ACTA
ORTHOPAEDICA
et
TRAUMATOLOGICA
TURCICA

Author's translation

Acta Orthop Traumatol Turc 2006;40(3):240-247

Blumensaat line and patellar height

Blumensaat çizgisi ve patella yüksekliği

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Amaç: Blumensaat yönteminin patella yükseklik indeksleri ile uyumu araştırıldı ve patella yüksekliği ölçümündeki kullanılabilirliği değerlendirildi.

Çalışma planı: Diz grafileri 30° fleksiyonda çekilen 77 hastanın (23 erkek, 54 kadın; ort. yaş 32; dağılım 21-62) 105 dijital diz grafisi çalışmaya alındı. Bu grafilerde, patella yükseklikleri Blumensaat, Insall-Salvati, modifiye Insall-Salvati ve Blackburne-Peel yöntemlerine göre kalitatif ve kantitatif olarak ölçüldü. Blumensaat çizgisinin femur şaftıyla yaptığı açı standardize edilerek (düzeltmeli Blumensaat yöntemi) ölçümler tekrarlandı. Elde edilen kalitatif sonuçlar açısından yöntemlerin uyumu, kantitatif sonuçlar açısından ise yöntemler arasındaki korelasyon incelendi.

Sonuçlar: Kalitatif sonuçlar açısından Blumensaat yöntemi ile Insall-Salvati, modifiye Insall-Salvati ve Blackburne-Peel indeksleri arasında çok zayıf bir uyum saptandı (sırasıyla, kappa= 0.21; -0.14 ve 0.12). Düzeltmeli Blumensaat yöntemiyle indeks sonuçları arasında yapılan karşılaştırmalarda da çok zayıf bir uyum bulundu (sırasıyla, kappa= 0.27; -0.11 ve 0.13). Kantitatif sonuçlara göre analizde, orta veya çok zayıf derecede korelasyonlar bulundu. Nispeten en iyi korelasyon Blumensaat yöntemi ile Insall-Salvati yöntemi arasındaydı ($r=0.514$, $p<0.05$). Blumensaat dışındaki yöntemlerin kendi aralarında da orta veya zayıf derecede korelasyon vardı. En iyi korelasyon modifiye Insall-Salvati ve Blackburne-Peel yöntemleri arasındaydı ($r=0.557$, $p<0.05$).

Çıkarımlar: Patella yüksekliğinin değerlendirilmesinde Blumensaat yöntemi, kullanılan patella yükseklik indeksleri ile uyumlu sonuçlar vermemektedir.

Anahtar sözcükler: Antropometri/yöntem; femur/radyografi; eklem hastalıkları/radyografi; diz eklemi; patella/anatomi ve histoloji/radyografi.

Objectives: We investigated the agreement between the Blumensaat method and patellar height ratios and evaluated the reliability of the method in patellar height measurements.

Methods: We retrospectively evaluated 105 digital knee x-rays of 77 patients (23 males, 54 females; mean age 32 years; range 21 to 62 years), whose radiographs were obtained at 30° of knee flexion. Patellar heights were measured with the use of the Blumensaat, Insall-Salvati, modified Insall-Salvati, and Blackburne-Peel methods. Patellar height was also evaluated after standardization of the angle between the femoral shaft and the Blumensaat's line (corrected Blumensaat method). Agreement and correlations were sought between the qualitative and quantitative results of the methods, respectively.

Results: When the qualitative results were considered, agreement of the Blumensaat method was very weak with the Insall-Salvati, modified Insall-Salvati, and Blackburne-Peel methods (kappa coefficients: 0.21, -0.14, and 0.12, respectively). The corrected Blumensaat method also had a very weak agreement with the other indices (kappa coefficients: 0.27, -0.11, and 0.13, respectively). Correlation analyses of the quantitative results showed very weak to moderate correlations between the methods used. The Blumensaat method was relatively well correlated with the modified Insall-Salvati method ($r=0.514$, $p<0.05$). Correlations were weak to moderate between the patellar height indices, the highest correlation being between the modified Insall-Salvati and Blackburne-Peel methods ($r=0.557$, $p<0.05$).

Conclusion: The results of the patellar height measurements obtained by the Blumensaat method do not agree with widely used patellar height indices.

Key words: Anthropometry/methods; femur/radiography; joint diseases/radiography; knee joint; patella/anatomy & histology/radiography.

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Received: 18.09.2005 **Accepted:** 05.12.2005

Patellar height can be assessed by direct or indirect methods. Indices such as Insall-Salvati (IS), Blackburne-Peel (BP) and Caton-Deschamps (CD) are indirect methods which measure patellar height by ratios based on the length of the patellar tendon or some reference points on the proximal part of the tibia.[1] The technique described by Blumensaat in 1938, which uses the roof of the intercondylar notch as a reference line, is one of the most commonly used direct methods for the assessment of patellar height.[1,4]

Blumensaat method has the main advantages of being practical and assessing the vertical position of the patella in respect to femur. This method takes place also in classical orthopedic textbooks and is occasionally utilized in studies related to patellar height.[1,5,6] The two drawbacks of the method are substantial effect of knee flexion and variability of the angle between Blumensaat line and the femoral shaft.[4,7,8] Presently, these issues have led to a tendency to implement indirect methods (patellar height indices). [1,2,8-10]

In the present study, we studied the agreement between the Blumensaat method and patellar height ratios, and evaluated the reliability of the Blumensaat method in patellar height measurements.

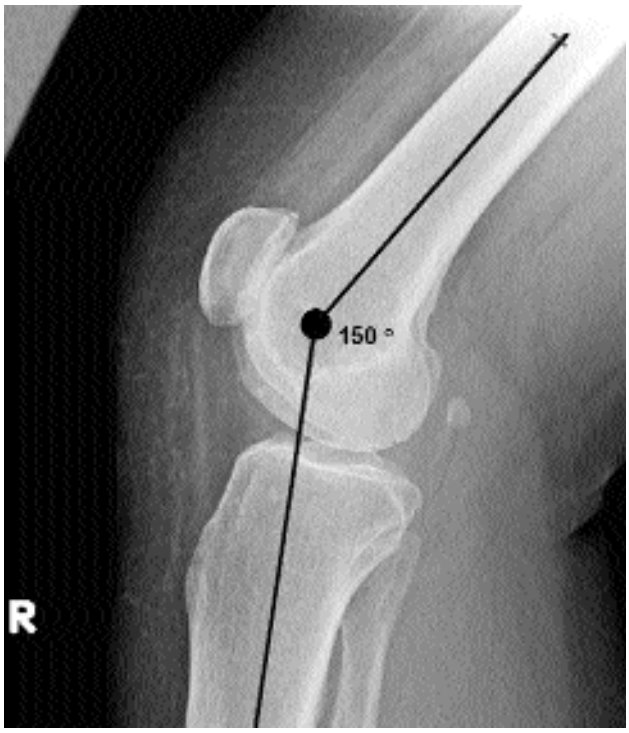

Figure 1. Study included only radiographs taken at 30 degrees of flexion and full lateral position.

In the present study, we investigated the congruence between the Blumensaat method and patellar height ratios, and evaluated the reliability of the method in patellar height measurements.

Materials and methods

We retrospectively examined the digital records of 854 patients who presented to our hospital between June 2004 – August 2005 and whose lateral knee radiographs were available. The inclusion criteria were based on: 1- radiographs taken at 30 degrees of flexion; 2- a distance less than 3 mm between the posterior borders of femoral condyles, and 3- absence of any degenerative change to a degree which may influence the selection of reference points.

A total of 105 knee radiographs (33 of males, and 72 of females) of 77 patients who met the inclusion criteria (23 males, 54 females; mean age 32 years; range 21 to 62 years) were included in the study (Figure 1).

Figure 2. Blumensaat line is drawn on the linear radioopacity of the roof of the intercondylar notch on the lateral knee radiograph. In this method, the patellar height is assessed according to the distance between the lower pole of the patella and the Blumensaat line in millimeters. The lower pole of the patella should normally lie on the Blumensaat line; if it is more than 10 mm above the line, it is classified as patella alta.

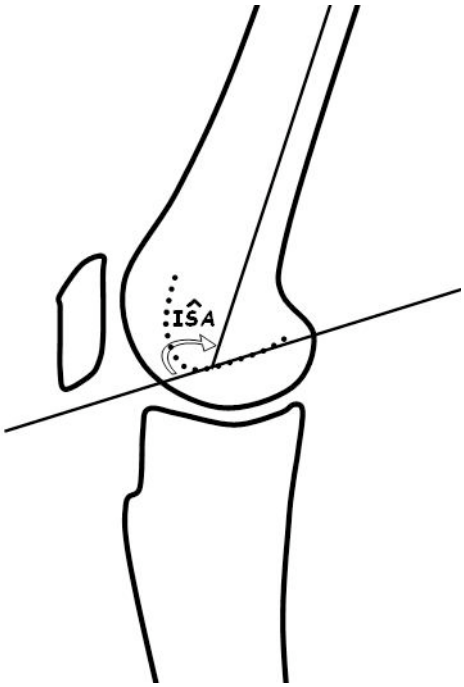

Figure 3. The intercondylar shelf angle, the angle between the roof of the intercondylar notch and the femoral diaphysis.

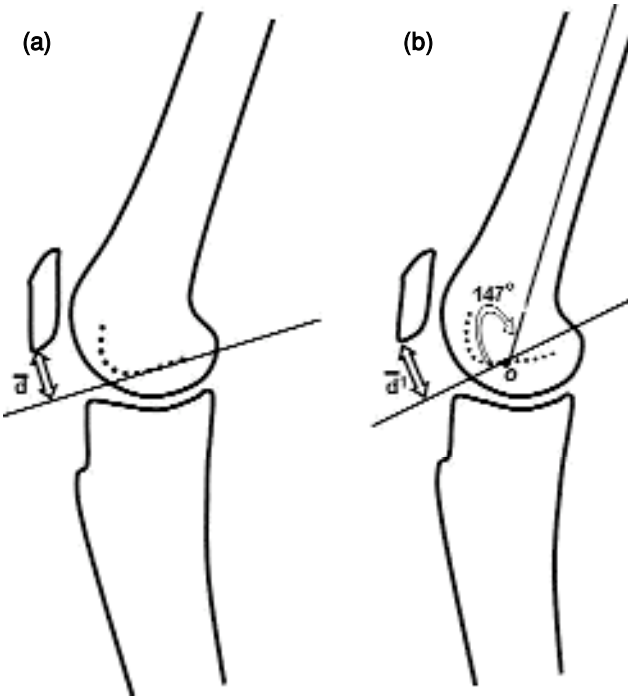

Figure 4. **(a)** Assessment of the patellar height ***d*** by the classical Blumensaat method. **(b)** Patellar height was also assessed with ISA corrected – Blumensaat method. In this method a common Blumensaat line with a fixed inclination (147°) was drawn on each knee and the position of the lower pole was assessed according to this line.

The flexion angles and distances on the digital radiographs were measured with the Hipax image processing tool (version 4.1.4) at a sensibility of 1/100 mm.

When assessing the patellar height by the Blumensaat method, the position of the lower pole of the patella (above or below the Blumensaat line) and the distance between the lower patellar pole and the Blumensat line in millimeters were noted (Figure 2).

The angle between the Blumensaat line and the femoral shaft (intercondylar shelf angle – ISA) was measured for each knee in order to evaluate the variability of the inclination of the Blumensaat line in respect to the femoral shaft and the effect of this variability on patellar height measurement (Figure 3). The mean ISA was calculated, and a common Blumensaat line in the inclination of this mean ISA, intersecting the midpoint of the Blumensaat line, was drawn on each radiograph. The patellar height was also evaluated based on this line ("ISA-corrected" Blumensaat Method) (Figure 4a, b).

Insall-Salvati (IS), modified Insall-Salvati (MIS) and Blackburne-Peel (BP) indices were calculated (Figure 5) and each knee was qualitatively classified (as patella baja, norma or alta).

The qualitative patellar height results as measured by the "classical" and "ISA-corrected" Blumensaat methods were compared to evaluate the agreement between these methods. The correlation of Blumensaat methods ("classical" and "ISA-corrected") and patellar height ratios was examined. And according to these correlations the effect of ISA variation on the patellar height was evaluated.

Statistical analysis

Statistical analysis was performed using the SPSS 13.0. The distribution characteristics of the data were evaluated with the Shapiro-Wilks test. Qualitative results of different methods were compared by chi-square test and Cohen's Kappa coefficient. Quantitative results were compared with chi-square test and Spearmann coefficient was used for correlation analysis. A $p<0.05$ was considered significant.

Results

The mean ISA was 146.73±3.21º. In the inclination of this fixed ISA angle of 147º, a common

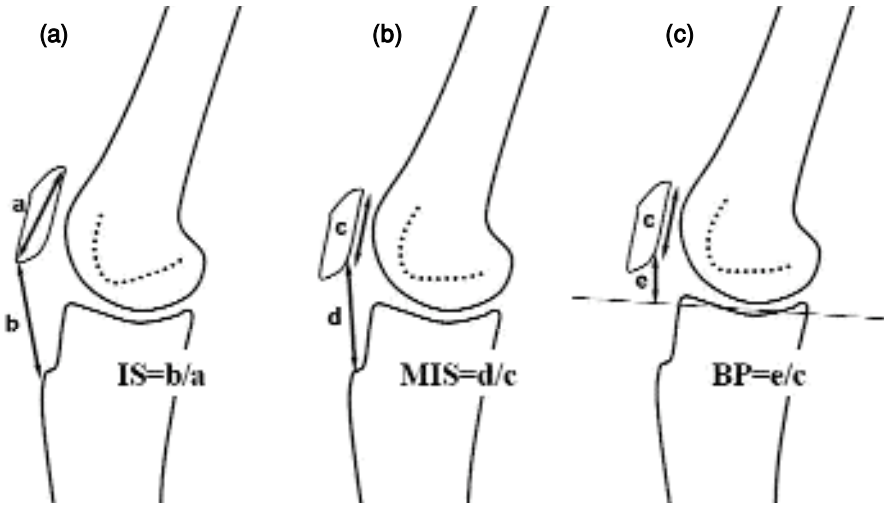

Figure 5. (a) The Insall-Salvati index is the ratio of the length of patellar tendon *(b)* (which is measured on its post surface from the lower pole of patella to its insertion on top of tibial tubercle) to the length of patella *(a)* (which is the greatest diagonal length measured). Usually ranges between 0.8 and 1.2. Any outcome >1.2 is classified as patella alta, and <0.8 as patella baja.[1]
(b) The modified Insall-Salvati ratio is based on the distance between the distal end of the articular surface of the patella *(d)* and the patellar tendon insertion on the tibia and the length of the articular surface of the patella *(c)*. Usually is less than 3, any outcome >2 is considered as patella alta.[1]
(c) The Blackburne-Peel method measures the ratio of the height of the lower pole of the articular surface above a tibial plateau line *(e)* to the articular surface length of the patella *(c)*. Usually range between 0.54-1.06. A ratio of less than 0.54 is considered to be patella infera.[1]

Blumensaat line, intersecting the midpoint of the radio-opaque line at the roof of the intercondylar notch, was drawn on each radiograph (Fig 4b). Patellar heights were also assessed based on this common line ISA corrected – Blumensaat method) as well as the classical Blumensaat line (Fig 4a).

The mean position of the lower patellar pole was 8.00±9.95 mm above the classical Blumensaat line and 8.08±10.76 mm above the ISA corrected – Blumensaat line. No statistically significant difference was found between the mean values of the two methods (t-test; p>0.05).

The mean and standard deviations of the patellar indices were found 1.12±0.17 according to the Insall-Salvati (IS) method; 1.92±0.19 according to the modified Insall-Salvati (MIS) method; and 0.93±0.18 according to the Blackburne-Peel (BP) method.

Table 1. Classification of qualitative results

	Qualitative results (n=105)		
Method	Patella alta	Patella norma	Patella baja
Blumensaat	43	60	2
ISA-corrected Blumensaat	38	64	3
Insall-Salvati	28	73	4
Modified Insall-Salvati	36	69	0
Blackburne-Peel	33	71	1

ISA: intercondylar shelf angle

Table 2. Correlations between the results of the classical and ISA corrected – Blumensaat methods and the patellar height ratios in the assessment of the patellar height.

	Insall-Salvati	Modified Insall-Salvati	Blackburne-Peel
Classical Blumensaat	r=0.514, p<0.05	r=0.089, p>0.05	r=0.429, p<0.05
ISA corrected-Blumensaat	r=0.478, p<0.05	r=0.052, p>0.05	r=0.514, p<0.05

ISA: Intercondylar shelf angle

Distribution of the qualitative results as measured by the classical Blumensaat, ISA corrected – Blumensaat methods and the IS, MIS and BP indices are shown in Table 1.

Qualitative results (patella alta, norma or baja) provided by the "classical" and ISA corrected – Blumensaat methods were the identical in 95 of 105 knees. There was a substantial agreement between these two methods (Cohen's Kappa coefficient, k=0.80). However qualitative results of the Blumensaat method did show a poor agreement with the results of patellar height ratios: Among 105 knees, the qualitative results of the classical Blumensaat method were identical with IS index results in 66 knees (k=0.21); identical with MIS index results in 48 knees (k=-0.14) and identical with BP index results in 61 knees (k=0.12). In sum, Blumensaat method gave the identical quantitative result with the patellar indices in only 175 of the 315 comparisons (56%).

Qualitative results of the ISA corrected – Blumensaat method did also show a poor agreement with the results of patellar height ratios: Among 105 knees, the qualitative results of the ISA corrected – Blumensaat method were identical with IS index results in 70 knees (k=0.27); identical with MIS index results in 51 knees (k=-0.11) and identical with BP index results in 63 knees (k=0.13). In sum, ISA corrected-Blumensaat method gave the identical quantitative result with the patellar indices in 184 of the 315 comparisons (58.4%).

Correlation analysis of the quantitative results of the Blumensaat method and patellar height indices revealed correlations at various levels. The correlation coefficients and significance levels are shown in Table 2. Blumensaat method showed the relatively best (moderate) correlation with the IS method (r=0.514, p<0.05 for the classical Blumensaat method, and r=0.478, p<0.05 for the ISA-corrected Blumensaat method). Blumensaat method showed the weakest correlation with the MIS method (r=0.089, p>0.05 for the classical Blumensaat method, and r=0.052, p>0.05 for the ISA-corrected Blumensaat method).

The analysis of the agreement of different patellar height indices, according to their qualitative results, showed a poor agreement between IS and MIS methods (k=-0.013, p>0.05), a poor agreement between IS and BP methods (k=-0.192, p<0.05); and a fair agreement between BP and MIS methods (k=-0.375, p<0.05).

Correlation analysis of the quantitative results of different patellar height indices revealed weak correlations. The relatively best (moderate) correlation was between MIS and BP methods (r=0.557, p<0.05; Table 3).

Discussion

In our study the Blumensaat method did not provide any congruent result with the patellar height indices.

When evaluating patellofemoral joint problems, one must consider the position of the patella in

Table 3. Correlations among the results of the patellar height ratios

	Insall-Salvati	Modified Insall-Salvati	Blackburne-Peel
Insall-Salvati	–	r=0.243, p<0.05	r=0.410, p<0.05
Modified Insall-Salvati	r=0.243, p<0.05	–	r=0.557, p<0.05
Blackburne-Peel	r=0.410, p<0.05	r=0.557, p<0.05	–

respect to the femur. Therefore, an ideal method should assess the patellar height directly, with a femoral reference landmark. However the most frequently used methods assess the patellar height by ratios which use several tibial reference points. [8,9,11-15] There are few studies comparing the patellar height assessment methods and there is no consensus on the superiority of any method and there is "no gold standard" method, agreed upon.[1,4,6,8-10,12] Therefore, one can not evaluate the sensitivity of a method about patellar height, but rather can assess its agreement and correlation with another method which is claimed to be good and ideal. In the present study, we evaluated the agreement of the Blumensaat method with the most frequently used methods, namely Insall-Salvati (IS), Modified Insall-Salvati (MIS) and Blackburne-Peel (BP) indices.

The major drawback which prevented the standardization and common use of the Blumensaat method is that it is largely affected by the knee flexion, [2,4,7-9] The effect of the knee flexion on the patellar height assessment is shown in Figure 6. We did not analyze this effect, which was beyond the scope of our study, and included only the radiographs taken at 30 degrees of flexion. However, it was noteworthy that the rate of radiographs, meeting the inclusion criteria among the knee radiographs screened, was very low. Only 105 of 854 knees (12.3%) met the inclusion criteria. Although our radiology department was committed to take the lateral knee radiographs routinely at 30 degrees of flexion, we found that the majority of them were taken at a flexion ranging from 20 to 45 degrees with a rotation to a degree where the posterior edges of the condyles could not have fully overlapped. The degree of flexion in lateral radiographs is also important for the index measurements.[8,9] Therefore, we believe that it is beneficial to inform the technician about radiographic positioning, when a knee radiographs is requested for the purpose of patellar height assessment.

The angle between the Blumensaat line and the femoral Shaft (ISA) can have individual variations.[3,7,16] Brattstrom[7] found that, in the knee radiographs of 100 randomly selected people, ISA was ranging between 120 and 153 degrees. This angle, which is also important in forensic anthropology, has racial variations. In two different studies (of 856 and 423 subjects), the mean ISA was 136.6±5.9º in the Malawian blacks and 137.8±4.2º in American blacks, while it was 146.2±4.3º in American whites. [3,16] In our study, the mean ISA of 105 knees was 146.73±3.21º (range 139 to 144º). Our results were consistent with the mean values of American whites, even though the number of our subjects was small.

It has been suggested that the variability of the ISA can change the inclination of the Blumensaat line, and thus affect the patellar height assessment with this method.[2,3] Figure 7 shows the effect of ISA variation on the patellar height assessment. However, the inclination of roof of the intercondylar

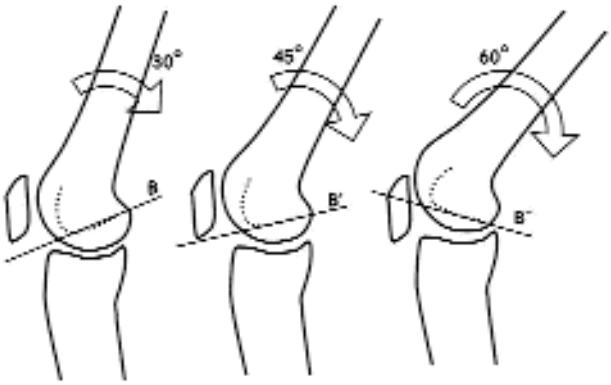

Figure 6. The effect of the degree of knee flexion on patellar height in the Blumensaat method. With the alteration of the degree of flexion, outcomes of patella alta (left side), patella norma (middle) and patella baja (right side) can be obtained on the same knee.

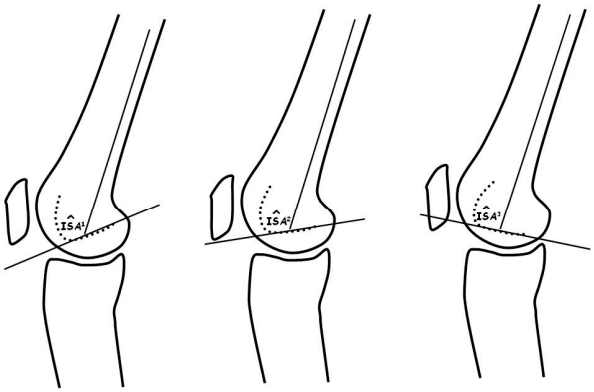

Figure 7. The effect of the intercondylar shelf angle variation on the assessment of the patellar height in the Blumensaat method. With a variation of the angle, outcomes of patella alta (left side), patella norma (middle) and patella baja (right side) can be obtained on the same knee.

notch can be considered as a component of the patellofemoral joint anatomy. Thus the Blumensaat line can be thought as a reference line with a specific inclination, independent from the femoral shaft. According to this hypothesis, the variability of ISA will have no effect on the patellar height. In order to test this hypothesis and demonstrate the effect of ISA variability on the patellar height, we also evaluated patellar height with a modified Blumensaat technique, where the Blumensaat line was drawn in the same inclination with the shaft for each knee (ISA corrected – Blumensaat method.) If the ISA variability would have no effect on the patellar height, it was anticipated that the measurements by the classical Blumensaat method would be more congruent with the patellar height indices and they would have a better correlation. On the other hand, obtaining a better agreement with the ISA corrected method would suggest that variability of ISA may be a confounding factor in the assessment of the patellar height.

No statistically significant difference was found between the quantitative results of the classical and ISA corrected – Blumensaat methods (mean difference 0.08 mm), while in 10 knees different qualitative results were obtained in terms of the qualitative results (patella alta, norma or baja). A comparison of the results of the classical and ISA corrected – Blumensaat methods with the results of patellar height indices showed poor agreements and weak correlations. No difference was observed in the agreement and correlation with the index results between the classical and ISA corrected methods. Those results provided no information about the relationship between the variability of ISA and patellar height assessment.

Obtaining such incongruent results and lack of any correlation suggested that variables such as the patellar length and depth of the notch which are neglected by the Blumensaat method might influence the results. We would like to address these issues in the following two paragraphs.

The Blumensaat method evaluates the position of the patella solely in respect to the lower pole of patella. However, the vertical length of the patella is also a feature of the patellofemoral joint anatomy. Thus, if we take two knees with the identical patellar tendon length and the identical patellar height, as measured by the Blumensaat method, then in the knee with the taller patella, the patellar height indices will paradoxically give a result in favor of a lower patella (Figure 8).

Another point that may lead to criticism of the Blumensaat method is the probable variation in the depth of the intercondylar notch. If we take two patellae in the identical vertical position to the femur, the Blumensaat line will be drawn more distally in the knee with a shallow notch, which will give the impression that the patella is located somewhat higher (Figure 9). In our study, we did not evaluate the relationship between the notch depth and

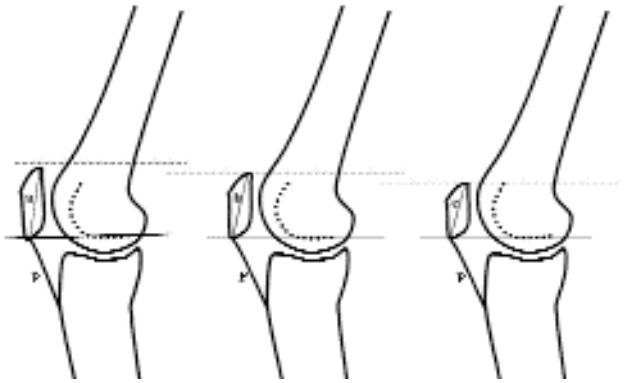

Figure 8. Which patella is higher? According to the Blumensaat method, they all have the same height. However, in the left knee with a taller patella (a>b>c), the position will paradoxically be lower according to the patellar height indices.

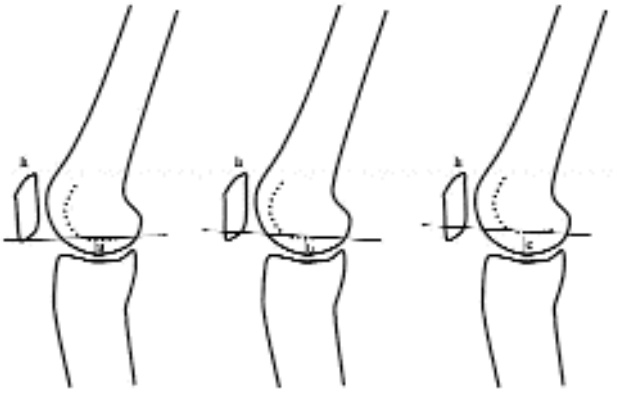

Figure 9. The effect of the depth of the intercondylar notch (lengths a, b and c, respectively) on the assessment of the patellar height by the Blumensaat method. In the three patellae located at the same vertical position to the femur, the Blumensaat line will be drawn more distally on the knee with a shallow notch (a), giving the impression that the patella is located higher.

the patellar height assessment. The Blumensaat method can provide more congruent results with the index methods when combined with the parameters such as patellar length and notch depth. Further studies including these variables and larger number of cases should be carried out for these evaluations.

The patellar height indices showed also weak correlations and poor agreements. The distribution characteristics, agreement and correlation of the patellar indices should be evaluated in a new study with a larger number of subjects. Such a study may provide important clues about the selection of a method which may be the golden standard in patellar height assessment. Studies which analyzed the patellar height indices compared the intra- and inter-observer reliability of the methods in repeated measurements, and the reliability of these methods was assessed based on the reproducibility. [1,10,13,14,17] However, while these studies show the consistency of the methods, they do not give information about their accuracy.

With the advances in the imaging methods, static radiographic measurements are likely to be replaced by dynamic measurement methods, which evaluate the tendon stress, contact pressure of the patellofemoral joint, patellar tilt and congruence angle of the joint as well as the patellar height. Therefore, the vertical position of patella may become a much more complex concept rather than a simple height.

The degree of knee flexion which has an effect on the Blumensaat method's results varies a lot during radiographic positioning. Although the angulation between the intercondylar notch and femoral shaft has been standardized, the poor agreement of the Blumensaat method and patellar height indices suggested that the intensity of the intercondylar notch (the Blumensaat line) can not be a beneficial landmark alone.

Patella length should be taken into consideration if any femoral reference landmark is used for the assessment of the patellar height. If this femoral landmark is on intercondyler notch roof radio-opacity, the depth of the notch should also be considered.

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