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## CHARACTERISTICS OF THE LINE OF BLUMENSAAT

### *An Experimental Analysis*

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The line of Blumensaat, l. Bl., is a faint condensed line on the lateral radiograph of the knee joint in the condylar massif of the femur. It represents the tangentially hit part of the roof in the intercondylar fossa. This line has gained its special interest from the fact that Blumensaat (1938) used it as a landmark for the vertical location of the patella: at a knee flexion of about 30 degrees, the normally located patella will touch the extension of the l. Bl.

In a previous paper we have stated (Jacobsen & Bertheussen 1974) that this definition is untenable, as the vertical location of the normal patella is considerably higher than suggested by Blumensaat. We have also called attention to the fact that the relation to the l. Bl. is a poor measure for the location of the patella as, during knee flexion, this line shows a marked alteration of its direction. The perpendicular distance,  $a$ , from the apex patellae to the l. Bl. is thus much more dependent on the degree of knee flexion than on the length of the patellar tendon. A more thorough analysis of the complicated movement of the l. Bl. is carried out in the present paper.

Another characteristic of the l. Bl. is the formation of an angle,  $\nu$ , between the line and the axis of the femoral shaft. In our previous work we found this angle to be 32.6 degrees on the average, with a small dispersion, while Brattström (1970) found a mean value of 45 degrees and a dispersion of from 27 to 60 degrees. An investigation of this matter is also carried out in the present paper.

## MATERIAL AND METHOD

For investigation of the movement of the l. Bl. during knee flexion, we used the lateral radiographs of 5 healthy subjects obtained in full knee joint extension and in increasing flexion up to 110 degrees (the 70 degree-position). The radiographs were made with intervals of 15 degrees.

The movements of the l. Bl. and the apex patellae are both analysed in relation to the tibia, which thus can be regarded as the fixed part. The outline of the tibia is drawn on a translucent template placed on the first radiograph, and so is the l. Bl. and the apex patellae. This template is placed successively on the following radiographs of the same subject, and both the l. Bl. and the apex patellae are marked for each new position, while the outline of the tibia on the template is brought to cover the outline on the radiograph. Figure 1 is the result of this procedure.

The 5 normal subjects satisfy the same clinical and radiological demands as the subjects in our previous work.

Alterations in the angle  $\nu$  caused by alterations in the position of the knee in the X-ray beam were investigated on 10 human knee specimens. These were fastened to a stake in the centre of a rotatable disc, with a degree scale in a circle around the disc. A pointer showed the rotation from the zero or neutral position. In this position, the direction of the X-ray beam was at right angles to the specimen from the tibial or fibular side. The joint was in 90 degrees of flexion. The zero or neutral position was defined as the one where the distal outlines of the two femoral condyles were tangentially hit by the same beam, which means they were projected onto each other on the radiograph. After exposure in this position radiographs were taken with 5, 10, 15, 30 and 45 degrees of rotation, both inwards and outwards.

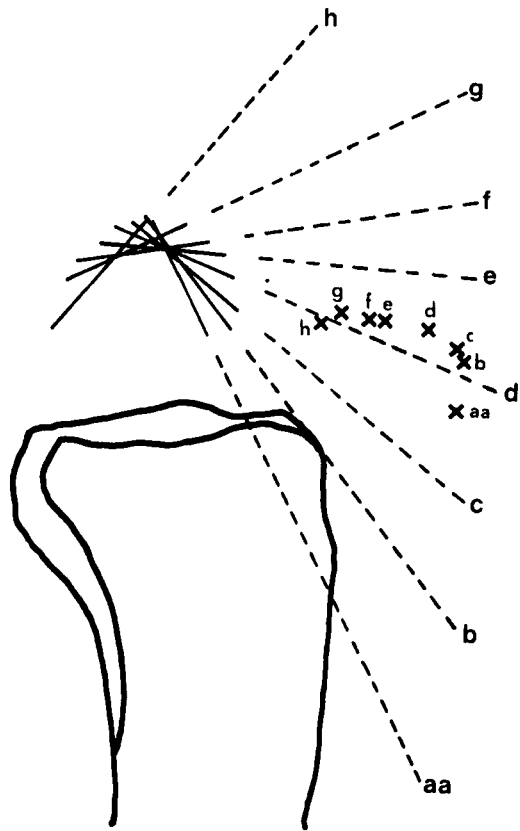
## RESULTS

Figure 1 has the same appearance in all the 5 investigated cases. The distance  $a$  at 30 degrees of knee flexion is in these cases 22 mm on the average, ranging from 15 to 26 mm. At an alteration of the flexion from 30 degrees to 45 degrees, the reduction of  $a$  is, on the average, 14 mm (ranging from 9 to 18 mm); while the reduction of  $a$  at an alteration from 15 degrees to 30 degrees of flexion averages 11 mm (ranging from 9 to 12 mm). So, the reduction of  $a$  is less from 15 to 30 degrees of flexion than it is from 30 to 45 degrees.

The point of intersection between the l. Bl. and the apex patellae among these subjects occurs at an average of 52 degrees of knee flexion.

The alterations of the angle  $\nu$  during rotation of the object in an X-ray beam of constant direction are given in Table 1. The variation of  $\nu$  in each specimen during rotation from the neutral position to a position of 45 degrees rotation, both outwards and inwards, ranges

Figure 1. The movements of the l. Bl. (unbroken lines) and the apex patellae (crosses) during knee flexion. The extension of the l. Bl. (broken lines). The position aa corresponds to knee extension (in these subjects very close to the 180 degree-position), the position b to 15 degrees, c to 30, d to 45, e to 60, f to 75, g to 90 and h to 110 degrees of flexion.



from 6 to 18 degree (with a mean of 10 degrees). The total dispersion of all measured values of  $v$  is from 29 degrees to 55 degrees. The smallest values are always measured in the neutral position, and values increase with rotation, both inwards and outwards. A medio-lateral beam gives the same values as a latero-medial one.

By additional rotation of the X-ray film 30 degrees inwards or outwards, only a few more degrees are gained in addition to the mentioned highest or lowest values of  $v$ .

#### DISCUSSION

The alteration of the direction of the l. Bl. during knee flexion, as well as the relation to the wandering apex patellae, appears from Figure 1. The marked wandering of the apex patellae from zero to 30 degrees of

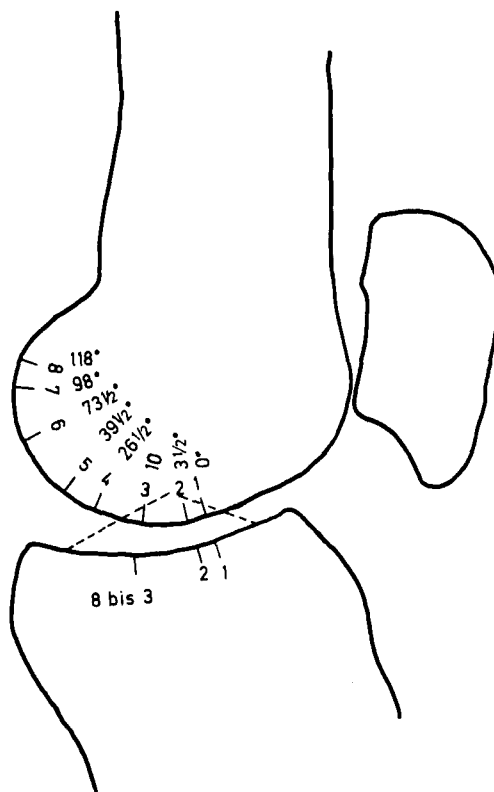
*Table 1. The variation of the angle  $v$  during rotation of the knee in a constantly directed X-ray beam.*

Position (rotation) degrees	Angle $v$ (degrees)	
	Mean	Range
0	33	30-38
15 outwards	35	31-42
30 outwards	37	32-47
45 outwards	39	32-50
15 inwards	36	29-41
30 inwards	39	33-46
45 inwards	42	31-55
Total variation		29-55

knee flexion is caused by alterations in the tension of the patellar tendon. The latter is slack in the extended knee and in small degrees of flexion, when the leg is supported as it is during the procedure of radiography. At about 30 degrees of flexion the tendon is taut, and the subsequent movement of the apex patellae takes place along an arc of a circle, whose centre is the insertion of the patellar tendon on the tuberosity of the tibia and whose radius is the tendon. The posterior part of the circle movement is made possible by the diminishing radius of the sliding surface on the femoral condyles (see below), which draws the condyles and also the l. Bl. backwards in relation to the tibia. The described movement of the apex patellae is almost vertical during the first part of the knee flexion, which means that the apex is withdrawn from the approaching l. Bl. This explains the previously mentioned fact that the reduction of  $a$  is less in the beginning of the knee flexion, from 15 to 30 degrees, than it is in the interval from 30 to 45 degrees. It is apparent that the point of intersection between the l. Bl. and the apex patellae occurs at a little more than 45 degrees of knee flexion, considerably above the level suggested by Blumensaat.

The movement of the l. Bl. as it is shown here is in agreement with the classic "mechanics of the joints", as stated by Fick (1904-11). Our interest lies especially in the intermingled rolling and sliding of the femoral condyles on the tibia during knee flexion. The analysis of this movement was originally carried out by Fischer (1907), by means of Zuppinger's lateral radiographs of the knee during flexion (1904). Figure 2 (Fischer) explains this movement. The corresponding points of contact on the condyles of the femur and the tibia are similarly

*Figure 2. Fischer's figure showing the corresponding points of contact on the condyles of the femur and tibia during knee flexion.*



numbered. The figures in degrees on the femoral condyle give the degree of knee flexion, which corresponds to contact of each point with the tibia. Note that the pure rolling movement takes place only in the beginning of flexion, using the distance from point 1 to point 3 on the femur and point 1 to point "8 bis 3" on the tibia. Figure 2 shows the medial condyles; in the lateral condyles, the rolling movement is continued a little longer. In further flexion the contact point will continue to be the same on the tibia, point "8 bis 3". The femoral condyle slides with its outline, evolvente (Fick), from point 3 to point 8, passing this same point on the tibia ("8 bis 3"). Figure 2 can be reproduced on a template, with the femur made movable on the tibia, leaving an equal part of "cartilage" on each of them; the l. Bl. can then be drawn on the femoral part (by means of a radiograph). Thus, the movement of the l. Bl. can be constructed by the template being moved according to the corresponding figures on the two condylar parts. The resulting Figure is identical to Figure 1.

The movement backwards and downwards of the posterior point of the l. Bl. is caused by the continuous posterior diminishing of the radius of the evolvente. This curved line (and a similar line described by the anterior point of the l. Bl. during knee flexion) may be followed on Figure 1. Owing to the intermingled rolling and sliding movement of the femoral condyles on the tibia, and owing to the diminishing radius of the evolvente, a simple mathematical formula of the curved lines cannot be given. But these complicated lines, as well as the movement of the whole l. Bl. and the movement of the apex patellae, stress the difficulties of the use of the l. Bl. as a "landmark" for the vertical location of the normal patella.

It is shown above that a considerable variation of the angle  $\nu$  is possible, even in the same specimen, if the radiography is carried out on varied positions of the specimen in an X-ray beam of constant direction.

In this connection it must be pointed out that the l. Bl. is defined as a line on the lateral radiograph of the knee joint, and that a line on the radiograph does not represent a definite line in the bone concerned. Sharp lines on the radiograph of bones are found where the cortical bone is hit tangentially as stated by Lachmann (1937) and at the cartilage-bone borderline in joints (Weiss 1943). The l. Bl. arises from the cortical bone in the roof of the femoral intercondylar fossa, where it is hit tangentially, which can be shown on a macerated bone (Lachmann and own experiments). However, the roof in the intercondylar fossa is curved in several directions and so different parts of it may be the cause of origin of the l. Bl., if the position in relation to the X-ray beam is altered. From this it follows that the location of the l. Bl. on the radiograph may be altered.

The cause of the discrepancy between the mean values of the angle  $\nu$ , as given by Brattström and as given by us in our previous paper, is that his radiographs were not made under the same conditions of projection as ours. The reason for his greater dispersion of the values of the angle  $\nu$  is that his radiographs were not made under strictly constant circumstances. Thus we have been able to produce the same dispersion (29 degrees to 55 degrees) as Brattström (27 to 60 degrees) by means of rotation of the knee joints in a constantly directed X-ray beam.

This characteristic of the l. Bl. (that is varying location on the radiograph dependent on the position of the knee in relation to the direction of the X-ray beam) also makes the use of the l. Bl. as a landmark for the vertical location of the patella unsatisfactory. As mentioned in our previous paper, we propose the index of Insall & Salvati

(1971), LT/LP (length of patellar tendon/length of patella), be used instead.

It should be pointed out that the mean value of the angle  $\nu$  (33 degrees) of the knee joint specimens in neutral position is the same as the mean value obtained from the 50 subjects in our previous work.

Incorrectness of the location of the I. Bl. because of an oblique X-ray film (instead of a right angle position to the X-ray beam) is of little significance—and may be avoided by means of a raster in the plate holder.

#### SUMMARY

An account of the movement of the line of Blumensaat during knee flexion is given in the light of investigations of lateral radiographs of 5 normal subjects. The results are correlated with the classic "mechanics of the joints". The simultaneous movement of the apex patellae is described as well. Both movements contribute to the variation of the perpendicular distance from the apex patellae to the line of Blumensaat during knee flexion.

A material of 10 human knee joint specimens is investigated for the variation of the angle  $\nu$ , between the axes of the femoral shaft and the line of Blumensaat, dependent on the position of the joint in relation to the X-ray beam. In this experiment a great dispersion of the values of  $\nu$  can be produced equal to the dispersion earlier found by Brattström. This fact also contributes to the view that the line of Blumensaat is an unsatisfactory landmark for the normal vertical location of the patella. We propose the index of Insall & Salvati be used instead.

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