Blumensaat-Epiphyseal Containment of the Knee (BECK): A New Radiological Guide to Determine Patellar Height

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Introduction: Characterizing the position of the patella in relationship to the femur has been problematic. Current methods to evaluate patellar height use ratios and calculations derived from measurements taken on lateral radiographs. Commonly used methods include Insall-Salvati [1], Blackburne-Peel [2], and Caton-Deschamps [3], with the Koshino-Sugimoto [4] used in pediatric patients. Unfortunately, these methods are often time consuming, involving two or more measurements in addition to calculations [5]. These techniques depend on ratios that take into account the relative size of the patella and its proportional relationship to landmarks on the tibia, femur, or both. In a child's knee, the exercise becomes more complex due to diffuse landmarks and maturity dependent ossification. Thus, current methods are age dependent, and depending on the quality of the radiograph can have significant inter- and intra-observer variability.

Ideally, a clinician should be able to look at a lateral knee radiograph and know whether the patella is in a normal position. There is a need for a simple method to accurately and reliably confirm the correct location of the patella when relocating it during surgery. On lateral radiographs, it has been observed that the angle formed by Blumenstaat's line (along the intercondylar notch) and the epiphyseal line, when extrapolated, form an area of patellar containment through a wide range of knee flexion angles. As angles are length independent, they subtend a space that is growth independent and should allow for characterization of patellar height without calculated ratios.

The objective of this study was to investigate this observation and define a simple method to identify patellar height. This observed angle has been deemed the Blumensaat-Epiphyseal Containment of the Knee (BECK). Using cadaveric specimens, a series of lateral radiographs were used to track and measure the relationship of the patella with the BECK angle through a range of knee flexion angles.

Methods: Ten fresh-frozen cadaveric knees were used for this study (n = 5 male and female each). The mean age was 19.5 years (range of 16 to 23). Specimens were potted in acrylic PMMA. The femoral pot was secured in a split clamp that allowed rotational alignment for an approximate true lateral radiograph (Figure 1). Once aligned, a series of radiographs were taken in 15° increments from 0° to 90° of knee flexion. At each flexed knee position, a secondary fixture was used to hold the tibia in place. To simulate the resting tension of the quadriceps tendon and ensure patellar tracking during flexion, a spring scale was used to apply a constant 22 N tension to the quadriceps tendon in line with the long axis of the femur.

Measurements were taken to define the knee flexion angle, pole-to-pole patellar length, and the BECK angle in order to track the relationship between the patella and the BECK angle on each series of radiographs (Figure 2). The flexion angle was measured between the posterior cortex of the tibial and
femoral shafts. Pole-to-pole patellar length was measured between the inferior and superior poles of the patella. The BECK angle was formed by the epiphyseal line and Blumensaat’s line as follows. First, a line was drawn parallel to the longest portion of the posterior cortex of the femur. Next, the most proximal point at the central peak of the distal femoral physis was identified. The epiphyseal line was then created from a line perpendicular to the posterior cortex, intersecting the proximal central peak of the physis (Figure 2A). Lastly, a line through the central third of Blumensaat’s line was drawn. Subsequently, the intersection of the epiphyseal line and Blumensaat’s line created the BECK angle. The patella was fully contained when the superior pole of the patella was below the epiphyseal line and the inferior pole was above Blumensaat’s line (Figure 2A). Patella alta was defined as the percentage of the overall pole-to-pole length that was positioned above the epiphyseal line (Figure 2B). Patella baja was defined as the percentage of the overall pole-to-pole length that was positioned below Blumensat’s line (Figure 2C).

Intra- and inter-observer variability was assessed from three different operators, each performing all measurements three separate times. Pearson’s correlation coefficient and a one-way ANOVA were used to measure reproducibility and repeatability. Pairwise post hoc comparisons were made using Tukey’s HSD procedure. The level of significance was p < 0.05.

**Results:** For all 10 specimens, the mean BECK angle was 49.1 ± 2.6° and the mean pole-to-pole patellar length was 46.1 ± 5.8 mm. At full extension, the patella was 87% alta. As the knee was flexed, the patella moved inferiorly. At 90° flexion, the patella was 60% baja. Maximum patellar containment occurred at 47° flexion, where 91% of the pole-to-pole patellar length was contained within the BECK angle. The patella had 75% or greater containment between 35° and 67° of knee flexion, and 50% or greater containment between 21° and 84° degrees of knee flexion (Figure 3).

Intra- and inter-observer variability was assessed for measured flexion angle, pole-to-pole patellar length, BECK angle, and percentage alta and baja. There were no significant intra- or inter-observer differences for all measurements, and all Pearson coefficients were greater than 0.80.

**Discussion:** Based on the results of this study, a lateral radiograph taken with the knee between 35° to 67° of flexion should show at least 75% patellar containment within the BECK angle for a normal knee. At knee flexion angles from 21° to 35° and 67° to 84° of flexion, at least 50% patellar containment should be seen in a normal knee.

It should be noted that, while measurements were standardized for the purposes of this study, the new proposed method is fast and in practice would require minimal measurements. Identification of containment can be performed in a simple manner through visual inspection of the radiograph. If the observer believes the patella is at or greater than the target level of containment, then a measurement should be taken to confirm patellar position within the BECK angle.

Examples of cases where such a method may prove useful are those of patellar pathology (dislocations), extensor mechanism repairs (quadriceps/patellar tendon ruptures, sleeve fractures), and surgery for cerebral palsy patients (tendon lengthening of the lower extremities). Ideally this should allow the surgeon to quickly use the method in conjunction with spot film radiography in the operating room, where one is otherwise unable to make exact measurements due to time and other constraints.

These findings are important, as they specifically provide a simple guide for proper patellar realignment while also providing the basis for determining patellar height. The next steps will be to determine age dependence to see if this method can be used (or altered) for the pediatric patient.
**Significance:** This cadaveric examination provides an objective means for examining normal patellar height using basic landmarks on a lateral radiograph. Based on the results, identification of the BECK angle within a designated flexion range would provide easy and useful means of diagnosing patellar height pathologies in a clinical setting.

![Image](image_url)

**Figure 1.** Knee setup for lateral radiographs. The femur was clamped in a fixture and the tibia was positioned to the target flexion angle. A spring scale was used to hold constant tension on the quadriceps tendon.
Figure 2. The BECK angle was defined between the epiphyseal line and Blumensaat’s line. Pole-to-pole patellar length was either fully contained (A), a portion above the epiphysis indicating patella alta (B), or a portion below Blumensaat’s line indicating patella baja (C). * Indicates the most proximal point at the central peak of the distal femoral physis.
Figure 3. Tracking the relationship of the patella to the BECK angle during flexion from $0^\circ$ to $90^\circ$. The patella is 50% or more contained within the BECK angle from $21^\circ$ to $84^\circ$ flexion, and 75% or more contained from $35^\circ$ to $67^\circ$ flexion ($n = 10$; ± SD error bars).