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**Implantation of the Femoral Component Relative to the Tibial Component in Medial  
Unicompartmental Knee Arthroplasty: A Clinical, Radiological and Biomechanical  
Study**

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## **Abstract**

**Background:** Unicompartmental Knee Arthroplasty (UKA) is a procedure with low morbidity and fast recovery. Anatomic implants or robotic assisted UKA have been proposed to improve outcomes with precise positioning. Femoral component position (FCP) relative to the tibial insert could be a factor influencing the contact stresses. We aimed to evaluate the effect of FCP relative to the tibial insert on clinical outcomes and stress distribution after medial UKA.

**Methods:** Sixty-two medial fixed-bearing UKA were evaluated at a minimum two years follow-up using the Knee Society Score (KSS). Post-operative radiological evaluation performed on frontal X-rays classified the FCP relative to the tibial insert in: group M (medial); group C (central) and group L (lateral). A finite element model was developed to evaluate the biomechanical effects of the FCP relative to the tibial component.

**Results:** The postoperative radiological evaluation showed 9 cases in group M, 46 cases in group C and 7 cases in group L. The maximum knee flexion angle, the 2 years postoperative “symptom” and “patient satisfaction” scores of the KSS were significantly higher in Group C. Compared to central positioning, a shift along the medio-lateral axis lead to a displacement of the contact pressure center.

**Conclusion:** The FCP relative to the tibial insert may increase patient outcomes at a minimum follow-up of two years after fixed-bearing medial UKA. Accordance between FCP and contact stresses on the PE insert could be a contributing factor of long-term survival of UKA.

**Keywords:** UKA – Femoral position – Radiology – Outcome - Biomechanics

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## 32 **Introduction**

33 Unicompartamental Knee Arthroplasty (UKA) has continued to increase in popularity for the  
34 treatment of isolated compartment osteoarthritis of the knee [1, 2]. The number of UKA has  
35 increased by 30% over the last decade, showing minimum intraoperative complications, and  
36 reduced post-operative recovery times compared to Total Knee Arthroplasty (TKA) [3,4].

37 Proper selection of indications, instrumentation, and implant designs have lead to results  
38 comparable to those reported for TKA [5]. UKA allows for preservation of both cruciate  
39 ligaments, and minimal bone resection, with better preservation of kinematics and  
40 proprioceptive activities of the knee [6–7].

41 However, registry data demonstrated overall higher revision rates compared to TKA [8].  
42 Interestingly revision for unexplained pain accounted for 23% of UKA revisions, and for only  
43 9% of TKA revisions [8], illustrating a lower threshold to revise UKA. Nevertheless, the  
44 evaluation of factors related to surgical technique appears relevant in UKA such precise  
45 component positioning to reduce suboptimal outcomes [9].

46 Some studies using Finite Element (FE) analysis have been carried out on inappropriate  
47 positioning or alignment of UKA components, possibly associated to the risk of early  
48 polyethylene (PE) wear [10-18]. **The biomechanical effects of the femoral component  
49 position (FCP) relative to the tibial insert can be evaluated through the contact stresses  
50 [10], the effect of FCP on clinical outcomes after UKA can be evaluated using a  
51 reproducible radiological classification according to the FCP relative to the tibial insert  
52 [19]. However to our knowledge, no study has previously described the effects of  
53 implants positioning based on both clinical and biomechanical outcomes.**

54 The aim of the present study was to evaluate the effect of FCP relative to the tibial insert on  
55 clinical outcomes and stress distribution after medial UKA.

## 56 **Materials and Methods**

### 57 Patients and Procedure

58 A post-operative clinical and radiological evaluation of 62 medial UKA implanted in 56  
59 patients (28 males and 28 females) was conducted, including 6 bilateral cases. Inclusion  
60 criteria were age > 50 years, BMI < 40 kg/m<sup>2</sup>, and functional cruciate and collateral  
61 ligaments. Patellofemoral (PF) joint Arthritis was not a contraindication except Kellgren and  
62 Lawrence grade 3 patients on the lateral part [20].

63 All patients underwent primary fixed-bearing UKA using morphometric implants (Persona  
64 Partial Knee, Zimmer-Biomet, Warsaw, IN, USA). All UKAs were performed by a well-  
65 trained senior arthroplasty surgeon, according to a previously described technique [21].  
66 Implant sizes for femoral and tibial components were equivalent among the three groups,  
67 with no significant differences.

### 68 Radiological Analysis

69 **Radiographic measurements are presented in figure 1.** Postoperative Assessment of the  
70 FCP relative to the tibial insert was based on a previously published methodology [19] using  
71 A/P radiographs, by calculating the a/A ratio with “A” the mediolateral width of the tibial  
72 component and “a” the distance from the lowest point of the femoral component to the lateral  
73 wall of the tibial component. All cases were classified into 3 groups according to the setting  
74 position of the femoral component: group M, medial (9 cases, ratio > 0.6; group C, center (46  
75 cases, ratio between 0.4 and 0.6); and group L, lateral (7 cases, ratio < 0.4).

76 All radiological measurements technique was standardized with radiographs taken in the  
77 same position within the same radiological department, to limit the potential of non-optimal  
78 visualisation of component orientation in A/P, M/L, and rotation, and according to previously  
79 published protocols [22-25]. **Postoperative assessment of the anatomical Tibial**  
80 **Component position relative to the proximal tibia in mediolateral (ml-TCP) in the**  
81 **coronal plane** and postoperative assessment of the anatomical FCP relative to the distal  
82 femur (ml-FCP) were taken on AP radiographs in flexion. The coronal and sagittal positions  
83 of the tibial and femoral components relative to the femoral and tibial axis were also  
84 measured.

85 Postoperative Posterior Condylar Offset Ratio was calculated on lateral radiographs and  
86 postoperative overall coronal limb alignment was assessed by using standing weight-bearing  
87 AP radiographs of the lower limbs. Assessment of Tibiofemoral Subluxation (TFS) was  
88 realized pre-operatively and post-operatively [25].

## 89 Clinical Outcome

90 The maximum knee flexion angle was evaluated using a goniometer, preoperatively and at 2  
91 years postoperatively.

92 We used the 2011 evolution of the Knee Society Score (KSS), which is including patient-  
93 reported outcome measures following knee arthroplasty and more specifically symptoms and  
94 patient satisfaction [26]. We hypothesized there would be improvement in maximum knee  
95 flexion and items of the KSS score at two years.

## 96 Biomechanical Analysis

97 A non-linear FEM was developed to simulate the biomechanical effects of femoral  
98 component misalignment relative to the tibial insert, in an operated 69-years old male patient.  
99 Patient images were acquired through Computed Tomography (CT), then processed using  
100 software Mimics (2021, Materialise, Leuven, Belgium) for images segmentation and 3D  
101 volume reconstruction as shown in **figure 2**.

102 In the modelling framework, all the materials were assumed to be homogenous isotropic and  
103 linear elastic, except for the PE insert assumed to exhibit an elastoplastic behaviour [27],  
104 using previously published material properties [10-18].

## 105 Statistical Analysis

106 All measurements were performed twice at minimum 2 weeks intervals. The intraclass  
107 correlation coefficients for the intraobserver reproducibility were 0.89, 0.88, 0.90, and 0.87  
108 and the interclass correlation coefficients for the interobserver reproducibility were 0.88,  
109 0.86, 0.85, and 0.90 for FCP relative to the tibial insert, ml-TCP, ml-FCP, and TFS,  
110 respectively.

111 To validate the accuracy of the radiographical measurements of the FCP relative to the tibial  
112 insert, we performed the ANOVA test to assess the correlation between the measurement  
113 values using computed tomography (CT) and AP radiographs for 15 patients with  
114 postoperative CT data. The correlation between the measurement values using CT and those  
115 with the AP radiograph was 0.85. All values are presented as mean  $\pm$  standard deviation  
116 (SD). An analysis of variance was used to compare the preoperative patient characteristics,  
117 prosthesis positional parameters, coronal limb alignment, TFS, maximum knee flexion angle,  
118 and 2011 KSS among the 3 groups.

119 **Results**

120 Preoperative clinical and radiological data evaluations of the patients among the 3 groups are  
121 shown in Table 1. No statistically significant differences were found among the three groups  
122 for: age, sex, BMI, preoperative coronal alignment, diagnostic with mainly osteoarthritis and  
123 knee flexion angle. The two preoperative sub-scales of the 2011 KSS evaluated, as  
124 “symptoms” and “patient satisfaction”, showed no significant differences among the three  
125 groups.

126 Radiological Results

127 **Mean ml-TCP was 0.69 (range, 0.51-0.72), with no significant differences among the**  
128 **three groups** and no significant correlation with FCP relative to the tibial insert.

129 Mean ml-FCP was 0.49 (range, 0.39-0.56), with a mean ml-FCP lower in group M (0.45 mm  
130 [range, 0.39-0.49 mm]) than in group C (0.44 mm [range, 0.42-0.52 mm]) and with group C  
131 showing a lower ml-FCP than group L (0.48 mm [0.41-0.52 mm]). A significant negative  
132 correlation with FCP relative to the tibial insert ( $r = 0.55$ ,  $P < .05$ ) was observed.

133 Tibial component varus/valgus alignment, posterior slope, femoral component varus/valgus  
134 alignment and flexion/extension values did not show any significant differences among the  
135 three groups (Table 2).

136 The postoperative posterior condylar offset ratio was respectively  $0.46 \pm 0.04$  in group L,  
137  $0.45 \pm 0.03$  in group C, and  $0.47 \pm 0.02$  in group M, with no significant differences.

138 The postoperative coronal limb alignment was respectively  $2.5^\circ \pm 2.2^\circ$  in group M,  $3.8^\circ \pm$   
139  $2.5^\circ$  in group C, and  $2.7.0^\circ \pm 2.1^\circ$  in group L, with no significant differences.

140 Mean TFS was corrected from 5.3 mm (range, 3.8-10.5 mm) preoperatively to 4.1 mm  
141 (range, 2.4-5.6 mm) post operatively, which is significant ( $p < .05$ ). There were no  
142 significant differences for preoperative TFS among the three groups, and no significant  
143 correlation between preoperative TFS and FCP relative to the tibial insert was found. The  
144 postoperative TFS was higher in group M (4.71 mm [range, 1.08-6.78 mm]) than in groups C  
145 (3.1 mm [range, 0.32-2.4 mm]) and L (1.3 mm [range, 0.69-1.42 mm]). A significant positive  
146 correlation with FCP relative to the tibial insert ( $P < .02$ ) was noted.

147 Grade of osteoarthritis in both tibiofemoral lateral and PF compartments showed no  
148 significant differences in distribution among the three groups.

149 Clinical Outcomes

150 Group C exhibited higher maximum knee flexion angle as well as higher 2-years  
151 postoperative improvement at 2 years, compared to group M and L. **Mean maximum knee**  
152 **flexion for group M, C and L were measured preoperatively at an angle of 103°, 110°,**  
153 **105.7° respectively, and postoperatively at an angle of 110°, 117.1°, 108.6° respectively.**  
154 **Significant differences were found comparing post-operative maximum knee flexion**  
155 **angle in group C with group M and L (p = 0.0005 and 0.0002 respectively).**

156 **The 2 years postoperative “symptom” and “patient satisfaction” scores of the KSS were**  
157 **higher in Group C, compared to group M and L, with respective values of 22 points**  
158 **compared to 19 and 17, and 30 points compared to 25 and 24.**

159 Neither failure nor revision was recorded during the two years postoperative period.

160 Biomechanical Results

161 The contact stress area was translated in respect of the FCP with minimal pressure value  
162 obtained in the central positioning (group C) and upward trend when moving away from the  
163 central alignment (**Figure 3**).

164 The pressure center of the contact area has been tracked for the 3 simulations. A calculation  
165 of a similar ratio  $a'/A$  is given in table 3 where  $a'$  is the location of the pressure center in the  
166 medio-lateral axis, and  $A$ , the mediolateral width of the tibia. The ratio was in very good  
167 accordance with the postoperative assessment method used on the radiological materials.

168

169 **Discussion**

170 This study showed that central implantation of the femoral component relative to the tibial  
171 insert after UKA influence positively both clinical outcome and contact stress distribution.  
172 The group of patients with central implantation showed higher knee flexion angle, and better  
173 results for patient satisfaction and patient symptoms at 2 years after fixed-bearing medial  
174 UKA. The FEM model showed that central positioning of the femoral component leads to a  
175 minimal overload on the PE insert.

176 Our study evaluated also the role of tibiofemoral subluxation (TFS) and position of the  
177 components in mediolateral planes. Regarding TFS our findings were consistent with



178 previous reports [17, 28], showing for the present study a significant difference in correction  
179 from 5.3 mm preoperatively to 4.1 mm post operatively. We also found larger postoperative  
180 TFS for group M patients (with medial implantation of the femoral component) compared to  
181 the patients in groups C and L. The logical consequence of an increased TFS is the higher  
182 risk of edge loading leading to early polyethylene wear and the potential of impingement with  
183 the intercondylar notch or the tibial spines [29]. In our study no direct relationship between  
184 TFS and clinical outcomes was found, perhaps related to the absence of soft-tissue release in  
185 performing medial UKA. **Regarding mediolateral positioning of components there was no**  
186 **significant correlation between ml-TCP and FCP relative to the tibial insert,**  
187 **strengthening the conclusion that FCP relative to the distal femur (ml-FCP) is the most**  
188 **influencing factor of FCP relative to the tibia,** as found in the study by Kamenaga et al.  
189 [19].

190 A femoral component implanted in an excessive lateral position has been shown to play a  
191 role in erratic bearing movement or tibial impingement following mobile bearing UKA [30].  
192 This is in accordance with the results of our study, using fixed bearing UKA, where patients  
193 with lateral placement of femoral component in relation to tibial insert (group L) had both  
194 lower post operative maximum knee flexion angle and improvement compared with the  
195 other two groups (group C and group M).

196 The biomechanical study has shown that the contact stress distribution in the PE insert is  
197 governed by the FCP relative to the tibial component. As previously described [10], medio-  
198 lateral translation of the distal femoral condyle center induces an equivalent translation of the  
199 pressure center (table 3). Those results lead to the conclusion that the postoperative  
200 assessment method relying on the a/A ratio calculation [19] is a relevant tool that can predict  
201 the stress distribution in the insert. The FEM model showed that neutral positioning (group  
202 C) leads to a minimal overload on the PE insert. This result can be linked to the 2 years  
203 postoperative KSS, significantly higher in Group C, suggesting that the ratio a/A could be a  
204 contributing factor of UKA long-term survival.

205 The results of the present study suggest that at the time of femoral implantation in fixed  
206 bearing medial UKA following the distal femoral cut, the optimal target for the surgeon  
207 should be a central implantation of the femoral component for expecting the best clinical and  
208 biomechanical outcome. The 74% of knees implanted with FCP found in central position

209 compares favourably with the results of Kamanega et al.[19], possibly related to the use of  
210 morphometric implants in the present study.

211 This study presents several limitations inherent to its retrospective design, and by using a  
212 unique implant design, aiming to optimize bone-implant fit on the femoral and tibial side  
213 [31]. **Groups M and L present a restricted number of patients due to the intuitively**  
214 **accepted goal of central implantation necessity. In this study we investigated the results**  
215 **at two years post operatively presenting no failure nor revision at last follow-up, and**  
216 **focusing on clinical outcomes. Studies with longer follow-up are necessary to establish**  
217 **the association between implant positioning and failure or revision, with survival**  
218 **analysis.** However this represent another contribution of the predominant role of FCP on  
219 clinical outcomes and patient satisfaction, in addition of what has been reported for mobile  
220 bearing and fixed bearing UKA using symmetrical implants, as demonstrated by the absence  
221 of significant differences with other prosthesis positional parameters found in our study.  
222 Regarding the biomechanical evaluation, the bone volume was assumed to be cortical, and  
223 ligaments were omitted from the FEM models. Relevance of including the ligaments in a  
224 numerical model to have physiological load distribution between the lateral and medial  
225 compartment has been shown [13], and can partly explain why the contact stresses may be  
226 overestimated here. Despite all the limitations stated, this is the first study to investigate the  
227 clinical and biomechanical effects of FCP in relation with the tibial insert in fixed bearing  
228 medial UKA using morphometric implants.

## 229 **Conclusion**

230 This study will give better view regarding the importance and adequacy in positioning of the  
231 femoral component in central position relative to tibial insert for improving outcomes in  
232 terms of pain, patient's satisfaction and maximum knee flexion angle, 2 years after fixed-  
233 bearing medial UKA. The biomechanical study has shown a strong influence of femoral  
234 implant positioning onto the stress distribution location of the insert, highlighting the  
235 importance of a central positioning of the femoral component relative to the tibial implant in  
236 the stress distribution through the UKA.

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## CAPTIONS

### Table 1. Preoperative Demographic Data

Group M : knees for which the  $a/A$  ratio was more than 0.6; Group C : cases in which the values were within the range from 0.4 to 0.6; Group L : cases in which the values were less than 0.4.

NS, not significant; OA, osteoarthritis; ON, osteonecrosis.

### Table 2. Comparison of Prosthesis Component Positional Parameters

Group M, patients whose femoral component position relative to the tibial insert was more than 0.6; group C, cases in which the values were within the range from 0.4 to 0.6; group L, cases in which the values were less than 0.4.

NS, not significant

### Table 3. Parameters used for the materials laws.

$a'$ : location of the pressure center in the medio-lateral axis

A: mediolateral width of the tibia.

The new ratio is in very good accordance with the postoperative assessment method ( $a/A$  ratio) used for the radiological analysis.

### Figure 1.

Mediolateral femoral component position relative to the tibial insert was assessed as  $a/A$  ratio (A).

Tibial component position relative to the proximal tibia (mediolateral tibial component position [ml-TCP]) was assessed as  $b/B$  ratio (B).

Femoral component position relative to the distal femur (mediolateral femoral component position [ml-FCP]) was assessed as  $c/C$  ratio (C).

### Figure 2.

PE insert geometry was built from an extrusion of the tibial tray.

(a) Native conditions: medial positioning of the femoral component relative to tibial component ( $a/A = 0.71$ , group M). The other two conditions were obtained by doing a virtual surgery, shifting the UKA prosthesis to neutral alignment: ratio  $a/A = 0.54$  (group C) and to lateral alignment: ratio  $a/A = 0.37$  (group L). Bone models were trimmed according to the surgical techniques.

(b) Patient CT-image Computed-assisted reconstruction

(c) Mesh model from the FEM. The 3 models were meshed with tetrahedral elements.

Total number of elements was 578 739.

Quasi-static mechanical load, namely a vertical compression force, was applied on the proximal transversal section of the femur (1950 N). This value corresponds to 2.5 times the body weight, equivalent to the maximal axial force during gait. The femoral component and the tibial tray were fully bonded to the bones (simulating bone cement usage). The PE insert was in contact with the metallic femoral and tibial components with a coefficient of friction of 0.04.

**Figure 3: Distribution of the contact pressure stress onto the PE insert.**

Contact stress area was translated according to the femoral component position. The minimal pressure value was obtained in the neutral positioning (group C) with an upward trend when moving away from the neutral alignment.



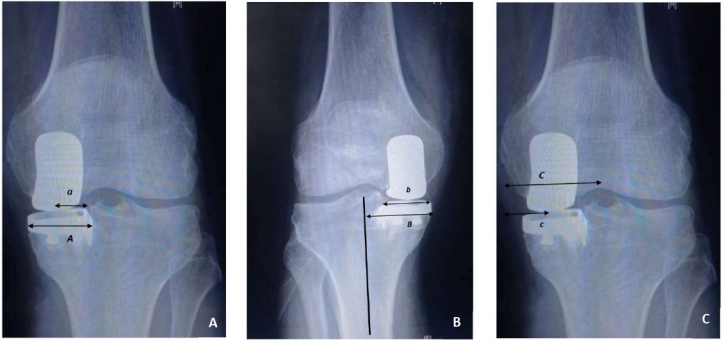
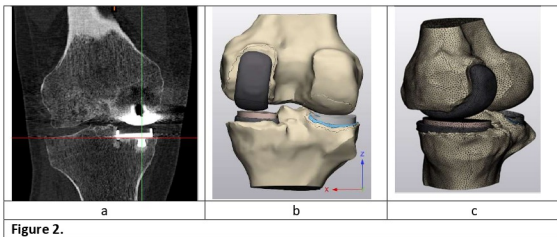


Figure 1.



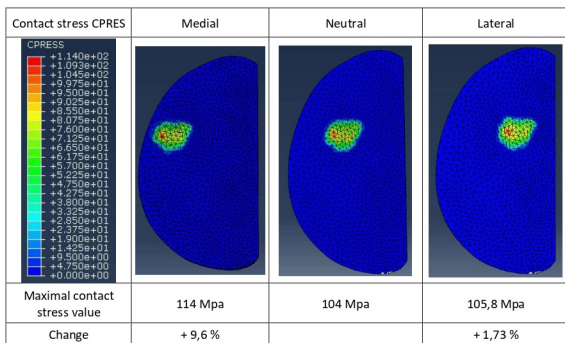


Figure 3.

| <b>Table 1.</b>                      |                  |                  |                  |         |
|--------------------------------------|------------------|------------------|------------------|---------|
| Characteristics                      | Group M          | Group C          | Group L          | P Value |
| Number of cases (%)                  | 9 (15)           | 46 (74)          | 7 (11)           |         |
| Sex, male/female                     | 6/12             | 12/24            | 2/5              | NS      |
| Diagnosis, OA/ON                     | 16/2             | 43/3             | 5/2              | NS      |
| Age (y)                              | 70.1 (65-83)     | 71.2 (50-88)     | 73.2 (61-79)     | NS      |
| Body mass index (kg/m <sup>2</sup> ) | 23.5 (20.2-27.3) | 22.9 (18.1-37.6) | 24.1 (19.8-32.1) | NS      |
| Coronal alignment in varus (°)       | 5.1 (3.2-12.2)   | 5.0 (0.5-11.3)   | 5.4 (2.8-9.7)    | NS      |
| Maximum knee flexion (°)             | 103 (95-110)     | 110 (80-120)     | 105 (90-110)     | NS      |

| <b>Table 2.</b>                         |           |           |           |         |
|---|-----------|-----------|-----------|---------|
| Parameter                               | Group M   | Group C   | Group L   | P Value |
| Tibial component varus/valgus (°)       | 2.3 ± 2.6 | 2.3 ± 3.4 | 2.0 ± 3.5 | NS      |
| Tibial component posterior slope (°)    | 7.0 ± 2.6 | 6.7 ± 2.2 | 7.4 ± 2.8 | NS      |
| Femoral component varus/valgus (°)      | 3.6 ± 2.8 | 3.2 ± 2.0 | 3.1 ± 2.4 | NS      |
| Femoral component flexion/extension (°) | 7.7 ± 4.4 | 6.8 ± 3.8 | 7.4 ± 3.7 | NS      |

|                       | Parameter | Medial | Neutral | Lateral |
|-----------------------|-----------|--------|---------|---------|
| Pressure Center Shift | $a'/A$    | 0.72   | 0.55    | 0.38    |
| Positionning          | $a/A$     | 0.71   | 0.54    | 0.37    |

**Table 3.**