

Alma Mater Studiorum Università di Bologna
Archivio istituzionale della ricerca

In vivo femorotibial kinematics of medial-stabilized total knee arthroplasty correlates to post-operative clinical outcomes

This is the final peer-reviewed author's accepted manuscript (postprint) of the following publication:

Published Version:

Alesi D., Marcheggiani Muccioli G.M., Roberti di Sarsina T., Bontempi M., Pizza N., Zinno R., et al. (2021). In vivo femorotibial kinematics of medial-stabilized total knee arthroplasty correlates to post-operative clinical outcomes. *KNEE SURGERY, SPORTS TRAUMATOLOGY, ARTHROSCOPY*, 29(2), 491-497 [10.1007/s00167-020-05975-w].

Availability:

This version is available at: <https://hdl.handle.net/11585/795865> since: 2024-08-02

Published:

DOI: <http://doi.org/10.1007/s00167-020-05975-w>

Terms of use:

Some rights reserved. The terms and conditions for the reuse of this version of the manuscript are specified in the publishing policy. For all terms of use and more information see the publisher's website.

This item was downloaded from IRIS Università di Bologna (<https://cris.unibo.it/>).
When citing, please refer to the published version.

(Article begins on next page)

In-vivo femorotibial kinematics of medial-stabilized total knee arthroplasty correlates to postoperative clinical outcomes

Domenico Alesi, M.D.*	domenicoalesi@ymail.com
Giulio Maria Marcheggiani Muccioli, M.D., Ph.D. *#	marcheggianimuccioli@me.com
Marco Bontempi, Ph.D. *	m.bontempi@biomec.it
Nicola Pizza *	nickpiz90@gmail.com
Raffaele Zinno MSc *	raffaele.zinno.ufficio@gmail.com
Stefano Di Paolo Eng *	stefano.dipaolo@ior.it
Stefano Zaffagnini, M.D., Full Professor *#	stefano.zaffagnini@unibo.it
Laura Bragonzoni Ph.D., Senior Assistant Professor #	laura.bragonzoni4@unibo.it

* 2nd Orthopaedic and Traumatologic Clinic – IRCCS – Istituto Ortopedico Rizzoli – Via G.B. Pupilli 1, 40136, Bologna, Italy

University of Bologna - Italy

Corresponding Author: Giulio Maria Marcheggiani Muccioli, M.D., Ph.D.

Orthopaedic Surgeon – IRCCS – Istituto Ortopedico Rizzoli

tel: +39 0516366509

mail: marcheggianimuccioli@me.com

Funding Statement

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Conflict of interest

Authors declare that they have no conflict of interest.

In-vivo femorotibial kinematics of medial-stabilized total knee arthroplasty correlates to postoperative clinical outcomes

3

4 ABSTRACT

5 **Purpose:** To evaluate if there was a correlation between in vivo kinematics of a medial-stabilized (MS) total knee
6 arthroplasty (TKA) and post-operative clinical scores. We hypothesized that (1) a MS-TKA would produce a medial pivot
7 movement and that (2) this specific pattern would be correlated with higher clinical scores.

8 **Methods:** 18 patients were evaluated through clinical and functional scores evaluation (Knee Society Score clinical and
9 functional, Womac, Oxford), and kinematically through dynamic radiostereometric analysis (RSA) at 9 months after MS-
10 TKA, during the execution of a sit-to-stand and a lunge motor task. The anteroposterior (AP) Low Point translation of
11 medial and lateral femoral compartments were compared through Student's t-test ($p < 0.05$). A correlation analysis between
12 scores and kinematics was performed through the Pearson's correlation coefficient r .

13 **Results:** A significantly greater ($p < 0.0001$) anterior translation of the lateral compartment with respect to the medial one
14 was found in both sit-to-stand (medial $2.9 \text{ mm} \pm 0.7 \text{ mm}$, lateral $7.1 \text{ mm} \pm 0.6 \text{ mm}$) and lunge (medial $5.3 \text{ mm} \pm 0.9 \text{ mm}$,
15 lateral $10.9 \text{ mm} \pm 0.7 \text{ mm}$) motor tasks, thus resulting in a medial pivot pattern in about 70% of patients. Significant
16 positive correlation in sit-to-stand was found between the peak of AP translation in the lateral compartment and clinical
17 scores ($r = 0.59$ for Knee Society Score clinical and $r = 0.61$ for Oxford). Moreover, we found that the higher peak of AP
18 translation of the medial compartment correlated with lower clinical scores ($r = -0.55$ for Knee Society Score clinical, $r =$
19 -0.61 for Womac and $r = -0.53$ for Oxford) in the lunge. A negative correlation was found between Knee Society Score
20 clinical and VV laxity during sit-to-stand ($r = -0.56$) and peak of external rotation in the lunge motor task ($r = -0.66$).

21 **Conclusions:** The MS-TKA investigated produced in-vivo a medial pivot movement in about 70% of patients in both
22 examined motor tasks. There was a correlation between the presence of medial pivot and higher post-operative scores.

23 **Level of evidence:** IV

24 **Keywords:** medial-stabilized, TKA, dynamic RSA, medial pivot

25

26

27 **Introduction**

28

29 Nowadays, about 20% of patients who underwent total knee arthroplasty (TKA) is not fully satisfied in terms of pain
30 relief and functional outcomes [11]. Despite good coronal and sagittal alignment, the restoration of normal knee
31 kinematics, which is supposed to be a crucial factor, is not always reached [2, 9]. Many studies focusing on the motion of
32 the native knee joint revealed that the lateral compartment performs a wider anterior-posterior (AP) translation during
33 flexion-extension compared to the medial one. This type of motion is known as “medial pivoting” movement of the knee
34 [9, 13].

35 Several TKA designs have been developed with the aim of reproducing this pattern as much as possible. A new concept
36 of TKA, the medial-stabilized (MS) knee prosthesis, has been developed trying to mimic distal femur and tibial plateau
37 geometry, thus reproducing the natural knee motion. The MS-TKA guarantees anteroposterior (AP) stability of the medial
38 compartment thanks to the “ball-in-socket” geometry, coupling with a greater AP translation of the external compartment
39 during knee flexion allowed by the flat lateral surface of the insert [18].

40 Multiple studies reported favourable outcomes for the MS-TKA, with satisfactory results at medium to long-term follow-
41 up [5, 8, 12, 14]. Nevertheless, to authors’ knowledge, there is lack of evidence of better clinical outcomes in presence of
42 specific kinematic patterns. In particular, just few investigations have been focused on the correlation between in-vivo
43 kinematics of MS prosthesis and post-operative clinical outcomes [19].

44 Hence, the aim of the present study was to evaluate if the in vivo kinematics of a MS total knee arthroplasty, designed to
45 produce medial pivot pattern, was somehow correlated with post-operative clinical scores. The hypotheses were that (1)
46 the MS-TKA would be able to produce medial pivot movement during the examined motor tasks, that (2) this specific
47 pattern would be correlated with higher clinical scores.

48

49 **Materials and Methods**

50 A cohort of 18 randomly selected not consecutive patients in waiting list for TKA at our institution was enrolled in this
51 study after providing an informed consent. The randomization was carried out using a random number generator, available
52 on the web site of National Health System, which generated 18 casual numbers within the interval (1, 45). These numbers
53 were used to select the patients from the waiting list for TKA. The inclusion criteria were: (1) age (50-85 years old); (2)
54 severe radiographic primary osteoarthritis (Kellgren-Lawrence grade 3 and grade 4); (3) patients scheduled for a primary
55 TKA. The exclusion criteria were: (1) previous corrective osteotomy on the affected lower limb; (2) post-traumatic
56 arthritis; (3) severe preoperative varus-valgus deformity (Hip Knee Ankle angle > 10°); Body Mass Index > 40 kg/m²;
57 (4) rheumatoid arthritis; (5) chronic inflammatory joint diseases; (6) patients with a pre-pathological abnormal gait
58 (amputated, neuromuscular disorders, poliomyelitis, developmental dysplasia of the hip); (7) severe ankle osteoarthritis
59 (Kellgren-Lawrence grade 3 and grade 4); (8) severe hip osteoarthritis (Kellgren-Lawrence grade 3 and grade 4); (9)
60 previous total hip or ankle replacement; (10) unwillingness to take part in this study and providing Health Insurance
61 Portability and Accountability Act (HIPAA) authorisation.

62 The mean age of the patients was 72.1 ± 7.4 years old (95% CI). The cohort included 7 right legs and 11 left legs, with 9
63 females and 9 males. All patients were operated with the standard technique (medial parapatellar approach, adjusted
64 mechanical alignment)[21] receiving a cemented MS-TKA (GMK Sphere, Medacta International, Switzerland) with
65 patellar resurfacing. Patients were evaluated after a minimum 9-month follow-up by Model-based dynamic

66 radiostereometric analysis (RSA). The RSA set-up was analogous to the ones already published in previous articles from
67 the same study group [3, 4, 6, 15].

68 All patients performed two motor tasks that represent common daily activities, a sit-to-stand and a lunge movement:

- 69 - Sit-to-stand: from the sitting position, the patient had to stand up, without support for the upper limbs. The chair
70 was made of a radiolucent material and was 40 cm high. The chair rising movement was not standardised to best
71 simulate the natural movement that the patient would have done in daily life.
- 72 - Lunge: from the standing position, the patient made a bending with the operated limb, reaching their maximum
73 flexion according to their possibilities, then returned in the standing position. Patients were not allowed to use
74 supports for the upper limbs. Also, this motor task was not strictly standardised.

75

76 The global accuracy of dynamic RSA in model positioning and orientation, evaluated in terms of “trueness \pm precision”,
77 resulted to be sub-millimetric, respectively $0.2 \text{ mm} \pm 0.5 \text{ mm}$ and $0.3^\circ \pm 0.2^\circ$. Data are presented as mean \pm standard
78 error.

79 Moreover, pre-operative and post-operative visit at 9 months, patients were clinically evaluated by one single expert
80 orthopaedic surgeon which calculated the clinical and functional Knee Society Score (KSSC and KSSF), Womac and
81 Oxford scores. These scores are commonly used to assess patients’ clinical status in terms of pain and functionality. For
82 the KSSC, KSSF and Womac, the scores range from 0 to 100, and is considered good over 69. The Oxford score ranges
83 from 0 to 48 and is considered good over 39.

84 This study obtained the approval from Institutional Review Board (IRB) of the IRCCS Rizzoli Orthopaedic Institute (ID:
85 003603 February 16th, 2016).

86 **Statistical Analysis**

87 Statistical analysis was performed with MATLAB®. For each of the two movements, the AP translation of medial and
88 lateral compartments was compared in order to assess the presence of medial pivot pattern: a “pivoting ratio” was
89 assessed within $(-1, 1)$ for each task. In all tasks with ratio between 0 and 1, prostheses were considered to perform
90 consistent medial pivot.

91 The matched pairs Student’s t-test was used to assess the statistical differences, with $p < 0.05$. Furthermore, a ratio
92 between medial and lateral AP translation was calculated to evaluate how many knees showed the medial pivot pattern.

93 A correlation analysis between post-operative clinical scores and kinematic parameters was performed for each of the
94 two tasks through the Pearson’s correlation coefficient r ($p < 0.05$). A correlation coefficient $r < 0.4$ was considered poor, r
95 between 0.4 and 0.75 was considered fair, $r > 0.75$ was considered good.

96 In order to calculate the sample size, an a priori power analysis was performed. The two sample T-test was used with $p <$
97 0.05 . Based on previously published studies with the same technology, the true difference of means between medial and
98 lateral compartment was set to 3 mm for both motor tasks [6, 15], while the standard deviation was considered 3 mm.
99 The power value was 0.95. Based on this analysis, the number of patients resulted to be 16.

100

101 **Results**

102 All the patients were able to perform the sit-to-stand motor task, while all the patients except one were able to perform
103 the lunge motor task. The average time of follow-up evaluation was 10.0 ± 1.8 months. The sex distribution was not found
104 to statistically influence the kinematic and outcome analyses ($p < 0.05$).

105 Regarding the sit-to-stand, the kinematic analysis showed the presence of medial pivot, with a significantly greater
106 ($p < 0.0001$) anterior translation of the lateral condyle ($7.1 \text{ mm} \pm 0.6 \text{ mm}$) compared to the medial one ($2.9 \text{ mm} \pm 0.7 \text{ mm}$)
107 on average (Fig.1 and Tab.1). A consistent medial pivot pattern was found in 12 patients out of 18 (67%). Thus, the
108 kinematic analysis was repeated in the sub-group of patients performing medial pivot and in the sub-group of patients not
109 performing it. A significantly greater anterior translation of lateral condyle ($p < 0.0001$) was found in the sub-group of
110 patients performing medial pivot, while no statistical difference was found in the sub-group of patients not performing
111 medial pivot. Also, regarding the lunge motor task, the lateral condyle showed a significantly larger ($p < 0.0001$) anterior
112 translation ($10.9 \text{ mm} \pm 0.7 \text{ mm}$) with respect to the medial one ($5.3 \text{ mm} \pm 0.9 \text{ mm}$) (Fig.2 and Tab.1) on average. A
113 consistent medial pivot pattern was found in 11 patients out of 17 (65%). As for the sit-to-stand, the initial cohort was
114 split in two sub-groups, and the same trend was found (Tab.1). The Freeman graphics regarding the kinematical results
115 split in two groups of patients, performing a consistent medial pivot or not, are provided in supplementary material A.

116 Regarding the post-operative clinical outcomes, significant correlations ($p < 0.05$) were found between clinical outcomes
117 and knee kinematics (Tab.2). In particular, a positive correlation was found between the peak of AP translation in the
118 lateral compartment and both the KSSC ($r = 0.59$) and the Oxford ($r = 0.61$) scores in the sit-to-stand motor task. In
119 addition, we found that the higher the peak of AP translation in the medial compartment the lowest the KSSC score ($r =$
120 -0.55 lunge), the WOMAC ($r = -0.60$ lunge), and the Oxford ($r = -0.53$ lunge). We found also a negative correlation
121 between KSSC score and VV laxity regarding the sit-to-stand ($r = -0.56$) motor task and between the peak of external
122 rotation and the KSSC ($r = -0.66$) regarding the lunge motor task. A specific post-hoc power analysis for the clinical
123 outcomes was performed. Using a sample size of 18 patients and the correlation coefficient with the lowest absolute
124 magnitude, i.e. $r = 0.53$, the power resulted 0.81. The complete list of patients' outcomes in relation to the medial pivot
125 pattern is provided in the supplementary material B.

126

127 **Discussion**

128 The most important findings of the present study were that (1) the MS TKA produced medial pivot movement during
129 both sit-to-stand and lunge motor tasks in the 70% of patients; that (2) higher values of AP translation of the lateral
130 compartment correlated with higher clinical scores, while the higher values of AP translation of the medial compartment
131 correlated with lower clinical scores. Moreover, higher values of VV laxity during sit-to-stand and peak of external
132 rotation during the lunge motor task were correlated with lower clinical scores.

133 The medial pivot motion of the healthy knee joint has been widely described in literature [7, 10, 13, 16]. The restoration
134 of normal knee biomechanics is a crucial point of TKA surgery, but it can be highly related to implant design and patients
135 activity [1]. The MS prosthesis evaluated in this study (GMK Sphere, Medacta International, Switzerland) demonstrated
136 a consistent medial pivot movement both in the sit-to-stand and in the lunge motor tasks, two common activities of daily
137 life with different levels of engagement. This prosthetic design is intended to reproduce posterior femoral rollback and

138 medial pivot motion, avoiding paradoxical anterior sliding or rolling forward of the femoral component with respect to
139 the tibia during flexion-extension.

140 The medial pivot pattern was found in about 70% of patients for both motor tasks, thus confirming the average trend. Our
141 kinematic results are in line with the ones of different authors, reproduced in either an in-vivo or in-vitro setting.
142 Steinbrück A. et al. [18] tested the GMK Sphere MS TKA in an in-vitro setting during loaded squat from 20° to 120° of
143 flexion. They found a combination of anterior translation of the lateral compartment (14.7 mm ± 6 mm) with a lower
144 anterior translation on the medial one (3.5 mm ± 4.8 mm), concluding that the specific TKA was able to mimic the
145 physiological knee kinematics. Also Scott G. et al.[17] reported a greater AP translation on the lateral side (8 mm ± 4
146 mm) with respect to the medial one (2 mm ± 3 mm) in 16 knees implanted with the same prosthesis during in-vivo lunge
147 movement. The range of AP translation of the present study resulted lower than the one presented by Steinbrück A. et al.
148 and similar to the one of Scott G. et al. This difference could be explained by the higher range of knee flexion (20-120°)
149 reached in-vitro and in the absence of patients' active muscle control [18].

150 On average, the cohort of patients reported good clinical and functional outcomes. Regarding the correlation between the
151 clinical outcomes and AP Low Point translations of medial and lateral compartments, it seems that the medial pivot
152 movement has a positive effect on the clinical and functional outcomes of the patients. Analogue results were found in a
153 recent paper by Van Onsem et al. The authors reported that patients with poor post-operative patient-reported outcomes
154 (PROMs), after a Posterior-Stabilized (PS) TKA implantation experienced more anterior translation on the medial side
155 and less posterior translation on the lateral side during deep flexion activities. Meanwhile the patients who reported good
156 clinical outcomes showed a greater AP stability on the medial compartment with respect to the lateral one [21]. It must
157 be outlined that the TKA model examined by Van Onsem is substantially different from the one of the present study,
158 since AP stability of PS-TKA relies more on the post-cam mechanism. However, the concept of higher congruency of the
159 medial compartment with respect to the lateral one seems to be equally important to ensure AP stability of the implant.

160 Furthermore, the negative correlation between VV laxity and peak of external rotation with clinical outcomes suggests
161 that excessive coronal and rotational laxity could play a role in knee function after TKA. To our knowledge, no article
162 has been published about correlation between dynamic rotational or coronal laxity with clinical outcomes. In addition,
163 this correlation seems to highlight the importance of soft tissue balancing during surgery. Medial compartment stability
164 and lateral compartment wider AP translation allow proper implant function. On the medial side, the stability is provided
165 by the high congruency of the inlay with the medial condyle and by the integrity of medial soft tissues (superficial medial
166 collateral ligament). On the lateral side, the flat surface of the inlay facilitates the rollback, thus, lateral soft tissue release
167 is more likely to be done. However, to avoid excessive lateral compartment laxity, the anterior fibers of the ileo-tibial
168 band should remain intact, as suggested also by Van Overschelde et al.[20]. However, the ranges of VV laxity found for
169 the patients of our study were always below 5°, thus suggesting that intraoperative stability was achieved properly. As
170 recently confirmed by Watanabe et al., valgus laxity averaging 3.6° correlates with good PROMs after PS TKA, while
171 increasing joint laxity reversely affected some of the clinical outcomes [22].

172 The present study has some limitations. First of all, the RSA evaluation was performed only after surgery, as specifically
173 required by our IRB in order to reduce x-rays exposure. Thus, it was not possible to compare joint kinematics before and
174 after implantation. Anyway, joint kinematics of an arthritic knee cannot be assumed as the one of the native joint. Second,
175 a strict standardization of patients' movement in terms of movement magnitude and velocity was not performed. Patients
176 were required to perform the motor tasks in the most natural way as possible, in order to mimic daily life conditions.

177 However, to generate comparable data, all the movements were normalized in the post processing (see Methods for
178 details). Furthermore, the correlation analysis between the clinical outcomes and the kinematical data did not allow us to
179 define a cut-off for laxity, over which the clinical outcomes becomes poor. This aspect is more likely to be investigated
180 in a wider cohort of patients. Finally, all the pre-operative and post-operative clinical evaluations was carried out by one
181 single expert surgeon (who did not participate to surgeries nor to dynamic RSA analysis) to avoid inter-rater variability.

182 The results of this study have an important clinical relevance. In fact, the knowledge that a medial pivot kinematics after
183 the implantation of a MS-TKA leads to better clinical results will push research in obtaining it in a higher ratio of patients.

184

185 **Conclusions**

186 The MS-TKA investigated produced in-vivo a medial pivot movement in about 70% of patients in both examined motor
187 tasks. There was a correlation between the presence of medial pivot and higher post-operative scores.

188

190 **References**

- 191 1. Banks SA, Hodge WA (2004) 2003 Hap Paul Award Paper of the International Society for Technology in
192 Arthroplasty. Design and activity dependence of kinematics in fixed and mobile-bearing knee arthroplasties. *J*
193 *Arthroplasty* 19:809–816
- 194 2. Behrend H, Giesinger K, Giesinger JM, Kuster MS (2012) The “forgotten joint” as the ultimate goal in joint
195 arthroplasty: validation of a new patient-reported outcome measure. *J Arthroplasty* 27:430-436.e1
- 196 3. Bontempi M, Roberti di Sarsina T, Marcheggiani Muccioli GM, Pizza N, Cardinale U, Bragonzoni L, Zaffagnini
197 S (2019) J-curve design total knee arthroplasty: the posterior stabilized shows wider medial pivot compared to the cruciate
198 retaining during chair raising. *Knee Surg Sports Traumatol Arthrosc* doi: 10.1007/s00167-019-05645-6.
- 199 4. Bragonzoni L, Marcheggiani Muccioli GM, Bontempi M, Roberti di Sarsina T, Cardinale U, Alesi D, Iacono F,
200 Neri MP, Zaffagnini S (2018) New design total knee arthroplasty shows medial pivoting movement under weight-bearing
201 conditions. *Knee Surg Sports Traumatol Arthrosc* 27(4):1049-1056
- 202 5. Brinkman J-M, Bubra PS, Walker P, Walsh WR, Bruce WJM (2014) Midterm results using a medial pivot total
203 knee replacement compared with the Australian National Joint Replacement Registry data. *ANZ J Surg* 84:172–176
- 204 6. Cardinale U, Bragonzoni L, Bontempi M, Alesi D, Roberti di Sarsina T, Lo Presti M, Zaffagnini S, Marcheggiani
205 Muccioli GM, Iacono F (2019) Knee kinematics after cruciate retaining highly congruent mobile bearing total knee
206 arthroplasty: An in vivo dynamic RSA study. *Knee pii: S0968-0160(19)30258-3*. doi: 10.1016/j.knee.2019.11.003
- 207 7. Dennis DA, Mahfouz MR, Komistek RD, Hoff W (2005) In vivo determination of normal and anterior cruciate
208 ligament-deficient knee kinematics. *J Biomech* 38:241–253
- 209 8. Fan C-Y, Hsieh JT-S, Hsieh M-S, Shih Y-C, Lee C-H (2010) Primitive results after medial-pivot knee
210 arthroplasties: a minimum 5-year follow-up study. *J Arthroplasty* 25:492–496
- 211 9. Freeman M a. R, Pinskerova V (2005) The movement of the normal tibio-femoral joint. *J Biomech* 38:197–208
- 212 10. Freeman M a. R, Pinskerova V (2003) The movement of the knee studied by magnetic resonance imaging. *Clin*
213 *Orthop Relat Res* (410):35–43
- 214 11. Gunaratne R, Pratt DN, Banda J, Fick DP, Khan RJK, Robertson BW (2017) Patient Dissatisfaction Following
215 Total Knee Arthroplasty: A Systematic Review of the Literature. *J Arthroplasty* 32:3854–3860
- 216 12. Hossain F, Patel S, Rhee S-J, Haddad FS (2011) Knee arthroplasty with a medially conforming ball-and-socket
217 tibiofemoral articulation provides better function. *Clin Orthop Relat Res* 469:55–63
- 218 13. Johal P, Williams A, Wragg P, Hunt D, Gedroyc W (2005) Tibio-femoral movement in the living knee. A study
219 of weight bearing and non-weight bearing knee kinematics using ‘interventional’ MRI. *Journal of Biomechanics* 38:269–
220 276
- 221 14. Karachalios T, Roidis N, Giotikas D, Bargiotas K, Varitimidis S, Malizos KN (2009) A mid-term clinical
222 outcome study of the Advance Medial Pivot knee arthroplasty. *Knee* 16:484–488

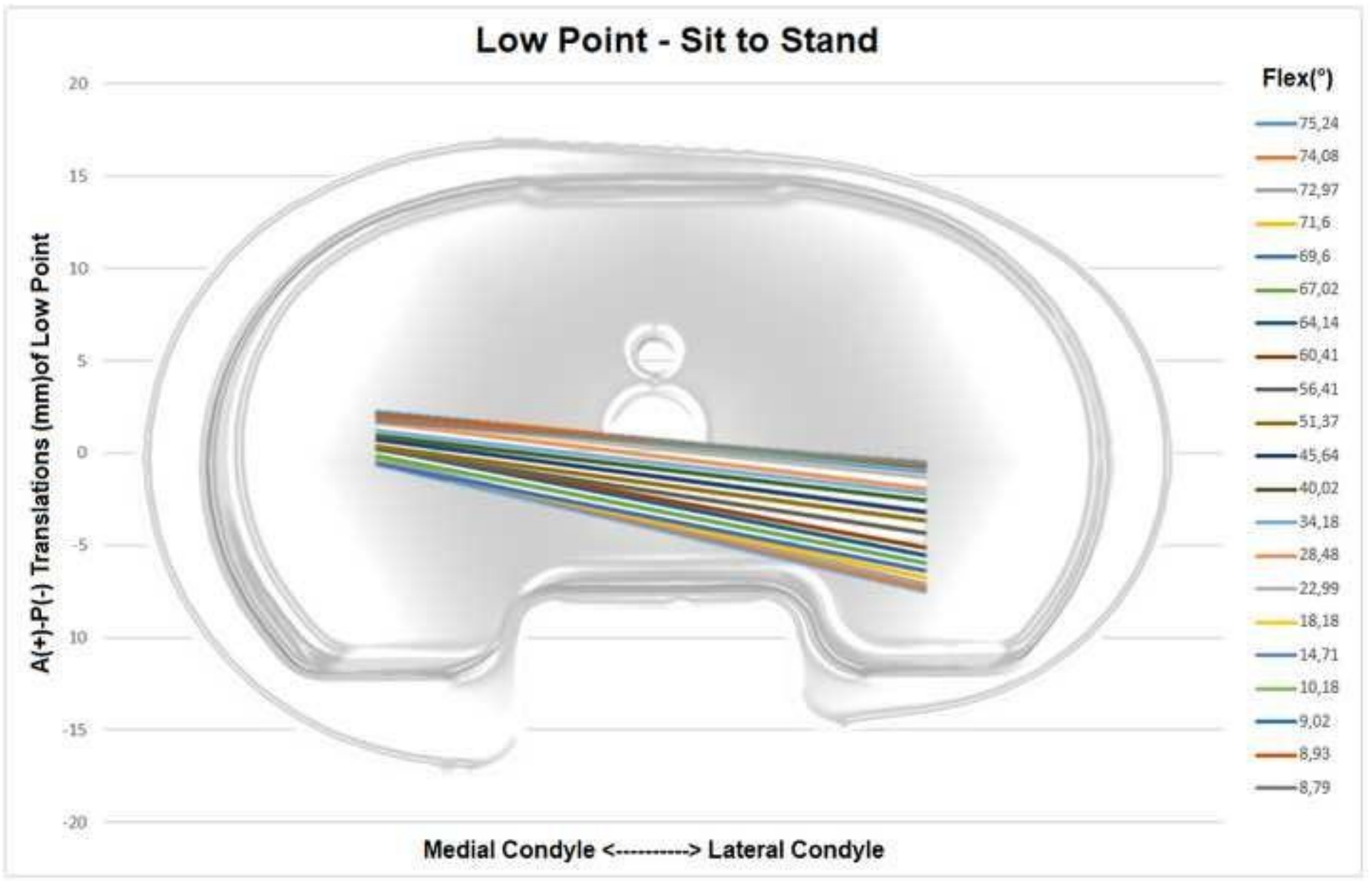
- 223 15. Marcheggiani Muccioli GM, Pizza N, Di Paolo S, Zinno R, Alesi D, Roberti Di Sarsina T, Bontempi M,
224 Zaffagnini S, Bragonzoni L (2020) Multi-radius posterior-stabilized mobile-bearing total knee arthroplasty partially
225 produces in-vivo medial pivot during activity of daily living and high demanding motor task. *Knee Surg Sports Traumatol*
226 *Arthrosc* doi: 10.1007/s00167-020-05846-4
- 227 16. Nakagawa S, Kadoya Y, Todo S, Kobayashi A, Sakamoto H, Freeman MA, Yamano Y (2000) Tibiofemoral
228 movement 3: full flexion in the living knee studied by MRI. *J Bone Joint Surg Br* 82:1199–1200
- 229 17. Scott G, Imam MA, Eifert A, Freeman M a. R, Pinskerova V, Field RE, Skinner J, Banks SA (2016) Can a total
230 knee arthroplasty be both rotationally unconstrained and anteroposteriorly stabilised? A pulsed fluoroscopic investigation.
231 *Bone Joint Res* 5:80–86
- 232 18. Steinbrück A, Schröder C, Woiczinski M, Fottner A, Pinskerova V, Müller PE, Jansson V (2016) Femorotibial
233 kinematics and load patterns after total knee arthroplasty: An in vitro comparison of posterior-stabilized versus medial-
234 stabilized design. *Clin Biomech (Bristol, Avon)* 33:42–48
- 235 19. Van Onsem S, Verstraete M, Van Eenoo W, Van Der Straeten C, Victor J (2019) Are TKA Kinematics During
236 Closed Kinetic Chain Exercises Associated with Patient-reported Outcomes? A Preliminary Analysis. *Clin Orthop Relat*
237 *Res* 478(2):255-263
- 238 20. Van Overschelde P, Pinskerova V, Koch PP, Fornasieri C, Fucentese S (2017) Redefining Knee Balance in a
239 Medially Stabilized Prosthesis: An In-Vitro Study. *Open Orthop J* 11:1165–1172
- 240 21. Vanlommel L, Vanlommel J, Claes S, Bellemans J (2013) Slight undercorrection following total knee
241 arthroplasty results in superior clinical outcomes in varus knees. *Knee Surg Sports Traumatol Arthrosc* 21:2325–2330
- 242 22. Watanabe T, Koga H, Katagiri H, Otabe K, Nakagawa Y, Muneta T, Sekiya I, Jinno T (2019) Coronal and
243 sagittal laxity affects clinical outcomes in posterior-stabilized total knee arthroplasty: assessment of well-functioning
244 knees. *Knee Surg Sports Traumatol Arthrosc* doi: 10.1007/s00167-019-05500-8

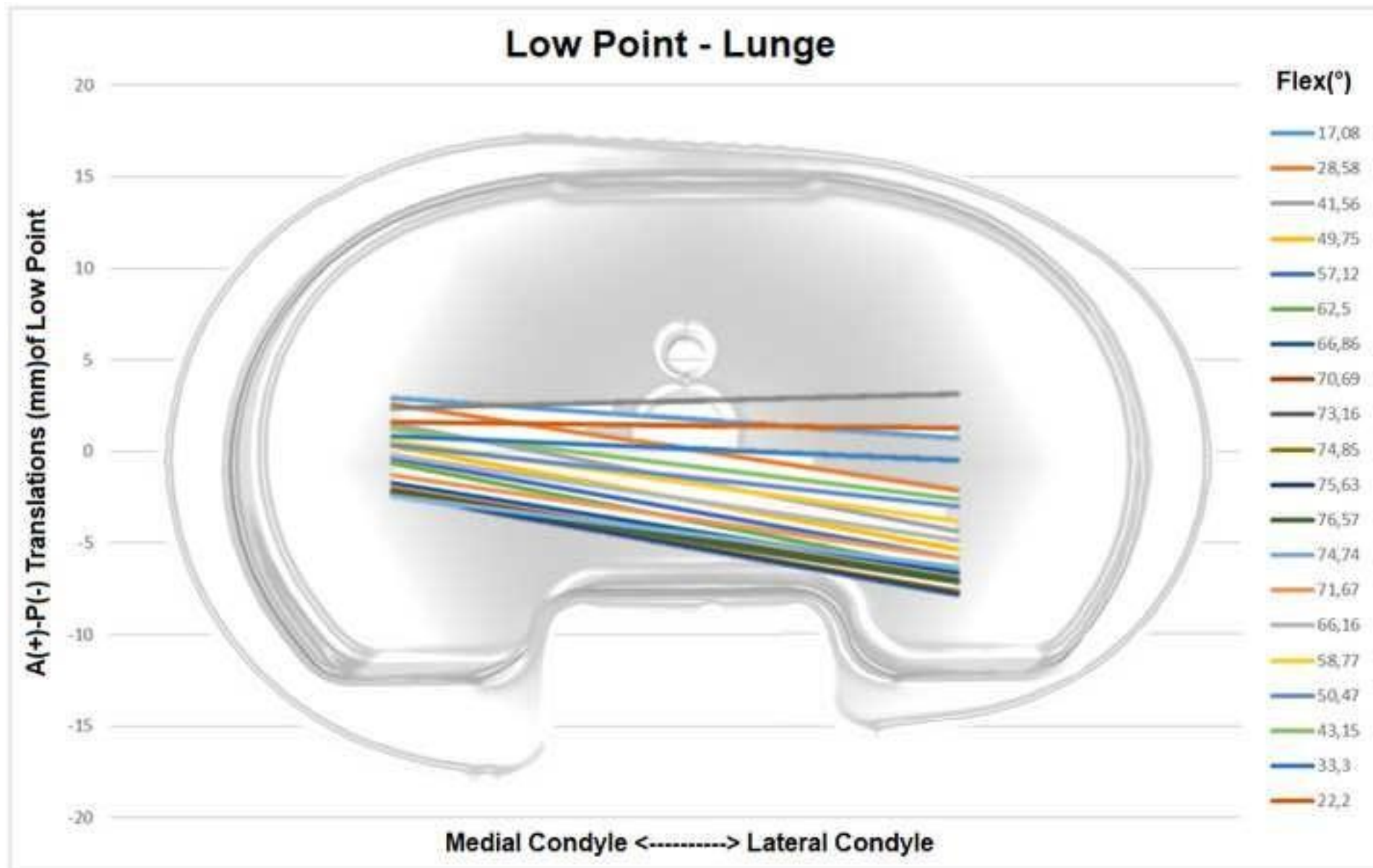
245 **Figure captions**

246

247 **Fig.1** Average of the AP translation of the Low Point of medial and lateral compartment during sit-to-stand over the entire
248 cohort of patients, represented as Freeman graphic. On the right are represented the knee flexion angles.

249 **Fig.2** Average of the AP translation of the Low Point of medial and lateral compartment during lunge over the entire
250 cohort of patients, represented as Freeman graphic. On the right are represented the knee flexion angles.





LOW POINT KINEMATICS		Medial Condyle AP translation (mm)	Lateral Condyle AP translation (mm)	p-value
Sit to stand	<i>Entire cohort (n=18)</i>	2.9 ± 0.7	7.1 ± 0.6	< 0.0001 *
	<i>Medial pivot pt (n=12)</i>	1.2 ± 0.8	8.2 ± 1.1	< 0.0001 *
	<i>No medial pivot pt (n=6)</i>	5.1 ± 1.4	4.7 ± 1.7	n.s
Lunge	<i>Entire cohort (n=17)</i>	5.3 ± 0.9	10.9 ± 0.7	< 0.0001 *
	<i>Medial pivot pt (n=12)</i>	5.7 ± 0.8	11.9 ± 0.8	< 0.0001 *
	<i>No medial pivot pt (n=5)</i>	6.3 ± 2.4	6.6 ± 1.9	n.s

*Table 1 – Anteroposterior (AP) Low Point translation of medial and lateral condyles during sit to stand (top) and lunge (bottom) evaluated through dynamic RSA. Data are reported as entire cohort, patients performing consistent medial pivot and patients not performing consistent medial pivot. * represent statistically significant differences ($p < 0.05$).*

CORRELATION COEFFICIENT [r]	Sit to Stand				Lunge			
	<i>KSSC</i>	<i>KSSF</i>	<i>WOMAC</i>	<i>OXFORD</i>	<i>KSSC</i>	<i>KSSF</i>	<i>WOMAC</i>	<i>OXFORD</i>
Peak of AP translation lateral compartment	0.59 *	n.s.	n.s.	0.61 *	n.s.	n.s.	n.s.	n.s.
Peak of AP translation medial compartment	n.s.	n.s.	n.s.	n.s.	-0.55 *	n.s.	-0.60 *	-0.53 *
VV laxity	-0.56 *	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Peak Ext-rotation	n.s.	n.s.	n.s.	n.s.	-0.66 *	n.s.	n.s.	n.s.

Table 2 – Pearson's correlation coefficients (r) between kinematical parameters and patient-reported outcomes. * represent statistically significant differences ($p < 0.05$).

