88408_Auto_Edited.docx

WORD COUNT 5708
TIME SUBMITTED 06-DEC-2023 03:57PM
PAPER ID 105111949

Name of Journal: *World Journal of Orthopedics*
Manuscript NO: 88408
Manuscript Type: MINIREVIEWS

Effective time, correction speed and termination time of hemi-epiphysiodesis in children

Jianfa Zeng, Yuyin Xie, Can Liu, Zhen-Qi Song, Zheng Xu, Zhong-Wen Tang, Jie Wen, Sheng Xiao

Abstract

In children with asymmetric growth on the medial and lateral side of limbs, if there still remains growth potential, the guided growth technique of hemi-epiphysiodesis on one side of the epiphysis is recognized as a safe and effective method. However, when the hemi-epiphysiodesis start to correct the deformities, how many degrees could hemi-epiphysiodesis bring every month and when to remove the hemi-epiphysiodesis implant without rebound phenomenon are still on debate. This article reviews the current studies focus on the effective time, correction speed and termination time of hemi-epiphysiodesis.

INTRODUCTION

Epiphysiodesis is an effective treatment for limb deformity in children with growth potential[1-6]. At present, there are two main methods for epiphysiodesis in children with limb deformity. One is permanent epiphysiodesis. Percutaneous epiphysiodesis trans-epiphyseal screws (PETS) were proposed by Metaizeau *et al* [1] for epiphyseal plate fixation. They suggested that this technique is a simple operation with short operation time and fast postoperative rehabilitation, which is a reliable treatment method with few complications. The other is temporary epiphysiodesis, and the current

mainstream procedure is a guided growth technique called eight plate, which relies on the tension band principle. The correction rates observed were about 30 percent faster than those observed with the once widely used stapling, and there was no permanent growth arrest. If the timing of epiphysiodesis is not well chosen, the opposite deformity will occur, so Eastwood *et al* pointed out that the correct timing of intervention is still the biggest surgical challenge [7]. Siemensma recommended that the best treatment timing is dependent on the location of the deformity, distance of physeal bar, and calculated length discrepancy at skeletal maturity[8]. However, when the hemi-epiphysiodesis start to correct the deformities, how many degrees could hemi-epiphysiodesis bring every month and when to remove the hemi-epiphysiodesis implant without rebound phenomenon are still on debate. This article reviews the current studies focus on the effective time, correction speed and termination time of hemi-epiphysiodesis.

EPIPHYSIODESIS BY PERCUTANEOUS EPIPHYSIODESIS TRANS-EPIPHYSEAL SCREWS (PETS)

A study by Martine *et al* [9] included six patients, three male and three female. The data they used was a median age of 11(8-14) years. The median time from surgery to final measured Angle correction was 12(11-13) months, and the median mLDFA correction velocity was 0.55°/ month (0.43-0.71°/ month). In their follow-up study [10], Martine suggested that the median correction time was 12.3(9.2-22.3) months and the correction rate was 0.45°/ month (1.0-3.75° / month). In 2012, Sung *et al* [11] proposed that in young children (boys 14 years old or younger, girls 12 years old or younger), the correction rates of distal femur, proximal tibia and distal tibia valgus deformity were 0.71°/ month (8.5°/ year), 0.40°/ month (4.8°/ year) and 0.48°/ month (5.8°/ year), respectively. In older children, distal femur, proximal tibia, and distal tibia valgus deformity correction rate of 0.39 ° / month (4.7 ° / year), 0.29 ° / month (3.5 ° / year) and 0.48 ° / month (5.8 ° / year). They also pointed out that the correction rate of distal femur was significantly lower in older children, which had similar conclusions in other

studies. This may be related to the fact that the growth rate of the distal femur growth plate (9 mm / year) is higher than that of the proximal tibial growth plate (6 mm / month)[12]. In the study of Khoury *et al* [13], 60 patients (105 epiphyses) underwent percutaneous screw epiphyseal fixation or hemi-epiphyseal fixation, and 30 patients (66 epiphyses) underwent hemi-epiphyseal plate screw fixation to correct angulation deformity. After follow-up, the mean correction rate of distal femur was 0.75±0.45°/ month. PARK *et al* compared the outcomes of percutaneous trans-epiphyseal plate screws (PETS) with tension band plate techniques (TBP) in a comparative study in which 90 Limbs were treated with PETS in 33 patients and 60 Limbs were treated with TBP in 24 patients. In the distal femur, the mean correction rate of PETS group was higher than that of TBP group (0.92°/ month vs. 0.64°/ month) and proximal tibia (0.72°/ month vs. 0.55°/ month). The correction rate observed in the study was faster for PETS than for TBP. Compared with TBP, PETS correction may be more suitable for patients with close bone maturity [14]. In recent years, Abdelaziz *et al* [15] improved the technique of percutaneous epiphyseal plate screws. They changed the direction of screw entry to retrograde, starting from epiphyseal to metaphyseal. It used the technique on 40 patients, 17 women (29 epiphyses) and 23 men (36 epiphyses). The mean age was 11.75(8.4-14.5) years for females and 13.75(11.75-15.6) years for males. The mean mLDFA correction was 1.3° (0.5-1.857°) per month and the mean time to correction was 5.9 mo, they also noted that the mean correction was 1.2°/ month in the female group and 1.35°/ month in the male group. In the above studies using averages as indicators, the mean correction rate was 0.92°/ month and the median was 0.835°/ month.

Other studies used different correction judgment indicators. Mesa *et al* [16] used the tibiofemoral Angle (the intersection Angle between the mechanical axis of the femur and the mechanical axis of the tibia), and the included male and female children were 14 years and 7 mo (12.7-15.1 years) and 13 years and 6 mo (12.9-14.8 years), respectively. The average correction was 0.73°±0.45°/ month, and the average removal time of the percutaneous hollow screw was 20.2(18.9-25) months. In the study of Hu *et al* [17], a total of 41 patients were treated with cortical bone screws in 8 of them. The index of

correction was tibial talar Angle (the Angle between the center line of the tibial intercondylar eminence and the level of the ankle space and the articular surface of the fornix of the talus). The average correction rate was 0.61°/ month. The average correction time was 22.25±4.04 mo (17-27 mo).

EPIPHYSIODESIS BY EIGHT PLATE

MEASURED BY MLDFA/ MMPTA (TABLE 1)

In the prospective series of studies conducted by Stevensd *et al*, patients were followed for 14 to 26 mo after surgery, and 32 of 34 patients completed correction within an average of 11 mo. Among them, 4 patients with bilateral idiopathic valgus had malformed rebound [18]. In the study of Burghardt *et al* [19], a total of 11 patients were followed up and the eight plates were removed. The mean age at insertion was 10 years and 2 mo, and the mean time from insertion to removal was 9.5 mo. The mean mechanical axis deviation (MAD) was improved by 32.7 mm. Seven patients were evaluated using mLDFA, with a mean age of 10.2 years, a mean correction time of 10.3 mo, and a mean correction rate of 0.9°/ month. Burghardt noted that because the femur grows faster than the tibia, patients with splay plates for the femur should be seen every three to four months, while patients with splay plates for the tibia should be seen every four to six months to monitor growth and deformity correction. Burghardt *et al* [20] included 43 patients in their follow-up results, whose average age was 9 years and 7 mo(4-14), at the time of insertion of the figure eight plate. The average implantation time of the plate was 14.2(5.0-27.4) months. Average distal femoral mechanical lateral angle was 10.00 ° (1-18 °), the average correction rate was 0.65 ° / month (0.05 to 1.22 ° / month). Average proximal tibial medial angle change was 7.78 °(0 to 14 °), the average correction rate was 0.58 °/ month (0.13 to 1.67 ° / month). The mean mechanical axis displacement was improved by 25.4(0-74) mm, and the mean improvement rate was 1.73(0-6.4) mm/ month. After a longer follow-up (more than 10 mo), the average rebound distance of the 10 affected limbs was 15.7 mm, and the rebound speed was 1.0 mm/ month.

Jelinek *et al* [21] conducted a comparative study, including a total of 35 patients, among whom 17 were treated with eight plates. The average age of patients were 11.6±3.8 years old(2.9-16), and the removal time of internal fixation was 11.9±6.8 mo (1.9-27.9 mo). The mean mechanical lateral Angle (mLDFA) correction rate of the distal femur was 1°/ month. Two patients had hyperorthosis after the first orthosis, requiring hemi-epiphyseal fixation on the contralateral epiphyseal. Jelinek points out that there is insufficient data on the need for excessive correction, and therefore recommends that all cases be followed up at a three-month interval. If the patient is expected to grow rapidly, such as in the preadolescent stage, especially if the femur and tibial epiphyses are being treated simultaneously, it is necessary to shorten the interval between follow-up visits. A total of 40 patients were included in the study by Kumar *et al* [22], 3 patients were lost to follow-up, and 37 patients followed up for more than 2 years were evaluated. There were 19 cases in the eight plate group, the mean age was 7.8 years (4-12), the mean mLDFA correction rate was 1.3°/ month, and the mean correction time was 10.3 mo. The study of Eltayeby *et al* [23] included 35 patients with genu valva deformity, who were followed up 7-25 mo after surgery, with an average age of 12.2 mo, and the average age of patients was 11 years old (3-15). The average speed of correction was 0.74°/ month. The authors concluded that the initial screw Angle (0°-30°) had no significant effect on the orthopedic rate when using tension band plates for hemiepiphysiodesis, and therefore recommended that surgeons should avoid the insertion of growth plates according to the anatomical limitations, rather than favoring a parallel, divergent, or highly divergent configuration. The study of Danino *et al* [24] included a total of 206 patients, whose average age at the time of surgery was 12.5 years old, and the average follow-up time was 16 mo. 93% of the femoral distal mechanical lateral Angle (mLDFA) was 85°-89°. Two percent had no corrective effect, and five percent were overcorrected. The correction rate of femur was significantly faster than that of tibia (0.85°/ month and 0.78°/ month, respectively), and the correction rate of femoral varus deformity was significantly faster than that of varus deformity (0.90°/ month and 0.77°/ month, respectively). No such difference was found in the tibia.

Subsequently, Danino *et al* [25] included a total of 537 patients on the basis of previous studies, with an average age of 11.35 years at the time of plate implantation and an average follow-up of 16 mo after plate implantation. Of the femur correction, 444 (85%) patients completed treatment, of which 311 (70%) were corrected to the standard force line (mLDFA 85°-89°). 75 cases have not been corrected and the deformity is still worsening. mLDFA changes at an average of 0.77°/ month. In the correction of the tibia, 341 patients (75%) completed the treatment, of which 250 patients (80%) were corrected to the standard force line (mMPTA 85°-89°). 107 (24%) had not yet achieved correction and the deformity was still increasing. The mean change in the medial proximal tibial Angle was 0.79°/ month.

Ding *et al* [26] included a total of 27 patients in their study, including 15 males and 12 females, with an average age of 6.3 years. Postoperative follow-up was 1.9-5.9 years (mean 3.8 years). Twenty-four patients achieved complete correction and three patients did not achieve complete correction. Distal femur Angle correction 8.41°/ year, proximal tibia Angle correction 15.19°/ year, internal fixation time was 0.9-1.9 years, with an average of 1 year. One case of rebound deformity occurred 2 years after the operation, and reoperation was performed. In contrast to some studies [27], Ding's results showed that the average correction speed of tibia was faster than that of femur. They hypothesized that this might have something to do with the difference in mean age between the two groups: 3.8 years in the tibia group and 8.6 years in the femur group[28].

Ozdemir's study [29] included a total of 77 children with a mean age of 93±36 mo and a mean follow-up of 36±17 mo (12-88 mo) after implantation. The average removal time was 18±8 mo (7-47 mo). The mechanical lateral Angle correction rate of the distal femur was 0.94±0.43°/ month. The average age of children in Dai *et al* [30] study was younger and the overall correction speed was higher than that in other studies. A total of 66 patients were enrolled. The mean age at surgery was 4.69 years, the mean time to deformity correction was 13.26 mo, and the mean follow-up time after removal of the eight plates was 12.71 mo (12-24 mo). The mean mLDFA correction was 13.38°(2.6-32.7

°) and the mean mMPTA correction was 10.05°(0.45-22.21 °). Overall femur correction speed (1.28°/ month) was significantly higher than tibia correction speed (0.83°/ month). For the femur, the rate of correction of varus deformity was significantly higher than that of valgus deformity (1.50°/ month vs. 1.16°/ month). However, for tibia, the rate of correction of valgus malformations was significantly higher than that of varus malformations (1.03°/ month vs. 0.66°/ month). 3 cases of knee valgus showed rebound after removal of the eight plate.

Park *et al* [31] compared the efficacy of 8-figure plate and 3.5mm reconstructed plate, and 20 patients were fixed with 8-figure plate. 35 cases were fixed with reconstruction plates. The average correction time of 8-figure plate and reconstruction plate was 13.7 mo and 19.7 mo, respectively. The mean correction Angle of the distal lateral Angle of the mechanical femur was 9.0° for the 8-figure plate and 9.9° for the reconstructed plate. The mean correction Angle of the proximal medial tibial Angle was 7.1° with the figure eight plate and 9.0° with the reconstructed plate. There was no significant difference in the Angle correction rate between the distal femur (1.03°/ month vs. 0.77°/ month) and the proximal tibia (0.66°/ month vs. 0.63°/ month). Two cases of malformed rebound were observed in the study, requiring a second hemiepiphysial arrest.

Feng *et al* [32] retrospectively analyzed the clinical data of 26 children with X-linked hypophosphatemic rickets treated with 8-figure plates. The median age was 6.2 years, ranging from 2 to 13 years. The mean mechanical lateral Angle of the distal femur (mLDFA) was 11.7±8.7°, and the mean mechanical medial Angle of the proximal tibia (mMPTA) was 8.4±5.0°. The mean time for deformity correction was 22.7 mo (7-60 mo), and the mean follow-up time after eight plate removal was 43.9 mo (24-101 mo). The femoral correction speed (0.9°/ month) was significantly higher than that of the proximal tibia (0.6°/ month). One patient experienced rebound after removal of the eight plate.

Radtke *et al* [33] retrospectively analyzed the data of 355 patients with femoral neck fracture and divided them into idiopathic group and pathological group. The children ranged in age from 4 to 16 years, with an average age of 12.18 years. The average

correction time was 17.32 mo (2-62 mo). The mean time from (hemi-) epiphysiodesis to implant removal in the idiopathic and pathological groups was 13.24 mo and 21.3 mo, respectively. Among them, 139 patients were idiopathic eversion deformity group, the average correction time was 11.07, and the average correction rate was 0.4°/ month. The time for removal of internal fixation for idiopathic varus malformations was 18.39 mo, compared with 24.9 mo for the varus group and 20 mo for the valgus group. In the entire idiopathic malformation group, 13 patients showed rebound.

MEASURED BY TIBIFEMORAL ANGLE(TFA)

Boero *et al* [34] divided 58 patients into idiopathic and pathological groups according to the cause, with 30 cases of idiopathic deformity and 28 cases of pathological deformity. The age ranged from 2 years 3 mo to 14 years 11 mo, with an average of 10 years 10 mo. The figure eight plate was removed an average of 14 mo (2-37 mo) after implantation. The mean TFA correction for all patients was 11±4.9°(0-25 °), and the mean monthly correction was 0.93±0.82°. In idiopathic group, the average correction time was 11 mo, and the average correction rate was 0.82°/ month. In the pathological group, the mean correction time was 18 mo and the mean correction rate was 0.72°/ month. In the study of Gigante *et al* [35], 7 people were included, and the average correction time was 20 mo (7-30 mo). The average correction speed of the tibia was 0.49°/ month and that of the femur was 1.73°/ month.

Vaishya *et al* [36] included 24 participants, with an average corrected deformity rate of 0.91°/ month and an average correction time of 17 mo (10-28 mo). In Ballal's study [37], 25 children were followed up for an average of 12.4 mo (6-32 mo) after plate removal. The mean age was 11.6 years (5.5-14.9 years). The mean time to correction was 16.1 mo (7-37.3 mo). The distal femur is corrected an average of 0.7°(0.3-1.5°) / month, the proximal tibia is corrected an average of 0.5°(0.1-1.0°) / month, and if the femur and tibia are treated together, the average correction is 1.2°(0.1-2.2°) / month.

Kulkarni *et al* [38] included a total of 24 patients in their study, with an average of 15.6 mo (7-29 mo) of 8-figure plate implantation. The tibiofemoral Angle in the genu

valgus group was improved from 19.89° (10-40°) to 5.72°(2-10°). The average tibiofemoral Angle of patients with varus was improved from 28.27° before operation (range: 13° -41 °) to 1.59° after operation (range: 0-8°). The overall correction rate was 1.53°/ month (1.67°/ month for younger than 5 years and 1.39°/ month for older than 5 years).

Jamil *et al* [39] evaluated a total of 17 patients with a median age of 4.0(3.0-6.0) years by using the mechanical axis deviation (MAD) and tibifemoral angle (TFA) on the full-length X-rays of the lower limbs in standing position. Of the 22 knee joints successfully treated, the mean correction rate of the proximal tibia was 0.71°(0.39-1.55°)/ month, and the mean correction rate of the distal femur was 0.67°(0.61-1.38)/ month. The median correction rate was 0.71°/ month. The median correction time was 20 mo.

MEASURED BY OTHER PARAMETERS

Zajonz *et al* [40] included a total of 105 children in their study, with a median age of 12.7 years at the time of treatment. The median time for removal of the figure eight plate was 13 mo. The mean interankle correction distance was 0±2.1 cm, the mean anatomic femoro-tibial Angle was 9± 2.7°, and the mean mechanical lateral Angle of the distal femur was 7± 7.72°. The medial Angle of the proximal tibia was altered by an average of 4±6.02°, and the median time from implantation to removal of the implant was 13 mo. Guzman *et al* [41] used ananatomical lateral femur distal Angle (aLDFA) as an evaluation index and compared the single plate with the double plate. The change rate of femoral aLDFA in the single plate group and the double plate group was 0.81°(3.3°/ year) and 1.06°(4.2°/ year) every 3 mo on average, respectively. The mean follow-up was 12.7 mo, and statistical analysis showed a correction rate of 0.96° every 3 mo. Popkov's report [42] also used the anatomic lateral femur distal Angle (aLDFA) as an evaluation indicator, stating that the treatment time from surgery to complete correction of the deformity and removal of the plate was 18 mo, with a correction rate of 0.61°/ month for the right tibia and 0.67°/ month for the left tibia. Danino *et al* [43] used the mechanical medial proximal tibia angle (mMPTA) to evaluate the efficacy. A total of

45 patients were included, with an average age of 9.5 years (1.6-14.8 years) at the time of surgery. The mean ROC curve for all follow-up periods was 1°/ month and the mean correction time was 24.5 mo.

EPIPHYSIODESIS IN SAGITTAL PLANE

Al-aubaidi *et al* [44] included children with cerebral palsy (CP) and myelomeningocele (MMC) in their study, and the correction evaluation index used was fixed flexion contracture Angle. 12 of them were treated with 8-figure plates, with an average age of 9.6 (7.5-5) years. The average initial deformity was about 20°, and the orthosis time was 20 mo with an average correction rate of 0.5°/ month. Klatt *et al* [45] treated 18 patients (29 sides) with steel plates for knee flexion deformity, with an average preoperative fixed flexion deformity of 23.4° (10-50°). The mean fixed flexion deformity was 8° (0-30°) at the last follow-up. One patient (single knee) relapsed 18 mo after surgery. Stiel *et al* [46] included a total of 73 cases in the study, of which 68 cases were treated with portal nails and 5 cases were treated with 8-figure plates. After exclusion, a total of 49 cases were included. 83 knees) with an average age of 12 years (6-20 years). Patients were divided into three groups based on diagnosis: cerebral palsy, meningomyelocele, and other groups. The average follow-up after implant removal was 46 mo (12-78 mo). The average fixed knee flexion deformity was 21°(10°-60°) before surgery and improved to 8°(0°-50°) after surgery. Fixed knee flexion deformity at implant removal was corrected by an average of 13°. The average correction rate was 0.44°/ month, and the implant was removed after an average of 32 mo (6-72 mo). The monthly correction rate was the highest in the other groups (0.60°), followed by the meningocele group (0.52°). Patients with cerebral palsy had the lowest monthly correction rate (0.20°). Stiel proposes that improvement in flexion deformities decreases with age, and for patients with significant growth potential, minor overcorrection of fixed knee flexion deformities (about 5°) should be considered when removing implants to avoid recurrent knee flexion deformities.

In the study of Zaghloul *et al* [47], both distal anterior femur hemi-epiphyseal plate fixation and hamstring muscle release were used to treat children with neuromuscular diseases to evaluate the clinical and functional outcomes of patients with fixed knee flexion malformation. A total of 19 children were included, with an average age of 12±2.1 years. There were 15 males and 4 females. The main diagnosis was cerebral palsy (16 cases). The mean follow-up time was 3.8 years (1.5-7 years), and the mean fixed knee flexion deformity improved from 28.9° to 13.4°, with a mean correction rate of 0.94°/ month. The mean preoperative popliteal Angle was 81.8°, the mean early postoperative Angle was 44.4°, and the mean last follow-up was 51.8°. The average correction time was 18.9 mo.

EPIPHYSIODESIS IN SPECIAL DISEASES

Baghdadi *et al* [48] studied 6 cases of congenital insensitivity to pain (CIP). The median age was 10 years (5-12 years). The mean follow-up was 31 mo (16-56 mo). The average preoperative mLDFA was 74.6°. The mean mLDFA at the last follow-up was 81° (76-84 °), and the mean correction rate of femoral malformation was 0.28°/ month. They also noted in the study that children with CIP have lower growth rates and should therefore be given guided growth procedures earlier than non-CIP children.

Saglam *et al* [49] studied 11 children with skeletal dysplasia combined with genu valva, with an average age of 10.5 years. The mean duration of treatment with the figure eight plate was 35 mo (12-60 mo). Two uncorrected patients were excluded from the correction rate assessment. The correction rates of distal femur aLDFA and mLDFA were 0.384±0.5°/ month and 0.395±0.39°/ month, respectively. The MPTA correction rate of proximal tibia was 0.297±0.38°/ month.

EPIPHYSIODESIS IN ANKLE

In addition to the use of eight plates to correct the deformity of the knee valgus, there is another effective way to correct the malformations of the ankle valgus, namely

the medial malleolar trans-epiphyseal plate screw (MMS). Most studies have also shown that MMS is an effective and safe correction method.

Driscoll *et al* [50] used tibial distance Angle as an evaluation index in the treatment of ankle valgus, and included a total of 42 patients with an average postoperative follow-up time of 34 mo. In 35 patients with medial malleolar trans-epiphysial plate screws (MMS), the tibial distance Angle was corrected from 77.1° before surgery to 87.8° after surgery, and the correction rate was 0.55°/ month. The Angle of 25 patients in TBP group ranged from 81.3° before surgery to 87.6° after surgery, and the correction rate was 0.36°/ month. Bayhan *et al* [51] used medial malleolar screw hemi-epiphysiodesis in the treatment of malleolar valgus in children with spina bifida, and retrospectively analyzed the clinical data of 10 patients (18 ankles) with malleolar valgus. The effect of correction was evaluated by measuring the tibial distance Angle. The mean age of the patients was 10.05 years. The mean follow-up was 15.33 mo (11-21 mo). The mean tibial distal Angle was improved from 16.27° before operation to 2.88° after operation. No serious complications occurred after operation. After summarizing the data from the study, the authors suggest that hemi-epiphysial arrest is a safe and effective method to correct malformations of ankle varus in children with spina bifida. Chang *et al* [52] studied and analyzed the clinical data of ankle valgus patients treated with MMS hemi-epiphysial arrest, including 16 males and 21 females (63 ankles), with an average age of 11.0 years (5.4-14.8 years). All patients had a mean postoperative follow-up of 1.6 years (0.4-4.9 years). The average time from screw insertion to screw removal was 1.4 years (0.4-5.2 years). The average correction rate of tibial distance Angle was 0.37±0.04°/ month. Ankle valgus recurred in 18 of 22 ankles after screw removal. The average recurrence rate of screw removal patients was 0.28±0.08°/ month. The study of Macneille *et al* [53] included a total of 22 patients (34 ankle). There were 11 males and 11 females. The mean follow-up time was 7.2 years (2-13 years). The mean age was 10.3 years (6.3-12.9 years). This study used LDTA as an evaluation index, with a mean preoperative LDTA of 79.2° (65-86°). The mean LDTA at the last follow-up was 88.1° (74-105°). The mean variation in LDTA is 8.9°(0-19°). The average correction rate is 0.4°/

month (0-1.4 °). All 20 ankle joints were corrected to neutral position. Less than 10 sides were corrected, and 4 sides were over-corrected. The average age of the 4 over-corrected patients was 9.8 years, and the ankle LDTA was about 100 degrees. Trans-epiphyseal plate screws were removed in 12 patients (19 ankle). Screw removal time ranged from 30 to 214 wk (mean 81 wk). In the study population of van Oosterbos *et al* [54], children with inherited multiple exostoses were treated with an 8-figure plate to correct ankle varus deformity. A total of 18 children were included, including 10 males and 8 females, and the average age of the first operation was 12.6 years old (9.5-15 years old). The average follow-up was 22 mo (3-40 mo) until the implant was removed or the epiphysis closed completely. The mean preoperative LDTA was 76.9°(68.5° -83.5 °). The mean LDTA at implant removal or epiphyseal closure was 83.6°(76.5-90°). The average LDTA correction is 6.9°(1-16.5°). In this study, none of the patients had overcorrection of the varus deformity. After data analysis, the authors concluded that the correction of valgus deformity was significantly related to age at the time of hemi-epiphysial arrest, with the greatest correction in younger patients.

In the treatment of malformation of the ankle, Stevens *et al* [55] pointed out that due to the difficulty of screw extraction, the eight plate was selected for treatment. A total of 33 patients (57 ankle) were included, with an average age of 10.4 years (6.08-14.58 years) at the time of implantation, and an average postoperative follow-up of 27.12 mo (12-57.5 mo). The mean preoperative LDTA was 78.7° (68-85°). The average LDTA at removal is 90°(76-103°). The mean LDTA at the last follow-up was 88.2° (71-104 °) and the mean correction rate was 0.6°/ month (0.15-1.6°/ month).

OTHER TREATMENT OPTIONS

The case report of Ghaffari *et al* [56] suggested that 3.5mm non-hollow screws and reconstruction plates should be used instead of the eight plate. They believed that the effect of reconstruction plates was as ideal as that of eight plates, and it was more cost-effective, accessible and suitable for young people. The duration of correction was 8 mo. Kurupz *et al* [57] used 2-hole reconstruction plates, and they believed that 2-hole

reconstruction plates and 8-figure plates had similar correction effects at the same time, without additional complications, and with lower cost and easy to obtain. A total of 23 patients were implanted with 2-hole reconstruction plates. The mean age at the time of surgery was 11.25 years. The mean postoperative follow-up was 36 mo, the mean correction time was 18.64 mo, and the mean mLDFA correction rate was 0.61°/ month. Bakircioglu *et al* [58] used an 8-figure plate. However, the difference between the application of the 8-figure plate and the conventional 8-figure plate was that they compared the recurrence rate and fastening effect of the metaphysis screw extraction alone (sleeper plate technique) and the conventional full plate extraction. A total of 72 patients (107 Limbs) were enrolled, of whom only metaphyseal screws were removed in 25 patients (35 Limbs) and both screws and plates were removed in 47 patients (72 Limbs). The mean age of patients at the time of initial surgery was 97 mo (80-129 mo). After an average of 49 mo (16-86 mo), stable correction was expected in 17 Limbs (48.5%) of the screw removal group and 59 Limbs (72.2%) of the total removal group. The recurrence rate of screw removal group and total removal group was 34.3% and 27.8%, respectively, and the difference was not statistically significant. Metaphyseal screws were re-placed in 8 of the 12 Limbs, and the remaining 4 Limbs required further surgery. In the screw extraction group, 6 Limbs (17.3%) were tethered, 4 of which required further corrective surgery. The remaining two limbs are slightly tethered and require no further surgery. By comparing the above data, the authors concluded that the removal of metaphyseal screws alone would increase the risk of teaming. If only metaphyseal screws are removed, close follow-up is required. But Retzky[59] indicated that Sleeper plates technique should be avoided to use in patients with proximal tibia MHE, surgeons should be extreme caution when considering this technique.

REBOUND PHENOMENON

The correction effect of epiphysiodesis varies with age, disease nature, and nutritional status. When the temporary arrest is terminated, recurrence of the deformity is relatively common [60, 61], which is called rebound phenomenon. Some studies [62-69]

have advocated the use of mild overcorrection to compensate for the rebound that occurs after termination of treatment. It is recommended to follow up once every 3 mo after surgery and once a year after 1 year. If rebound is found, follow-up is continued for 3 mo until further surgery is required. For example, for patients with valgus malformations, some scholars [70,71] advocate excessive correction of 5° to 10°(mild varus) for children with risk factors (dysplasia, obesity, *etc.*) to prevent possible recurrence of malformations. Kang *et al* [72] analyzed 37 Limbs of 34 children and measured mLDFA or MPTA to assess correction. Multiple logistic regression analysis showed that orthotic rate body mass index (BMI), age and initial valgus angle were significantly correlated with rebound. With respect to the magnitude of rebound Angle, the annual correction rate of 8.5° and BMI of 21 kg/m² were significant thresholds, and the authors divided them into three groups: Group A was children with a correction rate ≥8.5°/ year; Group B was children with correction rate < 8.5°/ year and BMI < 21 kg/m². Group C consisted of children with a correction rate < 8.5°/ year and BMI≥21 kg/m². A total of 14 Limbs were included in group A, and 11 Limbs showed rebound. In group B, 7 Limbs and 3 Limbs showed rebound. Group C has 16 Limbs, no rebound. The highest incidence of rebound occurred in children with rapid orthosis (79%), while the incidence of rebound was lower in children with slow orthosis at low BMI (43%), and no rebound occurred at BMI≥21 kg/m². Choi *et al* [73] retrospectively analyzed 50 children with tension band plate hemi-epiphyseal plate fixation due to coronal angulation deformity of lower limbs, with an average age of 11.0±2.5 years, and a total of 94 epiphyseal plates were included. mLDFA and mMPTA were measured to evaluate the effect of correction. The mean correction rate was 8.1±4.7°/ year for valgus deformity 66 and varus deformity 2. The rebound group was defined as the mLDFA or mMPTA returning more than 5° to the original deformity. The rebound group had 41 epiphyses and the non-rebound group 53 epiphyses. The correction rate is significantly associated with rebound phenomenon, and the risk of rebound phenomenon increases by 1.2 times when the correction rate increases by 1° per year. The critical correction rate between the two groups was 6.9°/ year ($p < 0.001$). Compared with the non-

rebound group (mean age 11.7 years, mean correction rate 6.5 ± 4.4°/ year), the rebound group children were younger (mean 10.2 ± 2.5 years) and the correction rate was faster (10.2 ± 4.3°/ year). The authors note that children with a faster rate of correction (> 7°/ year) should be closely monitored after implant removal. Kyung *et al* [74] reviewed 68 patients with idiopathic knee valgus treated with tension band plates (plate group) or trans-epiphyseal plate screws (screw group) and followed up until bone maturity. A total of 68 Limbs were treated in 68 patients. The mean hip - knee - ankle force line was -5.4°±1.8°(valgus) at temporary hemi-epiphysis fixation, 2.6°±2.1° at extraction and internal fixation, and 0.7°±2.6° at last follow-up. The rebound amplitude of the plate group (4.1°±1.9°) was greater than that of the screw group (1.1°±3.1°). By regression analysis, the authors suggest that the rebound phenomenon is positively associated with plate use and faster correction, but not with more severe deformity or greater Angle of correction before surgery.

CONCLUSION

Epiphysiodesis is an effective treatment for limb deformity in children with unclosed epiphyseal. Different techniques of epiphysiodesis and different age of correction bring different rate of deformity correction. While there is still debate about when to remove the implant after correction, children with risk factors can be overcorrected by 5° to 10°, given the potential for rebound, and should be closely followed for optimal deformity correction.

88408_Auto_Edited.docx

ORIGINALITY REPORT

11%
SIMILARITY INDEX

PRIMARY SOURCES

1	www.ncbi.nlm.nih.gov Internet	131 words — 2%
2	bmcmusculoskeletdisord.biomedcentral.com Internet	109 words — 2%
3	posna.org Internet	49 words — 1%
4	www.researchgate.net Internet	47 words — 1%
5	www.science.gov Internet	46 words — 1%
6	J. Javier Masquijo, Cristian Artigas, Julio de Pablos. "Growth modulation with tension-band plates for the correction of paediatric lower limb angular deformity: current concepts and indications for a rational use", EFORT Open Reviews, 2021 Crossref	44 words — 1%
7	www.tandfonline.com Internet	31 words — < 1%
8	online.boneandjoint.org.uk Internet	27 words — < 1%

9	B Danino, R. Rödl, J. E. Herzenberg, L. Shabtai, F. Grill, U. Narayanan, E. Segev, S. Wientroub. "Growth modulation in idiopathic angular knee deformities: is it predictable?", Journal of Children's Orthopaedics, 2019 Crossref	26 words —	< 1%
10	josr-online.biomedcentral.com Internet	25 words —	< 1%
11	link.springer.com Internet	25 words —	< 1%
12	www.pubfacts.com Internet	21 words —	< 1%
13	Xiongke Hu, Anping Li, Kun Liu, Jiangyan Wu, Haibo Mei. "Design of a New “U”-shaped Staple and Its Clinical Application in Postoperative Ankle Valgus of Congenital Pseudarthrosis of the Tibia in Children", Orthopaedic Surgery, 2022 Crossref	19 words —	< 1%
14	Carl T. Talmo, Andrew J. Cooper, Tom Wuerz, Jason E. Lang, James V. Bono. "Tibial Component Alignment After Total Knee Arthroplasty with Intramedullary Instrumentation: A Prospective Analysis", The Journal of Arthroplasty, 2010 Crossref	18 words —	< 1%
15	Lu Liu, Wei Zhang, Yulei Liang, Yang Gao, Guang Zuo, Chuanchuan Gu, Tianci Gao. "小角度推按抗旋正骨手法提高支具治疗青少年特发性脊柱侧弯的即时疗效", Journal of Acupuncture and Tuina Science, 2023 Crossref	18 words —	< 1%
16	B. Danino, R. Rödl, J. E. Herzenberg, L. Shabtai, F. Grill, U. Narayanan, E. Segev, S. Wientroub.	14 words —	< 1%

"Guided growth: preliminary results of a multinational study of 967 physes in 537 patients", Journal of Children's Orthopaedics, 2018
Crossref

17 Ruth Stuckey, Santiago Sánchez-Sosa, Paula Estupiñan Cabrera, Cristian Cruz Rodríguez et al. "Biological Factors Associated with Treatment-Free Remission in Clinical Practice: Data from the Canarian Registry of CML", Blood, 2023 — 13 words — < 1%
Crossref

18 Dariusz Naskret, Michal Kulecki, Mikolaj Kaminski, Dominika Kasprzak et al. "Vascular age and arterial stiffness in the assessment of cardiovascular risk among young adults with type 1 diabetes.", Research Square Platform LLC, 2023 — 12 words — < 1%
Crossref Posted Content

19 G. Martínez, S. Drago, C. Avilés, A. Ibañez, F. Hodgson, C. Ramírez. "Distal femoral hemiepiphysiodesis using screw and non-absorbable filament for the treatment of idiopathic genu valgum. Preliminary results of 12 knees", Orthopaedics & Traumatology: Surgery & Research, 2017 — 12 words — < 1%
Crossref

EXCLUDE QUOTES	ON	EXCLUDE SOURCES	OFF
EXCLUDE BIBLIOGRAPHY	ON	EXCLUDE MATCHES	< 12 WORDS