

Research Article

Tibial slope changes following guided growth by the eight-plate: A retrospective comparative study

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ABSTRACT

Objective: The aims of this study were (1) to investigate the tibial slope (TS) changes following guided growth by the eight-plate and to determine the relationship between the TS change in the sagittal plane and the plate position.

Methods: In this retrospective study, children who underwent guided growth by the eight-plate for genu varum or valgum were included. Thirty-eight extremities of 23 children (14 girls and 9 boys; mean age = 9.2 years, age range = 3-17 years) were then divided into two groups according to the plate location in the sagittal plane (anterior or midline). Preoperative and postoperative TS were measured from the medial and lateral tibial plateaus separately.

Results: The mean follow-up was 34.3 (range = 12-96) months. The mean preoperative and postoperative medial TS were 4.05 ± 5.65 and 0.83 ± 3.91 degrees, respectively, in 18 patients in whom anterior epiphyseal plates were placed ($P = 0.004$). The mean preoperative and postoperative lateral TS were 4.88 ± 5.33 and 0.11 ± 3.34 degrees, respectively, in 18 patients in whom anterior epiphyseal plates were placed ($P < 0.001$). The mean preoperative and postoperative medial TS were 4.2 ± 5.19 and 4.9 ± 6.02 degrees, respectively, in 20 patients in whom midline epiphyseal plates were placed ($P = 0.532$). The mean preoperative and postoperative lateral TS were 5 ± 5.51 and 4.8 ± 5.7 degrees, respectively, in 20 patients in whom midline epiphyseal plates were placed ($P = 0.871$). Postoperative TS was decreased in anteriorly located eight-plates, and medial and lateral plateau measurement was significant ($P = 0.004$ and $P < 0.001$, respectively). Postoperative TS changes in midline-placed eight-plates were not significant regarding the medial and lateral plateaus ($P = 0.532$ and $P = 0.871$, respectively).

Conclusion: The results of this study have shown that TS decreases following guided growth by the eight-plate in children in whom plates are placed at the anterior epiphysis. To prevent TS changes, the eight-plate should be placed in the midline position at the sagittal plane.

Level of Evidence: Level IV, Therapeutic Study

Introduction

Vertical growth of long bones occurs in the growth plate. A better understanding of the growth plate and application of epiphysiodesis has allowed growth control. Growth guidance with temporary epiphysiodesis is usually the temporary arrest of epiphyseal growth with the assistance of an eight-plate or screw. The eight-plate shows its effect by limiting the growth of the epiphysis over which it is applied. The opposite side of the eight-plate continues to grow and expand.¹ With unilateral epiphysis enlargement, the angle between the screws changes. Marangoz et al. calculated Interscrew Angle (ISA) and Joint Orientation Angle (JOA) of patients who applied eight-plates due to knee deformities (genu varum, genu valgum). They found a strong correlation between ISA and JOA. Also, ISA has been reported as an independent predictor factor for the change in the JOA.² The most common indications for epiphysiodesis are coronal plane angular deformities. Recently, upper limb deformities,³ spinal growth modulation³ and knee flexion contractures have been included as indications for epiphysiodesis.^{4,5} Lower extremity coronal plane deformities (genu valgum and varum) are common deformities in childhood.

However, most cases are physiological and resolve spontaneously. The standard treatment of deformities that do not heal spontaneously is corrective osteotomy, but osteotomy is an invasive procedure with morbid and long recovery periods.⁶⁻¹⁰ As a result, osteotomy has been replaced by epiphysiodesis in the correction of such deformities during the growth period. Growth guidance can be performed with temporary epiphysiodesis in patients whose mechanical axis does not pass through the centre of the knee and has a growth potential of more than six months.^{6,11,12} Growth guidance is usually performed in the distal femoral epiphysis, proximal tibial epiphysis, or both. The decision depends on the location of the deformity, and the ultimate goal is the alignment of the hip, knee, and ankle.

The TS slope is the anatomical slope of the tibial plateau in the sagittal plane. It is 7-9 degrees, on average.¹³ The load on the knee at the tibial inclination angle is evenly distributed in the sagittal plane. Changes in this angle will also change the load distribution in the tibial plateau.

There are no existing studies regarding TS changes that may occur following epiphysiodesis to correct

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angular deformities in the frontal plane. In this study, we examined changes in the sagittal plane while correcting coronal plane deformities with growth guidance using eight-plates. We evaluated the relationship of the changes in the sagittal plane with the position of the plate we placed.

Materials and Methods

The study was accepted by the Medical Faculty Ethics Committee (2020/166). Thirty-eight extremities of 23 patients (14 female and 9 male), undergoing growth guidance with temporary epiphysiodesis between 2008 and 2017 due to coronal deformity, were included in the study (Table 1). All measurements were performed by the same investigator (VY). All preoperative measurements were performed on the lateral radiograph taken just before the operation. Lateral radiographs were taken with the femoral condyles overlapping. A maximum deviation of 3 mm was accepted in the condyles. All measurements were performed digitally in the Picture Archive and Communication System (PACS). The anatomical axis of the posterior tibial cortex was used for TS in both the preoperative and postoperative periods. The medial and lateral plateaus were measured separately during TS measurements. The medial and lateral plateau tangent was taken as the proximal reference line on the lateral radiography. The line connecting the anterior and posterior aspects of the tibial plateaus was considered as the first reference line and the posterior tibial cortex line as the second reference line. The angle between the perpendicular line drawn between the second reference line and the first reference line was accepted as TS (Figure 1). While lateral and medial slope measurements were taken, the medial TS was considered as the one with a sharper intercondylar side and posterior on the lateral radiograph and lateral TS was considered as the oval medial one (Figure 2). The same surgeon (EC) performed the surgery on all patients. Eight-plates (Response Ortho teknolojik

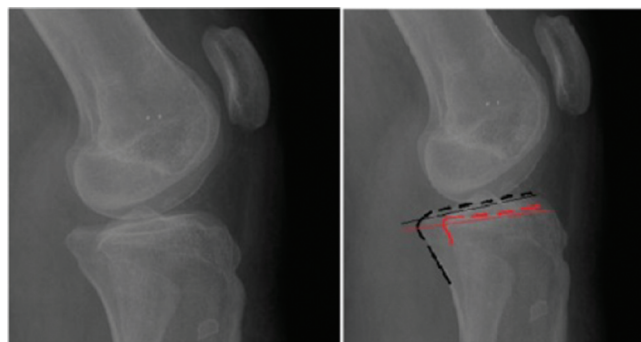


Figure 2. Measure of medial and lateral TS.

üretime A.S. İstanbul/Türkiye) were placed medially or laterally according to the patient's needs. Midline placement of all plates were attempted by fluoroscopy; however, the retrospective evaluation revealed 18 anteriorly placed plates and 20 midline-placed plates. There was no posteriorly placed plate. Immobilisation was not required after the operation and a rapid return to normal activities was encouraged. Follow-ups were performed at intervals of 1, 3, 6, and 12 months and then at 6 months for evaluation of deformity correction. Two patients with knee joint Range of Motion (ROM) limitation in the first week required physical therapy. Finally, the ROM of all patients returned to normal. It was observed in one patient who had implant removal that the screws were removed, but the plate was accidentally left in place. While determining the position of the plate, the line drawn vertically in the midline on the lateral radiograph was taken as a reference. Plates corresponding to the baseline were regarded as midline plates (Figure 3). The plates in front of the reference line were considered front plates (Figure 4). The length of the epiphysis was measured in the sagittal plane in all patients in whom plates were placed in the anterior epiphysis. The distance of the plates to the mid reference line was measured and the correlation between this distance and the TS angle was evaluated (Figure 5). There were no plates at the rear of the reference line.

Postoperative and preoperative TS measurements were compared using the Statistical Package for the Social Sciences (SPSS) 21.0 and paired sample *t*-test. The normal distribution of the variables was examined by the Kolmogorov-Smirnov test. As all variables were normally distributed, the mean values in the descriptive statistics were shown as $\pm$ standard deviation. In the comparison of the groups, the *t*-test was used for independent groups and paired samples *t*-test was used for pre-test and post-test comparisons. Pearson correlation test was used for values showing normal distribution, and $P < 0.005$ was considered significant.

Results

Patients that did not attend follow-up appointments and did not have convenient radiographs were excluded from the study. There were 38 segments of 23 patients included in the study. Nine were males and 14 were females. The mean age at surgery was 9.2 (range, 3-17) years. Mean follow-up time was 34.3 (range, 12-96) months. Twenty plates corresponding to the baseline were regarded as midline plates (Figure 3). The 18 plates in front of the reference line were considered front plates (Figure 4). The length of the epiphysis was measured in the sagittal plane in all patients in whom plates were placed in the anterior epiphysis. The distance of the plates to the mid reference line was measured and



Figure 1. Measure of TS on lateral X-ray.



Figure 3. Midline plate.



Figure 4. Anterior plate.



Figure 5. Measure of anteriorly placed plate.

the correlation between this distance, and the TS angle was evaluated (Figure 5).

The mean preoperative medial TS was measured as 4.05 (± 5.65) degrees and the mean postoperative medial TS as 0.83 (± 3.91) degrees in 18 cases, whose eight-plates were applied anterior from the midline. A statistically significant decrease of 3.22 degrees was observed ($P = 0.004$). The mean preoperative lateral TS was 4.88 (± 5.33) degrees and the mean postoperative lateral TS was 0.11 (± 3.34) degrees ($P < 0.001$) (Table 2). In the 20 cases in which the plates were placed midline, the mean preoperative medial TS was measured as 4.20 (± 5.19) degrees and the mean postoperative medial TS as 4.90 (± 6.02) degrees ($P = 0.532$). The mean preoperative lateral TS was measured as 5.00 (± 5.51) degrees and the mean postoperative lateral TS as 4.80 (± 5.70) degrees ($P = 0.871$) (Table 3). There was no significant difference between the medial and lateral changes of TS in anterior plate-

Table 2. TS changes in cases of epiphysiodesis in which the plate was placed on the anterior aspect

Anterior	N	Preoperative mean ($\pm$ SD)	Postoperative mean ($\pm$ SD)	P
MTS	18	4.055 (± 5.65)	0.833 (± 3.91)	0.004
LTS	18	4.889 (± 5.33)	0.111 (± 3.34)	0.000

TS, tibial slope; LTS, lateral tibial slope; MTS, medial tibial slope; SD, standard deviation.

Table 3. TS changes in cases of epiphysiodesis in which the plate was placed midline

Midline	N	Preoperative mean (±SD)	Postoperative mean (±SD)	P
MTS	20	4.200 (±5.19)	4.900 (±6.02)	0.532
LTS	20	5.000 (±5.51)	4.800 (±5.70)	0.871

TS, tibial slope; LTS, lateral tibial slope; MTS, medial tibial slope; SD, standard deviation.

applied patients ($P = 0.821$). There was no significant difference between the medial and lateral changes of TS in midline plate-applied patients ($P = 0.866$).

The average length of the epiphysis in the sagittal plane was measured as 56.4 (range, 48.2-64.6) mm and the mean between the distance from the reference line to the anterior plate was measured as 14.96 (8.0-28.8) mm in 18 patients in whom anterior epiphyseal plates were placed. There was a moderate (0.668) negative correlation between the anteriorly placed plate distance to and the TS angle ($P = 0.002$).

Discussion

Guided growth with temporary hemiepiphysiodesis is a method used for the treatment of angular deformities in the frontal plane in children with adequate growth. Patients undergoing eight-plate hemiepiphysiodesis should be closely followed for the correction rate. In this way, potential problems can be identified in advance and intervention can be planned if required. This study shows that eight plates placed anteriorly reduce TS. Similar studies regarding the possible effects and complications of epiphysiodesis have recently started to increase. Sinha et al. reported that the angle of the roof decreased and the angle of the slope in the coronal plane increased after eight-plate guided growth when they examined tibial changes in the coronal plane.¹⁴ In the studies conducted by Goedegebuure et al., Makarov et al., and Ilharreborde et al., patients undergoing growth guidance generally had axial deformities when their long-term complications were examined.¹⁵⁻¹⁷ Gorman et al. conducted a study on the importance of the anatomical site of epiphysiodesis. They found that an epiphysiodesis of the proximal tibia caused more axial dislocation than the distal femur and the proximal lateral aspect of the tibia was the most inadequate location for epiphysiodesis.¹⁸ In 2013, Kievit et al. placed eight-plates in front of the distal femoral epiphysis of a patient with lower limb deformity and found that the knee advanced 15 degrees recurvatum in the sagittal plane after one year. They reported that the recurvatum later improved when the eight-plates were removed and placed posterior to the previous position.¹⁹ In the study by Paloceran et al., eight-plates were implanted in the anterior epiphysis of the distal femur to correct flexion contracture in children with arthrogryposis. They found that this technique was effective in correcting flexion contractures below 45 degrees.²⁰ All of these studies seem to have focused on the changes in the coronal plane following growth guidance. Although a study reported that some patients had genu recurvatum due to changes in the sagittal plane after guided growth, no special study was conducted on the TS in the sagittal plane.¹⁹

In our study, we observed that the plates anteriorly placed in the medial and lateral aspect of the tibial plateau as a mass that decreased the TS angle both in the medial and lateral plateaus. Similar results were observed in another study,²¹ which might be due to the massive impact in the epiphysis, which is parallel to the screw lengths of the eight-plate in the coronal plane. Changing the TS angle of the anteriorly placed plates may result in various effects. The TS angle in the sagittal plane, which has an important place in knee surgery, is

considered to be the posterior anatomical slope of the tibial plateau in the sagittal plane. At an average tibial tilt angle of 7-9 degrees, the load on the knee is evenly distributed in the sagittal plane. When this angle changes, the load on the tibial plateau in the sagittal plane will also change. In general, a decrease or reversal in TS causes an increase in tension on the Anterior Cruciate Ligament (ACL) and Posterior Cruciate Ligament (PCL). A decrease in slopes increases the load on the PCL and an increase in slopes increases the load on the ACL.¹³ Therefore, eight-plates should be placed at the midline in the sagittal view to prevent TS changes.

There is no widely used standard technique to measure TS, which should be considered in operations such as arthroplasty, cruciate ligament repair, and high tibial osteotomy, which are important in knee kinematics. Cullu et al. applied six different tibial tilt measurement techniques, including Posterior Tibial Cortex (PTC) measurements in 94 knees of 50 patients, and investigated the differences and correlations between these measurement techniques and normal values. They reported a correlation between the data, according to six different measurement results.^{22,23} In our study, we also used PTC measurements. Considering similar studies in the literature, lateral graphs with overlapping femoral condyles were evaluated. A maximum deviation of 3 mm in the condyles was accepted.^{22,24} We evaluated the position of the plates by lateral X-ray. We aimed to place all the plates in the midline. Although we checked with fluoroscopy during the operation, we accidentally placed some plates anteriorly. However, we noticed this situation during the postoperative follow-ups, not during the operation. The mean distance of the reference line to the anteriorly placed plate was measured as 14.96 (8.0-28.8) mm in 18 patients. We also observed that the TS angle decreased as the plate moved forward from the mid-epiphyseal line. In our opinion, the reason for this is that the plate placed in the epiphysis affects only at a certain distance. Plates and screws placed in the midline affect the entire epiphysis equally like a mass and completely stop growth. However, the posterior epiphysis continues to grow because the plates placed anteriorly only suppress the anterior epiphysis and do not affect the posterior epiphysis.

Also, our literature review included studies on tibial tilt changes that occurred after anterior distal femur epiphysiodesis was applied to correct angular deformities in the sagittal plane.^{5,25,26} However, no studies were found regarding tibial tilt changes in patients who underwent epiphysiodesis by applying eight-plates to the tibia to correct angular deformities in the coronal plane (genu varum and valgum).

Limitations of our study included a relatively short period of follow-up, the retrospective design of the study, and the absence of CT measurements. The other limitation of our study was the inclusion of patients aged between 3 and 17 years.

In this study, we evaluated the relationship of the changes in the sagittal plane with the position of the eight-plate. A decrease was observed in TS after with eight-plate growth guidance. This decrease was significant only in the anteriorly placed plates. We also investigated one-side applied plates (medially or laterally) effects on postoperative TS measurements. We found that both TS changes were equal in all one-sided applied plates (medially or laterally). Based on this conclusion, eight-plates should be placed in the midline in the sagittal view to prevent TS changes. Eight-plates placed in the epiphysis affect the medial and lateral TS equally, so it can be measured from both sides. Correction of the deformity with anteriorly placed plates in patients with knee deformities may affect the angle of TS in the sagittal plane and cause knee flexion contracture or recurvatum.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethics Committee of Aydın Adnan Menderes University (2020/166).

Informed Consent: N/A.

Author Contributions: Concept - E.Ç.; Design - E.Ç.; Data Collection and/or Processing - V.Y.; Writing - V.Y., E.Ç.

Conflict of Interest: The authors have no conflicts of interest to declare.

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