019/249

Financial or Other, Competing Interest: None.
Submission 19-03-2019, Peer Review 26-03-2019,
Acceptance 10-04-2019, Published 15-04-2019.
Corresponding Author:
Dr. Mahendra Solanki,
Associate Professor, Department of Orthopaedics,
MGM Medical College and MY Hospital,
Indore, Madhya Pradesh.
E-mail: drmahendrasolanki@gmail.com
DOI: 10.18410/jebmh/2019/249

BACKGROUND

The 8-plate introduced by Dr. Peter M Stevens involving the application of an extra-periosteal tension band to a given physis proved to be a versatile solution for a variety of deformities. The hinge action of the growth plate avoids the compression of the growth plate. The plates allow a divergence of up to 45° and along with the flexibility of the plate, the chances of screw bending, or breakage are minimal. Sustained pressure over the epiphysis inhibits the chondrocytes, inhibiting the growth of the physis.

Aim and Objectives

To investigate the clinical and biomechanical effects of growth modulation in paediatric patients undergoing correction of angular deformities of the knee.

To assess outcome of growth modulation by eight plate for paediatric angular knee deformities.

To assess the possible complications associated with this technique and their management.

METHODS

The study was carried out in the Department of Orthopaedics and Traumatology, Mahatma Gandhi Memorial Medical College and Maharaja Yashwantrao Hospital, Indore.

The study was prospective in design and of interventional type that included cases that underwent growth modulation surgery using 8-plate for angular deformities of the knee joint from August 2014 to August 2016.

After complete clinical examination and investigation all the patients who fulfilled the inclusion criteria were subjected to radiological investigation. Full length standing radiographs were taken from the pelvis down to the ankle joint with the patella facing forwards. Lateral radiographs were also taken to rule out any deformities in the sagittal plane. Patellar (skyline) views were also taken to see if there is any associated subluxation/dislocation of the patella which can also be treated at the same time as application of the growth plate. Photographs of the patient were taken in standing position from the front and also from the sides. The flexion test was also performed to see if the majority of the deformity was present in the tibia or the femur.

Definitions

Mechanical Axis of The Lower Extremity (MA-LE)

A line in the AP plane that begins at the center of the femoral head, passes through the center of the knee and continues to the center of the ankle (Figure 1). This line is often referred to as the mechanical axis of the lower extremity (MA-LE). If the line passes medially to the knee center, a varus deformity is present; if the line passes laterally to the knee center or center of the distal femur, a valgus deformity exists.

Mechanical Axis of The Femur (MAF)

A line from the center of the femoral head to the center of the distal femur or center of the knee

Femoral Shaft Axis (FShA)

A line drawn from the center of the proximal femur to the center of the distal femur or center of the knee, indicating the overall position of the femoral shaft (Figure 1).

Tibial Shaft Axis (TShA) and Mechanical Axis of The Tibia (MAT)

It is a line extending from the center of the proximal tibia to the center of the ankle (Figure 1).

Mechanical Tibio-Femoral Angle (Or Mechanical Axis Deviation)

The angle formed when the line that forms the mechanical axis of the femur is extended through the distal femur to form an angle between the mechanical axis of the femur and the tibial shaft axis, this angle is represented by numbers that supplement the normal angle of alignment (e.g., 3°, 6°, etc.) and indicates the extent of mechanical misalignment or deformity.

Anatomic Tibio-Femoral Angle

The angle formed when the line that forms the femoral shaft axis is extended through the distal femur to form an angle between the femoral shaft axis and the tibial shaft axis (Figure 1). The angle is represented by numbers that supplement the normal angle of alignment (e.g., 3°, 6°, etc.) and indicates the extent of anatomic misalignment or deformity.

Lateral Distal Femoral Angle

The distal femur normally has about 6 degrees of anatomic valgus relative to its shaft, expressed as a lateral distal femoral angle (LDFA) of 84 degrees (Figure 1).

Medial Proximal Tibial Angle

The proximal tibia has 3 degrees of varus relative to its shaft; consequently, the medial proximal tibial angle (MPTA) is 87 degrees (Figure 1).

The Mechanical Axis Zones

The ideal mechanical axis would bisect the knee (0), with medial zone (–1) or lateral zone (+1) being within physiologic range. Medial or lateral zones 2 or 3 would likely manifest symptoms and gait disturbance and thereby warrant surgical intervention (Figure 1).

The parameters measured and documented were

1. Tibio-femoral angle
2. Lateral distal femoral angle
3. Medial proximal tibial angle
4. Mechanical axis zone

These parameters were collected at each follow up until the deformity was corrected. The data was analysed statistically.

A paired t-test was applied to compare the pre-operative tibio-femoral angles and the tibio-femoral angles at various durations of follow-up.

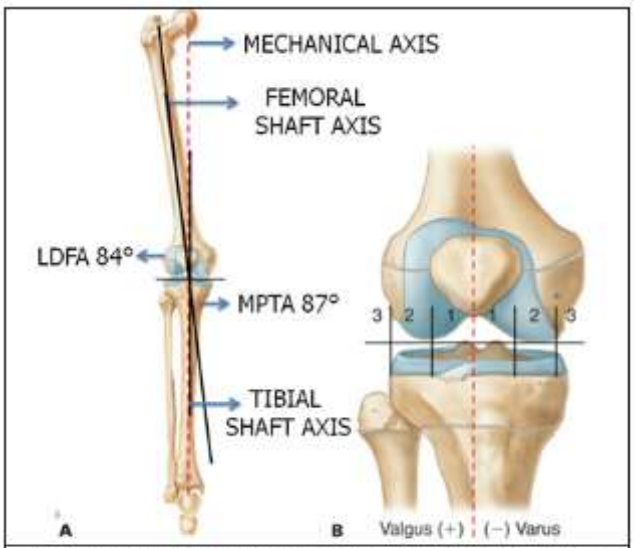

Figure 1. Various Axes and Angles Measured (a); Mechanical Axis Zones (b);

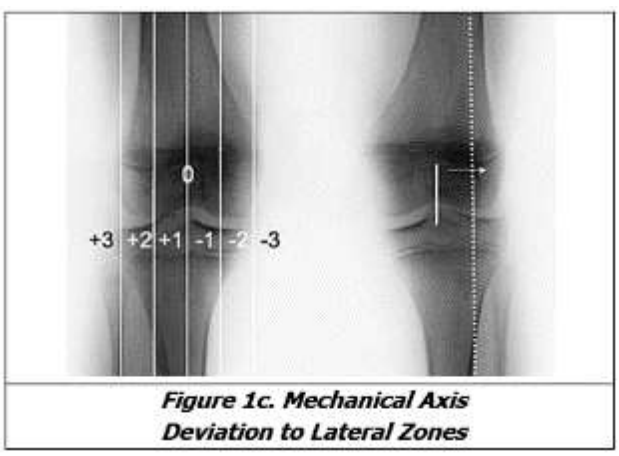

Figure 1c. Mechanical Axis Deviation to Lateral Zones

Surgical Implant

Various sizes of the 8-Plate (2-hole non-locking titanium plate): 12 mm, 14 mm, 16 mm and 20 mm. The 8-plate kit also has sequentially arranged fully and partially threaded 4.5 mm cannulated cancellous titanium screws of different sizes. 3.2-mm cannulated drill bit, a 1.5 mm K-wire and two 1.5 mm guide wires, a screw driver and a drill guide/ sleeve. The cannulated screws are inserted over the guide wires. The k-wire acts a centering wire for temporary fixation. The screws are able to pivot within the 8-Plate (greater than 45 degrees of rotation is possible).

Surgical Technique

The procedure was either performed under spinal anaesthesia or general anaesthesia. Tourniquet was applied and a 1.5 mm k –wire was passed through the physis and the centering was checked on antero-posterior and lateral radiographs under the guidance of image intensifier. A 2 cm incision was given centering over this k-wire. Dissection was carried out without violating the periosteum. The appropriately sized 8-plate was taken and passed over this k-wire through the centering hole and aligned to the shaft of the femur/ tibia. The alignment was checked under the C-arm and two guide wires were passed through the holes in the 8-plate (one in the metaphysis and the other in the epiphysis) parallel to each other. Appropriately sized (about 50% bone width) cannulated cancellous screws were passed over the guide wires and the screws were tightened. The guide wires and the centering k-wire were then removed. The final position of the plate was checked. Wound was irrigated thoroughly, and closure was done with absorbable and non-absorbable sutures.

Post-Operative Care

On the post-operative day 1, mobilization of the knee was started. And the child was discharged after satisfactory physiotherapy. Normal activity was usually regained in 3 to 4 weeks. The patients were followed up at 2 weeks for suture removal and every 3 months with full length standing AP radiographs of the lower limbs. Lateral views were also taken to look for any deformities in the sagittal plane. Divergence of the screws was looked for which confirms that the system is working.

Follow-Up

The minimum follow-up in our study following surgery was 6 months. The radiographs were evaluated by measuring the deviation of the mechanical axis, tibio-femoral angle, lateral distal femoral angle and medial proximal tibial angle. Implant removal was done when there was no clinically visible deformity and the mechanical axis was corrected to zone 1 or with mild over-correction to compensate for rebound deformity if any.

Inclusion Criteria

Age Group: 6 to 15 years.

1. Genu valgum deformity of the knee due to any of the following:
   a. Idiopathic
   b. Post-traumatic
   c. Post-infective
   d. Disorders affecting the growth plate (e.g., Epiphyseal dysplasia, rickets, infection etc.)

Exclusion Criteria

1. Physiological genu valgum: follow-up evaluation at 6-month intervals
2. Any tumor influencing the growth plate
3. Cerebral palsy

RESULTS

A total of 18 patients were included in the study(N=18) out of which 8 were females (44%) and 10 were males (56%). The average age at surgery was 11.61 years with the youngest being 6 years and the oldest being 15 years old. Etiology of majority of the cases was idiopathic (11 patients). There were 5 cases of nutritional rickets, 1 infective and 1 female patient had multiple epiphyseal dysplasia. The mean pre-operative TFA was 19.41° (range: 11° to 43°). The mean pre-operative LDFA was 75.17° (range: 60° to 85°) and the mean pre-operative MPTA was 94.19° (range: 50° to 104°). The rate of correction in completely corrected

deformities overall was 1.515°/ month with the highest being 2.83°/month and the least being 0.67°/month. The rate of correction in patients aged 6 to 10 years was 1.554°/ month and the rate of correction in patients above 10 years was 1.503°/ month (Figure 2, Figure 3, Figure 4). Overcorrection was seen in 1 limb. 4 limbs have had joint stiffness. 1 limb had screw breakage and also developed a rebound deformity after implant removal. Physeal arrest was seen in 2 patients.None of the cases had any signs of infection postoperatively. The mean follow up was 8.13 months.The minimum follow-up being 6 months and a maximum of 15 months. A paired t-test was applied to compare the pre-operative tibio-femoral angles and the tibio-femoral angles at various durations of follow-up (Table-1).

	Mean	SD	SE Mean
TFA (Pre-op)	15.60	3.65	1.63
TFA (12 month follow up)	0.00	6.16	2.76
Difference	15.60	4.83	2.16

Table 1. Comparison Between Pre-Operative TFA and TFA at 12 Month Follow-Up of 15 Patients Attended. t-Value= 7.23

Figure 2. (Patient 5:15 years/ Male) Pre-operative (a1, a2); 3 Month Follow-up (b1, b2); 6 Month Follow-up Showing the Correction in the Alignment of the Limbs with Divergence of Screws (c1, c2).

Figure 3. (Patient 13: 6 Years/ Male) Pre-operative (a); 3 Month Follow-up (b); 6 Month Follow-up (c); 9 Month Follow-up of a 6 Year Old Male Child Showing Complete Correction of the Deformity (d)

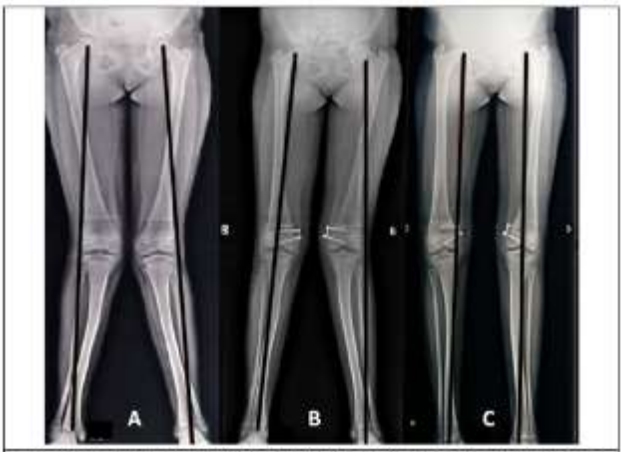

Figure 4. (Patient 15: 13 Years/ Female) Standing AP Radiographs Showing the Deviation of the Mechanical Axes: Pre-operative (a); 6 Month Follow-up (b); 12 Month Follow-up (c)

There was one case of multiple epiphyseal dysplasia. The pre-operative tibio-femoral angle was 16°. It had improved to 11° at 3 month follow-up and at 6 months after surgery the tibio-femoral angle had improved to 5°. No complications have been reported.

DISCUSSION

Heuter and Volkmann studied the effect of compression and tension forces on the physis and the consequent bone remodelling and growth.[1,2] Sustained pressure on the physis inhibit the chondrocytes, inhibiting the growth of the physis. Stevens and Klatt, in 2008 have shown improvement in not only the limb alignment but also the pathological state of the physis. This is due to the elimination of the eccentric loading of the physis thus aiding in faster recovery.[3] Burghardt et al reviewed 65 patients with a mechanical failure of the system. In all the cases, the screws have broken and not the plate.[4] Schroelucke et al in their study reported breakage of the metaphyseal screws in 8 of the 31 patients operated upon all of which suffered from blount's disease which is rare in India.[5] In studies done by Sakti Prasad Das et al and Ruta M Kulkarni the mean pre-operative tibio-femoral angles in patients with genu valgum were 17° and 19.89° respectively.[6,7] At correction, the angles had improved to a mean of 9.56° and 5.72° (Table-2).

	Pre-Operative TFA (Genu Valgum)	TFA When Correction was Achieved (Mechanical Axis of +1/0/-1)
Sakti Prasad Das et al	17°	9.56°
Ruta M Kulkarni	19.89°	5.72°
Present Study	16.1°	4.67°

Table 2. Comparison of Pre-operative TFA and TFA at Correction (Mechanical Axis +1/0/-1) Amongst Indian Studies

In a study conducted by Guzman et al, the TFA had improved from a pre-operative mean of 11.2° to 6° at correction and the mean LDFA improved from a pre-operative mean of 77.5° to 88.14° at correction.[8] In our study, the tibio-femoral angles had improved from 16.1° to 4.67° post-operatively. Mean LDFA had improved from 77.5° pre-operatively to 88.14°at correction. Boero et al observed the correction in patients with pathological physes. In their study the mean TFA improved from 22° pre-operatively to a post-operative mean of 15.9°.[9] In our study it had improved from 15.9° to 3.2°. Dilemma persists when it comes to timing of the implant removal. Most studies have advocated an overcorrection into mechanical axis zone -1 keeping the rebound phenomenon in mind. One of our patients (one limb) suffered rebound phenomenon 3 months after the removal of the 8-plate. The patients have to be followed up even after the implant removal to look for the rebound.

Limitations

Significantly smaller sample size limits statistical conclusions. Paired t-test was applied to the final outcome with deformity corrected to zero excluding over correction. Hence no true p-value could be calculated.

CONCLUSIONS

8-plate hemi-epiphysiodesis is an effective means for correcting genu valgum deformities in skeletally immature patients. It is minimally invasive, and there is no permanent damage to the bone. It is a modular, diverse, and a reversible procedure which accommodates the dynamic and ever-changing physis while promoting angular correction. The outlook for guided growth looks very promising, but as with all the new techniques, the results have to be evaluated carefully and the indications refined. Corrective osteomies hold their position inspite of growth modulation techniques.

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