

Finding the Physeal Midpoint using Anatomical Landmarks: A Novel Approach for Guidance of Hemiepiphysiodesis Plating on Digitally Reconstructed Lateral Radiographs

Ameen Z Khalil, Stephen K Aoki, Joseph Featherall, Allan Kenneth Metz, Reece Meyer Rosenthal¹, Devin Louis Froerer, Natalya Elle McNamara, Christopher A Makarewich²

¹University of Utah Department of Orthopaedics, ²University of Utah

INTRODUCTION:

During puberty, the distal femoral physis is the fastest growing growth plate in the human body. Hemiepiphysiodesis is an alternative to corrective osteotomy that is less invasive, using multiple plates to compress the physis and optimize femoral development. Given the delicate nature of the physis, plate placement must be aligned with the physeal midline to minimize the risk of anteroposterior deformities, such as procurvatum or recurvatum deformity, which if uncorrected could lead to abnormal gait, gross deformity, or pain (Figure 1). In widespread practice, an intraoperative lateral radiograph is used to visualize the medial and lateral aspects of the physis and a visual approximation of the center point of the physis is made prior to placement of hemiepiphysiodesis plates. However, since the lateral radiograph creates a two-dimensional visualization of a multifaceted three-dimensional physis, there remains a substantial risk of misplacement of the hemiepiphysiodesis plate. Despite this, there is no formal methodology on best practices for visual estimation of the midpoint. Therefore, the purpose of this study is to investigate the proximity and reliability of easily identifiable anatomic structures surrounding the physeal midpoint on lateral radiographs. These include the diaphyseal midpoint, the superior physeal undulation apex, and the inferior curvature of Blumensaat's line. We hypothesize that Blumensaat's line will serve as the strongest predictor of physeal midline location.

METHODS:

Digitally reconstructed perfect lateral radiographs (DRR) were created from high-resolution computer tomography (CT) imaging studies of pediatric patients with an open physis. CT data were imported into an open-source image processing software and a ray-casting algorithm was used to create the DRR.

On each lateral DRR, the anterior and posterior edges of the open physis were determined and connected with a straight line. The standardized midpoint was then marked with a fiducial point at the precise mathematical center of this line. Each method of estimating the center of the physis was compared to this standardized midpoint. In the diaphyseal midpoint estimation method, the midpoint of the diaphysis was marked using a line drawn from the anterior to posterior cortex at a point three centimeters superior to the anterior margin of the open physis (Figure 2A). In the undulation apex method, a fiducial marker was placed at the apex of the physeal undulation (Figure 2B). Finally, in the Blumensaat's method, a fiducial marker was placed at the inferior curvature of Blumensaat's line (Figure 2C). Measurements were then taken from all three marked landmarks to a vertical line through the standardized physeal midpoint. Positive values indicated anterior distance from the midpoint, and negative values indicated posterior placement.

RESULTS:

Twenty-seven total patients were included for measurement, with twenty males and seven females (Table 1), with a mean age of 13.6. On average, the midpoint of the diaphysis, taken 3 cm above the physis, was 5.1 mm anterior to the midpoint of the physis with a standard deviation of 2.0 mm. The measurement taken at the apex of the undulation, was 2.8 mm anterior to this same line with a standard deviation of 2.0 mm. Lastly, the inferior rim of Blumensaat's point was 0.6 mm anterior with a standard deviation of 1.2 mm (Table 2).

DISCUSSION AND CONCLUSION:

In this cohort of pediatric patients, the inferior curvature of Blumensaat's line was found to be the most reliable predictor of physeal midpoint location, averaging 0.6 mm anterior to the midpoint. The apex undulation of the superior physeal line and the diaphyseal method were found to be less precise predictors.

The discrepancy between these points relative to the physeal midpoint is multifactorial in nature. Variances in bony anatomy, age of the physis, as well as quality and angle of imaging modality all contribute to the perceived appearance of the growth plate on imaging. Still, the results of the present study support our hypothesis that there are multiple previously unidentified proximal radiographic landmarks that can aid in approximating location of the physeal midpoint. Although Blumensaat's method had the most precision among the three, multiple points of reference can and should be used when determining orientation within this region.

Misplacement of hemiepiphysiodesis plates and subsequent growth abnormalities are a source of concern for both patients and surgeons. The results of this study can help reassure surgeons that they are in the correct vicinity of their desired target and provide a frame of reference as to where the midpoint of the physis ought to be in relation to various visible anatomic structures on the intraoperative lateral radiograph.



Figure 1: Aberrant placement of hemiphyseal plate, causing procurvatum deformity.

Descriptive Stats of Cohort (Percentage of Cohort)	
Sex	
Male	20 (0.740)
Female	3 (0.110)
Laterality	
Right	16 (0.563)
Left	11 (0.407)
Age at Placement	13.600

Table 1: Patient demographics.

Measurement	Minimum (mm)	Maximum (mm)	Mean (mm)	Standard Deviation (mm)	Median (mm)
Midpoint of Diaphysis-Method	1.1	8.8	5.1	2.0	5.6
Apex of Epiphysis of Superior Physis-Linear Method	-0.4	5.5	3.8	3.0	3.0
Blumensaat's Point-Method	-1.8	2.3	0.6	1.2	1.1

Table 2: Measurement values and indices of skewness using three analytic methods from the distance of the line created from the center point of the physis, which was then placed directly perpendicular to the plate. Positive and negative values indicate a measurement that is anterior or posterior to the line drawn from the midpoint of the physis, respectively.

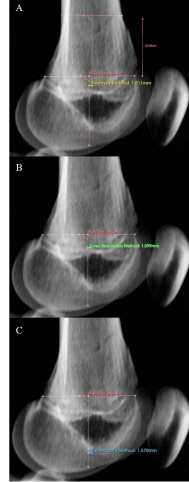


Figure 2: Measurements taken on perfect lateral DRB: (A) Distance between diaphyseal midpoint relative to physeal midpoint. (B) Distance between apex epiphysis relative to physeal midpoint. (C) Distance between inferior rim of Blumensaat's line relative to physeal midpoint.