



HAL
open science

Influence of Patella Height on Total Knee Arthroplasty: Outcomes and Survival

Romain Gaillard, Christopher Bankhead, Nicolaas Budhiparama, Cécile Batailler, Elvire Servien, Sebastien Lustig

► **To cite this version:**

Romain Gaillard, Christopher Bankhead, Nicolaas Budhiparama, Cécile Batailler, Elvire Servien, et al.. Influence of Patella Height on Total Knee Arthroplasty: Outcomes and Survival. *The Journal of Arthroplasty*, 2019, 34 (3), pp. 469-477. 10.1016/j.arth.2018.10.037 . hal-02138483

HAL Id: hal-02138483

<https://hal.science/hal-02138483v1>

Submitted on 22 Oct 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution - NonCommercial 4.0 International License

Clinical article

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

Romain GAILLARD^a, Christopher BANKHEAD^b, Nicolaas BUDHIPARAMA^c, Cécile BATAILLER^a, Elvire SERVIEN^a, Sébastien LUSTIG^a

^aHôpital de la Croix-Rousse; Université Lyon 1, 103 grande rue de la Croix-Rousse, 69004 LYON, France

romain.gaillard@chu-lyon.fr

cecile.batailler@chu-lyon.fr

elvire.servien@chu-lyon.fr

sebastien.lustig@gmail.com

^bDepartment of Orthopaedics, University of New Mexico; 1 University of New Mexico, MSC 10 5600, ALBUQUERQUE, NM 87106, USA

cbankhead@salud.unm.edu

^cNicolaas Institute of Constructive Orthopaedics Research and Education Foundation for Arthroplasty & Sports Medicine, Medistra Hospital, Jl. Jend. Gatot Subroto Kav. 59, Jakarta, 12950 Indonesia

ncbjr@yahoo.com

Corresponding author:

Sébastien LUSTIG

Hôpital de la Croix-Rousse; Université Lyon 1,

103 grande rue de la Croix-Rousse,

69004 LYON, France

sebastien.lustig@gmail.com

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

3

4 **ABSTRACT**

5

6 **BACKGROUND**

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

9

10 **METHODS**

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

18

19 **RESULTS**

20 223 TKAs with pre-operative patella alta, 307 TKAs with pre-operative patella baja and 2248
21 with pre-operative normal patella height, mean follow-up 39.3 months (range 24-239), were
22 ultimately included. Post-operatively, there was no difference between the three groups in
23 terms of KSS (knee and function scores). Patella baja statistically decreased the maximal
24 flexion (118.2° vs 115.5° ; $p = 0.002$) and increased the rate of patellar fracture (0.9% vs 2% ;
25 $p = 0.05$). Finally, survival rates were similar in the three groups with each above 91% (\pm
26 2%) at 10 years.

27

28 **CONCLUSION**

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

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

33

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.

37

38

39

40

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

52 **INTRODUCTION**

53

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

59

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

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

68

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

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

76

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

80

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

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

88

89

90 **MATERIALS AND METHODS**

91

92 *Study population*

93

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

98

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

102 The measurement was performed on a lateral radiograph, with 30° of flexion
103 according to the same established radiological protocol. The measurements were initially
104 made by a junior surgeon (resident) and then independently verified by a senior surgeon. If
105 there was a discrepancy greater than 5%, a new measurement was independently performed
106 by a second senior surgeon. Freehand measurements on acetate films were performed before
107 2002, while digital computer software with numeric measurements was used after 2002.

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

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

114

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

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

120

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

128

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

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

140

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

144

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

148

149 *Operative technique*

150

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

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

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

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

165

166 *Statistical analysis*

167

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

174

175

176 **RESULTS**

177

178 *Pre-operative (Table 1)*

179

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

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

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

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

192

193 *Post-operative (Table 2)*

194

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

198 A statistically significant difference was found between the normal pre-operative
199 patellar height group and the patella baja group for the mean post-operative maximal flexion
200 (118.2° vs 115.5° ; $p=0.002$) and the mean post-operative mFTA (mechanical Femoro-Tibial
201 Axis) (178.9° vs 178.2° ; $p=0.006$).

202

203 *Patello-femoral complications (Table 3)*

204

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

210

211 *Survival analysis*

212

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

218

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

220

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

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

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

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

236

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

238

239 For patients with pre-operative patella baja, stiffness is statistically more responsible
240 for tibial tubercle osteotomy than for patients with normal pre-operative patellar height
241 (33.3% vs 10.9%; $p=0.02$).

242 The risk of post-operative patella baja after TKA with tibial tubercle osteotomy is
243 statistically higher than for patients with normal pre-operative patellar height (46.7% vs
244 28.7%; $p=0.03$).

245

246

247 **DISCUSSION**

248

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

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

255

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

265

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

271

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

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

283

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

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

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

293

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

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

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

306

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

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

315

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

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

322

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

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

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

337

338

339 **CONCLUSION**

340

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

347 **COMPLIANCE WITH ETHICAL STANDARDS.**

348

349 - Conflict of Interest:

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

352

353 - Funding:

354 This research did not receive any specific grant from funding agencies in the public,
355 commercial, or not-for-profit sectors.

356 **REFERENCES**

357

358 [1] Geenen E, Molenaers G, Martens M. Patella alta in patellofemoral instability. *Acta*
359 *Orthop Belg* 1989;55:387–93.

360 [2] Møller BN, Krebs B, Jurik AG. Patellar height and patellofemoral congruence. *Arch*
361 *Orthop Trauma Surg Arch Für Orthop Unf-Chir* 1986;104:380–1.

362 [3] Dejour H, Walch G, Nove-Josserand L, Guier C. Factors of patellar instability: an
363 anatomic radiographic study. *Knee Surg Sports Traumatol Arthrosc Off J ESSKA* 1994;2:19–
364 26.

365 [4] Caton J, Deschamps G, Chambat P, Lerat JL, Dejour H. [Patella infera. Apropos of
366 128 cases]. *Rev Chir Orthopédique Réparatrice Appar Mot* 1982;68:317–25.

367 [5] Chonko DJ, Lombardi AV, Berend KR. Patella baja and total knee arthroplasty
368 (TKA): etiology, diagnosis, and management. *Surg Technol Int* 2004;12:231–8.

369 [6] Mariani PP, Del Signore S, Perugia L. Early development of patella infera after knee
370 fractures. *Knee Surg Sports Traumatol Arthrosc Off J ESSKA* 1994;2:166–9.

371 [7] Ward SR, Terk MR, Powers CM. Influence of patella alta on knee extensor mechanics.
372 *J Biomech* 2005;38:2415–22. doi:10.1016/j.jbiomech.2004.10.010.

373 [8] Luyckx T, Didden K, Vandenneucker H, Labey L, Innocenti B, Bellemans J. Is there a
374 biomechanical explanation for anterior knee pain in patients with patella alta?: influence of
375 patellar height on patellofemoral contact force, contact area and contact pressure. *J Bone Joint*
376 *Surg Br* 2009;91:344–50. doi:10.1302/0301-620X.91B3.21592.

377 [9] Ward SR, Powers CM. The influence of patella alta on patellofemoral joint stress
378 during normal and fast walking. *Clin Biomech Bristol Avon* 2004;19:1040–7.
379 doi:10.1016/j.clinbiomech.2004.07.009.

380 [10] Ahlbäck S, Mattsson S. Patella alta and gonarthrosis. *Acta Radiol Diagn (Stockh)*
381 1978;19:578–84.

382 [11] Stefanik JJ, Zhu Y, Zumwalt AC, Gross KD, Clancy M, Lynch JA, et al. Association
383 between patella alta and the prevalence and worsening of structural features of patellofemoral
384 joint osteoarthritis: the multicenter osteoarthritis study. *Arthritis Care Res* 2010;62:1258–65.
385 doi:10.1002/acr.20214.

386 [12] Briard JL, Hungerford DS. Patellofemoral instability in total knee arthroplasty. *J*
387 *Arthroplasty* 1989;4 Suppl:S87-97.

388 [13] Schiavone Panni A, Cerciello S, Del Regno C, Felici A, Vasso M. Patellar resurfacing
389 complications in total knee arthroplasty. *Int Orthop* 2014;38:313–7. doi:10.1007/s00264-013-

- 390 2244-3.
- 391 [14] Drexler M, Dwyer T, Marmor M, Sternheim A, Cameron HU, Cameron JC. The
392 treatment of acquired patella baja with proximalize the tibial tuberosity. *Knee Surg Sports*
393 *Traumatol Arthrosc Off J ESSKA* 2013;21:2578–83. doi:10.1007/s00167-012-2278-x.
- 394 [15] Singerman R, Davy DT, Goldberg VM. Effects of patella alta and patella infera on
395 patellofemoral contact forces. *J Biomech* 1994;27:1059–65.
- 396 [16] Kim J, Nelson CL, Lotke PA. Stiffness after total knee arthroplasty. Prevalence of the
397 complication and outcomes of revision. *J Bone Joint Surg Am* 2004;86-A:1479–84.
- 398 [17] Blackburne JS, Peel TE. A new method of measuring patellar height. *J Bone Joint*
399 *Surg Br* 1977;59:241–2.
- 400 [18] Lingard EA, Katz JN, Wright RJ, Wright EA, Sledge CB, Kinemax Outcomes Group.
401 Validity and responsiveness of the Knee Society Clinical Rating System in comparison with
402 the SF-36 and WOMAC. *J Bone Joint Surg Am* 2001;83-A:1856–64.
- 403 [19] Ewald FC. The Knee Society total knee arthroplasty roentgenographic evaluation and
404 scoring system. *Clin Orthop* 1989;9–12.
- 405 [20] Healy WL, Della Valle CJ, Iorio R, Berend KR, Cushner FD, Dalury DF, et al.
406 Complications of total knee arthroplasty: standardized list and definitions of the Knee Society.
407 *Clin Orthop* 2013;471:215–20. doi:10.1007/s11999-012-2489-y.
- 408 [21] Keblish PA. The lateral approach to the valgus knee. Surgical technique and analysis
409 of 53 cases with over two-year follow-up evaluation. *Clin Orthop* 1991:52–62.
- 410 [22] Demey G, Servien E, Lustig S, Ait Si Selmi T, Neyret P. Cemented versus
411 uncemented femoral components in total knee arthroplasty. *Knee Surg Sports Traumatol*
412 *Arthrosc Off J ESSKA* 2011;19:1053–9. doi:10.1007/s00167-010-1347-2.
- 413 [23] Berg EE, Mason SL, Lucas MJ. Patellar height ratios. A comparison of four
414 measurement methods. *Am J Sports Med* 1996;24:218–21.
- 415 [24] Seil R, Müller B, Georg T, Kohn D, Rupp S. Reliability and interobserver variability
416 in radiological patellar height ratios. *Knee Surg Sports Traumatol Arthrosc Off J ESSKA*
417 2000;8:231–6. doi:10.1007/s001670000121.
- 418 [25] Narkbunnam R, Chareancholvanich K. Effect of patient position on measurement of
419 patellar height ratio. *Arch Orthop Trauma Surg* 2015;135:1151–6. doi:10.1007/s00402-015-
420 2268-9.
- 421 [26] Jiang X, Zhang Y, Liu J. Patella infera following patellar tendon contracture after
422 closed trauma. *Chin Med J (Engl)* 2013;126:3990–1.
- 423 [27] Kaper BP, Bourne RB, Rorabeck CH, Macdonald SJ. Patellar infera after high tibial

424 osteotomy. *J Arthroplasty* 2001;16:168–73. doi:10.1054/arth.2001.20538.

425 [28] Gokay NS, Erginer R, Dervisoglu S, Yalcin MB, Gokce A. Patella infera or patellar
426 tendon adherence after high tibial osteotomy. *Knee Surg Sports Traumatol Arthrosc Off J*
427 *ESSKA* 2014;22:1591–8. doi:10.1007/s00167-012-2293-y.

428 [29] Hermans K, Claes S, Bellemans J. Valgus instability as a cause for recurrent lateral
429 patellar dislocation: a new mechanism for patellofemoral instability? *Acta Orthop Belg*
430 2013;79:495–501.

431 [30] Kazemi SM, Daftari Besheli L, Eajazi A, Miniator Sajadi MR, Okhovatpoor MA,
432 Farhang Zanganeh R, et al. Pseudo-Patella Baja after total knee arthroplasty. *Med Sci Monit*
433 2011;17:CR292–6. doi:10.12659/MSM.881770.

434 [31] Khakharia S, Scuderi GR. Restoration of the distal femur impacts patellar height in
435 revision TKA. *Clin Orthop* 2012;470:205–10. doi:10.1007/s11999-011-1995-7.

436 [32] Weale AE, Murray DW, Newman JH, Ackroyd CE. The length of the patellar tendon
437 after unicompartmental and total knee replacement. *J Bone Joint Surg Br* 1999;81:790–5.

438

439 TABLES

440

441

442 **Table 1** Pre-operative clinical and radiological characteristics

443

	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

444

445 BP index: Blackburne-Peel index; BMI: Body Mass Index; DFO: Distal Femoral Osteotomy; HTO: High Tibial

446 Osteotomy; KSS: Knee Society Score; mFA: mechanical Femoral Axis; mFTA: mechanical Femoro-Tibial Axis;

447 mTA: mechanical Tibial Axis

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

449

450

451 **Table 2** Post-operative clinical and radiological characteristics

452

	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%)

453

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

455 mechanical Femoro-Tibial Axis; mTA: mechanical Tibial Axis

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

457

458

459 **Table 3** Patello-femoral complications

460

	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%) *

461

462

463 **Table 4** Post-operative clinical and radiological characteristics of TKAs with normal pre-operative
 464 patellar height (N=2248)
 465

	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%)

466
 467 BP index: Blackburne-Peel index; KSS: Knee Society Score; mFA: mechanical Femoral Axis; mFTA:
 468 mechanical Femoro-Tibial Axis; mTA: mechanical Tibial Axis
 469 * significant difference (p<0.05) comparing the group with BP index = 0.54-1.06
 470

471 **Table 5** Post-operative clinical and radiological characteristics of TKAs with pre-operative patella
 472 alta (N=223)
 473

	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

474
 475 BP index: Blackburne-Peel index; KSS: Knee Society Score; mFA: mechanical Femoral Axis; mFTA:
 476 mechanical Femoro-Tibial Axis; mTA: mechanical Tibial Axis
 477 * significant difference (p<0.05) comparing the group with BP index = 0.54-1.06
 478

479 **Table 6** Post-operative clinical and radiological characteristics of TKAs with pre-operative patella
 480 baja (N=307)
 481

	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%)

482
 483 BP index: Blackburne-Peel index; KSS: Knee Society Score; mFA: mechanical Femoral Axis; mFTA:
 484 mechanical Femoro-Tibial Axis; mTA: mechanical Tibial Axis
 485 * significant difference (p<0.05) comparing the group with BP index = 0.54-1.06
 486

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

488

	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%) *

489

490 BP index: Blackburne-Peel index

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

492

493

494 **FIGURES**

495

496

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

498 a: on native knee

499 b: on TKA

500

501

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

503

504

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

506

507

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

509

510

511 **Fig. 5** Flowchart

512

513

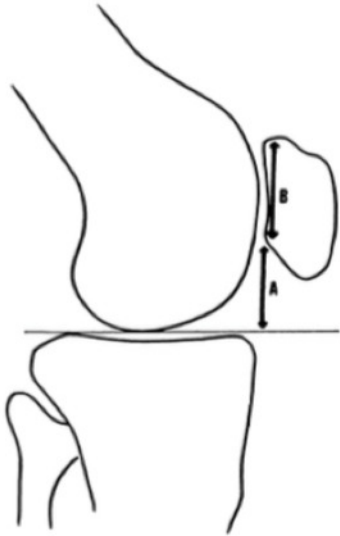
514 **Fig. 6** Survival curves of TKA

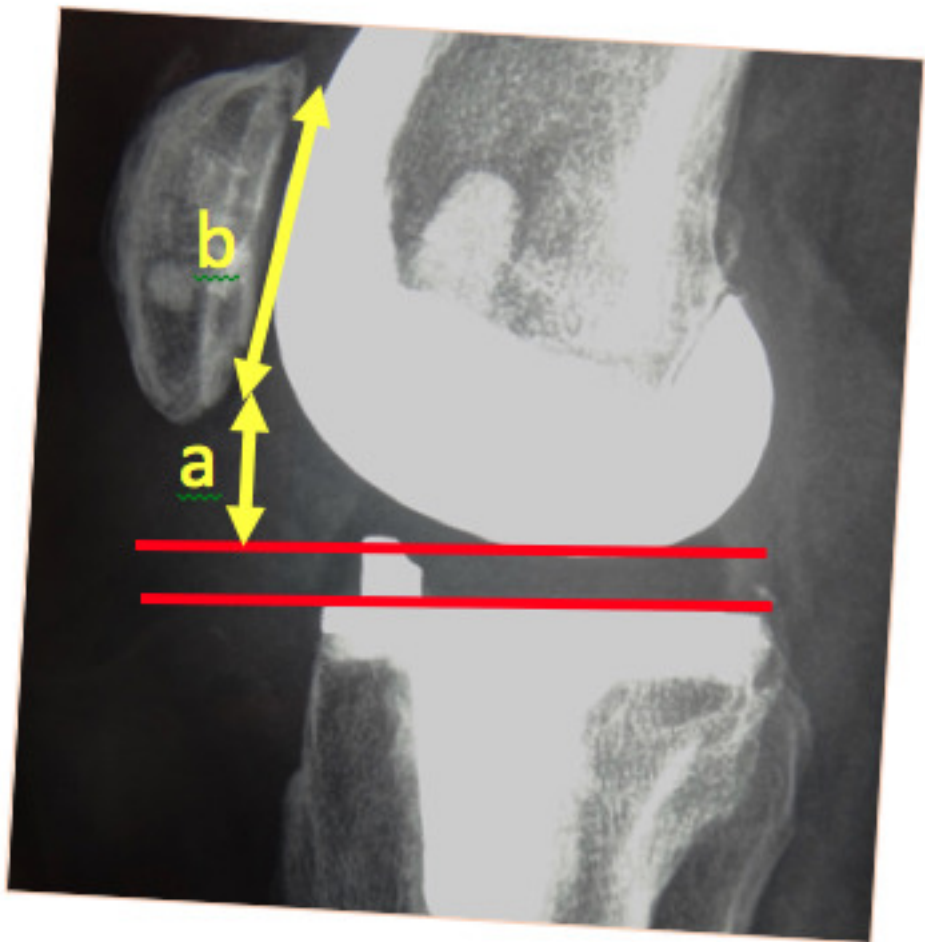
515 a: with pre-operative normal patellar height

516 b: with pre-operative patella alta

517 c: with pre-operative patella baja

518

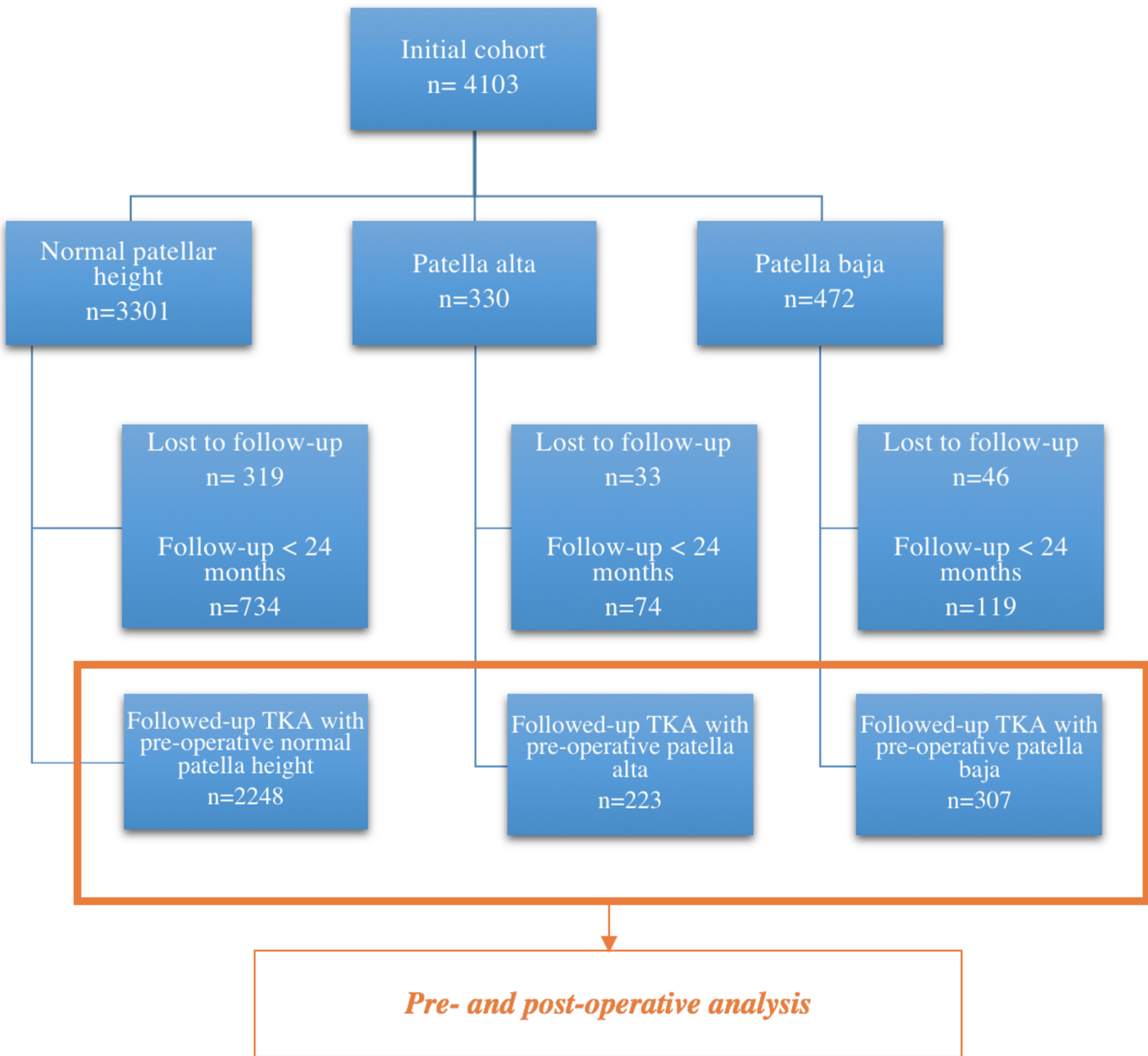




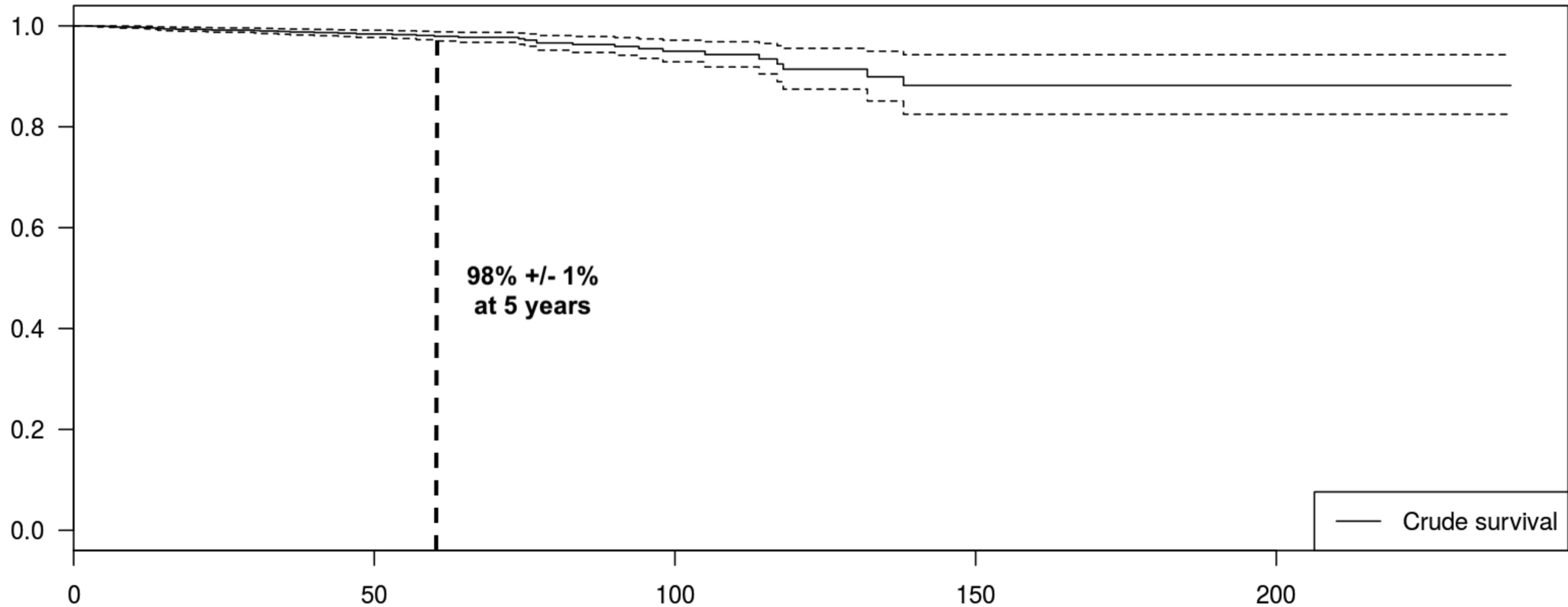




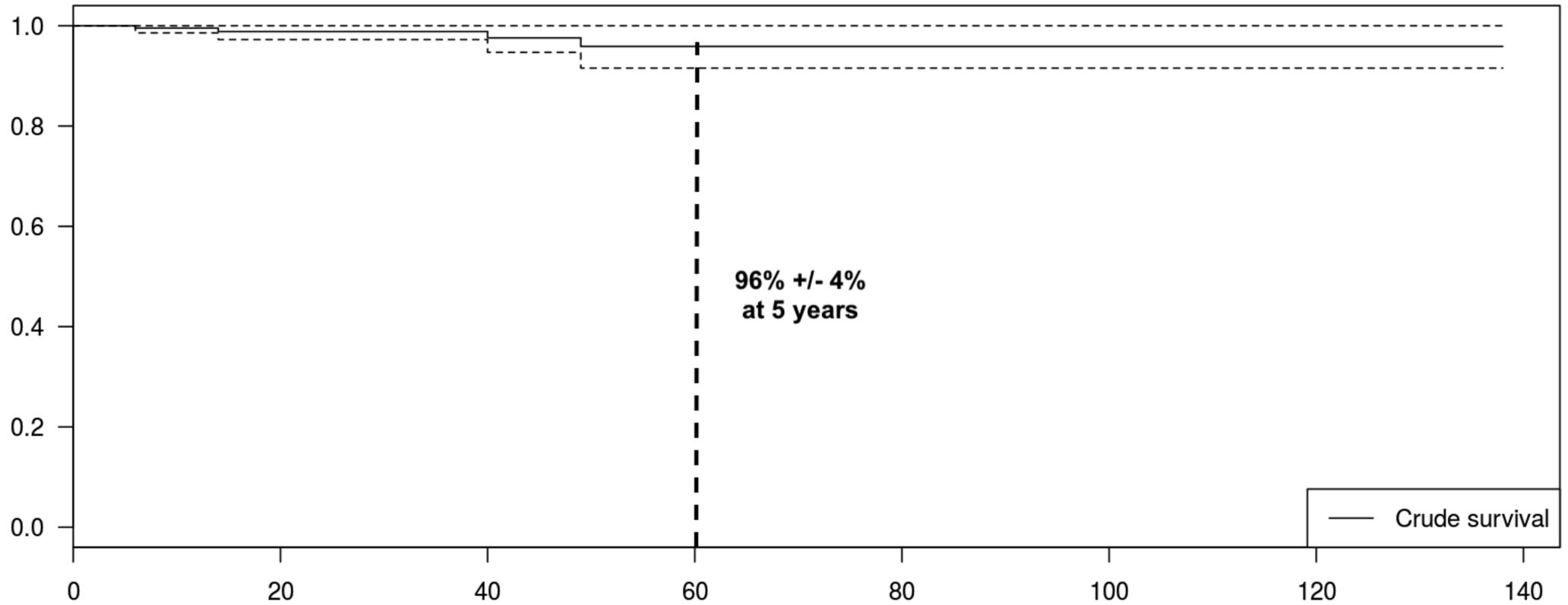




« Normal patellar height group » (N=2248)



« Patella alta group » (N=223)



« Patella baja group » (N=307)

