

1 **Title: The role of the patellar tendon angle and patellar flexion angle in the interpretation of sagittal**
2 **plane kinematics of the knee after knee arthroplasty: a modelling analysis.**

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36

37 **Abstract:**

38 *Background*

39 Many different measures have been used to describe knee kinematics. This study investigated the changes
40 of two measures, the patellar tendon angle and the patellar flexion angle, to variations in the geometry of the
41 knee due to surgical technique or implant design.

42

43 *Methods*

44 A mathematical model was developed to calculate the equilibrium position of the extensor mechanism for a
45 particular tibiofemoral position. Calculating the position of the extensor mechanism allowed for the
46 determination of the patellar tendon angle and patellar flexion angle relationships to the knee flexion angle.
47 The model was used to investigate the effect of anterior-posterior position of the femur, change in joint line,
48 patellar thickness (overstuffing, understuffing), and patellar tendon length; these parameters were varied to
49 determine the effect on the patellar tendon angle/knee flexion angle and patellar flexion angle/knee flexion
50 angle relationships.

51

52 *Findings*

53 Results showed the patellar tendon angle was a good indicator of anterior-posterior femoral position and
54 change in patellar thickness, and the patellar flexion angle a good indicator of change in joint line, and
55 patellar tendon length.

56

57 *Interpretation*

58 The patellar tendon angle/knee flexion angle relationship was found to be an effective means of identifying
59 abnormal kinematics post knee arthroplasty. However, the use of both the patellar tendon angle and patellar
60 flexion angle together provided a more informative overview of the sagittal plane kinematics of the knee.

61

62

63 Introduction:

64

65 Knee arthroplasty is considered an effective procedure however a significant proportion of patients
66 experience pain after the procedure[1–3]. The kinematics of the knee can be altered by both surgical
67 technique and implant design. Undergoing total knee arthroplasty may affect the anterior-posterior position of
68 the femur, the joint line, the patellar thickness (overstuffing/understuffing of the patellofemoral joint) and the
69 patellar tendon shortening post surgery[4–6]. Knee component designs also play an important part in
70 controlling the kinematics of the knee joint due to their geometry as well as the addition of constraints such
71 as a cam-post mechanism[7–9]. As such kinematic measures of the knee joint are regularly used to assess
72 the whether knee arthroplasty designs[9–16] achieve intended design aims or restore native knee
73 kinematics.

74

75 Many techniques have been used to investigate the kinematics of the knee using gait analysis, mechanical
76 measurement, magnetic resonance imaging, fluoroscopy, and radiostereomatographic imaging[11,17–21]. A
77 well-recognised method used to assess the kinematics of total knee arthroplasty is 2D to 3D reconstruction
78 of fluoroscopic imaging[11,14,15] which has also been used to study kinematics of native knees[22]. More
79 recently the use of MRI has allowed for improved studies of native knee kinematics[19–21]. These methods
80 are complex, time consuming, and resource demanding. Additionally the descriptors most commonly used
81 are tibiofemoral contact points and relative tibiofemoral motion. It may be more accurate to consider both
82 tibiofemoral and patellofemoral joint interaction when assessing the kinematics of the knee. The motion of
83 the patella relative to the tibia is dependant on both the tibiofemoral and patellofemoral joint interactions and
84 has been adopted in the form of the patellar tendon angle (PTA) as a simplified measure of sagittal plane
85 kinematics of the knee[23–29] and can be measured using conventional fluoroscopy [24,30]. The PTA is the
86 angle subtended between the axis of the patella tendon and the tibial axis as illustrated in *figure 1*. The PTA
87 has been shown to be effective in differentiating the kinematics of normal and prosthetic knees[9,16,31]
88 however the interpretation of the PTA is not straightforward[24]. The PTA is often interpreted as an indicator
89 of relative anterior-posterior motion of the femur on the tibia which Stagni *et al.*[24] conclude is not entirely
90 correct. In addition to the PTA other studies looking at sagittal plane kinematics have made the additional use
91 of the patellar flexion angle (PFA) to describe patellofemoral kinematics [9,16,25,32]. The PFA is the angle
92 subtended between the femoral axis and the axis through the midline of the patella in the sagittal plane
93 (*figure 1*). It is felt that the use of both PTA and PFA gives a more complete picture of the overall sagittal
94 kinematics of the knee[9,16,25,32].

95

96 Both the PTA and PFA are influenced by multiple parameters. In this study a computational sagittal plane
97 model of the knee was used to determine PTA versus knee flexion angle (KFA) and PFA versus KFA
98 relationships to determine their response to alterations in parameters representing changes of interest in a
99 clinical context such as the: 1) AP position of the femur relative to the tibia 2) DP position of the femur
100 relative to the tibia leading to an altered joint line 3) change in patellar thickness causing overstuffing or
101 understuffing of the patellofemoral joint 4) alteration in patellar tendon length leading to patella baja or alta.
102 This study postulated that the synchronous use of both PTA/KFA and PFA/KFA relationships can provide
103 clinically relevant information of sagittal plane knee kinematics over the use of the PTA alone.

104 **Methods:**

105

106 *Sagittal Plane Model*

107 A two-dimensional mathematical sagittal plane model of the knee was developed, similar to previously
108 described models[26,33,34], to calculate the equilibrium position of the extensor mechanism for a specified
109 position of the femur relative to the tibia. The model described the geometry of the femur as a curve and the
110 patella as rectangular. To describe the calculation the parameters used must first be defined. The parameters
111 are illustrated in *figure 1* and described below:

112

113 • Tibial tubercle position (*O*): The tibial tubercle is the point on the tibia where the patellar tendon is
114 attached. The tibial tubercle is taken as the origin (0,0) of the model.

115

116 • Femoral geometry: This is the sagittal plane outline of the femur. In the case of this model this is
117 taken as a circle described by the equation:

118
$$(x - h)^2 + (y - k)^2 = r^2$$
 equation 1

119 where (*h,k*) describes the position of the femur relative to *O*, and *r* is the radius.

120

121 • patellar length (*p*): This is the length of the patella taken to be the distance between the patellar
122 tendon attachment at the distal pole (*dp*) of the patella and the quadriceps tendon attachment to the
123 proximal pole (*pp*) of the patella.

124

125 • patellar tendon length (*ptl*): This is the length of the patellar tendon representing the distance
126 between *O* and *dp*.

127

128 • patellar thickness (*pw*): This was the distance between the patellar axis (line through *dp* and *pp*) and
129 the contact surface of the patella on the femur.

130

131 • Knee flexion angle (*KFA*): This is the angle between the femoral axis and the tibial axis.

132

133 • patellar tendon angle (*PTA*): This is the angle between the patellar tendon and the tibial axis.

134

135 • patellar flexion angle (*PFA*): This is the angle between the femoral axis and the patellar axis.

136

137 As in previously described sagittal plane models[26,34] number of assumptions were made:

138

139 • The difference in thickness between the trochlea groove and the patellar facet contact surfaces on
140 the femoral condyles of the implant was assumed negligible. This allowed the patella to be
141 represented as being rectangular as proposed by Yamaguchi[35].

142

143 • The patellar tendon was considered inextensible.

144

145 • The force acting through the quadriceps tendon was parallel to the femoral axis until quadriceps
146 tendon wrap took place.

147

148 • Both the patella and quadriceps tendons were in tension at all times.

149

150 • At higher degrees of flexion, the quadriceps tendon wraps around the antero-distal femur which
151 changes its angle of action on the patella. This was accounted for by keeping the quadriceps axis
152 unchanged beyond 87.5 of knee flexion; which is the angle at which quadriceps wrap was taken to
153 occur[26].

154

155 The driving input to the model was the relative position (h,k) of the femur relative to the tibial tubercle (O) .
156 Knowing the position of the femur relative to O and its description in the form of *equation 1* meant that the
157 curve describing the femur could be described with in the axis (O) .

158

159 *Step 1:*

160 Having determined the femoral contact surface within O the patella contact point on the femur could be
161 calculated. The patellofemoral contact point (x_{cp}, y_{cp}) was assumed to lie on the femur where $h-r \leq x_{cp} \leq h$ and
162 $y \geq 0$. Assuming the contact between patella and femur to be frictionless meant that the patellar axis lay
163 parallel to the tangent of the curve at (x_{cp}, y_{cp}) . The patellar axis could then be described using the equation of
164 a line:

165 $y = mx + c$ *equation 2*

166 Where m is the gradient which is equal to the gradient of the tangent of the femur, which in turn is the
167 derivative (y') of *equation 1*. The definition of the femoral geometry in *equation 1* is an implicit function which
168 could be differentiated by applying the chain rule: so for any point (x_{cp}, y_{cp}) on a curve defined by *equation 1*
169 the tangent at this point has the gradient:

170
$$m = y' = \frac{(h - x_{cp})}{(y_{cp} - k)}$$
 equation 3

171 The patellar axis is parallel to the tangent where the distance between the two lines is the thickness of the
172 patella (pw) .

173

174 *Step 2:*

175 Knowing the patellar axis and the length of the patellar tendon meant that the position of the distal pole of the
176 patella could be determined by finding the point of intersection between the patellar axis and a circle of
177 radius ptl circumscribed around the tibial tubercle (O) . Having determined the distal pole of the patella the
178 equation of a line describing the patellar tendon between (O) and (dp) axis could be determined.

179

180 *Step 3:*

181 Having determined the position of the patellar axis in *step 1*, the dp in *step 2*, and knowing the patellar length

182 (pl) meant the position of the proximal pole of the patella (pp) could be calculated.

183

184 *Step 4:*

185 The quadriceps axis was then described as the line parallel to the femoral axis passing through pp .

186

187 *Step 5:*

188 Based on the assumption that the extensor mechanism was in equilibrium at any given moment during
189 extension and flexion it follows that the forces acting on the patella were in equilibrium. This meant that the
190 patellar axis, quadriceps axis, and the normal to the tangent of the femur through the patellofemoral contact
191 point would be concurrent[26,34].

192

193 The fixed parameters used in the calculations were: $O = (0,0)$, $r = 25$ mm, $ptl = 50$ mm, $pl = 30$ mm, $pth = 7.5$
194 mm. For each input (femoral position h,k) for a corresponding KFA) the equilibrium position of the extensor
195 mechanism was found by optimizing for x_{cp} . For each value of x_{cp} the the *steps 1-5* were performed to
196 minimize the point of convergence between the axes acting through the patella to give PTA and PFA outputs.
197 The calculation described was performed using Microsoft Excel (v12, Microsoft, Washington, USA) and
198 Microsoft Visual Basic (Microsoft, Washington, USA) macros.

199

200 *Calculation of baseline femoral positions (h,k)*

201

202 The femur is known to move posteriorly relative to the tibia with flexion [19-21]. To calculate the effect of a
203 change in parameters throughout a range of flexion baseline positions of the femur relative to the tibia for
204 each point in flexion were required. To determine the starting femoral input positions (h,k) for every 10° of
205 knee flexion between 10° and 90° KFA the calculation was performed in reverse to determine the femoral
206 positions. Using the mathematical model described with the PTA and KFA as an input allowed for the
207 calculation of the position (h,k) as an output. For every 10° of knee flexion between 10° and 90° KFA the
208 normal values for the PTA were input into the model to obtain baseline values for h,k at 10° intervals
209 between 10° and 90° KFA. The input PTA/KFA values were taken to be those measured for a group of 20
210 healthy knees using fluoroscopic measurement in a previous study [31].

211

212 *Variation of Parameters*

213

214 The effect on PTA and PFA of variation in relative AP femoral position, joint line, patellar thickness
215 (overstuffing/understuffing of the patellofemoral joint), and patellar tendon length were investigated. To
216 investigate the effect of changing specific parameters influenced during surgery or implant design the model
217 was run whilst varying the relevant parameters individually:

- 218 1. AP position of the femur (h) was varied between -2.5mm and 2.5mm at 0.5mm intervals either side
219 of the baseline position.
- 220 2. The joint line (k) was varied between -2.5mm and 2.5mm at 0.5mm intervals either side of the
221 baseline position.
- 222 3. The patellar thickness (pw) was varied between -2.5mm and 2.5mm at 0.5mm intervals either side of
223 the baseline position.

4. The patellar tendon length (*ptl*) was varied between -2.5mm and 2.5mm at 0.5mm intervals either side of the baseline position.

Parameter Response

The model outputs were the PTA/KFA and PFA/KFA relationships. In addition to these a measure of responsiveness for both the PTA and KFA was calculated for each of the four variables under investigation. To quantify the response the amount of change was plotted against the average change in parameter to determine the associated gradient. The gradients were calculated in RStudio (Version 0.99.484, 2009-2015 RStudio, Inc.) using linear least squares regression. In addition to individual gradients representing the changes seen by the PTA and PFA profile relative to changes in respective parameters a *response ratio* representing the responses of the two output parameters (PTA & PFA) ; a large ratio representing the PTA being more sensitive to a change in a particular parameter and a smaller ratio indicating that the PFA was more sensitive.

Results:

The PTA and PFA relationships with knee flexion illustrating the effect of change with variation of the AP position of the femur (*h*), DP position of the femur (*k*), patellar thickness (*pw*), and patellar tendon length (*ptl*) are shown in *figures 2&3*.

AP position of the femur (h):

With variation of the AP position of the femur (*h*) the PTA increased with a more anterior position of the femur and similarly the PTA decreased with a more posterior position of the femur as illustrated by the range in *figure 2a*. Similarly the PFA increased with anterior movement of the femur and decreased with posterior motion of the femur (*figure 3a*) however the range of change in PFA was less than that seen for the PTA. This difference in range of the two measures is illustrated in *figure 4-top left* which shows the average change in angle associated with a change in *h*. The gradient of the PTA is greater than that of the PFA meaning it is more sensitive/responsive to AP change than the PFA.

DP change (k):

The PTA change with DP change (*k*) decreased with proximal movement of the femur and vice versa however, the range of change in angle was narrow (*figure 2-top right*). Conversely the change in PFA with variation in *k* showed a wide range in change of angle increasing with proximal movement and decreasing with distal movement of the femur (*figure 3-top right*).

patellar tendon length (ptl):

The effect of variation of the patellar tendon length (*ptl*) on the PTA and PFA is shown in *figure 2-bottom right*. Both PTA and PFA decreased with an increase in patellar tendon length (*figure 3-bottom right*). The difference in range of the two measures is illustrated in *figure 4-bottom right* which showed the average change in angle in PFA associated with a change in *ptl* was significantly greater than the PTA.

265

266 patellar thickness (pw):

267 The effect of variation of the patellar thickness (pw) on the PTA and PFA is shown in *figures 2-bottom left &*
268 *3-bottom left*. Both PTA and PFA show a positive gradient representing an increase of PTA and PFA
269 corresponding with an increase in patellar thickness. The range of change in angle with variation was greater
270 for the PTA as compared to the PFA which is illustrated by the increased gradients of the PTA an PFA versus
271 change in pw plots in *figure 4-bottom left*.

272

273 *Response ratios:*

274 The sensitivity of the PTA and PFA to changes in respective parameters are summarized in *Table 1* with the
275 corresponding response ratios.

276

277 **Discussion:**

278

279 A mathematical model of the knee extensor mechanism in two-dimensions was used to determine the
280 kinematics of the patellofemoral joint in the sagittal plane. Specifically, the model calculated the PTA/KFA and
281 PFA/KFA relationships for which the extensor mechanism was in equilibrium for a particular tibiofemoral
282 position and KFA was developed. With the use of the model it was noted that PTA/KFA and PFA/KFA
283 relationships were influenced to different extents by a change in parameters illustrating that the use of both
284 measurements in tandem would be more meaningful than using each as a single measure. Calculation of the
285 PTA and PFA using mathematical formulae allowed the changes in specific parameters to be directly linked
286 to observed changes in PTA and PFA. Where in the past these parameter changes were inferred,
287 mathematical description of the extensor mechanism allows for the detailed analysis of the influence
288 changing particular parameters related to design and surgical technique had on the extensor mechanism.
289 The modelling technique used is similar to those described in previous studies[26,34] . A previous paper by
290 van Duren et al.[34] showed that the use of a patellofemoral model to predict the PTA/KFA relationship
291 correlated closely with values measured in vivo.

292

293 The value of the PTA decreases with flexion from extension corresponding to rollback of the femur on the
294 tibia[18,27,28,31,32]. To investigate what effect the AP position of the femur had on the sagittal plane
295 kinematics the AP position of the femur (h) was varied between -2.5mm and 2.5mm at 0.5mm intervals either
296 side of the starting value. Both the PTA and PFA increased with anterior movement of the femur (*figure 4*).
297 This increase in PTA with anterior motion of the femur corresponds with observations reported in the
298 literature[24,26,34] and the decrease with flexion due to femoral rollback relative to the tibia. The steeper
299 gradient of the PTA curve in *figure 4* indicates that the PTA is more sensitive to anterior posterior movement
300 than the PFA. The AP position of the femur relative to the tibia is an important consideration in many total
301 knee replacement designs. In the normal knee the position of the femur is, in part, maintained by the cruciate
302 ligaments and meniscal constraints which are removed during knee replacement. Knee replacement designs
303 incorporate constraints such as conforming bearing surfaces and cam/post mechanisms to influence the AP
304 position of the femur to recreate femoral rollback. The results show that both the PTA and PFA respond to
305 the change in AP position however the PTA was more sensitive and so would be a more effective measure of
306 AP change.

307

308 Variation in the patellar width (pw) showed a similar response as was shown to variation in AP position; with
309 both the PTA and PFA increasing with an increase in patellar thickness, and the was PTA more sensitive to
310 change. Often the patella is resurfaced during total knee arthroplasty; it is important to retain the correct
311 patellar thickness which has been shown to alter both kinematics of the patellofemoral joint as well as the
312 tibiofemoral joint[36–38]. In contrast the distal proximal movement of the femur relative to the tibia (k)
313 resulted in a larger change in the PFA but with little change in the PTA (*figure 5*). DP change corresponds to
314 a change in the joint line which has a tendency to become elevated during surgery which has been shown to
315 result in both patellofemoral and tibiofemoral kinematics[39–41]. Fornalski et al.[39] performed a cadaveric
316 study looking at the effect of joint line elevation and similar to our results showed a significant increase in
317 PFA with an increase height of the joint line. The corresponding change in PTA with variation in the DP
318 position of the femur was very small which showed that it is a less effective indicator of DP change.

319

320 The patellar tendon length is often changed after surgery with studies reporting that the patellar tendon
321 shortened after TKR[4,5,42,43] and others noting lengthening after lateral UKA[44]. The effect on sagittal
322 kinematics[41] and clinical outcome[45] of patellar infra or alta after TKA has been addressed previously in
323 the literature but remains unclear. In this study the the effect of change in patellar tendon length on sagittal
324 plane kinematics was modelled by varying the patellar tendon length (ptl). Varying the ptl resulted in the PFA
325 decreasing with an increase in the patellar tendon length. The PTA also decreased with an increasing ptl but
326 the response of the PTA was very small in comparison to that of the PFA (*figures 2c & 3c*) as was the case in
327 variation of the patellar thickness. This indicated that the PTA is a bad measure of change in the patellar
328 tendon length. In contrast the PFA was shown to be an effective measure of changes to the patellar tendon
329 length.

330

331 The patellar tendon angle was shown to be a good indicator of changes in AP position of the femur but a bad
332 indicator of changes in DP femoral position and patellar tendon length. This was shown by the response
333 indicated by the gradients in *figure 4*. The PFA in contrast responded well to DP femoral position and patellar
334 tendon length. These observations are summarized as response ratios in *Table 1*. However, it should be
335 noted that apart from the parameters investigated in this study there are other influences on the PTA/KFA
336 and PFA/KFA relationships. For example, the shape of the femoral component such curvature and depth of
337 the trochlea groove will effect a change in the PTA and PFA. This means it is important to be aware of the
338 changes made to the knee joint when interpreting sagittal plane kinematic outcomes. Stagni *et. al.* [24]
339 conclude that the PTA/KFA relationship cannot demonstrate anterior posterior translation of the femur on the
340 tibia and therefore cannot disclose much about femoral rollback. We agree that the PTA/KFA relationship is
341 not a direct measure of femoral roll back but it is sensitive to AP motion of the femur relative to the tibia and
342 as such it remains eligible as a clinical indicator of AP change after knee arthroplasty. Additionally if it is used
343 in conjunction with the PFA/KFA relationship the interpretation of the sagittal plane kinematics is more
344 reliable as an overall representation of the extensor mechanism.

345

346 It is interesting to note from graphs of PTA/KFA and PFA/KFA (*figure 2 & 3*) that changes in parameters
347 appear to have a larger effect on PTA as compared to PFA. This is because the relative change over the
348 range of flexion (approximately 15° for the PTA and 50° for the PFA) rather than absolute change. It is

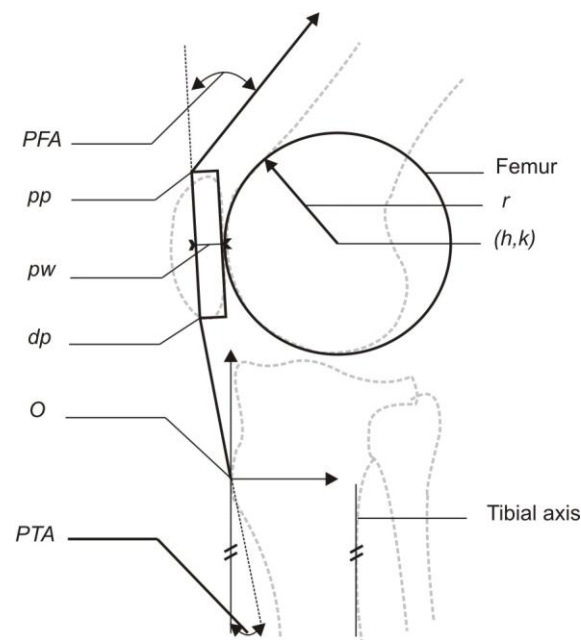
349 possible that this will make it more difficult to get clinical measures of PFA that are accurate enough to detect
350 the changes due to parameter alterations. This will make the clinical measurement of PFA more prone to
351 error.

352
353 Study limitations do exist. There are the inherent limitations as with any modelling study. In this study the
354 model was limited to the sagittal plane. Although the majority of motion in the knee occurs in the sagittal
355 plane the tibiofemoral and patellofemoral joints are three-dimensional joints. We have limited this study to
356 investigating the effect of parameters predominantly relevant in the sagittal plane but the model was unable
357 to quantify the effect of parameters outside of the sagittal plane. Additionally a number of geometric
358 assumptions were made as described in the methods. The foremost of this is the representation of the femur
359 as a circle which is simplified compared to the complex geometry of the distal femur[46]. This potentially
360 introduces errors, however these are unlikely to affect the conclusions made in this study. This would be an
361 area for improvement in future models. Although simplified the sagittal model has previously been shown to
362 correspond with *in vivo* measurements[34]. The parameter variations explored in our model were chosen for
363 the purposes of exploring the effect on the extensor mechanism measures but did not necessarily
364 correspond to clinically significant values; joint line elevation in practice can easily exceed the 2.5mm change
365 we analysed[39] and the patellar tendon length is only deemed significant with a change of greater than
366 10%[4]. Taking this into account suggests that a future study corresponding actual changes seen *in vivo* to
367 their effect in PFA and PTA would prove informative.

368 In summary the PTA is a good indicator of changes in relative tibiofemoral position and changes in patellar
369 thickness or patellofemoral over/under stuffing, and the PFA a good indicator of change in joint line and
370 changes in patellar tendon length. Although the PTA/KFA relationship is an established means of identifying
371 abnormal kinematics post knee arthroplasty we propose, based on our findings, that the use of both the
372 PTA/KFA and PFA/KFA together would give a more complete overview of the sagittal plane kinematics of the
373 knee. Consequently this would be a more accurate and informative measurement of sagittal plane kinematic
374 changes after knee arthroplasty.

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376

377 **Figures:**

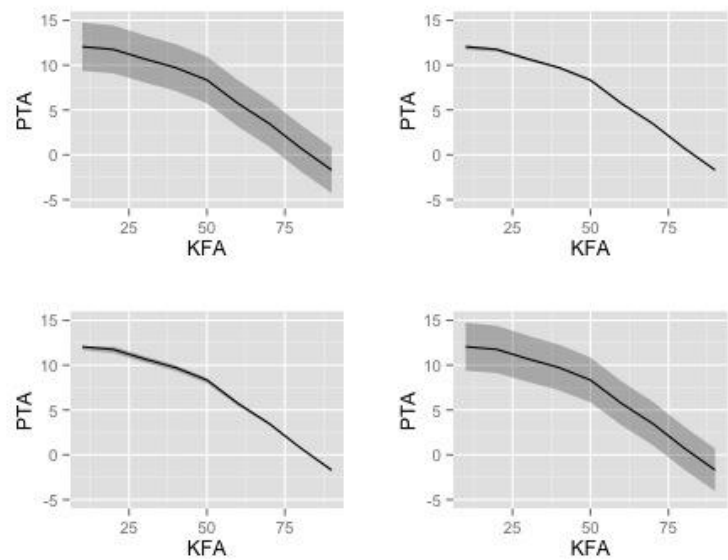


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379

380 **figure 1:** Illustration of the model setup overlaying the sagittal representation of the knee showing the
381 parameter descriptions: tibial tubercle (O), distal pole of the patella (dp), patellar thickness/width (pw),
382 proximal pole patella (pp), femur origin (h, k), radius of femur (r), patellar tendon angle (PTA), and patellar
383 flexion/femoral angle (PFA).

384



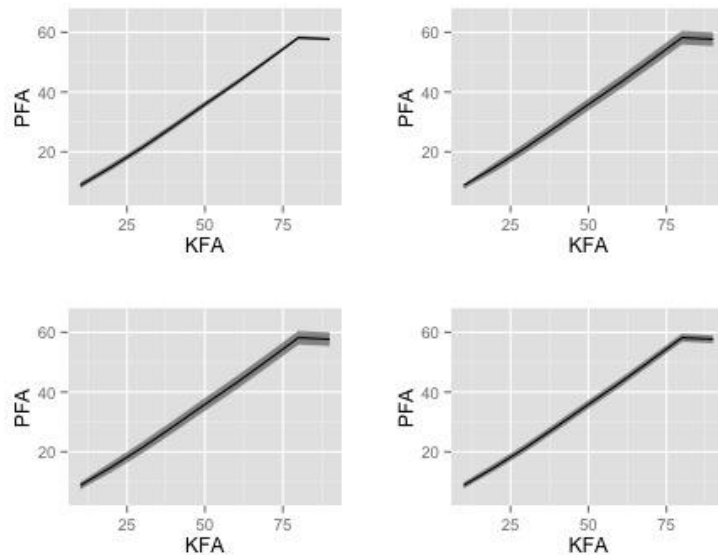
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386 **figure 2:** Chart showing the patellar tendon angle / knee flexion angle (PTA/KFA) relationship. The bold line
387 represents the original relationship and the shaded area represents the range of change in the PTA
388 corresponding to the -2.5mm to +2.5mm change in (top left) AP position (h), (top right) DP position (k),
389 (bottom right) patellar thickness (pw), (bottom left) patellar tendon length (ptl).

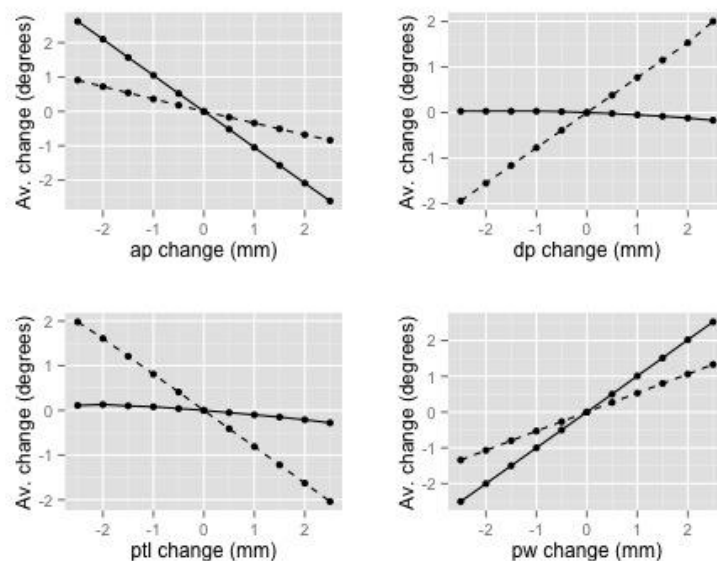
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 394 **figure 3:** Chart showing the patellar flexion angle / knee flexion angle (PFA/KFA) relationship. The bold line
 395 represents the original relationship and the shaded area represents the range of change in the PFA
 396 corresponding to the -2.5mm to +2.5mm change in (top left) AP position (h), (top right) DP position (k),
 397 (bottom right) patellar thickness (pw), (bottom left) patellar tendon length (ptl) .
 398



399 **figure 4:** Chart showing the the change in patellar tendon angle (PTA) v. parameter change (bold line) and
 400 patellar flexion angle (PFA) v. parameter change (broken line) relationships for variations corresponding to
 401 the -2.5mm to +2.5mm change in (top left) AP position (h) {please note AP change refers to the position h
 402 (see figure 1) as such negative values correspond to anterior displacement and positive values with posterior
 403 displacement of the femur relative to the tibia} ,(top right) DP position (k), (bottom right) patellar thickness
 404 (pw), (bottom left) patellar tendon length (ptl) .
 405
 406

407 **Tables:**
408

	PTA	PFA	PTA/PFA
<i>h</i>	-1.05	-0.35	3.00
<i>k</i>	-0.04	0.78	-0.05
<i>pw</i>	1	0.53	1.89
<i>ptl</i>	-0.08	-0.81	0.10

409
410

411 **Table 1:** table showing an overview of the gradients for the PTA/parameter variation & PFA/ parameter
412 variation relationships as seen on the plots in figure 4 as well as the ratios comparing the PTA to PFA
413 gradients. The ratios represent the response of the two output parameters; a large ratio representing the
414 PTA being more responsive to a change in parameter; a smaller ratio indicating that the PFA was more
415 responsive.

416
417
418

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