Eur J Orthop Surg Traumatol (2015) 25:757–762
DOI 10.1007/s00590-014-1572-3

ORIGINAL ARTICLE

Assessing the validity of the modified Blumensaat method for radiographic evaluation of patellar height

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Received: 13 August 2014 / Accepted: 24 November 2014 / Published online: 7 December 2014

Abstract
Purpose Although several indexes have been used for patellar height evaluation, the literature on patellar height evaluation using a femoral reference point is scant. We have previously reported on a new index, the modified Blumensaat (MB) method, which evaluates the patellar height using a femoral reference point. The purpose of this study was to evaluate the validity of the MB method.
Methods In addition to 10 volunteers (group C), 10 men (group M) and 10 women (group F) who underwent knee surgery were selected for the study. The Insall–Salvati (IS), modified IS (MIS), Blackburne–Peel (BP), MB, and modified intercondylar-shelf-angle-corrected Blumensaat (MIB) ratios were measured on lateral knee radiographs with the knee in 30°, 40°, and 50° flexion.
Results In group C, the MB and MIB ratios were similar; the IS ratio was not dependent on the knee flexion angle, and there was no significant difference in the MIS and BP ratios between 40° and 50° of knee flexion and in the MB and the MIB ratios between 30° and 40° of knee flexion. There were no differences between group M and group F with respect to any of the indexes. Furthermore, the differences in all indexes among the different knee flexion angles, in groups M and F, were similar to those in group C.
Conclusions The MB method is applicable for patellar height evaluation and is recommended with a knee flexion angle of 30°–40°.

Keywords Patellar height · Blumensaat line · Insall–Salvati index · Blackburne–Peel index · Modified Blumensaat index

Introduction

Several indexes such as the Insall–Salvati (IS) [1], the Blackburne–Peel (BP) [2], and the Caton–Deschamps (CD) [3] are used to evaluate patellar height. The IS index is the ratio of the patellar tendon length to the diagonal patellar length and is influenced by elongation and shortening of the patellar tendon and by patellar morphology. Grelsamer et al. [4] recommended the use of a modified IS ratio (MIS). The BP index is the ratio of the distance between the distal pole of the patellar articular surface and a perpendicular line at the level of the tibial plateau to the length of the patellar articular surface of the patellofemoral joint. Seil et al. [5] recommend the BP method because of its low interobserver variability and discrimination of patellar alta, norma, and baja. However, the BP ratio is affected by the slope of the tibial plateau. The CD index is a ratio of the distance between the anterior border of the tibial articular surface and the distal end of the patella to the length of the patellar articular surface of the patellofemoral joint. The patellar height calculated with the IS ratio represents the length of the patellar tendon, and the patellar height with the BP and CD ratios represents the distance from the patella to tibia. However, the patellar height is believed to influence the patellofemoral joint condition and responsible for patellofemoral pathology. Therefore, a reliable method

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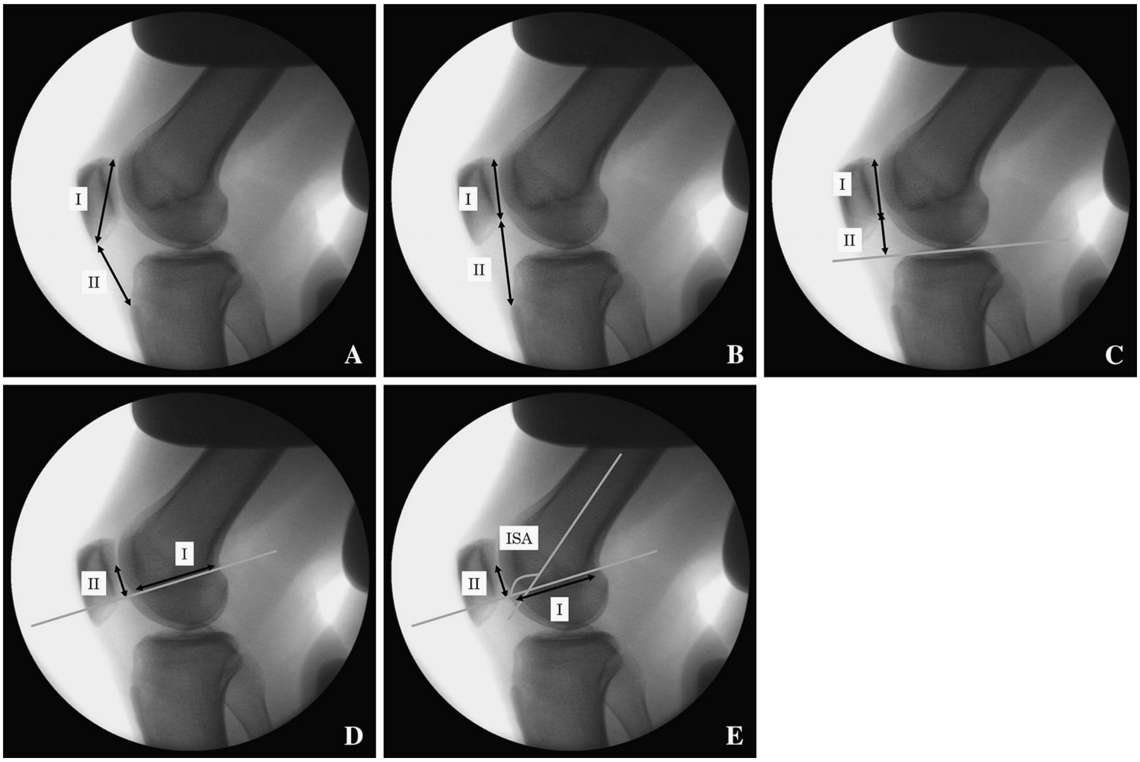

Fig. 1 Indexes of patellar height; **a** IS, **b** MIS, **c** BP, **d** MB, **e** MIB. All indexes are measured in *II/I*

for evaluation of the patellar height with a femoral reference point is required in cases of patellar dislocation, high tibial osteotomy, and total knee arthroplasty for an assessment of the patellofemoral joint condition.

In the previous Blumensaat method, the distance between the Blumensaat line and the patellar lower pole is measured. However, it is considered that indexes with the distance may have interindividual difference. Therefore, we used the rate to measure patellar height, not distance [6]. Furthermore, Seyahi et al. [7] reported that the intercondylar shelf angle (ISA) and the degree of knee flexion affected the results of the Blumensaat method. Based on this, the change in patellar height after high tibial osteotomy might affect the patellofemoral joint; we therefore reported on a new method, the modified Blumensaat (MB) ratio, to evaluate the patellar height with a femoral reference point in a previous study [6]. The purpose of this study was to evaluate the validity of the MB method previously described by us as a new index for patellar height evaluation and to examine the factors associated with its application.

Subjects and methods

Ten university students (group C) volunteered for this study. Lateral radiographs of the knee in 0° (full extension), 30°, 40°, and 50° of flexion were obtained with fluoroscope. We defined the knee flexion angle as the angle between femoral and tibial axis with two-middle-point method in lateral radiographs of the knee. Furthermore, we retrospectively extracted radiographs of patients who underwent surgery for meniscus tear or anterior cruciate ligament rupture by arthroscopy from 2005 to 2010 and who did not have a history of knee osteoarthritis. From these, lateral knee radiographs (30°, 40°, and 50° knee flexion) of 10 men (group M) and 10 women (group F) were selected randomly. In all groups, lateral radiographs of the knee, in which the medial femoral condyle was completely overlapped by the lateral femoral condyle, were obtained. The error in each of the knee flexion angles was defined as <2°. One orthopedic surgeon measured all indexes. The patellar heights were measured using the IS [1], MIS [6], BP [2], and MB ratios [5], which were reported previously (Fig. 1). We defined MB ratio as the ratio of distance from Blumensaat line to the midpoint at patellofemoral joint of the patella against the length of Blumensaat line in intercondyle of femur. In addition, the modified ISA-corrected Blumensaat (MIB) ratio, which is the ratio between the length of Blumensaat line among intercondyle of femur and distance from Blumensaat line to the midpoint at patellofemoral joint of the patella, was measured in reference to the report by Seyahi [4].

Table 1 Values of indexes for each knee flexion angle in group C (mean ± SD)

Index	Flexion angle of the knee			
	0°	30°	40°	50°
IS	0.87 ± 0.13	0.93 ± 0.16	0.97 ± 0.17	0.97 ± 0.18
MIS	1.64 ± 0.23	1.50 ± 0.12	1.70 ± 0.16	1.72 ± 0.19
BP	0.85 ± 0.14	0.75 ± 0.14	0.89 ± 0.14	0.87 ± 0.12
MB	1.40 ± 0.10	0.82 ± 0.15	0.80 ± 0.12	0.62 ± 0.13
MIB	1.46 ± 0.11	0.82 ± 0.12	0.79 ± 0.16	0.64 ± 0.13

Statistical analysis

In group C, the differences in each index (IS, MIS, BP, MB, and MIB) based on the knee flexion angle (0°, 30°, 40° and 50°) were statistically analyzed using Wilcoxon signed-rank test. In group M and group F, differences in each index based on the knee flexion angle (30°, 40°, and 50°) were also statistically analyzed using Wilcoxon signed-rank test. The comparisons between groups M and F were statistically analyzed using Mann–Whitney *U* test, and the correlations among the indexes in all knee flexion angles were statistically analyzed with Spearman's rank correlation coefficient. The IBM SPSS statistics version 21 (IBM Corporation, New York, USA) was used for statistical analysis. A p value of 0.05 was considered to be statistically significant.

Results

The mean ISA was 142.7 ± 3.8° in group C. With this fixed ISA angle of 143°, a common Blumensaat line, intersecting the midpoint of the line at the roof of the intercondylar notch, was drawn using the method described by Seyahi [4]. The MIB ratio was assessed based on this common line corrected by 143° as the ISA.

The results of mean values and standard deviations (SD) of all indexes in group C are presented in Table 1. The value of the MB was similar to that of the MIB. Figure 2 shows the significant difference among the indexes for each angle. There was no significant difference in the values of the IS among the flexion angles. There was no significant difference in the MIS and the BP values between 40° and 50° of knee flexion. There were no significant differences in the MB and the MIB values between 30° and 40° of knee flexion.

Table 2 shows the results of the correlation among all indexes for each knee flexion angle in group C. There was a significant correlation between the MB and MIB ratios for all flexion angles as the MB and MIB values were almost equal. The MIS ratio had a significant correlation with the IS and BP ratios for 40° and 50° knee flexion.

Figure 3 shows the results of the measurement of all indexes in groups M and F. The mean values of the IS, MIS, and BP ratios for 30° knee flexion were similar to the normal values reported [1, 2, 6]. There was no difference in the indexes between groups M and F. Furthermore, the differences in all indexes from 30° to 50° of knee flexion in groups M and F were similar to that in group C.

Discussion

Several indexes are used for patellar height evaluation; the IS ratio is commonly used for this purpose. In the present study, the IS ratio was relatively independent of knee flexion angle, even in the full extension position of the knee, and the IS ratio could be confirmed as the stable and accurate index for determining patellar height. However, the IS ratio is affected by patellar morphology and the patellar tendon condition. For example, the IS ratio in patients with elongation of the patellar distal pole is lower than that in patients with the normal patellar form. Therefore, the MIS has been used to negate the influence of patellar morphology. The MIS was correlated not only to the IS ratio but also to the BP ratio for 40° and 50° knee flexion in the current study. We considered that the MIS and BP ratios also show the patellar position in reference to the tibia. Therefore, the IS, MIS, and BP ratios in patients who have undergone high tibial osteotomy, which shifts the tibial tuberosity and changes the tibial slope, may not exactly define the patellar height. In these cases, the IS, MIS, and BP ratios cannot be an appropriate method for evaluation of the patellar height. Furthermore, when patellofemoral joint pathology due to patellar height is considered, utilizing an evaluation of the patellar height with a femoral reference point is suitable.

To our knowledge, the literature on a method of patellar height measurement with a femoral reference point is scant, though there are several studies that have reported that patellar height is changed after high tibial osteotomy [8–11]. There is a significant difference in the patellar height change between open high tibial osteotomy and close high tibial osteotomy [8, 10]. There are contradictory reports on the patellar height change evaluated by the IS method after open-wedge high tibial osteotomy [9–11]. However, because the tibial tuberosity is moved in both closed- and open-wedge high tibial osteotomy, there are inconsistent results regarding patellar height change evaluated by the IS method. In addition, because the tibial posterior slope undergoes a change after high tibial osteotomy [10–12], the BP method may not be appropriate for patellar height evaluation.

Therefore, we considered a new index for the evaluation of patellar height with a femoral reference point. In the

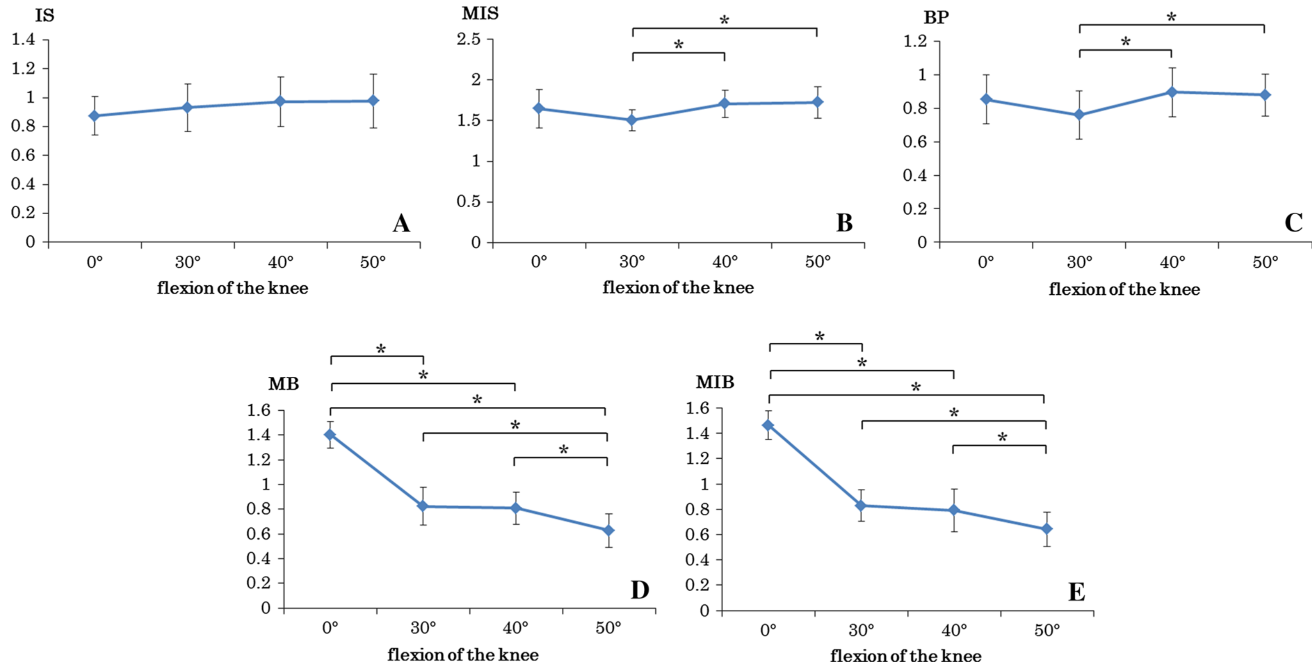

Fig. 2 Results of all indexes for each knee flexion angle in group C; **a** IS, **b** MIS, **c** BP, **d** MB, **e** MIB. The IS ratio is not dependent on knee flexion angle. There is no significant difference in the MIS and BP values between 40° and 50° knee flexion. There is no significant difference in the MB and the MIB values between 30° and 40° knee flexion angles. The MB and MIB values for 0° knee flexion were significantly higher than the values for 30°, 40°, and 50° of knee flexion. $*p < 0.05$

Table 2 Correlation among indexes for each knee flexion angle; A: 0° flexion (full extension) of the knee, B: 30°, C: 40°, D: 50°

	MIS	BP	MB	MIB
0°				
IS	$r = 0.609$, $p = 0.0540$	$r = 0.0909$, $p = 0.773$	$r = 0.0818$, $p = 0.795$	$r = 0.300$, $p = 0.342$
MIS		$r = 0.463$, $p = 0.142$	$r = 0.127$, $p = 0.687$	$r = 0.0181$, $p = 0.954$
BP			$r = 0.572$, $p = 0.0701$	$r = 0.645$, $p = 0.0412$
MB				$r = 0.945$, $p = 0.00279$
30°				
IS	$r = 0.463$, $p = 0.142$	$r = 0.163$, $p = 0.604$	$r = 0.281$, $p = 0.372$	$r = 0.336$, $p = 0.287$
MIS		$r = 0.463$, $p = 0.142$	$r = 0.127$, $p = 0.687$	$r = 0.309$, $p = 0.328$
BP			$r = 0.572$, $p = 0.0701$	$r = 0.200$, $p = 0.527$
MB				$r = 0.927$, $p = 0.00336$
40°				
IS	$r = 0.645$, $p = 0.0412$	$r = 0.0454$, $p = 0.885$	$r = 0.418$, $p = 0.186$	$r = 0.236$, $p = 0.454$
MIS		$r = 0.718$, $p = 0.0231$	$r = 0.218$, $p = 0.490$	$r = 0.0336$, $p = 0.921$
BP			$r = 0.100$, $p = 0.751$	$r = 0.100$, $p = 0.751$
MB				$r = 0.909$, $p = 0.00404$
50°				
IS	$r = 0.645$, $p = 0.0412$	$r = 0.409$, $p = 0.195$	$r = 0.627$, $p = 0.0472$	$r = 0.554$, $p = 0.0794$
MIS		$r = 0.727$, $p = 0.0214$	$r = 0.236$, $p = 0.454$	$r = 0.254$, $p = 0.420$
BP			$r = 0.236$, $p = 0.454$	$r = 0.254$, $p = 0.420$
MB				$r = 0.590$, $p = 0.00484$

current study, we examined the validity of the MB method, which we reported previously as an index for patellar height evaluation [7]. It is necessary to unify the flexion angles in measuring the MB ratio because there is a difference in the values of the MB ratio based on the knee flexion angle, as the MB ratio for 50° knee flexion was significantly lower than those for 30° and 40° knee flexion. Measuring the MB ratio with the knee in 30°–40° flexion is recommended.

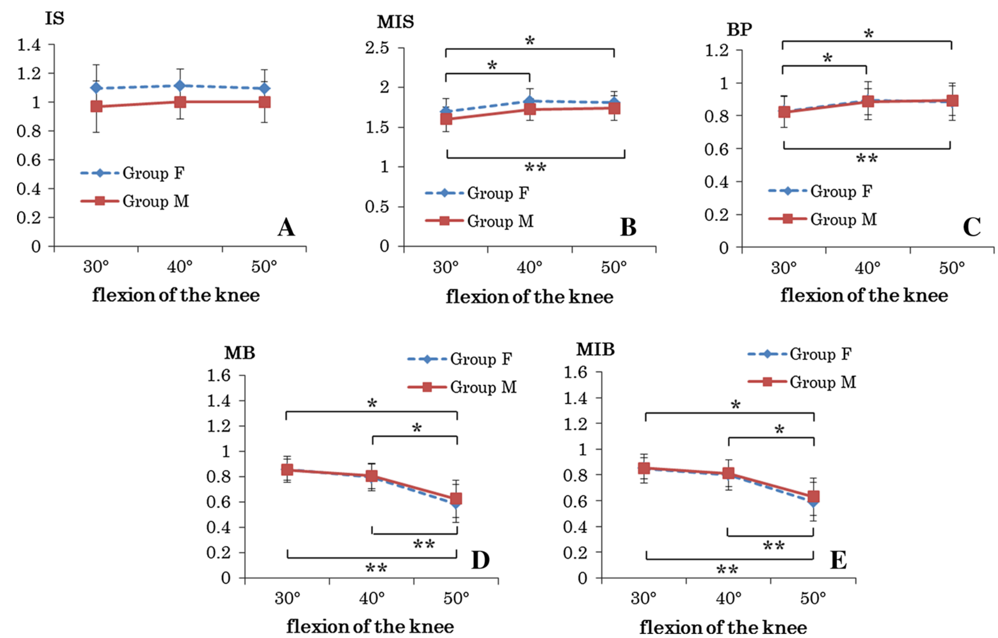

Fig. 3 Results of indexes for each knee flexion angle in groups M and F; **a** IS, **b** MIS, **c** BP, **d** MB, **e** MIB. The differences among indexes between 30° and 50° of knee flexion in groups M and F were similar to those in group C, indicating independence of the IS ratio from the knee flexion angle. $^{**}p < 0.05$ (in Group M), $^{*}p < 0.05$ (in group F)

Furthermore, because there is no correlation between the MB ratio and the IS and BP ratios, the MB ratio is useful in those cases in which the IS and BP ratios cannot be applied. Although Seyahi et al. recommended modification with ISA, in the present study, the MB and MIB ratios were almost equal and were significantly correlated. Therefore, we are convinced that measurement of the MB ratio without the ISA modification is reliable enough.

This study has limitations. First, each radiograph in group M and group F was taken at different points in time during the follow-up. In other words, radiographs with 30°, 40°, and 50° of knee flexion in group M and group F were not taken on the same day. Second, one surgeon investigated the parameters and interobserver reliability was not assessed. Third, the subjects in the current study were young Japanese, and the subjects in group C were all men. Therefore, because the results of this study may not be directly applicable to non-Japanese or elderly subjects, we consider that the scope for future research on these subjects is needed. However, we are convinced of the accuracy of this study because the values of all parameters measured in this study are very similar to those reported in previous articles.

Conclusion

We examined the validity of the MB method as a new index for evaluation of patellar height. We conclude that the MB method is applicable for patellar height evaluation and that the knee flexion angle is an important consideration when using this method.

Conflict of interest None of the authors have received any financial support from any company.

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