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Clinical article

**INFLUENCE OF PATELLA HEIGHT ON TOTAL KNEE ARTHROPLASTY:
OUTCOMES AND SURVIVAL**

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INFLUENCE OF PATELLA HEIGHT ON TOTAL KNEE ARTHROPLASTY: OUTCOMES AND SURVIVAL

ABSTRACT

BACKGROUND

To assess clinical results of total knee arthroplasty (TKA) with pre-operative patella alta or patella baja, compared to TKA with pre-operative normal patellar height.

METHODS

Patella height was measured using the Blackburne-Peel (BP) method in an initial, prospective cohort of 4103 TKAs performed at a single center. Three groups were defined: normal patella height ($0.54 < \text{BP index} \leq 1.06$), patella alta ($\text{BP index} > 1.06$) and patella baja ($\text{BP index} \leq 0.54$). Pre-operative and post-operative clinical and radiological characteristics were collected and compared. All prostheses used a system of posterior stabilization by a third condyle. The primary outcome measure was the post-operative Knee Society Score (KSS). Statistical analysis was performed using Student t-test and Chi-2 test, with $p < 0.05$.

RESULTS

223 TKAs with pre-operative patella alta, 307 TKAs with pre-operative patella baja and 2248 with pre-operative normal patella height, mean follow-up 39.3 months (range 24-239), were ultimately included. Post-operatively, there was no difference between the three groups in terms of KSS (knee and function scores). Patella baja statistically decreased the maximal flexion (118.2° vs 115.5° ; $p = 0.002$) and increased the rate of patellar fracture (0.9% vs 2%; $p = 0.05$). Finally, survival rates were similar in the three groups with each above 91% ($\pm 2\%$) at 10 years.

CONCLUSION

Clinical and radiological results for TKAs with pre-operative patella alta and patella baja were comparable to TKAs with a normal pre-operative patellar height. Risk of post-operative patellar fracture increased for patients with pre-operative patella baja.

32 KEYWORDS: Total knee arthroplasty, patella alta, patella baja, KSS, Blackburne-Peel index

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34 CLINICAL RELEVANCE: Equivalent clinical and radiological results between TKAs with
35 pre-operative patella alta or baja and TKA with a pre-operative normal patellar height.

36 Original subject never explored in the literature.

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41 **ABBREVIATIONS:**

42 BP: Blackburne-Peel index

43 BMI: Body Mass Index

44 DFO: Distal Femoral Osteotomy

45 HKA: Hip Knee Ankle

46 HTO: High Tibial Osteotomy

47 KSS: Knee Society Score

48 mFA: mechanical Femoral Axis

49 mFTA: mechanical Femoro-Tibial Axis

50 mTA: mechanical Tibial Axis

51 TKA: Total Knee Arthroplasty

INTRODUCTION

Variation of the patellar height in the general population is not uncommon. On the one hand, patella alta may be asymptomatic and incidentally discovered, or it may be part of patello-femoral instability syndrome[1–3]. On the other hand, patella baja is frequently secondary to a previous surgery or trauma about the knee with a shortening of the patellar tendon[4–6].

Patella alta causes, from a biomechanical point of view, a migration of the contact point of the patello-femoral joint near the apex of the patella, which in turn causes a decrease in the effective lever arm of the extensor mechanism[7], an increase in transmitted patello-femoral forces[8,9], and ultimately the appearance of premature inferior patello-femoral arthritis[10,11].

Each of these biomechanical elements which are detrimental to the native knee can also occur in the prosthetic knee, potentially leading to post-operative patello-femoral complications such as instability or patella button loosening[12,13].

Patella baja in the native knee is responsible for pain and limited flexion, due to the distalisation of the patella in the femoral groove[4,14]. Biomechanically, this causes a superior migration of the contact point on the patella with a decrease of the patellar height[15], leading to a risk of early patello-femoral osteoarthritis.

The induced stiffness can result in a difficult approach to the knee for prosthesis implantation, with a risk of patellar fracture, extensor mechanism lesion and implant malpositioning[5,16].

There are currently few studies which report the results of total knee arthroplasty (TKA) with patellar resurfacing performed in pre-operative patella alta or baja, or the possible post-operative patello-femoral complications that could result.

The objective of this study was to compare the clinical and radiographic results of two cohorts of TKA patients with pre-operative patella alta and pre-operative patella baja with a group of patients having normal pre-operative patellar height. The post-operative complications as well as the implant survival of each of these three populations were analyzed and compared. We hypothesized that there would be no clinical or radiographic difference

between the three groups and that the post-operative patello-femoral complication rate would be similar.

MATERIALS AND METHODS

Study population

Between November 1987 and March 2015 we prospectively followed all primary TKAs performed at a single center by 16 senior surgeons using the same surgical technique. Patients were followed clinically and radiographically after surgery first at 2 months, then 1 year, and then every 2 years afterwards. This series consists of 4103 primary TKAs.

Patellar height was measured on each pre- and post-operative lateral radiograph, using the Blackburne-Peel (BP) index[17] (Fig. 1). All radiographs were performed in our institution with a standardized method, increasing reproducibility.

The measurement was performed on a lateral radiograph, with 30° of flexion according to the same established radiological protocol. The measurements were initially made by a junior surgeon (resident) and then independently verified by a senior surgeon. If there was a discrepancy greater than 5%, a new measurement was independently performed by a second senior surgeon. Freehand measurements on acetate films were performed before 2002, while digital computer software with numeric measurements was used after 2002.

For the measurement of the BP index on the native knee, the joint line was defined on the lateral radiograph by the tangent to the upper edge of the tibial plateau. The patellar measurement consisted of only the articular portion of the patella.

For measurement of the BP index on TKA, the joint line was defined on the lateral radiograph by the tangent to the upper edge of the tibial polyethylene. The patellar measurement consisted of only the patellar button.

This index made it possible to define 3 separate pre-operative groups, according to the standards defined by Blackburne and Peel[17]:

- Normal patellar height with a BP index = 0.54-1.06 (N=3301) (Fig. 2);
- Patella alta with a BP index > 1.06 (N=330) (Fig. 3);
- Patella baja with a BP index < 0.54 (N=472) (Fig. 4).

Excluded from the study due to lack of follow up were knees having clinical and radiographic follow-up less than 24 months, which consisted of knees lost to follow-up (N=398) and knees operated on after March 2013 (N=927). In total, a cohort of 2248 knees were included for pre- and post-operative analysis of TKA with normal pre-operative patellar height, and 223 were included in the cohort of TKA with pre-operative patella alta, and 307 were included in the cohort of TKA with pre-operative patella baja (Fig. 5), all with an average follow-up of 39.3 months (24-239).

All operative technical data including the operative reports as well as pre- and post-operative clinical and radiographic data were prospectively collected in a computer database created in 1995 (data from TKA's performed between 1987 and 1995 were entered in the database retrospectively).

Clinical follow-up was performed using the Knee Society Score (KSS) questionnaire to calculate the corresponding KSS score at each follow-up visit[18]. The Knee Society radiographic evaluation consisted of an anteroposterior and lateral view of the operative knee, a skyline view of the patella at 45° of knee flexion, as well as a standing bilateral hip to ankle radiograph to assess mechanical axis[19]. All local and systemic complications resulting from the surgery were noted and recorded in the database, according to the standardized list and definitions of the Knee Society[20].

The primary outcome of this study was the mean post-operative KSS score at the last follow-up. The secondary outcomes were the mean maximal flexion, the patello-femoral complications, and the survival of the different cohorts.

The Advisory Committee on the Treatment of Health Research Information (CCTIRS) approved this study on January 24, 2012 and on March 9, 2015 under the identification number 11-681.

Operative technique

Before 1996, the medial approach was systematically used. After 1996, the choice of approach became a function of the pre-operative deformity: medial for genu varum, lateral for

genu valgum, and with tibial tubercle osteotomy if necessary (128 patients in this series for stiffness and/or difficult lateral approach for valgus[21]).

The surgical technique used a posterior reference, beginning with the tibial cut and followed by the posterior femoral cut (balancing is performed in flexion then checked in extension and balanced with a distractor before the distal femoral cut is performed). All patellae were resurfaced. All of the implants were cemented, except for 132 femoral components (3.2%) which were coated with hydroxyapatite and had been the subject of another prospective study published in 2011[22].

Since 1987, all of the implants have been designed and fabricated by the same manufacturer (Wright-Tornier-Corin®, 38330 Montbonnot Saint Martin, FRANCE). All of the implants have a similar design, using posterior stabilization through a third condyle (HLS family implants).

Statistical analysis

Statistical data was analyzed using the chi2 test for comparison of distributions between the two groups and the Student's t-test for quantitative values (large and normal-law variables), using R© software (R Foundation for Statistical Computing, <http://www.R-project.org>). The Kaplan-Meier survival curves were made and compared using a LogRank test with the help of the Technical University of Denmark's online site (<https://www.statcom.dk>). The results were considered significant if $p < 0.05$.

RESULTS

Pre-operative (Table 1)

The rate of lateral tibio-femoral arthritis was statistically greater in the cohort with pre-operative patella alta ($p=0.04$) compared to the cohort with normal pre-operative patellar height, while there was an increased incidence of medial tibio-femoral arthritis in the cohort with pre-operative patella baja ($p=0.02$).

The average maximum flexion was statistically greater in the cohort with pre-operative patella alta ($p=0.004$) compared to the cohort with normal pre-operative patellar

height, while there was statistically decreased flexion in the cohort with pre-operative patella baja ($p=0.006$).

The mean KSS Knee and Function scores were statistically greater in the cohort with pre-operative patella alta ($p=0.003$ and $p=0.02$) compared to the cohort with normal pre-operative patellar height, while there were statistically lower scores in the cohort with pre-operative patella baja ($p<0.001$ and $p=0.03$).

Post-operative (Table 2)

No statistically significant difference was found in the selected clinical and radiographic parameters between the normal pre-operative patellar height group and the patella alta group.

A statistically significant difference was found between the normal pre-operative patellar height group and the patella baja group for the mean post-operative maximal flexion (118.2° vs 115.5° ; $p=0.002$) and the mean post-operative mFTA (mechanical Femoro-Tibial Axis) (178.9° vs 178.2° ; $p=0.006$).

Patello-femoral complications (Table 3)

No statistically significant difference was found in the rates of complication between the different groups in terms of stiffness, clunk syndrome, extensor mechanism rupture, patella button loosening and patello-femoral instability. A statistically significant difference was found for patella fracture between patella baja and normal patellar height cohorts, with an increased rate of patella fracture in patella baja group (0.9% vs 2%; $p=0.05$).

Survival analysis

Figure 6 demonstrates the survival curves of TKA with normal pre-operative patellar height (98% +/- 1% at 5 years), TKA with pre-operative patella alta (96% +/- 4% at 5 years) and TKA with pre-operative patella baja (98% +/- 4% at 5 years). An event was defined as the revision of at least one prosthetic component, patella button and polyethylene insert excluded. No statistical difference was found between the three groups ($p=0.6$).

Specific post-operative results of the different groups matched on the post-operative BP index

From the cohort of the patients with normal pre-operative patellar height (Table 4), no statistically significant difference was found if patients had post-operative patella alta or baja, compared to the cohort with normal post-operative patellar height.

From the cohort of the patients with pre-operative patella alta (Table 5), no statistically significant difference was found if patients had post-operative patella alta, compared to the cohort with normal post-operative patellar height. A statistically significant difference was found between the normal post-operative patellar height group and the post-operative patella baja group for the mean post-operative KSS knee score (89.3 vs 84.8; $p=0.02$).

From the cohort of the patients with pre-operative patella baja (Table 6), no statistically significant difference was found if patients had post-operative patella alta, compared to the cohort with normal post-operative patellar height. A statistically significant difference was found between the normal post-operative patellar height group and the post-operative patella baja group for the rate of post-operative stiffness (1.9% vs 5.5%; $p=0.03$).

No correlation was found between the level of BP index for patients with pre-operative patella baja and the KSS knee and function scores at the end of the follow-up

Specific results of patients with tibial tubercle osteotomy (Table 7)

For patients with pre-operative patella baja, stiffness is statistically more responsible for tibial tubercle osteotomy than for patients with normal pre-operative patellar height (33.3% vs 10.9%; $p=0.02$).

The risk of post-operative patella baja after TKA with tibial tubercle osteotomy is statistically higher than for patients with normal pre-operative patellar height (46.7% vs 28.7%; $p=0.03$).

DISCUSSION

The main contribution of this study is to demonstrate there is no significant difference in post-operative KSS scores, patient satisfaction or in survival rates of TKA performed with pre-operative patella alta or patella baja when compared to TKA performed on knees having a normal pre-operative patellar height. However, in patients with pre-operative patella baja, it

demonstrates a correlated decrease in post-operative flexion and an increased risk of patellar fracture post-operatively.

The concept of patella alta/baja is correlated with the measurement index that is used. A number of methods to measure the height of the patella exist (Blackburne-Peel, Caton-Deschamps, Insall-Salvati, Labelle-Laurin, etc.). The choice to use the Blackburne-Peel index[17], described in 1977, was motivated by its excellent inter- and intra-observer reproducibility as demonstrated by Berg et al.[23] in 1996, as well as Seil et al.[24] in 2000. Additionally, this index seems to be the best able to objectively measure patella height in a prosthetic knee. On the other hand it is essential to standardize the knee position at 30° of flexion during the lateral radiograph in order to avoid a significant variation in the measurements that could distort the values of the index[25].

Patella alta provides relatively favorable pre-operative clinical conditions such as a significantly increased degree of flexion compared with knees having normal pre-operative patellar height (120.5° vs 117°), as well as better overall KSS scores. In contrast, cases of patella baja are significantly more likely to present with pre-operative stiffness, usually related to patella tendon retraction secondary to trauma[6,26] or previous surgery[27,28].

Our study found a significant increase in lower limb valgus alignment in the cohort of knees with patella alta, corroborating recent findings[29] that show a significant link between patella instability (often associated with patella alta) and lower limb valgus. Conversely, we discovered a majority of lower limb varus alignment in the cohort of knees with patella baja.

Paradoxically, we found a significant decrease in the rate of patello-femoral arthritis in the patellae alta and baja cohorts compared to the knees with normal patellar height. This finding is at odds with previous studies showing a change in patello-femoral contact forces in cases of patellae alta or baja which are responsible for premature arthritis of the patella[9,11,15]. This observed inconsistency seems to be related to the method used to assess patello-femoral arthritis in our series, which takes into account only an axial patellar view and cannot detect more inferior patello-femoral arthritis.

Our study found no significant difference in post-operative KSS scores, patient satisfaction or in survival rates of TKA performed with pre-operative patella alta or patella

baja when compared to TKA performed on knees having a normal pre-operative patellar height.

However, there exists a correlated decrease in post-operative flexion for patients with pre-operative patella baja and an increased risk of patellar fracture post-operatively. These results corroborate with the studies from Singerman et al.[15] and Chonko et al.[5] that showed a correlation between patella baja and modification of the patella-femoral contact forces, responsible for decreasing range of motion and increasing rate of patellar fracture.

It has also been shown several times there is a moderate decrease in patellar height following TKA, called pseudo patella baja[30], which is related to both the management of the distal femoral cut[5,31], and also a decrease in the length of the patella tendon[32].

It can explain the normalization of the mean post-operative Blackburne-Peel index in the cohort with pre-operative patella alta (0.67 post-operative vs 1.32 pre-operative). Therefore, it is quite logical to deduce that the pathological biomechanics secondary to patella alta are also normalized after TKA, thus producing no negative consequences on the clinical or radiographic results of the implants.

We need to moderate this purpose for patients with persistent post-operative patella baja, or important decrease of patellar height for patients with pre-operative patella alta. The post-operative results consist in an increase rate of post-operative stiffness in the first case, and a decrease of the mean KSS knee score in the second case.

Thus, the presence of pre-operative patella alta does not appear to be responsible for systematic post-operative patella alta, which can lead to patella button mechanical stress or cause patella instability. It also does not affect implant survival after TKA when compared to the normal patellar height.

Conversely, pre-operative patella baja seems to be a major risk for post-operative patellar fracture and stiffness, especially if there is no correction of the patellar height during the surgery. In these cases, a surgeon may elect to avoid patella resurfacing, or to combine the TKA implantation with a proximalization of the anterior tibial tuberosity[14].

Tibial tubercle osteotomy was often combined with lateral approach for severe valgus before the 2000s, as described by Keblish[21]. Then it was reserved for knees with severe stiffness (flexion < 90°) to help with exposure of the joint, especially in patients with pre-operative patella baja. Otherwise, tibial tubercle osteotomy in patients with pre-operative

patella baja increased the risk of keeping a post-operative patella baja secondary to potential inflammation and shortening of the patellar tendon[32].

Our study had several limitations. Despite regular monitoring, those lost to follow-up remain numerous (10% of the initial cohort). This deficiency biases our results. Additionally, the mean duration to latest follow-up remains short (3.3 years), introducing a positive bias toward long-term complications and survival analysis. In addition, there is a great variability in the duration of follow-up of patients (from 24 to 239 months), and only the clinical score at the last follow-up was taken into account in our study.

Despite the repeated and validated measurements of the BP index, we could not calculate the inter-observer reliability coefficient because the data pertaining to the various measurements is not present in the database. Nevertheless, due to the large size of each population analyzed, the power of our study is quite satisfactory.

Moreover, given the uniformity of our initial cohort used, we can reasonably conclude there is no negative impact of pre-operative patella alta or baja on clinical and radiographic results when performing TKA, especially if the management of the patellar height during the surgery is performed to avoid post-operative patella baja.

CONCLUSION

This study highlights the absence of any significant difference in terms of post-operative KSS scores, patient satisfaction or survival results in TKA performed with pre-operative patella alta or baja compared to TKA performed on knees with normal pre-operative patellar height. However, an increased risk of patellar fracture is correlated with pre-operative patella baja. This result invites to reconsider the systematic patella resurfacing in patients with pre-operative patella baja.

COMPLIANCE WITH ETHICAL STANDARDS.

- Conflict of Interest:

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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438

TABLES

Table 1 Pre-operative clinical and radiological characteristics

	Normal (N=2248)	Alta (N=223)	Baja (N=307)
Mean pre-operative BP index	0.77 [0.54-1.06]	1.32 [1.07-4.4] *	0.45 [0.06-0.53] *
Mean age	70.7 years [26-92]	70.9 years [28-91]	69.4 years [26-91]
Mean BMI	29 kg/m ² [15-52]	28.8 kg/m ² [18-49]	28.7 kg/m ² [16-51]
Sex			
<i>Male</i>	639 (28%)	76 (34%) *	93 (30%)
<i>Female</i>	1609 (72%)	147 (66%) *	147 (70%)
Previous surgery			
<i>Closing HTO</i>	25 (1.1%)	4 (1.8%)	3 (1%)
<i>Opening HTO</i>	134 (6%)	9 (4%)	19 (5.9%)
<i>Opening DFO</i>	8 (0.4%)	1 (0.5%)	0
<i>Tibial tubercle transfer</i>	32 (1.4%)	3 (1.4%)	5 (1.6%)
<i>Osteosynthesis</i>	30 (1.3%)	6 (2.7%)	6 (2%)
<i>Arthroscopic arthrolisis</i>	4 (0.2%)	0	3 (1%) *
Type of arthritis			
<i>Medial compartment</i>	1540 (68.5%)	131 (58.7%) *	246 (80.1%) *
<i>Lateral compartment</i>	348 (15.5%)	48 (21.5%) *	26 (8.5%) *
<i>Global</i>	35 (1.6%)	3 (1.4%)	8 (2.6%)
<i>Patello-femoral compartment</i>	92 (4.1%)	11 (4.9%)	2 (0.7%) *
<i>NC</i>	233 (10.3%)	30 (13.5%) *	25 (8.1%)
Range of motion			
<i>Mean flexion contracture</i>	3.73° [0-30]	2.94° [0-45]	4.3° [0-30]
<i>Mean maximal flexion</i>	117° [35-140]	120.5° [40-140] *	113.1° [30-140] *
Mean KSS score			
<i>Knee</i>	49.6 [0-100]	53.3 [3-97] *	44.2 [0-100] *
<i>Function</i>	57.5 [0-100]	60.7 [0-100] *	55.4 [0-100]
Long leg films			
<i>Mean mFTA</i>	176,2° [155-207]	176.7° [158-201]	173.4° [156-202] *
<i>Mean mFA</i>	91,3° [73-110]	91.4° [81-104]	90.6° [79-118] *
<i>Mean mTA</i>	87° [69-106]	87.2° [70-103]	85.9° [74-100] *
Patello-femoral arthritis			
<i>Normal</i>	502 (22.3%)	76 (34.1%) *	43 (14%) *
<i>Remodeling</i>	749 (33.3%)	57 (25.6%) *	95 (30.9%) *
<i>Medial side</i>	204 (9.1%)	18 (8.1%)	37 (12.1%) *

<i>Lateral side</i>	342 (15.2%)	35 (15.7%)	43 (14%)
<i>Global</i>	426 (19%)	36 (15.7%) *	88 (28.7%) *
<i>Chondrocalcinosis</i>	14 (0.6%)	2 (0.8%)	1 (0.3%)
<i>NC</i>	11 (0.5%)	0	0
Patello-femoral positioning			
<i>Medial dislocation</i>	18 (0.8%)	1 (0.4%)	1 (0.3%)
<i>Lateral subluxation</i>	286 (12.7%)	24 (10.8%)	32 (10.4%)
<i>Centered</i>	1919 (85.4%)	195 (87.4%)	271 (88.3%)
<i>Medial subluxation</i>	16 (0.7%)	2 (1%)	3 (1%)
<i>NC</i>	9 (0.5%)	1 (0.4%)	0

BP index: Blackburne-Peel index; BMI: Body Mass Index; DFO: Distal Femoral Osteotomy; HTO: High Tibial Osteotomy; KSS: Knee Society Score; mFA: mechanical Femoral Axis; mFTA: mechanical Femoro-Tibial Axis; mTA: mechanical Tibial Axis

* significant difference (p<0.05) comparing the normal group

Table 2 Post-operative clinical and radiological characteristics

	Normal (N=2248)	Alta (N=223)	Baja (N=307)
Mean follow-up (months)	40.1 [24-239]	34.4 [24-138]	37.1 [24-179]
Mean post-operative BP index	0.64 [0.1-2]	0.67 [0.1-1.36] *	0.56 [0.1-1.16] *
Range of motion			
<i>Mean flexion contracture</i>	0.5° [0-25]	0.5° [0-15]	0.6° [0-15]
<i>Mean maximal flexion</i>	118.2° [60-140]	118.7° [70-140]	115.5° [70-140] *
Mean KSS score			
<i>Knee</i>	88.3 [24-100]	88.1 [42-100]	87.6 [33-100]
<i>Function</i>	77.9 [0-100]	80.4 [20-100]	78.2 [0-100]
Satisfaction			
<i>Very good and good</i>	2067 (92%)	204 (91.5%)	285 (92.8%)
<i>Bad and very bad</i>	158 (7%)	18 (7.7%)	20 (6.5%)
<i>NC</i>	23 (1%)	1 (0.8%)	2 (0.7%)
Long leg films			
<i>Mean mFTA</i>	178.9° [170-188]	178.8° [171-186]	178.2° [168-192] *
<i>Mean mFA</i>	89.5° [80-98]	89.6° [82-95]	89.1° [81-95] *
<i>Mean mTA</i>	89.5° [80-96]	89.5° [85-96]	89.2° [76-98]
Sagittal positioning of patella button			
<i>High</i>	137 (6.1%)	11 (4.9%)	18 (5.9%)

<i>Centered</i>	1923 (85.5%)	198 (88.8%)	266 (86.6%)
<i>Low</i>	10 (0.5%)	0	0
<i>NC</i>	178 (7.9%)	14 (6.3%)	23 (7.5%)
Coronal positioning of patella button			
<i>Lateral</i>	18 (0.8%)	0	2 (0.7%)
<i>Centered</i>	2028 (90.2%)	207 (92.8%)	280 (91.1%)
<i>Medial</i>	20 (0.9%)	2 (0.9%)	2 (0.7%)
<i>NC</i>	182 (8.1%)	14 (6.3%)	23 (7.5%)
Patello-femoral positioning			
<i>Medial dislocation</i>	5 (0.2%)	0	0
<i>Lateral subluxation</i>	122 (5.5%)	16 (7.2%)	17 (5.5%)
<i>Centered</i>	1956 (87%)	192 (86.1%)	270 (88%)
<i>Medial subluxation</i>	3 (0.1%)	0	1 (0.3%)
<i>NC</i>	162 (7.2%)	15 (6.7%)	19 (6.2%)

BP index: Blackburne-Peel index; KSS: Knee Society Score; mFA: mechanical Femoral Axis; mFTA: mechanical Femoro-Tibial Axis; mTA: mechanical Tibial Axis
 * significant difference ($p < 0.05$) comparing the normal group

Table 3 Patello-femoral complications

	Normal (N=2248)	Alta (N=223)	Baja (N=307)
Stiffness	48 (2.1%)	2 (0.9%)	11 (3.6%)
Clunk syndrome	18 (0.8%)	2 (0.9%)	4 (1.3%)
Extensor mechanism rupture	4 (0.2%)	0	0
Patella button loosening	2 (0.09%)	0	0
Patello-femoral instability	6 (0.3%)	1 (0.5%)	0
Patella fracture	19 (0.9%)	1 (0.5%)	6 (2%) *

Table 4 Post-operative clinical and radiological characteristics of TKAs with normal pre-operative patellar height (N=2248)

	BP index = 0.54-1.06 (N=1466)	BP index > 1.06 (N=57)	BP index < 0.54 (N=725)
Range of motion			
<i>Mean flexion contracture</i>	0.5° [0-20]	1.3° [0-40]	0.5° [0-25]
<i>Mean maximal flexion</i>	119° [30-140]	115.5° [90-140]	116.9° [10-140]
Mean KSS score			
<i>Knee</i>	88.3 [24-100]	88 [45-100]	88.2 [19-100]
<i>Function</i>	78.1 [0-100]	74.7 [0-100]	78 [0-100]
Satisfaction			
<i>Very good and good</i>	1350 (92.1%)	51 (89.5%)	666 (91.9%)
<i>Bad and very bad</i>	100 (6.8%)	4 (7%)	54 (7.4%)
<i>NC</i>	16 (1.1%)	2 (3.5%)	5 (0.7%)
Long leg films			
<i>Mean mFTA</i>	179° [168-193]	179° [169-189]	178.7° [157-192]
<i>Mean mFA</i>	89.6° [78-98]	89.4° [83-94]	89.3° [77-98]
<i>Mean mTA</i>	89.5° [77-96]	89.8° [85-94]	89.4° [77-95]
Complications			
<i>Stiffness</i>	31 (2.1%)	2 (3.5%)	15 (2.1%)
<i>Clunk syndrome</i>	13 (0.9%)	0	5 (0.7%)
<i>Extensor mechanism rupture</i>	3 (0.2%)	0	1 (0.1%)
<i>Patella button loosening</i>	1 (0.1%)	0	1 (0.1%)
<i>Patello-femoral instability</i>	5 (0.3%)	0	1 (0.1%)
<i>Patella fracture</i>	11 (0.8%)	1 (1.8%)	7 (1%)

BP index: Blackburne-Peel index; KSS: Knee Society Score; mFA: mechanical Femoral Axis; mFTA: mechanical Femoro-Tibial Axis

* significant difference (p<0.05) comparing the group with BP index = 0.54-1.06

Table 5 Post-operative clinical and radiological characteristics of TKAs with pre-operative patella alta (N=223)

	BP index = 0.54-1.06 (N=152)	BP index > 1.06 (N=10)	BP index < 0.54 (N=61)
Range of motion			
<i>Mean flexion contracture</i>	0.5° [0-15]	0.6° [0-5]	0.4° [0-10]
<i>Mean maximal flexion</i>	120.3° [85-140]	114.5° [35-135]	115.4° [20-140]
Mean KSS score			
<i>Knee</i>	89.3 [49-100]	89.3 [52-100]	84.8 [42-100] *
<i>Function</i>	79.9 [20-100]	83 [45-100]	81.3 [40-100]
Satisfaction			
<i>Very good and good</i>	140 (92.1%)	9 (90%)	55 (90.2%)
<i>Bad and very bad</i>	12 (7.9%)	0	6 (9.8%)
<i>NC</i>	0	1 (10%)	0
Long leg films			
<i>Mean mFTA</i>	178.8° [171-184]	180° [177-183]	178.8° [171-186]
<i>Mean mFA</i>	89.3° [83-94]	90.3° [88-92]	90° [82-96]
<i>Mean mTA</i>	89.5° [86-96]	90° [88-92]	89.1° [85-96]
Complications			
<i>Stiffness</i>	1 (0.7%)	0	1 (1.6%)
<i>Clunk syndrome</i>	1 (0.7%)	0	1 (1.6%)
<i>Extensor mechanism rupture</i>	0	0	0
<i>Patella button loosening</i>	0	0	0
<i>Patello-femoral instability</i>	1 (0.7%)	0	0
<i>Patella fracture</i>	1 (0.7%)	0	0

BP index: Blackburne-Peel index; KSS: Knee Society Score; mFA: mechanical Femoral Axis; mFTA: mechanical Femoro-Tibial Axis

* significant difference (p<0.05) comparing the group with BP index = 0.54-1.06

Table 6 Post-operative clinical and radiological characteristics of TKAs with pre-operative patella baja (N=307)

	BP index = 0.54-1.06 (N=158)	BP index > 1.06 (N=3)	BP index < 0.54 (N=146)
Range of motion			
<i>Mean flexion contracture</i>	0.7° [0-15]	1.7° [0-5]	0.4° [0-10]
<i>Mean maximal flexion</i>	118.4° [70-140]	116.7° [85-105]	112.8° [70-140]
Mean KSS score			
<i>Knee</i>	88.1 [46-100]	76.7 [49-91]	87.2 [33-100]
<i>Function</i>	78.7 [0-100]	71.7 [50-90]	78.1 [0-100]
Satisfaction			
<i>Very good and good</i>	148 (93.7%)	2 (67%)	135 (92.5%)
<i>Bad and very bad</i>	9 (5.7%)	1 (33%)	10 (6.8%)
<i>NC</i>	1 (0.6%)	0	1 (0.7%)
Long leg films			
<i>Mean mFTA</i>	178.8° [171-184]	179.3° [178-180]	177.9° [168-185]
<i>Mean mFA</i>	89.3° [83-94]	90° [90-90]	89° [83-95]
<i>Mean mTA</i>	89.5° [86-96]	89.3° [88-90]	89.2° [83-95]
Complications			
<i>Stiffness</i>	3 (1.9%)	0	8 (5.5%) *
<i>Clunk syndrome</i>	2 (1.3%)	0	2 (1.4%)
<i>Extensor mechanism rupture</i>	0	0	0
<i>Patella button loosening</i>	0	0	0
<i>Patello-femoral instability</i>	0	0	0
<i>Patella fracture</i>	3 (1.9%)	0	3 (2.1%)

BP index: Blackburne-Peel index; KSS: Knee Society Score; mFA: mechanical Femoral Axis; mFTA: mechanical Femoro-Tibial Axis; mTA: mechanical Tibial Axis

* significant difference (p<0.05) comparing the group with BP index = 0.54-1.06

487 **Table 7** Specific results of patients with tibial tubercle osteotomy (N=128)

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	Pre-operative BP index = 0.54-1.06 (N=101)	Pre-operative BP index > 1.06 (N=12)	Pre-operative BP index < 0.54 (N=15)
Medical history			
<i>Lateral approach for valgus</i>	90 (89.1%)	11 (91.7%)	10 (66.7%) *
<i>Stiffness</i>	11 (10.9%)	1 (8.3%)	5 (33.3%) *
Post-operative BP index			
<i>BP index = 0.54-1.06</i>	69 (68.3%)	8 (66.7%)	8 (53.3%)
<i>BP index > 1.06</i>	3 (3%)	1 (8.3%)	0
<i>BP index < 0.54</i>	29 (28.7%)	3 (25%)	7 (46.7%) *

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490 BP index: Blackburne-Peel index

491 * significant difference (p<0.05) comparing the group with BP index = 0.54-1.06

492

FIGURES

Fig. 1 Blackburne-Peel index = A/B (profile view)

a: on native knee

b: on TKA

Fig. 2 Native knee with normal patellar height (profile view)

Fig. 3 Native knee with patella alta (profile view)

Fig. 4 Native knee with patella baja (profile view)

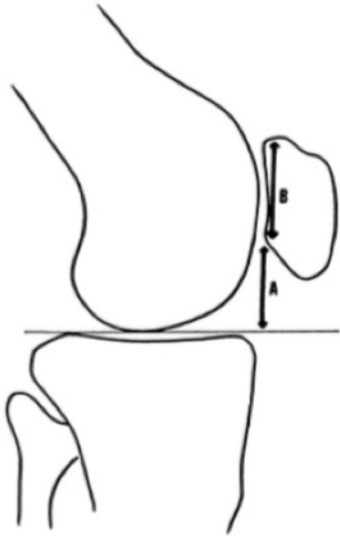
Fig. 5 Flowchart

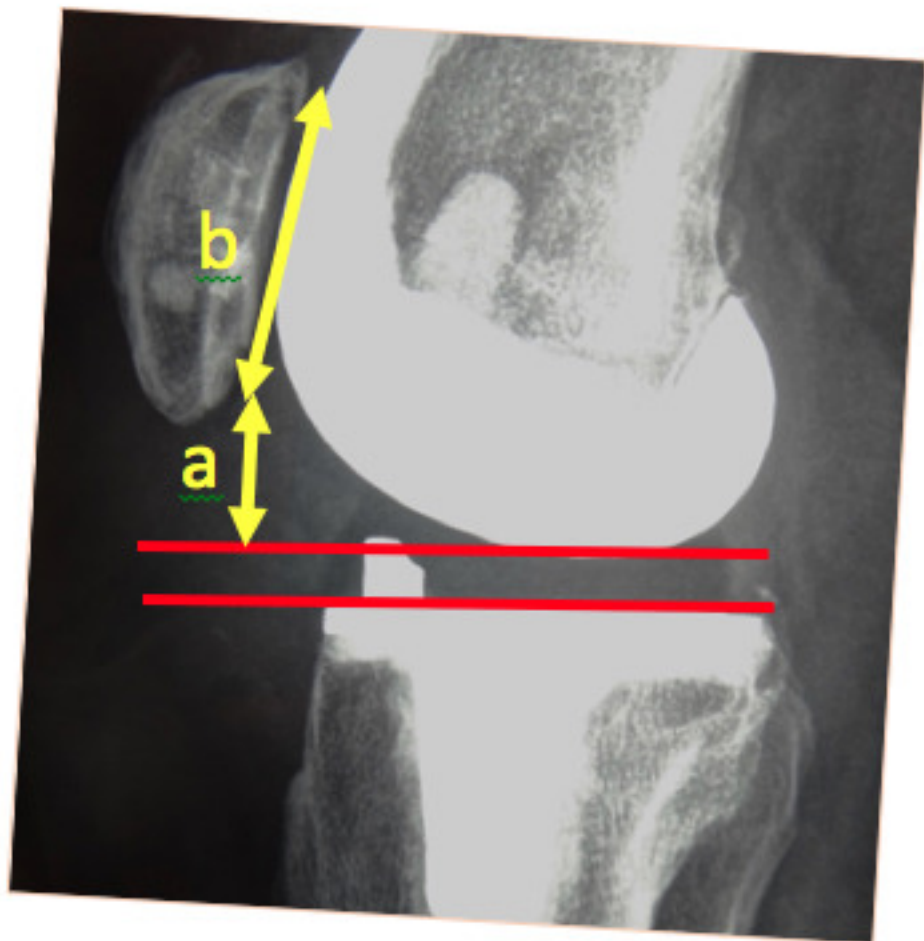
Fig. 6 Survival curves of TKA

a: with pre-operative normal patellar height

b: with pre-operative patella alta

c: with pre-operative patella baja

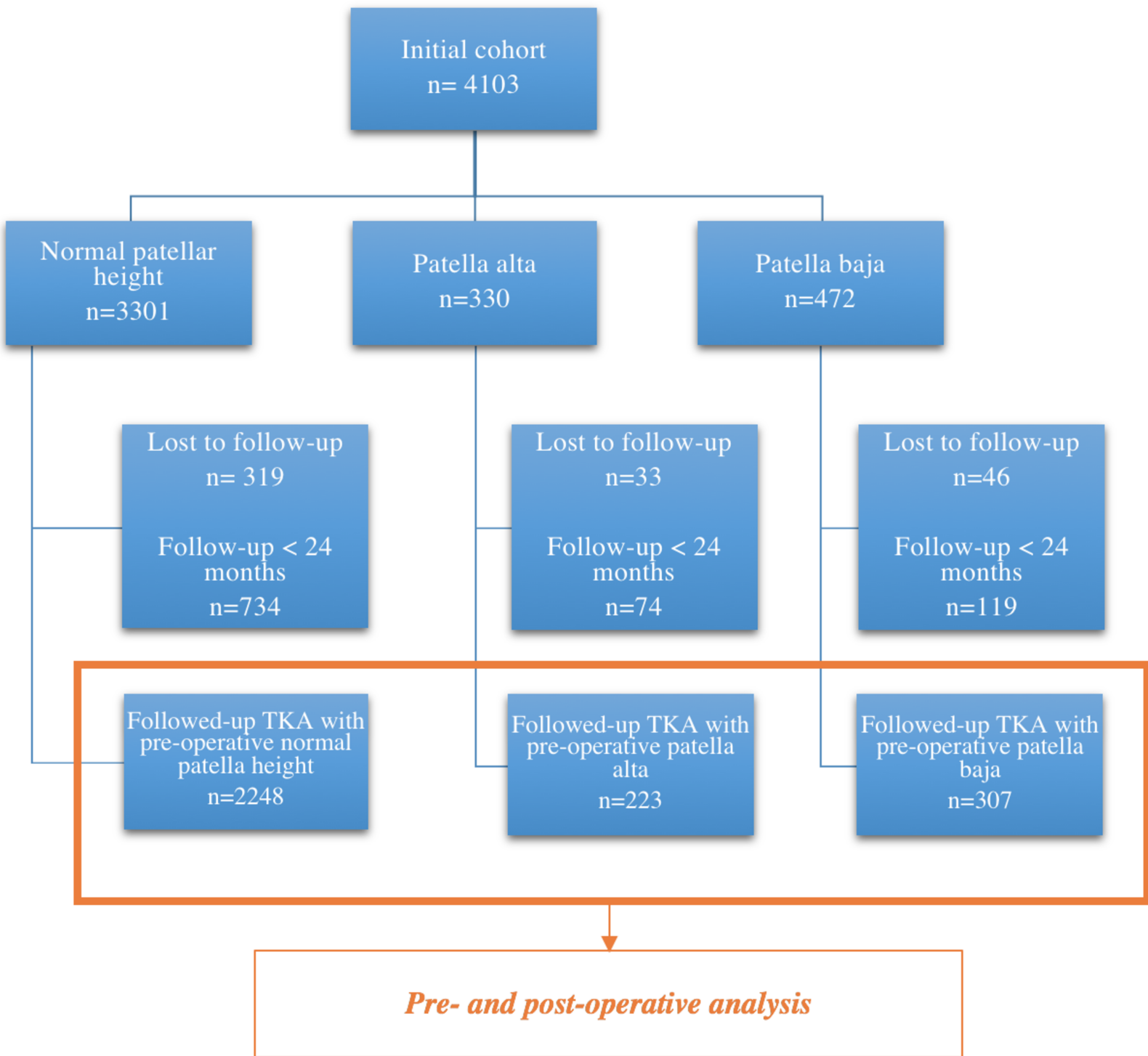




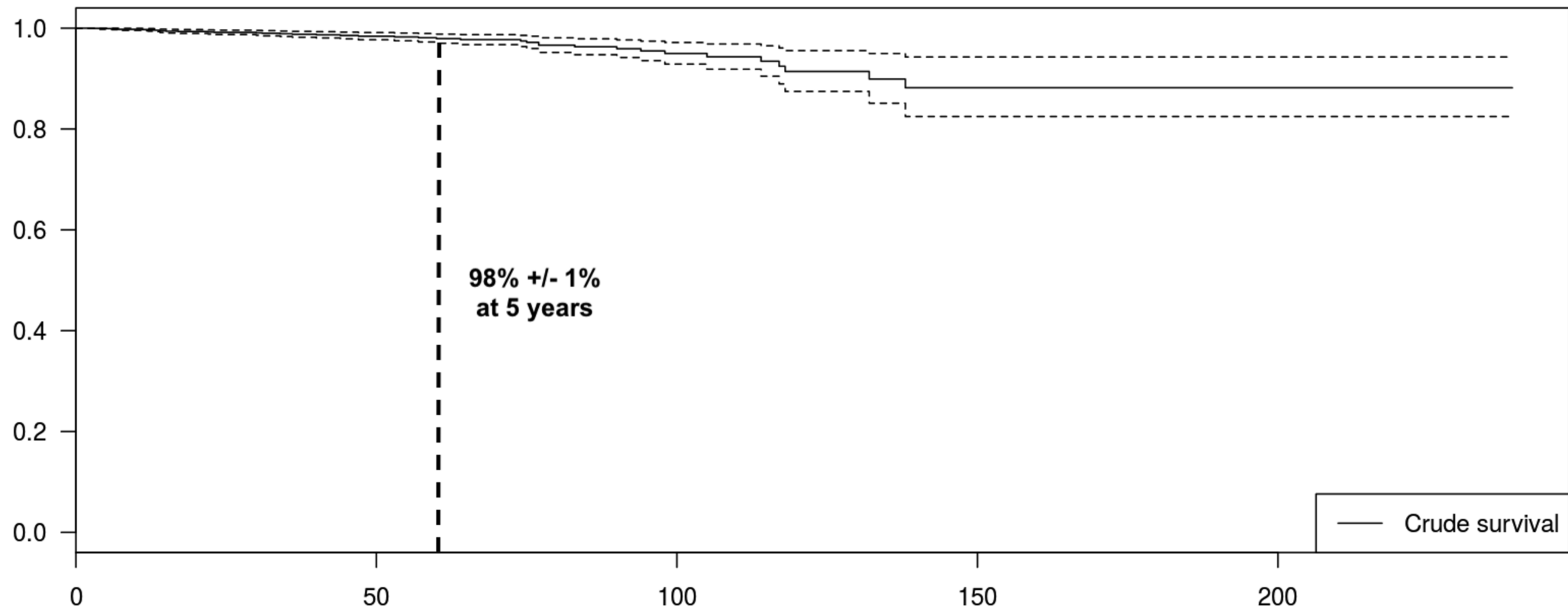




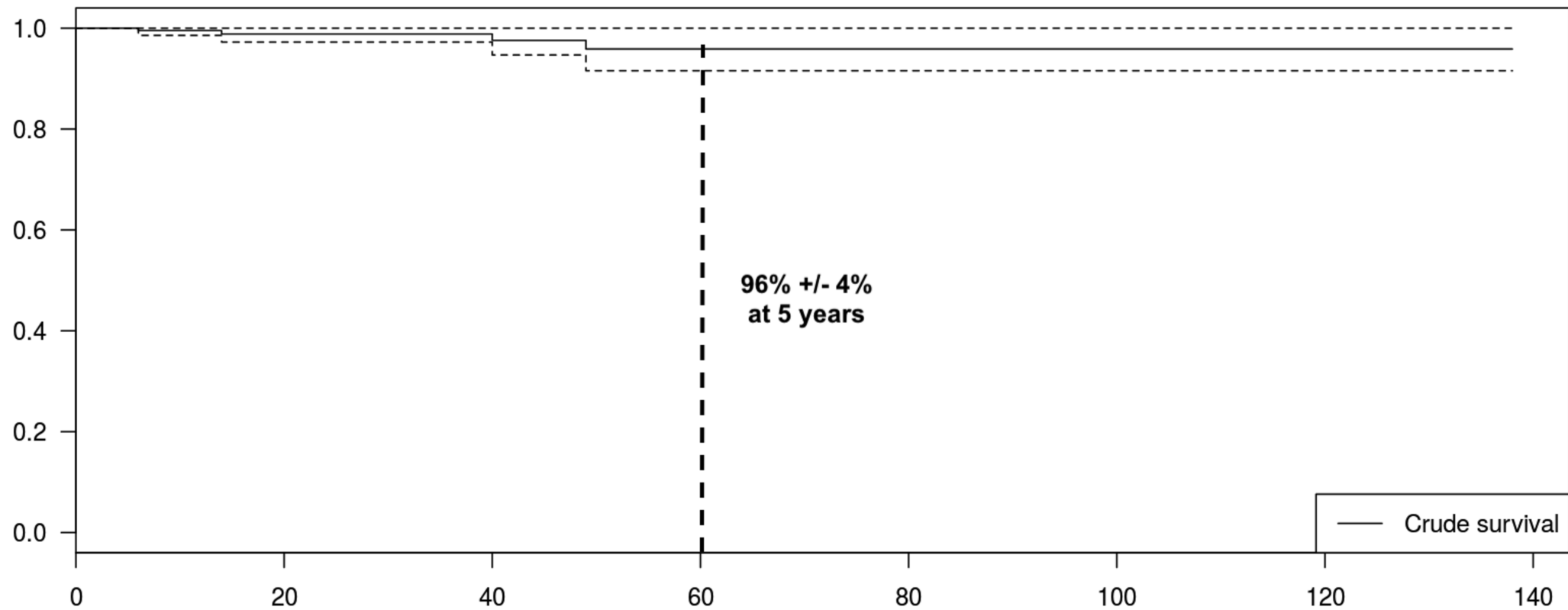




« Normal patellar height group » (N=2248)



« Patella alta group » (N=223)



« Patella baja group » (N=307)

