RESEARCH ARTICLE

Outcomes of Temporary Hemi-Epiphysiodesis Using a New Device for The Treatment of Pediatric Valgus Knee Deformity: A Preliminary Report

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Abstract

Background: This study aimed to evaluate the efficacy of hemi-epiphysiodesis using a new device (X-plate) for the correction of genu valgum.

Methods: In total, 22 children with a total of 34 pathologic knee valgus deformities underwent the procedure and were followed up 25.3 months on average.

Results: The mean time to clinical correction of genu valgum was 10.9±2.2 months. Furthermore, the mean preoperative anatomic Lateral Distal Femoral Angle (aLDFA) and mechanical Tibia Femoral angle (mTFA) were obtained at 75.1±3.8 and 6±2.8 degrees, respectively. When clinical correction of the deformity was achieved, the mean of aLDFA and mTFA corrections were determined at 8.9±5.3 and 6.5±3.2 degrees, respectively. The mean speed of aLDFA and mTFA corrections were estimated at 0.8±0.45 and 0.6±0.3 degrees per month, respectively. The postoperative aLDFA and mTFA were measured at 84±4.2 and -0.8±2.9 on average. With a mean of 25.3±14.5 months at final follow-up, there were 6 (17.6%) mild valgus knees, 26 (75.5%) normal alignment knees, and only 2 (5.9%) mild varus knee within an acceptable clinical limit.

Conclusion: Hemi-epiphysiodesis using X-plate at the distal physis of the femur is an effective and safe method for the treatment of valgus knee deformity in children.

Level of evidence: IV

Keywords: Complication, Deformity, Genu valgum, Temporary hemiepiphysiodesis

Introduction

Genu valgum is one of the most common skeletal anatomic variations referred to pediatric orthopedic surgeons. It is part of the natural evolution, which is called physiologic genu valgum in 2-6-year-old children with a peak at 4 years of age. Valgus alignment decreases toward the physiologic adult alignment of slight valgus, and by age of 7, a child usually reaches the adult lower-extremity alignment (1, 2). Spontaneous correction of the deformity is highly unlikely if the intermalleolar distance (IMD) is more than 10 cm and/or mechanical axis deviation is more than 3 degrees in children older than 10 years (3). Therefore, it is critical to differentiate between a physiologic and pathologic process.

Pathological bilateral genu valgum could also stem from rickets and congenital syndromes, such as multiple epiphyseal dysplasia; however, trauma, infection or vascular insult, proximal metaphyseal tibia fracture, and benign tumors give rise to a unilateral deformity (4, 5). Regardless of the etiology, valgus deformities over 10 degrees can result in anterior knee pain, circumduction gait, as well as occasionally patellofemoral instability, and should be addressed to prevent articular cartilage attrition (2, 5, 6). There is a multitude of options for the correction of angular deformities, and the standard treatment method is osteotomy; however, needed postoperative immobilization, delayed weight-bearing, and potential complications are always worrisome.

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Physeal manipulation or guided growth provides a means for the correction of angular deformity that carries much smaller morbidity, compared to the osteotomy. Temporary hemi-epiphysiodesis has been shown to be a valuable method for the treatment of knee deformities in children (7, 8). So far, three devices have been used in clinical practice, namely staples, transphyseal cannulated screws, and plates (9, 10). The main goal of these methods is to arrest longitudinal growth in the convex side of knee angular deformity (11, 12). The effects of these methods have been evaluated in previous studies. The percutaneous transphyseal cannulated screw is an effective surgical method for correcting both idiopathic and pathologic genu valgum with low rates of complications (2, 9). However, screw tip pulled off epiphysis is probable during the rapid growth phase in short epiphyses, such as proximal tibia. Their off-centric insertion could potentially give rise to sagittal plan deformities, including knee recurvatum. Moreover, the removal of the cannulated screws after achieving enough correction could be troublesome. On the other hand, some authors believe that hemi-epiphysiodesis using staples is a logical means of physeal manipulation highlighting its good results for improving knee deformities (7, 11, 13). However, stapling can cause loss of fixation, permanent iatrogenic physeal arrest, or such hardware complications as breakage or extrusion (14-18). As a newer method, the 8-plate method has been used successfully to correct an angular deformity of the knee in skeletally immature children with lower rates of complication, compared to stapling (4).

Affordable devices, such as reconstruction plates can reproduce similar results; nevertheless, the risk of screw head breakage and loss of correction could be tantamount to the 8-plate method (4). This technique would suffer from a sagittal plane unintentional deformity if inserted off-centric and would theoretically entertain as a single staple. In order to improve the design of the 8-plate method by widening its guided growth area and to decrease the hardware reported complications, an X-like plate has been designed by the senior author (MK) (Tether Plate, patent-holding, Canada) [Figure 1]. This study was conducted to scrutinize the efficacy of hemi-epiphysiodesis using X-plate for the treatment of genu valgum in children.

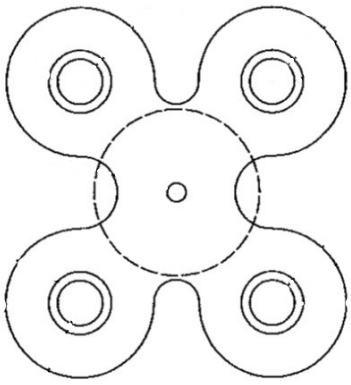

Figure 1. Schematic drawing of an X-plate consisting of four extensions which accommodates 4-solid cancellous screws.

Materials and Methods

This preliminary report describes a prospective consecutive series of 22 children with a mean age of 11.8±1.1 years (age range: 9.2-14 years). They presented with 34 knee valgus deformities, for whom hemi-epiphysiodesis procedure was performed using the X-plate technique. The patients were followed up for 25.3±14.5 months (range: 12-66 months). The inclusion criterion was pathologic genu valgum induced by distal femoral deformity after age 9 (7, 8). The pathologic genu valgum which was considered for the surgery was when the mechanical axis of the lower limb passed behind the mid-point of lateral tibial condyle. On the other hand, the exclusion criteria were pathologic genu valgum due to a proximal tibial deformity, a physeal destructive process (e.g., fracture or infection), and mal-rotation syndromes.

Written informed consent was obtained from all parents at the beginning of the study. In order to obtain parents' informed consent, the options of osteotomy at a later age or hemi-epiphysiodesis using other methods have been offered. The study protocol was approved by the Ethics Committee and the Review Board of Shahid Beheshti University of Medical Sciences, Tehran, Iran (Project No. SBMU.22717). The preoperative workup comprised of the measurement of the body mass index (BMI), IMD, the clinical tibiofemoral angle (cTFA), and rotational deformities. For measuring the IMD and taking standing X-rays, the patients were asked to stand with the knees touched at the medial side with parallel feet (19). Ligamentous laxity and patellar tracking were noted as well. For the evaluation of the cTFA, the anterior superior iliac spine, the center of the patella, and the midpoint of the ankle joint were marked, and the marked points were connected respectively to each other. The measurement was then performed using a goniometer (20). The radiological evaluations were made up of measuring the angle between the mechanical axis of the tibia and femur (mTFA) and anatomic lateral distal femoral metaphyseal angle (aLDFA) on a standard full-length radiograph (21). In valgus deformity, the mechanical axis is displaced laterally. For the older adolescents, a hand film was taken to assess the predicted time of growth remaining. If less than two years were expected, the procedure was not recommended.

Surgical technique

The surgery was performed under general anesthesia. Through a C-arm guided 2-3-cm incision, the medial distal femoral physeal plate was located centrally using a 0.8-mm K-wire under fluoroscopic control [Figure 2]. Subsequently, the X-plate (Nouvimplant, Canada, Medicalex, France) was inserted on the K-wire and fixed with four fully threaded cancellous screws inserted parallel to the physeal line. The length of the screws was about one-third of the physeal diameter on AP X-ray measurement (usually 34mm). Early ambulation

and return to normal activities were encouraged as tolerated. After surgery, each patient was followed every other month by measuring their cTFA.

After full clinical correction of cTFA, a standing radiograph was taken. If the neutralization of the mechanical axis was achieved and the distal femoral physeal plate was still open, the plate and screws were removed [Figuer 3]. Afterward, the patients were followed every six months until the full closure of the physeal plate. The mTFA and aLDFA were measured at clinical correction radiograph and last follow-up radiograph. The statistical analysis was conducted using SPSS (version 22.0; SPSS Inc, Armonk, NJ, USA). Furthermore, the comparison of means between different etiologies of the valgus deformity was performed using analysis of variance. Pearson Correlation was also utilized to evaluate the relationship among different variables.

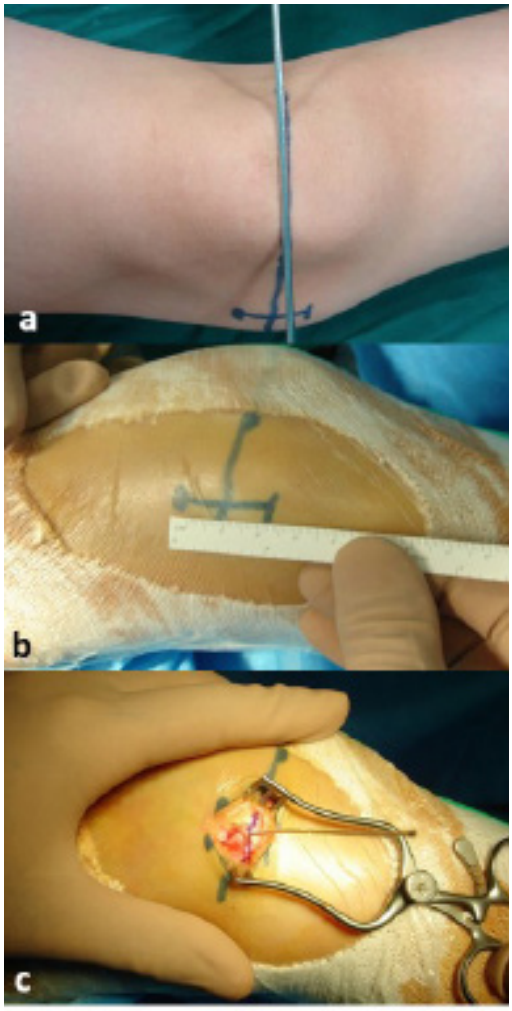

Figure 2. (a and b) The physeal plate was located through a C-arm guided incision, (c) Using a 0.8-mm K-wire to find the central portion of the physis.

Sample t-tests were employed to compare quantitative variables before and after surgery. A p-value less than 0.05 was considered statistically significant.

Results

In total, 9 (40.9%) boys and 13 (59.1%) girls were investigated in this study, and 12 (54.5%) patients had bilateral valgus knees. The etiologies of the valgus deformity were idiopathic (28 knees), multiple epiphyseal dysplasia (2 knees), multiple exostosis (1 knee), sequel of osteomyelitis (1 knee), and Down syndrome (2 knees). The mean BMI was obtained at 22.8±2.7 (range: 20-29), and the mean values of the procedure duration and the incision length were estimated at 22.7±4.9 min (range: 18-34 min) and 24.9±4 mm (range: 20-33 mm), respectively. The mean time to the clinical correction of genu valgum (cTFA 0±2 degrees) was 10.9±2.2 months (range: 6-18 months). At that moment, the plate was removed of 17 (50%) knees. The mean IMD was obtained at 13±2 cm (range: 10-18cm) preoperatively, and this corresponding value was 1.5±1.9 cm (range: 0-6 cm) when clinical correction was achieved. Radiographically, only aLDFA had a significant but weak correlation with IMD (Pearson correlation -0.39, *P=0.02*) pre and postoperatively. The mean of aLDFA was 75.1±3.8 degrees (range: 60-80 degrees) preoperatively [Table 1]. When clinical correction was achieved, there were 10 (29.4%) varus knees and 24 (70.6%) normal or mild valgus knees. At the final follow up, with a mean duration of 25.3±14.5 months (range: 12-66 months), there were 6 (17.6%) mild valgus knees, 26 (75.5%) normal alignment knees, and only 2 (5.9%) mild varus knee, all within an acceptable clinical limit. When clinical correction of the deformity was achieved, the mean of aLDFA correction and mTFA correction were 8.9±5.3 and 6.5±3.2 degrees, respectively. The mean of the IMD correction was obtained at 11.4±2.6 cm. The mean speed of aLDFA and mTFA correction were 0.8±0.45 and 0.6± 0.3 degrees per month. The mean speed of IMD correction was determined at 1.06±0.3 cm per month (range: 0.6-1.8) [Table 1].

There were no statistically significant differences

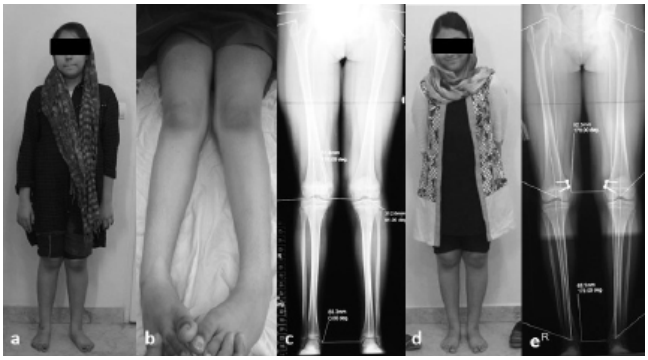

Figure 3. (a and b) Standing and supine picture of genu valgum in a 12-year-old girl, (c) Her standing lower limbs film. (d , e) She was operated using X-plate on both sides; her standing picture and X-rays; after a one-year follow-up, her plate has been removed.

Table 1. Statistic value of the studied variables

	Minimum	Maximum	Mean	Std. Deviation
Preoperative Variables				
Age (years)	9.2	14.0	11.814	1.1328
IMD*	10	18	13.06	2.061
aLDFA**	60	80	75.18	3.873
mTFA***	1	15	5.97	2.845
Variables when clinical correction was achieved				
IMD	0	6	1.52	1.873
aLDFA	77	93	84.09	4.217
mTFA	-7	6	-0.88	2.900
IMD correction	-18.00	-7.00	-11.4677	2.61067
aLDFA correction	2.00	22.00	8.9118	5.32215
mTFA correction	-12.00	-1.00	-6.5000	3.20282
Correction speed of IMD	1.80	0.62	1.0692	0.29005
Correction speed of aLDFA	0.25	2.20	0.8004	0.45527
correction Speed of mTFA	1.11	0.08	0.5941	0.27014

IMD: Intermalleolar Distance, **aLDFA: anatomic Lateral Distal Femoral metaphyseal Angle***mTFA: mechanical Tibio Femoral Angle*

among the various etiologies of genu valgum in terms of the amounts of aLDFA and IMD correction (*P=0.43* and *P=0.44*, respectively). Furthermore, there was a significant correlation between the amount of IMD correction and the age of the patients (r=0.49; *P=02*). However, there was no relationship between BMI and the amount of IMD or aLDFA correction *(P=0.21* and *P=0.45*, respectively). Femoral anteversion before surgery and after the last follow-up examination have not been changed statistically (*P=0.34*). In addition, gender had no significant effect on the mTFA correction (*P=0.32*) and also on the other parameters. In terms of complication, no clinical recurvatum or knee flexion contracture was detected at the last follow-up. There was a superficial infection in one knee (0.3%). Over the follow-up period, one screw head breakage was detected (0.3%); however, it has had no negative effect on the patient results.

Discussion

In this study, X-plate has been only implanted on the medial distal femoral physis to demonstrate consistent guided growth results. Theoretically, the use of 4-solid screws on an X-plate, compared to an 8-plate or a reconstruction plate, can provide more stability and strength. Its hardware complications, such as device dislodgment or screw head breakage, should therefore be lower than other devices. The speed of deformity correction and complication rate are the most important factors to substantiate the efficacy of a surgical method to address knee deformities (7, 9, 10). The valgus correction has been measured using TFA, Hip-Knee-Ankle angle (HKA), and distal femur angle (7, 22, 23). In this study, cTFA, mTFA (equivalent to HKA), and aLDFA were evaluated. Cho et al. measured the correction of valgus deformity using distal femoral angle in children with multiple epiphyseal dysplasia. Owing to the overcorrection or rebound deformity, they indicated that the use of staples for hemi-epiphysiodesis was an unpredictable method. However, the authors concluded that stapling was an effective method for the improvement of knee valgus deformity (22) [Table 2]. Degreef et al. utilized HKA angle to measure valgus deformity. They performed a temporary epiphysiodesis with Blount stapling for the treatment of idiopathic genu valgum in children. They showed no significant correction of genu valgum at the time of staple removal; however, the mean of the valgus deformity was acceptable (50) after bone maturity (23). On the other hand, Boero et al. used an 8-plate method in children with idiopathic genu valgum and pathologic knee deformities. They utilized the plate at the distal end of femur to correct TFA. Their results showed no rebound deformity, no fracture of the plates, and no partial or under-correction in the idiopathic group; however, they experienced a few complications in the pathologic group. They believe that the 8-plate is the best solution for the treatment of pediatric angular deformities. They also noted that the speed of TFA correction was clearly slower in pathologic knee deformities (4). Stewart et al. also reported the epiphysiodesis using the 8-plate method, which was associated with a longer duration of TFA correction (24) [Table 2].

Regarding the efficacy of the X-plate, the mean speed of mTFA correction was 0.6±0.3 degrees per months, which was in line with the results of similar studies. Nevertheless, the mean time to deformity correction was shorter than that in other studies (10.9±2.2 months versus 14.8 months) emphasizing the efficacy of the

Table 2. The comparison of the results of previous similar studies

Authors	Surgical technique	Average TFA[1]correction (degree)	Average time of TFA correction (month)	Average speed of TFA correction (degree per month)	Complications
Stevens et al., 1999 [18]	HE[2] using staples in distal femur for idiopathic GV[3]	9.4	10	0.94	Rebound valgus deformity, residual numbness, superficial wound infection
Degreef et al., 2003 [23] (using HKA[4])	HE using Blount staple for idiopathic GV	1	7	0.15	Rebound or recurrent GV
Mesa et al., 2009 [9]	HE using transphyseal cannulated Screws for GV	7.6± 5.25	20.2	0.73± 0.45	No complication
Cho et al., 2009 [22] (using distal femur angle)	HE using stapling in distal femur for MED[5] induced GV	15.3± 6.4	13.4	0.9± 0.3	Overcorrection, rebound GV
Ballal et al., 2010 [26]	HE using 8-plates in bilateral physis of knee joint for idiopathic GV	11.27	16.1	0.7	Plate and screw migration, deep infection
Guzman et al., 2011 [29]	HE using tension in distal femur for band plates for idiopathic GV	5.4	13.5	0.4	Genu recurvatum
Boero et al., 2011 [4]	HE using 8-plates in bilateral physis of knee joint for idiopathic GV	9± 1.9	11± 4.0	0.6	No complication
Average of previous studies		8.4	14.8	0.6	
Our study	HE using X-plates for idiopathic and pathologic GV	6.5±3.2	10.9± 2.2	0.6± 0.3	Superficial infection, uni-screw head breakage

Data reported are expressed as mean±SD.

1.TFA: tibiofemoral angle, 2. HE: hemiepiphysiodesis, 3. GV: Genu Valgum, 4. HKA: Hip-Knee angle, 5. MED: Multiple Epiphyseal Dysplasia

X-plate in the correction of genu valgum without having had any device dislodgment or bilateral screw head breakage. Tantamount to the results of the previous studies, the mean correction of mTFA in our study was almost comparable (6.5±3.2 degrees versus 8.4 degrees). Our case that was a mixture of idiopathic and pathologic genu valgum might have negatively affected this variable. However, it has not had any pivotal role in our patient's treatment process since it was connected to the required correction [Table 2].

Growth arrest and hardware complications are the two major problems after a surgical correction for knee axis deformities (7, 9 ,11). As far as struggling with hardware complications is concerned, some authors revealed mechanical failure for 8-plate and stapling methods (7, 10, 16, 25, 26). Studies in which staples were used showed more loosening and even damage to growth plates, compared to the 8-plate method (27). In previous studies, controversial results were reported about the complications of the 8-plate method. Some preliminary reports expressed no complications after using plates (4, 28). However, in some others, the authors reported

Figure 4. The X-plate on the left side was unintentionally inserted slightly on the anterior aspect of the physis, compared to his right side; however, the final x-ray after an 11-month follow-up showed no difference in the knee recurvatum bilaterally.

screw migration, deep infection, and recurvatum after using the plates (26, 29). More complications have been reported in recent studies (30-31). Zajonz et al. observed operational complications in up to 2.8% of the cases (wound infection [n=1] and corrective osteotomies [n=3] following the implantation of the 8-plate method [n=198]) (30). In the literature, complication rates (mainly breaking screws) of 6%-16% were reported for 8-plates and reconstruction plates (30-31). In this study, there was a screw head breakage before its removal without having any adverse effect on the results. If it did happen to an 8-plate, in all possibilities, it would seriously affect the results, which could range from under-correction of the deformity to asymmetric correction in bilateral cases.

In the same line, Aslani et al. reported 10% screw breakage of 58 two-hole reconstruction plates employed for hemi-epiphysiodesis. Their hardware broke off was the highest for their genu varum patients with four (40%) screw failures (31). Transphyseal cannulated screw is associated with a low rate of complication (9). The reported complications included broken implants, angulation changes, and revision epiphysiodesis in roughly 4% of the patients. Breakage of implants could occur at 2-3 years post-implantation (32). Despite some mal-placement of the X-plate in a more anterior or posterior position on the physeal plate, there were no sagittal plane abnormalities at final follow-up in this study [Figure 4]. However, there were two residual varus deformities (5%) at the final follow-up, which were not clinically significant; accordingly, no correction osteotomy has been offered. It could highlight the efficacy and lower complication rates of X-plate. Nevertheless, a longer follow-up of the cases will be required to determine the final results of the X-plate. It has a wider area of guided growth, compared to an 8-plate method, and potentially works as 3 to 4 staples. It provides four extensions, which make it a safer implant in terms of sagittal plane abnormalities when the device is inserted out of the center of physeal plate [Figure 4]. The results of our study indicated that the use of X-plates in temporary hemi-epiphysiodesis is effective for the correction of TFA with a lower rate of complications.

Although this study reported the results of an implant in a consistent knee deformity, other confounding variables might have influenced the results, such as the etiology of genu valgum and follow-up duration. The patients should have been followed for a longer time to substantiate residual deformities, which might need an osteotomy. Additionally, a randomized clinical study should be conducted to utilize various types of hemi-epiphysiodesis devices to validate their efficacy and complication rates. This may eliminate the possible bias pertaining to the different surgeons' skills and variations in the quality of corrective instruments (e.g., screws, staples, and plates).

In conclusion, temporary hemi-epiphysiodesis using an X-plate at the distal physis of the femur is an effective and safe method for the treatment of a valgus knee deformity in children. Longer follow-up and a randomized clinical study could throw light on the differences among various hardware utilized in hemi-epiphysiodesis.

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Contribution of authors: AE wrote the manuscript, SK performed the surgical procedure on some patients, MT and RA collected data and all measurements have been conducted by them, MK designed the implant and did most of the surgeries.

Conflict of interest: There is no conflict of interest regarding the publication of this study.

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