



**HAL**  
open science

## Medial closing-wedge distal femoral varus osteotomy: Symptoms and functional impact in cases of associated patellofemoral osteoarthritis. A two-year follow-up prospective pilot study

T. Barnavon, G.A. Odri, T. Vendevre, O. Labrada-Blanco, M. Bordes, G.  
Renard, J.L. Rouvillain, M. Severyns

### ► To cite this version:

T. Barnavon, G.A. Odri, T. Vendevre, O. Labrada-Blanco, M. Bordes, et al.. Medial closing-wedge distal femoral varus osteotomy: Symptoms and functional impact in cases of associated patellofemoral osteoarthritis. A two-year follow-up prospective pilot study. *The Knee*, 2020, 27, pp.615 - 623. 10.1016/j.knee.2020.02.001 . hal-03490862

**HAL Id: hal-03490862**

**<https://hal.science/hal-03490862>**

Submitted on 22 Aug 2022

**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

Original Article

**MEDIAL CLOSING-WEDGE DISTAL FEMORAL VARUS OSTEOTOMY:  
SYMPTOMS AND FUNCTIONAL IMPACT IN CASE OF ASSOCIATED  
PATELLOFEMORAL OSTEOARTHRITIS. A 2 YEARS FOLLOW-UP  
PROSPECTIVE PILOT STUDY.**

**Barnavon T<sup>1</sup>, Odri GA<sup>2</sup>, Vendevre T<sup>3</sup>, Labrada-Blanco O<sup>1</sup>, Bordes M<sup>1</sup>, Renard G<sup>1</sup>, Rouvillain JL<sup>1</sup>, Severyns M<sup>1</sup>**

<sup>1</sup> *CHU Martinique (University Hospital of Martinique), Orthopaedic and Traumatologic Department, F-97200 Fort-de-France, Martinique, FRANCE*

<sup>2</sup> *CHU Lariboisière, Orthopaedic and Traumatologic Department, F-75010 Paris, FRANCE*

<sup>3</sup> *CHU Poitiers, Orthopaedic and Traumatologic Department, F-86021 Poitiers, FRANCE*

**Corresponding Author:** Mathieu SEVERYNS

*CHU Martinique, Orthopaedic and Traumatologic Department, Pierre Zobda-Quitman Hospital, CS 90632, F- 97261, Fort-de-France, Martinique, France*

[mathieu.severyns@hotmail.fr](mailto:mathieu.severyns@hotmail.fr)

Phone Number: +596 596 552221

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21

**MEDIAL CLOSING-WEDGE DISTAL FEMORAL VARUS  
OSTEOTOMY: SYMPTOMS AND FUNCTIONAL IMPACT IN  
CASES OF ASSOCIATED PATELLOFEMORAL OSTEOARTHRITIS.  
A 2 YEARS FOLLOW-UP PROSPECTIVE PILOT STUDY.**

22

23 **Abstract**

24 *Purpose.* To date, indications for distal femoral varus osteotomy (FVO) in cases of associated  
25 patellofemoral osteoarthritis (PFO) have yet to be clarified. The purpose of this prospective  
26 study is to assess the short-term symptoms, functional and radiological impact of a medial  
27 closing-wedge femoral varus osteotomy on the patellofemoral joint in patients with valgus  
28 deformities who are afflicted with lateral tibiofemoral osteoarthritis (LTFO) associated with  
29 PFO.

30 *Methods.* 14 patients (15 knees) received a medial closing-wedge femoral varus osteotomy.  
31 The functional impact of an FVO on the patellofemoral joint was assessed based on the  
32 KOOS-PF (Knee Injury and Osteoarthritis Outcome Score - Patellofemoral Subscale), the  
33 Kujala score and the patellofemoral symptoms. Realignment of the patella was measured by  
34 the Merchant's patellofemoral congruence angle. The pre- and post-operative symptoms  
35 and functional scores were compiled prospectively and compared two years after the  
36 surgery.

37 *Results.* The Kujala patellofemoral functional scores and the KOOS-PF showed considerable  
38 improvement with a differential of +37.5 points  $\pm$  20.4 and + 42.7 points  $\pm$  19.3 ( $p < 0.01$ )  
39 respectively. The average Merchant's congruence angle went from 8.8° laterally to 3.6°  
40 medially, resulting in medialization of the patella, with a significant difference ( $p < 0.01$ ).  
41 Based on the specific clinical analysis of the patellar joint, preoperative J-sign was identified  
42 in 26.7% of patients ( $n=4$ ) and was not found during postoperative examination ( $p=0.1$ ).  
43 Preoperative apprehension test was identified in 33.3% of patients ( $n=5$ ) against 13.3% ( $n=2$ )

44 after surgery ( $p=0.39$ ). Preoperative pain extension test was identified in 40% of patients  
45 ( $n=6$ ) against 20% during postoperative clinical analysis ( $p=0.43$ ).

46

47 *Discussion.* Although the threshold of significance for patellofemoral symptoms was not  
48 reached, the medial closing-wedge femoral varus osteotomy induces a significant  
49 medialization of the patella (Merchant's congruence angle) and improves short-term  
50 functional results even with co-existing patellofemoral osteoarthritis. Due to the lack of  
51 specificity of the patellofemoral scores, patellofemoral osteoarthritis improvement is  
52 difficult to determine on it's own, but does not represent a contraindication to FVO.

53

54 **Keywords.** Distal femoral osteotomy; Patellofemoral osteoarthritis; Kujala score; KOOS-PF  
55 score

56 **Level of evidence:** III. Prospective clinical study

57

58

59

60

61

62

63 **1. Introduction**

64

65 A distal femoral varus osteotomy (FVO) is an interesting surgical alternative judging by the  
66 improved functional scores with satisfactory average survival rates 10 years after surgery  
67 (64% to 89.9%) and 15 years after surgery (45% to 78.9%) in cases of valgus deformities in

68 people afflicted with LTFO[1]. Tibiofemoral osteoarthritis is associated with an increased  
69 incidence of patellofemoral osteoarthritis (57%) in cases of osteoarthritis-related gonalgia  
70 [2]. Patellofemoral osteoarthritis (PFO) and LTFO each have an important role to play in  
71 cases of valgus deformities in people afflicted with gonalgia. To date, indications for FVO in  
72 cases of associated PFO have yet to be clarified [1,3]. While some studies are quick to  
73 exclude patients afflicted with associated PFO [4,5], others have included them, regardless  
74 of the stage of osteoarthritis [6–9]. According to the literature, only two retrospective  
75 studies based on low-level evidence address the link between corrective procedures on the  
76 distal femur axis and their impact on the patellofemoral joint [6,9]. The main purpose of this  
77 prospective study is to assess the short term clinical, functional and radiological impact of a  
78 medial closing-wedge femoral varus osteotomy on the patellofemoral joint. We also wanted  
79 to look for clinical and radiological factors influencing this functional outcome. Our working  
80 hypothesis is that a medial closing-wedge femoral varus osteotomy improves short-term  
81 clinical and functional results even with co-existing patellofemoral osteoarthritis in patients  
82 with valgus deformities.

83

## 84 **2. Materials and methods**

85

86 It's a single center prospective study conducted at the Centre Hospitalier Universitaire de  
87 Martinique [Martinique University Hospital Center] between the 1<sup>st</sup> of November 2016 and  
88 the 1<sup>st</sup> of November 2018, and an ethical approval has been given by our Institutional  
89 Review Board (N°IRB: 2019/20).

### 90 **2.1 Inclusion an exclusion criteria.**

91 The enrollment criteria were as follows: 65 years of age or under, slight to severe  
92 symptomatic LTFO (stage I to III Ahlbäck) [10] accompanied by valgus deformities ( $>5^\circ$  of  
93 valgus deformity), associated with slight to severe symptomatic PFO (stage I to III Iwano).  
94 The following patients were excluded: those with Ahlbäck stage I upper medial tibiofemoral  
95 osteoarthritis, inflammatory arthritis of the knee and/or an MRI-documented injury to the  
96 cruciate ligaments (Table 1). The preoperative data concerning BMI, trochlear dysplasia  
97 (Dejour classification [11]), congruence angle of Merchant, patellar dysplasia (Wiberg  
98 classification [12]), Caton and Deschamps index [13], patellofemoral symptoms are  
99 summarized in Table 2.

## 100 **2.2 Surgical technique**

101 Patients were operated on by two separate senior surgeons who used the same surgical and  
102 pre-operative planning technique as that initially described by Wylie et al [5]. During pre-  
103 operative planification (Figure 1), the postoperative Hip-Knee-Angle Angle (HKA) [14] target  
104 was  $0^\circ$  [15]. Having the patient lay flat on his/her back with distal support under the foot,  
105 the knee bent at  $90^\circ$  and the lower limb laterally rotated provided satisfactory exposure of  
106 the anteromedial distal side of the femur. A 10-cm incision centered on the femoral  
107 metaphysis was performed. The vastus medialis was reflected. Two Hohmann spacers were  
108 put into place after subperiosteal detachment of the anterior and posterior sides of the  
109 femoral metaphysis. In order to provide rotational control if the hinge of the femur ruptures,  
110 the femoral cortex was marked in the shaft axis straddling the future wedge in the  
111 osteotomy. The width of the wedge to be resected was calculated during the planning phase  
112 of the operation (Figure 1). The proximal and distal bone cuts were performed using a  
113 pendulum saw by following the guide pins for the distal cut, and using a cutting guide for the

114 proximal osteotomy line (Figure 2). The closing-wedge osteotomy was performed with great  
115 care so as to avoid a rupture of the lateral hinge. Then, osteosynthesis occurred via an OTIS-  
116 F® locked plate (SBM™, Lourdes, France) (Figure 3). No immobilization was required post-  
117 operatively. Resumption of full support was authorized 4 weeks after surgery.

### 118 **2.3 Study protocol.**

119 Pre and post-operative patellofemoral symptoms have been collected and compared: J-sign,  
120 apprehension and pain extension tests. The functional impact of an FVO on the medial  
121 patellofemoral joint closure, the main assessment criterion, was assessed based on the  
122 KOOS-PF [16] and the Kujala score [17]. The KOOS score [18] was helpful in completing our  
123 functional analysis. Realignment of the patella was measured by the Merchant's angle of  
124 congruence [19] in relation to a patellofemoral joint flexion of 30° (Figure 4). A pre- and  
125 post-operative pangenogram was helpful in assessing the HKA angle, in addition to  
126 identifying discrepancies in the length of the lower limbs (Figure 5). The post-operative  
127 target HKA angle was 0°. For each patient, patellofemoral symptoms and functional scores  
128 were compiled pre-operatively, then two years after surgery.

### 129 **2.4 Statistical analysis.**

130 Clinical parameters were collected pre-operatively and post-operatively during the follow-up  
131 examination at 2 years. All data was analyzed using JMP® 11.0.0 (SAS institute Inc.).  
132 Quantitative variables were checked for normal distribution by the Shapiro-Wilk test. Pre-  
133 operative and post-operative data were compared by bilateral Student's paired t-tests.  
134 Correlations between functional outcome gains and radiological angle changes were  
135 performed using Pearson's correlation coefficients. Statistical significance was considered  
136 when  $p < 0.05$ .

137

138 **3. Results**

139

140 A total of 14 patients were included in the study, or 15 knees receiving a medial closing-  
141 wedge femoral varus osteotomy. Out of these 14 patients, 13 were women. The average  
142 enrolment age was  $51.4 \pm 8.4$  years [min 25; max 61]. The average BMI was  $31.7 \pm 5.8$ . Based  
143 on the Ahlbäck classification, 33% of LTFOs were stage I (n=5) compared to 60% in stage II  
144 (n=9) and 7% in stage III (n=1). Based on the Iwano classification, 73% of PFOs were stage I  
145 (n=11) compared to 20% in stage II (n=3) and 7% in stage III (n=1). Trochlear dysplasia was  
146 identified pre-operatively in 33.3% of patients, based on the Dejour classification (n=6) with  
147 one case in stage 1A compared to five cases in stage 1B. According to Wiberg, 13 patellae  
148 (86.7%) were considered to be dysplastic (stage II or III). 29% of the patients operated on  
149 had a history of partial lateral meniscectomy.

150 Based on the specific clinical analysis of the patellar joint, preoperative J-sign was identified  
151 in 26.7% of patients (n=4) and was not found during postoperative examination (p=0.1).  
152 Preoperative apprehension test was identified in 33.3% of patients (n=5) against 13.3% (n=2)  
153 after surgery (p=0.39). Preoperative pain extension test was identified in 40% of patients  
154 (n=6) against 20% (n=3) during postoperative clinical analysis (p=0.43).

155 All of the pre- and post-operative variables as well as the how they compare with each other  
156 are listed in Table 3.

157 Changes in patellofemoral functional scores were  $37.6 \pm 19.7$  for the Kujala score and  $42.4 \pm$   
158  $19,3$  for the KOOS-PF score respectively. The change in KOOS score was  $47.7 \pm 19.7$ . Thus, a  
159 significant difference was observed in all of the functional scores (p<0.01).

160 The change in the HKA angle between the pre- and post-operative pangonogram was  $-11.1^{\circ}$   
161  $\pm 3.9^{\circ}$ , and  $8.5^{\circ} \pm 1^{\circ}$  for the HKS angle with a significant difference for each of them ( $p < 0.01$ ).  
162 The change in the medial distal femoral angle was  $-10.2^{\circ} \pm 3.1^{\circ}$  ( $p < 0.01$ ). The change in the  
163 Q-angle was  $-2.6^{\circ} \pm 0.8^{\circ}$  with a significant difference ( $p < 0.01$ ).  
164 A significant difference was also observed in Merchant's congruence angle ( $-8.2^{\circ} \pm 23.6^{\circ}$ ,  
165  $p < 0.01$ ), and in the length of the limbs between the pre- and post-operative length with a  
166 change of  $-1.02 \text{ cm} \pm 0.69 \text{ cm}$ . No significant difference was observed in the change in  
167 patellar height based on the Caton and Deschamps index ( $0.015 \text{ mm} \pm 0.02$ ,  $p = 0.36$ ).  
168 The change in Kujala score is correlated with the pre-operative Merchant angle ( $p = 0.0023$ ,  
169  $r^2 = 0.53$ ). The greater the patellar lateralization pre-operatively with a significant Merchant  
170 angle, the greater the increase in the Kujala score. The change in Kujala score was inversely  
171 correlated with the HKA angle ( $p = 0.02$ ,  $r^2 = 0.35$ ), as well as the change in Merchant angle  
172 pre-operatively compared to post-operatively ( $p = 0.009$ ,  $r^2 = 0.42$ ).  
173 The change in KOOS-PF score was correlated with the pre-operative Merchant angle  
174 ( $p = 0.026$ ,  $r^2 = 0.31$ ). It was inversely correlated with the post-operative HKA angle ( $p = 0.005$ ,  
175  $r^2 = 0.47$ ), and the change in pre- and post-operative HKA angle ( $p = 0.005$ ,  $r^2 = 0.47$ ).  
176 The change in KOOS score is correlated with the pre-operative Merchant angle ( $p = 0.03$ ,  
177  $r^2 = 0.27$ ). It was inversely correlated with the post-operative distal femoral angle ( $p = 0.04$ ,  
178  $r^2 = 0.28$ ), and the change in distal femoral angle ( $p = 0.02$ ,  $r^2 = 0.34$ ).  
179 Correlation with a trochlear or a patellar dysplasia have not been measured because of small  
180 size of subgroups.

181

#### 182 **4. Discussion**

183

184 As part of this prospective series, after a medial closing-wedge femoral varus osteotomy, the  
185 Kujala patellofemoral functional scores and the KOOS-PF showed considerable improvement  
186 with a differential of +37.5 points  $\pm$  20.4 and + 42.7 points  $\pm$  19.3 ( $p < 0.01$ ) respectively after  
187 two years of radio-clinical follow-up. The medial closing-wedge femoral varus osteotomy  
188 improves patellofemoral functional scores in patients with valgus deformities who are  
189 afflicted with LTFO associated with PFO. This score validates the starting assumption.  
190 According to the literature, only two retrospective studies based on low-level evidence deals  
191 with how PFO affects the functional result of the FVO. However, no specific patellofemoral  
192 joint functional score was measured in either of these studies. As an example, Wang et al [6]  
193 included 30 knees, of which 8 presented with severe PFO. Their functional results were  
194 assessed based on the HSS score and showed an improvement of 46 points ( $p < 0.001$ ).  
195 Zarrouk et al [9] included 20 patients, of which 9 were afflicted with severe PFO and  
196 reported on average a 25-point improvement in IKS score ( $p < 0.001$ ). Our study included 15  
197 knees, all of whom suffer from PFO, and showed a significant improvement in overall KOOS  
198 score of  $47.5 \pm 19.7$  ( $p < 0.0001$ ). These overall functional score results (KOOS) are close to  
199 those observed in the literature. In fact, Jacobi et al [20] showed an average pre-operative  
200 KOOS score of  $31 \pm 17$  compared to  $69 \pm 22$  post-operatively; in Forkel's study [1,21], this  
201 very score rose from 55 pre-operatively to 88.8/100 post-operatively. Overall, the results of  
202 the various scores reported in the literature have seen an improvement of 20 to 35  
203 points/100, showing a good functional increase in the final follow-up [22]. In all of these  
204 studies, the effect of PFO on the functional result was not a main assessment criterion.  
205 Modern knee outcome scores used to evaluate knee function do not monitor PF

206 degeneration and related symptoms in the context of knee osteoarthritis according to the  
207 Iwano classification [23]. For this reason, in our study, the KOOS-PF score was used as a main  
208 assessment criterion. It enabled us to assess changes in PFO after a medial closing-wedge  
209 femoral varus osteotomy. This score was used as a main assessment criterion because it is  
210 the first score published in the literature to determine the personal recovery outcome  
211 measure (PROM) [16]. The KUJALA score provided a parallel measurement of the KOOS-PF  
212 because it is the most commonly-used anterior knee pain score in the literature.  
213 Furthermore, this score proved to be reliable and valid [24], but has a low specificity in case  
214 of global knee osteoarthritis [23].

215 Improved functional scores may be attributed to the pathophysiology of the patellofemoral  
216 syndrome caused by the improper progression of the patella during knee mobilization,  
217 resulting in excessive compression on the lateral facet of the patella [25,26], which, over  
218 time, may lead to the onset or exacerbation of PFO. In this study, by correcting the  
219 mechanical axis of the limb, the medial closing-wedge femoral varus osteotomy tends to  
220 reduce significantly the Q angle ( $p < 0.01$ ) and the medial distal femoral angle ( $p < 0.01$ ). The  
221 biomechanics of the knee suggest that a smaller Q angle associated with a smaller medial  
222 distal femoral angle helped to improve the patellofemoral tracking and patellofemoral  
223 congruence. To provide the proof, in our study, patellofemoral congruence was analyzed by  
224 measuring Merchant's angle of congruence. In a case-control study, Inoue and al [27]  
225 measured an average congruence Marchant angle of  $5^\circ$  laterally in patients with subluxation  
226 of the patella, and  $10^\circ$  medially in the control subjects. For J-W Wang et al [6], the  
227 osteotomy also resulted in an improved Merchant congruence angle in 4 of the 6 patients  
228 who initially presented with patellofemoral subluxation. For Zarrouk [9], the FVO helped to

229 realign the patella in 7 of the 9 cases who were part of the associated patellofemoral  
230 osteoarthritis subgroup. In our study, this average angle went from 8.8° laterally to 3.6°  
231 medially with a significant difference ( $p > 0.01$ ). This data confirms that medial closing-  
232 wedge FVO procedure resulting in medialization of the patella.

233 Concerning patellofemoral symptoms, no significant difference was observed in the change  
234 in J-sign, apprehension and pain extension test. But, an expanded cohort patient group would  
235 have probably shown a significant difference with this subgroup analysis. In literature, no  
236 studies evaluated clinical patellofemoral signs after FVO. The disappearance of the J-sign in  
237 all patients suggest nevertheless the improvement of the patellofemoral joint congruence  
238 [25].

239 No secondary infection, displacement, non-union or medical complications were found in  
240 our series. However, the choice of operating technique for the femoral osteotomy seems to  
241 impact the risk of complications [20]. The use of locked plates as opposed to blade plates or  
242 staples seems to reduce the incidence of non-union [7]. Furthermore, there is no consensus  
243 on the technique to be used, i.e. opening-wedge versus closing-wedge osteotomy [1]. No  
244 comparative study helped to determine which technique is better in terms of functional  
245 result, correction or consolidation [22]. In our series, a discrepancy in the post-operative  
246 length of the lower limbs was observed after a closing-wedge osteotomy. Due to the  
247 removal of a wedge in a lateral osteotomy, the pre-operative functional length decreased  
248 from 86.0 cm  $\pm$  6.2 to 84.9 cm  $\pm$  6,3 ( $p < 0.0001$ ). It is also important to note the difficulty  
249 encountered in correcting the post-operative HKA angle with the utmost precision [28]. The  
250 percentage of knees achieving the target HKA was only 53%. However, the average post-  
251 operative HKA angle was satisfactory and ranged between 0° and 3° of varus ( $2.7^\circ \pm 3.0$

252 p<0.0001). A recent review of the literature found that a post-operative HKA angle after a  
253 distal femoral osteotomy ranged between 1.2° to 2° in relation to the valgus angle [1].  
254 Limitations of this study mainly concern the inhomogeneous patient group and the small  
255 cohort of patients. The enrollment criteria were as follows: 65 years of age or under, slight  
256 to severe symptomatic LTFO (stage I to III Ahlbäck) accompanied by valgus deformities (>5°),  
257 associated with slight to severe symptomatic PFO (stage I to III Iwano). For example, the  
258 Body Mass Index (BMI) was not an exclusion criterion. In French West Indies, prevalence of  
259 obesity is a public health problem [29]. Concerning BMI, ISAKOS criteria [30] are  
260 recommendations declined in: Ideal or Possible or No good candidate. But ISAKOS guidelines  
261 are not contraindications to FVO and are based on a Caucasian population [30]. Arthroplasty  
262 also remains problematic in these patients. In addition, in this predominantly female series,  
263 correlation with a trochlear or a patellar dysplasia have not been measured because of small  
264 size of subgroups. For authors, the main limit encountered is that of the lack of specificity of  
265 the patellofemoral scores [23]. For this reason, two functional scores and clinical outcomes  
266 were considered useful for analyzing the patellofemoral joint.

267

268

## 269 **5. Conclusion**

270 Although the threshold of significance for patellofemoral symptoms was not reached, the  
271 medial closing-wedge femoral varus osteotomy induces a significant medialization of the  
272 patella (Merchant's congruence angle) and improves short-term functional results even with  
273 co-existing patellofemoral osteoarthritis. Due to the lack of specificity of the patellofemoral

274 scores, patellofemoral osteoarthritis improvement is difficult to determine on it' s own, but  
275 does not represent a contraindication to FVO.

276

### 277 **Conflict of Interest**

278 Authors declare that they have no conflict of interest.

279

280

### 281 **Funding**

282 There is no funding source.

283

### 284 **References**

285

286 [1] Chahla J, Mitchell JJ, Liechti DJ, Moatshe G, Menge TJ, Dean CS. (2016) Opening- and  
287 Closing-Wedge Distal Femoral Osteotomy: A Systematic Review of Outcomes for Isolated  
288 Lateral Compartment Osteoarthritis. Orthop J Sports Med. 4:2325967116649901.

289 [2] Hart HF, Stefanik JJ, Wyndow N, Machotka Z, Crossley KM. (2017) The prevalence of  
290 radiographic and MRI-defined patellofemoral osteoarthritis and structural pathology: a  
291 systematic review and meta-analysis. Br J Sports Med. 51:1195-208.

292 [3] Saithna A, Kundra R, Modi CS, Getgood A, Spalding T. (2012) Distal femoral varus  
293 osteotomy for lateral compartment osteoarthritis in the valgus knee. A systematic  
294 review of the literature. Open Orthop J. 6:313-9.

- 295 [4] Stähelin T, Hardegger F, Ward JC. (2000) Supracondylar osteotomy of the femur with use  
296 of compression. Osteosynthesis with a malleable implant. J Bone Joint Surg Am.  
297 82:712-22.
- 298 [5] Wylie JD, Maak TG. (2016) Medial Closing-Wedge Distal Femoral Osteotomy for Genu  
299 Valgum With Lateral Compartment Disease. Arthrosc Tech. 5:1357-66.
- 300 [6] Wang J-W, Hsu C-C. (2005) Distal femoral varus osteotomy for osteoarthritis of the knee.  
301 J Bone Joint Surg Am. 87:127-33.
- 302 [7] Edgerton BC, Mariani EM, Morrey BF. (1993) Distal femoral varus osteotomy for painful  
303 genu valgum. A five-to-11-year follow-up study. Clin Orthop. 288:263-9.
- 304 [8] Finkelstein JA, Gross AE, Davis A. (1996) Varus osteotomy of the distal part of the femur.  
305 A survivorship analysis. J Bone Joint Surg Am. 78:1348-52.
- 306 [9] Zarrouk A, Bouzidi R, Karray B, Kammoun S, Mourali S, Kooli M. (2010) Distal femoral  
307 varus osteotomy outcome: Is associated femoropatellar osteoarthritis consequential?  
308 Orthop Traumatol Surg Res. 96:632-6.
- 309 [10] Ahlbäck SO. (1971) Classification of hip joint arthrosis; Nord Med. 85:157–8.
- 310 [11] Dejour H, Walch G, Nove-Josserand L, Guier C. (1994) Factors of patellar instability:  
311 an anatomic radiographic study, Knee Surg Sports Traumatol Arthrosc. 2:19–26.
- 312 [12] Wiberg G. (1941) Roentgenographic and anatomic studies on the femoro-patellar  
313 joint. Acta Orthop Scand. 12:319-410
- 314 [13] Caton J, Deschamps G, Chambat P, Lerat JL, Dejour H. (1982) Patella infera. Apropos  
315 of 128 cases. Rev Chir Orthop Reparatrice Appar Mot. 68:317–25.
- 316 [14] Nguyen C, Bryant JT, Cooke TDV, Chow D. (1989) Alignment and geometry of the  
317 normal knee in stance. J Bone Joint Surg (Br). 71(B):346

- 318 [15] Surer P. (2001) Ostéotomie fémorale de varisation de l'extrémité inférieure du  
319 fémur. *Ann.Orthop.Ouest.* 33:19-22
- 320 [16] Crossley KM, Macri EM, Cowan SM, Collins NJ, Roos EM. (2018) The patellofemoral  
321 pain and osteoarthritis subscale of the KOOS (KOOS-PF): development and validation  
322 using the COSMIN checklist. *Br J Sports Med.* 52: 1130-6.
- 323 [17] Kujala UM, Jaakkola LH, Koskinen SK, Taimela S, Hurme M, Nelimarkka O. (1993)  
324 Scoring of patellofemoral disorders. *Arthroscopy.* 9:159-63.
- 325 [18] Roos EM, Roos HP, Lohmander LS, Ekdahl C, Beynnon BD. (1998) Knee Injury and  
326 Osteoarthritis Outcome Score (KOOS)--development of a self-administered outcome  
327 measure. *J Orthop Sports Phys Ther.* 28:88-96.
- 328 [19] Merchant AC, Mercer RL, Jacobsen RH, Cool CR. (1974) Roentgenographic analysis of  
329 patellofemoral congruence. *J Bone Joint Surg Am.* 56:1391-6.
- 330 [20] Jacobi M, Wahl P, Bouaicha S, Jakob RP, Gautier E. (2011) Distal femoral varus  
331 osteotomy: problems associated with the lateral open-wedge technique. *Arch Orthop  
332 Trauma Surg.* 131:725-8.
- 333 [21] Forkel P, Achtnich A, Metzloff S, Zantop T, Petersen W. (2015) Midterm results  
334 following medial closed wedge distal femoral osteotomy stabilized with a locking  
335 internal fixation device. *Knee Surg Sports Traumatol Arthrosc.* 23:2061-7.
- 336 [22] Wylie JD, Jones DL, Hartley MK, Kapron AL, Krych AJ, Aoki SK. (2016) Distal Femoral  
337 Osteotomy for the Valgus Knee: Medial Closing Wedge Versus Lateral Opening Wedge: A  
338 Systematic Review. *Arthroscopy.* 32:2141-7.
- 339 [23] Bourlez J, Canovas F, Duflos C, Dagneaux L. (2019) Are modern knee outcomes scores  
340 appropriate for evaluating patellofemoral degeneration in osteoarthritis? Evaluation of

- 341 the ceiling and floor effects in knee outcomes scores. *Orthop Traumatol Surg Res.*  
342 105:599–603.
- 343 [24] Crossley KM, Bennell KL, Cowan SM, Green S. (2004) Analysis of outcome measures  
344 for persons with patellofemoral pain: which are reliable and valid? *Arch Phys Med*  
345 *Rehabil.* 85:815-22.
- 346 [25] Ficat P, Ficat C, Bailleux A. (1975) External hypertension syndrome of the patella. Its  
347 significance in the recognition of arthrosis. *Rev Chir Orthop Reparatrice Appar Mot.*  
348 61:39-59.
- 349 [26] Bolgla LA, Boling MC. (2011) An update for the conservative management of  
350 patellofemoral pain syndrome: a systematic review of the literature from 2000 to 2010.  
351 *Int J Sports Phys Ther.* 6:112-25.
- 352 [27] Inoue M, Shino K, Hirose H, Horibe S, Ono K. (1988) Subluxation of the patella.  
353 Computed tomography analysis of patellofemoral congruence, *J Bone Joint Surg Am.*  
354 70:1331–7.
- 355 [28] Cameron JJ, McCauley JC, Kermanshahi AY, Bugbee WD. (2015) Lateral Opening-  
356 wedge Distal Femoral Osteotomy: Pain Relief, Functional Improvement, and Survivorship  
357 at 5 Years. *Clin Orthop.* 473:2009-15.
- 358 [29] Daigre JL, Atallah A, Boissin JL, Jean-Baptiste G, Kangambega P, Chevalier H, Balkau B,  
359 Smadja D, Inamo J. (2012) The prevalence of overweight and obesity, and distribution of  
360 waist circumference, in adults and children in the French Overseas Territories: the  
361 PODIUM survey. *Diabetes Metab.* 38:404–11.

362 [30] Brinkman JM, Freiling D, Lobenhoffer P, Staubli AE, van Heerwaarden RJ. (2014)

363 Supracondylar femur osteotomies around the knee. Patient selection, planning,

364 operative techniques, stability of fixation, and bone healing. *Orthopade*. 43:988–99.

365

366

367

368

369

370

371

372

373

374

375

376

377

378

379

380

381

382

383

384

385

386

387

388

389

390

391

392

393

394

395

396

397

398

399

400

401

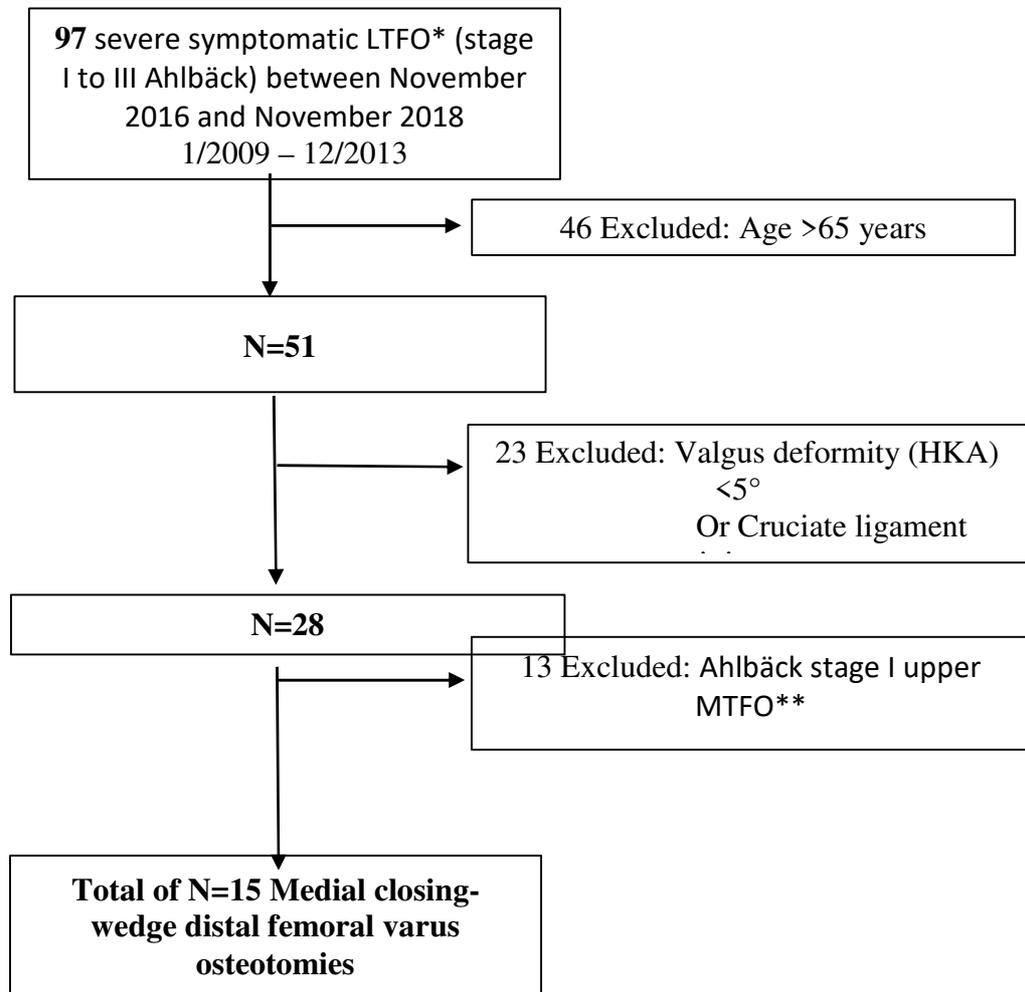
402

403

404

405  
406  
407  
408  
409  
410  
411  
412  
413  
414  
415  
416  
417  
418  
419  
420  
421  
422  
423  
424  
425  
426  
427  
428  
429  
430  
431  
432  
433  
434  
435  
436  
437  
438  
439  
440  
441  
442  
443

**Tables and figures**



\* LTFO: lateral tibiofemoral osteoarthritis  
\*\* MTFO: medial tibiofemoral osteoarthritis

**Table 1.** Patient flowchart

<b>Total study Group (n=15)</b>	
<b>Age at surgery, years</b>	
Mean ± SD*	51,4 ± 8.4
<b>Sex</b>	
Male	1
Female	14
<b>BMI**</b>	
Mean ± SD*	31,7 ± 5,8
<b>Preoperative HKA angle, degrees (valgus deformity)</b>	
Mean ± SD*	8,4 ± 2,3
<b>External femorotibial osteoarthritis (Ahlback classification)</b>	
1	5 (33.3%)
2	9 (60%)
3	1 (6.7%)
<b>Femoropatellar osteoarthritis (Iwano classification)</b>	
1	11 (73.3%)
2	3 (20%)
3	1 (6.7%)
<b>Patellar Dysplasia (Wrisberg classification)</b>	
None	2 (13.3%)
1	5 (33.3%)
2	5 (33.3%)
3	3 (20%)
<b>Trochlear dysplasia (Dejour Classification)</b>	
None	9 (60%)
1A	1 (6.7%)
1B	5 (33.3%)

\* Standard Deviation    \*\* Body Mass Index

444  
 445  
 446  
 447  
 448  
 449  
 450  
 451  
 452  
 453  
 454  
 455

**Table 2.** Preoperative data for all patients.

456

	Preoperative	Postoperative	p
<b>Kujala score (../100)</b>	37,1 ± 14,3	74,6 ± 12,0	<b>&lt;0,01</b>
<b>KOOS PF score (../100)</b>	20,8 ± 14,2	63,3 ± 17,0	<b>&lt;0,01</b>
<b>KOOS score (../100)</b>	24,2 ± 12,9	71,6 ± 16,4	<b>&lt;0,01</b>
<b>HKA angle (degrees, +=valgus, -=varus)</b>	+8,4 ± 2,3	-2,7 ± 3,0	<b>&lt;0,01</b>
<b>Lower limb length (cm)</b>	86,0 ± 6,2	84,9 ± 6,3	<b>&lt;0,01</b>
<b>Distal femoral angle (degrees)</b>	95,7° ± 2,1°	85,5° ± 3,4°	<b>&lt;0,01</b>
<b>Congruence angle of Merchant (degrees)</b>	+ 8,8° (lateral)	-3,6° (medial)	<b>&lt;0,01</b>
<b>Caton-Deschamps Index</b>	1,1 ± 0,1	1,0 ± 0,1	0,36

457

458

459

460

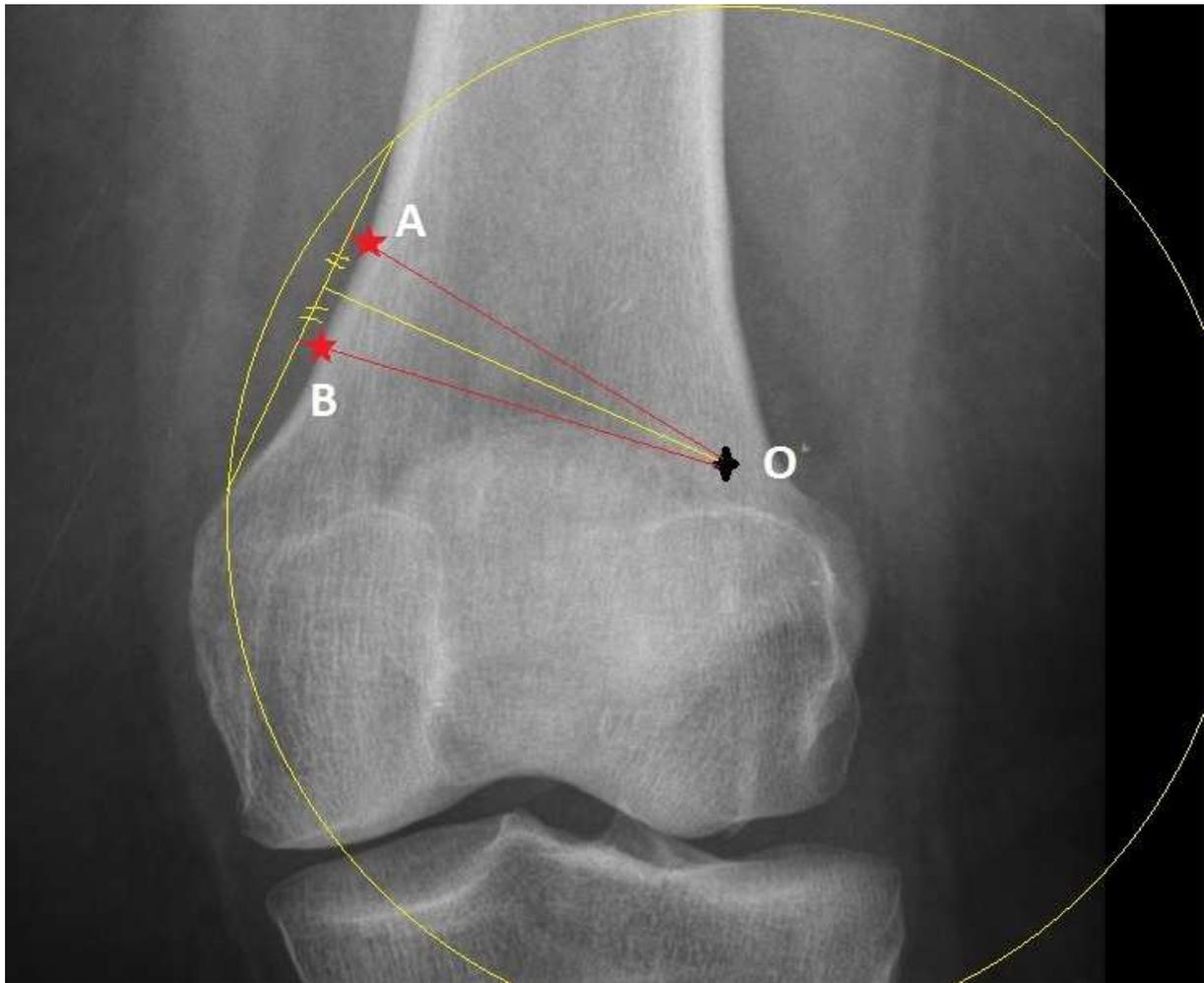
461

462

463 **Table 3.** Preoperative and postoperative data were compared by bilateral Student's paired t-  
464 tests.

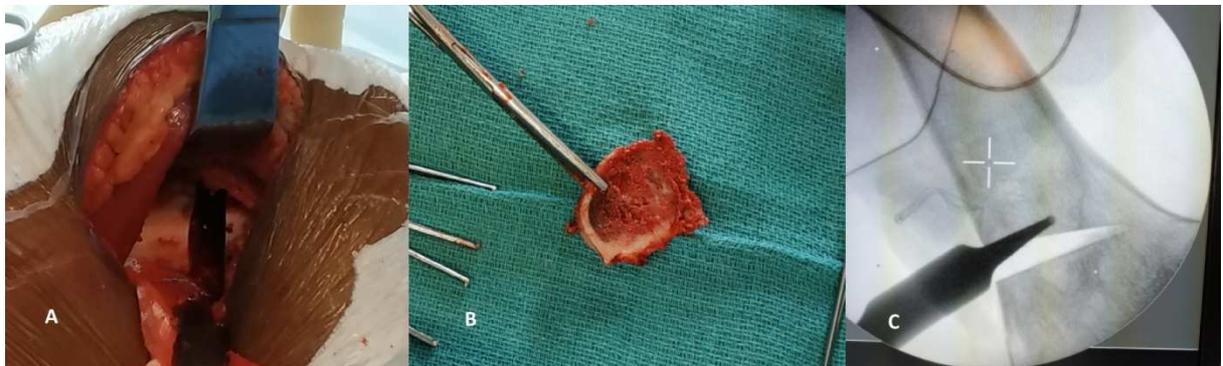
465

466



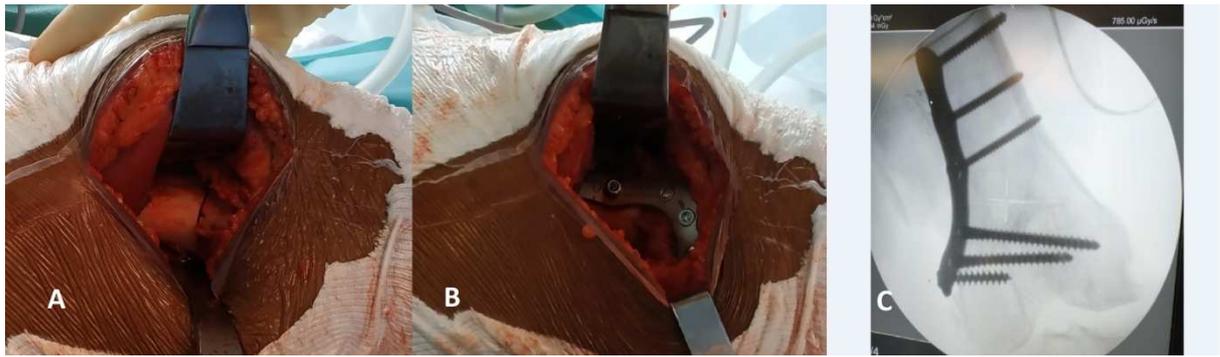
467  
468  
469  
470  
471  
472  
473  
474  
475

**Figure 1.** Osteotomy preoperative planning: drawing of the wedge to resect  
Point O: vertex of the resection triangle which is located at 5mm proximally and medially of  
the junction metaphysis-diaphysis. AO line: proximal resection line. BO line: distal resection  
line (planning according to Surer [15])



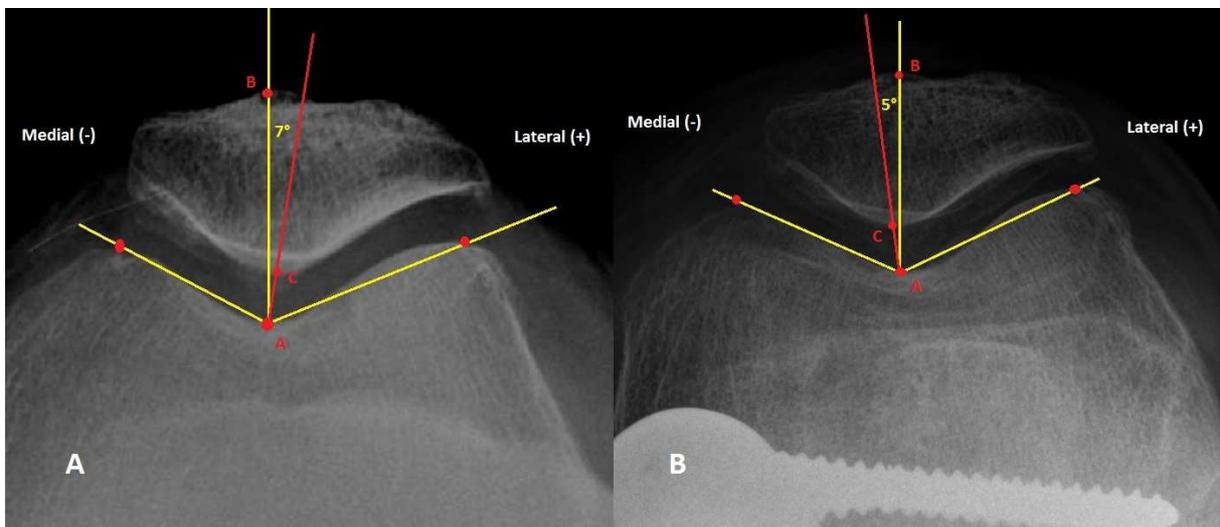
476  
477  
478  
479

**Figure 2.** Intraoperative view (A) after resection of the osteotomy wedge (B). Posteroanterior  
fluoroscopic image of the knee after resection (C).



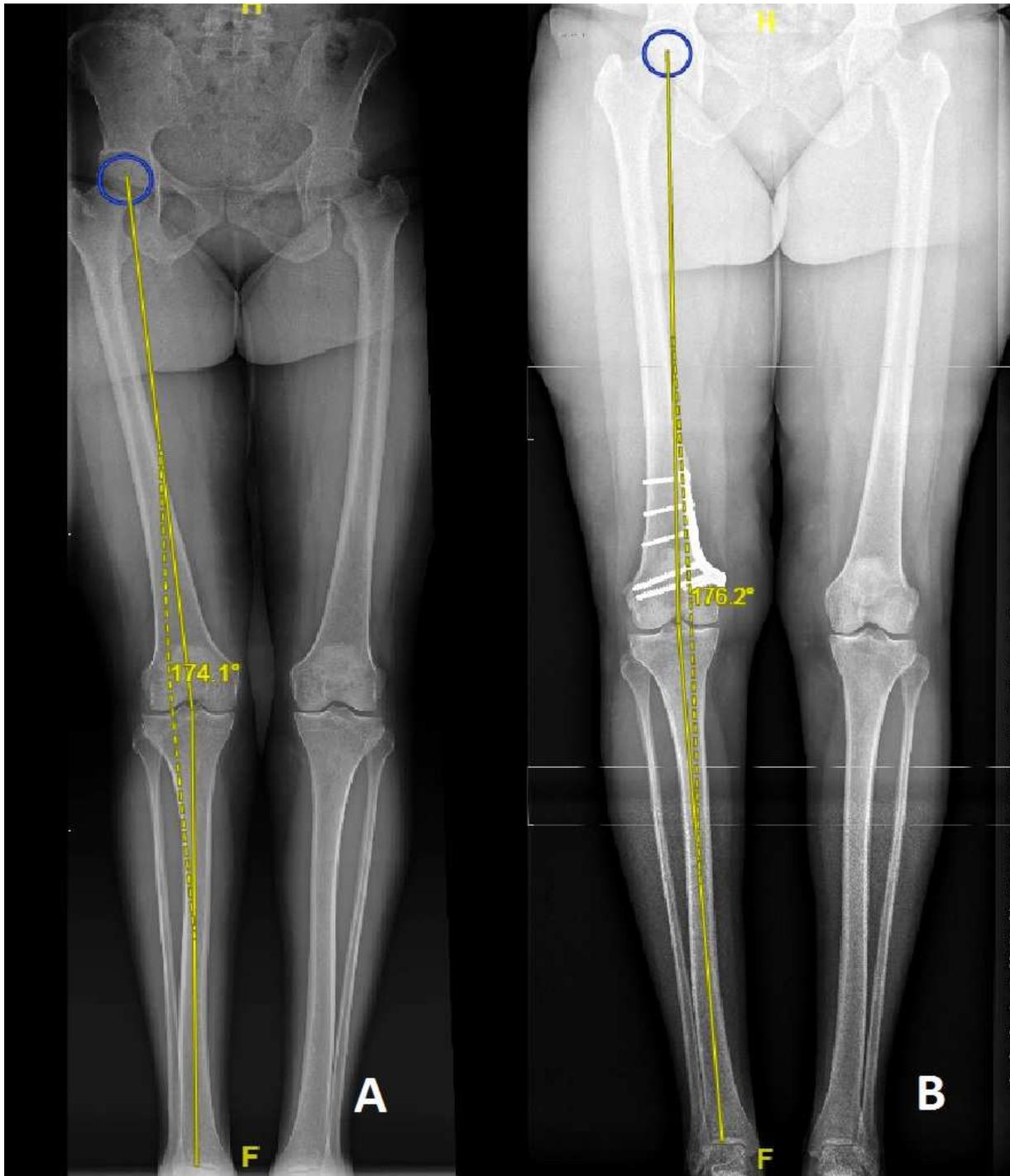
480  
481  
482  
483  
484

**Figure 3.** Intraoperative view after closing the osteotomy site (A). Distal femur osteosynthesis by locked plate (B). Final posteroanterior fluoroscopic image after osteosynthesis.



485  
486  
487  
488

**Figure 4.** Radiological measurement of congruence angle of Merchant. Patellofemoral plain axial radiographs show a medialisation of the patella between preoperative (A) and postoperative (B) congruence angle.



489  
490  
491  
492  
493  
494  
495

**Figure 5.** Example of osteotomy correction with a preoperative leg valgus malalignment (A) versus postoperative leg alignment (B).