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The effect of tibio-femoral over- distraction in primary knee arthroplasty

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18 **Abstract**

19 **Purpose:**

20 Overstuffing the Patellofemoral joint has been associated with poor post-operative outcomes. No
21 study has assessed the effect of over-distracting the tibio-femoral joint in the vertical plane and its
22 effects on function and quality of life. The purpose of this study is to assess the effect of tibio-
23 femoral joint distraction on function and quality of life after total knee arthroplasty.

24 **Methods:**

25 Measurements of knee joint distraction was devised using long-leg alignment radiographs and
26 lateral radiographs. Seventy-three patients were prospectively recruited and their joint-distraction
27 measured post-operatively. A comparison was made between the level of joint distraction and
28 functional outcomes as measured by the International Knee Society score and its components, such
29 as pain and flexion, and the Knee injury and Osteoarthritis Outcome Score and quality-of-life as
30 measured by the Short-Form 12 score. Twelve months follow-up was achieved.

31 **Results:**

32 Knee joint over-distraction post arthroplasty correlated significantly with Knee society score
33 ($p=0.041$), flexion ($p=0.005$) and pain ($p=0.002$). Those knees that were over-distracted post-
34 operatively suffered more pain, less flexion and a lower International Knee Society score compared
35 to their counterparts. No correlation was found between over-distracting the knee joint and quality-
36 of-life.

37 **Conclusion:**

38 Over-distracting the tibio-femoral joint during arthroplasty is a significant predictor of reduction of
39 function and increase of pain in the short to medium term. When between sizes of tibial inserts, the
40 surgeon should consider using the thinner option.

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44 **Key words:** Knee, arthroplasty, arthritis, flexion, overstuffing, distraction

45 **Level of evidence:** Level II: prospective cohort study

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48 The effect of tibio-femoral over- 49 distraction in primary knee 50 arthroplasty

51 **Introduction:**

52 A successful knee replacement is defined by its ability to achieve a pain-free, functional knee post-
53 operatively. This can be measured subjectively by surveys comparing pre and post-operative pain,
54 function and patient satisfaction, and objectively by measuring attributes such as range of motion,
55 stability and alignment. Research continues into factors which may be able to either improve these
56 measures of success, or at least predict which patients are likely to do well post-operatively.

57 Over-distracting or “Over-stuffing” a joint can occur when there is a mismatch between resected
58 bone and prosthesis thickness [11]. In the literature joint-stuffing refers to the patellofemoral joint,
59 and is a measure of increased anteroposterior (AP) dimensions of the femur and/or patella
60 compared to pre-operative levels [6,24]. No consensus currently exists defining an over-stuffed joint.
61 It has been linked to a decreased range of motion, increased patellofemoral stress and altered knee
62 biomechanics. It can result in decreased function, increased pain and the risk of component wear
63 through increased compression and shear forces[4,14,16,18,19,22,25,26]. An increased AP

64 dimension can occur when a surgeon attempts to prevent notching by upsizing to a larger femoral
65 component [18], thicker components are used, anterior implantation of the femoral component
66 when posterior referencing is used[26] or when the shape of the component, for example the
67 trochlea, does not match the patients original anatomy or resected bone.

68 Recent papers has suggested that tibial resection/prosthesis mismatch could result in over-
69 distraction and hence decrease range of motion[27] and distal femoral under-resection could reduce
70 flexion[23]. No study to date has assessed joint-distraction in the vertical plane. This study aims to
71 assess the role of over-distracting the joint in the vertical plane in patients undergoing primary knee
72 arthroplasty and its effects on functional outcomes such as flexion, pain and overall function and
73 quality of life. The hypothesis is that overdistracting the joint in the vertical plane will have a greater
74 effect on function then the AP plane, as the quadriceps mechanism is stretched to a greater extent.
75 The primary outcome measured in this study is function (as measured by the International Knee
76 Society Score), with secondary outcomes encompassing components of the functional score and
77 quality of life (as measured by the Short-Form 12)

78 **Materials and Methods:**

79 A prospective trial was conducted assessing the change in vertical height of the knee joint in primary
80 knee arthroplasty. The study was approved by the hospital's Human Research and Ethics committee
81 (HREC-A 021/09, approved 02/04/2009).

82 All patients scheduled for an elective primary knee joint replacement by two participating surgeons
83 between October 2009 and September 2010 were eligible for enrolment. Patients attended a
84 routine pre-admission clinic where they were invited to participate. No patient was excluded.

85 **Radiological outcomes**

86 Vertical joint-height was calculated in using AP long-leg radiographs (LLRs). All measurements were
87 calculated using Centricity imaging tool (GE Healthcare, Buckinghamshire, UK).

88 Level of joint over-distraction was calculated by initially measuring the change in joint height from
89 the femoral and tibial side independently, then combining these two values. All measures were
90 calculated using weight-bearing LLRs, which were standardised using a custom made Perspex stand,
91 ensuring that the malleoli were 10cm apart with the tibial tubercle facing forward. This stand is
92 helpful in reducing inaccuracy caused by flexion deformity and rotation[3].

93 From the femoral side a straight line was drawn from the centre of the femoral head to the midpoint
94 of the tibial spine (figure 1, line A). A line was drawn perpendicular to this line, from the tip of the
95 adductor tubercle (figure 2, line B). The femoral measure was taken from where these lines
96 intersected to a line joining the femoral condyles (figure 2, line C).

97 From the tibial side a straight line was drawn passing between the mid-point of the tibial spine pre-
98 operatively and midpoint of the tibial plate post-operatively and the midpoint between the inner
99 edges of the malleoli (figure 1, line D). A line perpendicular to this line was drawn from the proximal
100 tip of the fibula (figure 2, line E). The tibial measure was taken from where these lines intersected to
101 a line joining the femoral condyles (figure 2, line C).

102 These values were then combined to give an overall measure of joint vertical length. The change
103 between pre- and post-operative values reflected a measure of joint-line distraction.

104 Magnification was accounted for in a number of ways (see equation below). The height of the keel of
105 the tibial tray determined the differences in magnification between patients (figure 2, line F). The
106 width of the Perspex stand's base-plate determining magnification between pre- and post-operative
107 films (figure 1, line G) and rotational profile was checked using the width of the tibia at the level of
108 the fibular head (figure 2, line E). . All radiographs were measured three times by a single
109 researcher. The correlation coefficient between groups ranged from 0.535 to 0.790 with a mean of
110 0.70. Twenty-five radiographs were subsequently measured by a senior colleague. Correlation

111 coefficient between observers averaged 0.503. The mean difference of measured over-distraction
112 between observers was of 0.7mm (SD 2.4mm).

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Vertical Height (Tibial or Femoral) = Preop height – Postop height

$$= \left(\frac{M_{Post} \cdot K_r}{K_x} \right) - \left(\frac{M_{Pre} \cdot K_r \cdot W_{post}}{K_x \cdot W_{Pre}} \right)$$

115 M_{pre}, M_{post} = Pre and post-operative joint line measures

116 K_r, K_x = Keel length; real and measured

117 W_{pre}, W_{post} = Width of Prespex stand base, pre and post.

118

119 The researcher, who performed all radiological analyses, was blinded via de-identification and
120 randomisation of radiographs and was not aware of the clinical findings of the patients or functional
121 scores until all radiographic measurements were completed.

122 To compare measured data to the literature, patello-femoral overstuffing was also measured using
123 lateral radiographs. This measure was a combined measure of the patella thickness at its greatest
124 point added to AP thickness of the distal femur at its greatest point. The change from pre-operative
125 values determined patello-femoral overstuffing.

126 **Functional outcomes**

127 Functional outcomes were measured using the International Knee Society Score (IKSS) and the Short
128 Form of the Knee injury (SF-12) and Osteoarthritis Outcome Score (KOOS-PS) surveys.

129 The IKSS [15] totals 200 points and can be divided into two components, being the Knee score
130 (maximum 100 points) and Function score (maximum 100 points). The Knee component
131 encompasses alignment, flexion and stability of the knee. The functional score results from the
132 ability of the patient to perform tasks such as walking, the ability to climb stairs and the need for
133 gait-aids. A pain score can also be derived from the IKSS, ranging from 0 points for severe pain to 50

points for no pain. A higher IKSS is indicative of better function. This is a validated scoring system for knee arthroplasty [8].

The KOOS-PS is also a measure of function. It encompasses 7 questions, analysing the patient's ability to complete everyday tasks such as getting out of bed, putting socks on and kneeling. It is specifically developed to be parsimonious and cross-culturally valid[20].

Quality of life outcomes were also measured using the SF-12 survey. The SF-12 score is a measure of quality-of-life and encompasses two components; the physical and mental component. The physical component assesses the patient's ability to complete everyday tasks essential to good quality of life, while the mental component assesses the patient's mental well-being. Higher scores indicate better quality of life[2].

Prosthesis and procedure

All included patients received a modular, cruciate retaining total condylar prosthesis (PFC DePuy, Warsaw, Indiana) with all components cemented and the patella replaced in all cases. An imageless computerised navigation system (Ci System; Depuy) was used to assist in placement of the components.

The aim in all cases was to achieve a neutral coronal alignment, that is, a 0° mechanical axis, femoral rotation aligned with the Whiteside's line and checked using the epicondylar axis. The tibia was cut with a 3° posterior slope. Soft-tissue balancing was standardised using the same sequence in all patients as previously described by Whiteside [29]. A tourniquet was used in all cases.

Continuous parametric data was analysed using one-way analysis of variance (ANOVA), while non-parametric data were tested using Mann-Whitney non-parametric rank-sum test. Linear regression modelling was used to determine correlation coefficients.

Results:

Overall 73 patients were recruited, with a mean age of 70.1 (Range 51-84). Forty-eight patients (48/73, 66%) were female. All patients had a minimum of 12 months follow-up. The antecedent diagnosis was osteoarthritis in all patients. Of the 73 patients, a measure of distraction, as described above, could not accurately be achieved in five patients using the LLR method due to an inability to define all of the anatomical points required. These patients were excluded from the final analysis, leaving 68 patients with complete.

The measure of distraction ranged from over-distraction by 6.8mm to under-distraction by 13.2mm, with a median of 0.2mm over-distraction and mean of 0.4mm of under-distraction (SD 4.1mm).

No correlation was found between tibio-femoral and patello-femoral joint distraction. Patello-femoral joint distraction was also not found to significantly correlate with function or quality of life in this cohort.

The effect of overstuffing on function and quality of life

Correlation between distraction and functional and quality of life outcomes were sought using linear regression. Results can be found in **Table 1**.

Patients were subsequently split into two groups (Table 2); those that were over-distractioned and those that were not, with a cut-off of 4mm defining a maintained coronal length. These groups were compared.

The effects of over-distraction on flexion:

A significant correlation was found between knee joint over-distraction and flexion at 12 months ($p=0.005$, figure 3) and change in flexion at 12 months from pre-operative levels ($p=0.018$). The more

the knee joint was distracted in the vertical plane, the less flexion the patient was likely to have at 12 months and the less likely they were to improve in flexion levels from pre-operative levels.

When comparing those patients who were over-distracted to those maintained, with a cut-off of 4mm, those that were over-distracted had a significantly lower flexion at 12months (95 degrees mean) compared to those that were not (108 degrees mean, $p=0.038$). The change in flexion from pre-operative levels was not significant.

The effects of over-distraction on pain:

A significant correlation was found between over-distracting the knee joint in the coronal plane and pain (Table 3, figure 4).

These results were partially reflected when splitting and analysing the cohort between those that were over-distracted and those not (Table 4).

Discussion:

The most important finding of this study was that a change in the vertical dimension of the knee joint, i.e. over-distracting the tibio-femoral joint, may have an adverse effect on post-operative pain and subsequent functional scores. This predictor of outcome has not previously been described in the literature, and its measure highlights the importance of maintenance of the joint's dimension. Over-distraction has no significant effect on functional scores as measured by the KOOS-PS or quality of life (SF-12) at 1 year.

Pierson and Ritter [21] in their large retrospective study of 830 knees analysed the role of overstuffing the patella-femoral joint on functional scores, flexion and pain. Using linear regression they found a correlation between anterior patellar displacement and range of motion and Knee Society function score. The authors concluded that even though significant correlations were found, these were inconsistent and clinically irrelevant due to their small effect sizes.

201 This study's cohort was smaller than Pierson's [21], but its results were surprisingly more significant
202 and clinically relevant. There are a number of possible explanations for this.

203 The measure of stuffiness of this study was vertical, not antero-posterior. It has been hypothesized
204 that the effects of overstuffing on flexion and pain could be due to the altered quadriceps
205 mechanism; essentially it being stretched. Using a simple diagram the quadriceps mechanism can be
206 considered as two simple right-angled triangles (figure 5). The hypotenuse of the larger triangle (Q1)
207 can be considered the functional length of the quadriceps mechanism, with the adjacent (F) being
208 the femoral length and the opposite (AP) being the AP thickness of the femur and patella, i.e. the
209 radius of the axis of rotation. The functional femoral length of the patients was measured and found
210 the mean to be 483.5mm (SD 33.1mm); the functional AP width of the patellofemoral complex in a
211 number of patients was also measured and found its width to be 55.2mm (SD 7.3mm) on average.
212 Using these values the functional length of the hypotenuse is calculated as 486.6mm. A change of
213 4mm to the AP width will result in a change of only 0.5mm to the functional quadriceps mechanism
214 (Q2). Not a large change at all. But a change of 4mm in the vertical height results in a change to the
215 quadriceps mechanism of 3.9mm (Q3), eight-fold larger than that caused by altering the AP
216 dimensions to the same degree (Q2). This would also hold true in flexion, as in flexion it is the
217 femoral length change that would be a significant determinant in quadriceps mechanism stretch.
218 This stretch could alter patellofemoral biomechanics and stress. The smaller triangle would result in
219 similar changes in soft-tissue stretch regardless of whether distraction is in the AP or vertical plane,
220 with the concerned lengths being within the same magnitude as each-other.

221 An increase in the vertical height of the knee joint may also result in physiological patella baja.
222 Patella baja has been associated with decreased flexion [9,10], pain [10], impingement [1], wear and
223 extensor lag, all culminating in an overall poorer functional outcome [9,10,1,17,28]. This theory was
224 tested by measuring the modified Insall-Salvati ratio [13] for patella baja and Blackburne-Peel [5]
225 index for pseudo-patella baja. Although not reaching significance, a trend was noted between the

pseudo-patella baja as measured by the Blackburne-Peel index and over-distraction of the tibio-femoral joint ($p= 0.060$), with increasing joint-distraction leading to increased pseudo-patella baja.

This study does suffer from limitations. The cohort was relatively small and the length of follow-up short and its result can only be indicative of short to medium-term outcomes. A notable number of patients could not be analysed due to inaccuracy of their radiographs. The accuracy of the measurements was a priority of this study and a decision was made that sacrificing numbers to maintain accuracy was essential. Any patient where adequate landmarks could not be identified was excluded. Any attempt at measuring minute details on a two-dimensional radiograph will always result in a level of error. Intra-observer correlation was satisfactory but not excellent. These radiographic findings could suffer from bias resulting from flexion contractures. However flexion contractures were measured in all patients pre- and post-operatively and found not to significantly correlate with vertical joint height.

The findings of this study can help decision making in the surgical setting. For example, when between component sizes, especially in regards to the tibial insert, using a thinner tibial insert may be beneficial. Unfortunately due to the variability of anatomical landmarks, especially between varus and valgus knees, it is difficult to ascertain intra-operative landmarks to help prevent over-distraction [7,12].

Conclusion

The change in vertical height of the knee joint length can affect the outcomes of a knee joint-replacement in the short to medium term. This factor may be particularly pertinent to pain and flexion. This is the first time this measure has been studied in the literature. The surgeon should be aware of how much bone is resected and attempt to prevent over-replacing it. Further research is still required in this field, especially with larger cohorts and an increased follow-up time.

Conflicts of interest: The authors declare that they have no conflict of interest.

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Figure Captions:

Figure 1: Long leg radiograph used to measure joint-distraction. A: Femoral mechanical axis, D: Tibial mechanical axis, G: width of Perspex box base used to determine magnification

Figure 2: Close-up of knee from long leg radiographs. A: Femoral mechanical axis, B: Line perpendicular to femoral mechanical axis, bisecting adductor tubercle, C: Line connecting distal condyles of the femur, D: Tibial mechanical axis, E: Line perpendicular to the tibial mechanical axis, bisecting the tip of the fibula, F: Length of tibial keel used to determine magnification

Figure 3: Graph of linear regression comparing over-distraction (mm) with flexion at 12 months.

Figure 4: Graph of linear regression comparing over-distraction (mm) with change in the pain component of the IKSS at 12 months from pre-operative values.

Figure 5: Diagram explaining hypotheses of why overstuffing may affect function. Q: Quadriceps mechanism, F: femur, AP: width of combined patella-femoral joint, P: patella tendon.

Table Captions:

Table 1: Linear regression comparing joint height change with functional and quality of life scores.
(* = significant, NS = not significant)

Table 2: Comparison between those overstuffed and those maintained and functional and quality of life scores (* = significant, NS = not significant)

Table 3: Linear regression comparing vertical joint height change and pain (* = significant, NS = not significant)

Table 4: Comparing those overstuffed and those not and level of pain (* = significant, NS = not significant)

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Comparison – Linear regression	Time-point	P-value
IKSS – Total score	Pre-operative	NS
	3 month	NS
	6 month	NS
	12 month	NS
	Change from pre-op values	0.048*
IKSS – Knee score	Pre-operative	0.037*
	3 month	NS
	6 month	NS
	12 month	NS
	Change from pre-op values	0.013*

IKSS –Function score	Not significant at any time point	
12 Physical score	Not significant at any time point	
SF-12 Mental score	Not significant at any time point	
Koos-PS score	Pre-operative	0.020*
	3 month	NS
	6 month	NS
	12 month	NS
	Change from pre-op values	NS

Table 1: Linear regression comparing joint height change with functional and quality of life scores. (*= significant, NS = not significant)

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		Over-distracted	Maintained	P-value
IKSS -Total	Pre-op	79	90	NS
	3 month	140	147	NS
	6m	124	160	NS
	12m	138	161	0.041*
	Change	57	67	NS
IKSS- Knee	Pre-op	47	45	NS
	3m	82	85	NS
	6m	64	85	0.021*
	12m	70	90	0.001*
	Change	21	41	0.011*
IKSS- Function	Not significant at any time point			
SF-12 Physical	Not significant at any time point			
SF-12 Mental	Not significant at any time point			
KOOS-PS	Not significant at any time point			

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Table 2: Comparison between those overstuffed and those maintained and functional and quality of life scores (*= significant, NS = not significant)

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Pain – Linear regression	p-value
Pre-operative	0.025*
3 months	NS
6 months	NS
12 months	NS
Change from pre-op values	0.008*

352 **Table 3: Linear regression comparing vertical joint height change and pain (*= significant, NS = not significant)**

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	Over- distracted	Maintained	P-value
Pre-operative	20	10	NS
3 months	45	45	NS
6 months	20	45	NS
12 months	30	40	0.009*
Change from pre- op values	10	30	0.008*

355 **Table 4: Comparing those overstuffed and those not and level of pain (*= significant, NS = not significant)**

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