**Annals of Surgery: International**
Received: Mar 09, 2017, Accepted: Mar 25, 2017, Published: Mar 29, 2017
Ann Surg Int, Volume 3, Issue 1
http://crescopublications.org/pdf/ASI/ASI-3-040.pdf
Article Number: ASI-3-040

Research Open Access

# Impact of Operation Technique in Total Knee Arthroplasty (TKA): Gap Balancing versus Measured Resection

**René Hutter[1*], Vilijam Zdravkovic[2], Holger Grehn[1], Arno Frigg[1] and Heinz Bereiter[1]**

[1]Clinic for Orthopedic Surgery, Kantonsspital Graubünden, Chur, Switzerland
[2]Clinic for Orthopedic Surgery, Kantonsspital St. Gallen, Switzerland

***Corresponding Author:** René Hutter, MD, Clinic for Orthopedic Surgery, Kantonsspital Graubünden, CH-7000 Chur, Switzerland, Tel: +41 81 256 72 98; Fax: +41 81 256 66 62; E-mail: rene.hutter@ksgr.ch

**Citation:** René Hutter, Vilijam Zdravkovic, Holger Grehn, Arno Frigg and Heinz Bereiter (2017) Impact of Operation Technique in Total Knee Arthroplasty (TKA): Gap Balancing versus Measured Resection**.** Ann SurgInt 3: 040.


## Abstract

**Aim:** The objective of this study was to compare the outcome of measured resection technique and gap balancing technique in Total Knee Arthroplasty (TKA).

**Methods:** A total of 111 consecutive cases were included between 2009 and 2012. The measured resection technique was performed in group 1 (femur first technique, n=51, 32 women and 19 men) and the gap balancing technique in group 2 (tibia first technique, n=60, 39 women and 21 men). Range of motion, medial and lateral knee stability in extension, post-operative radiography, operative information, intra-operative surgical complications, need of revision surgery and functional knee scores (patient questionnaire score and Oxford Knee Score) were documented at 6 weeks and 1 year.

**Results:** There was no significant difference in operating time between the two groups (femur first: 114.8 min, range 90 to 150 min; tibia first: 115.7 min, range 75 to 206; p=0.83). At 6 weeks and 1-year follow-up group 1 and 2 showed no significant difference in the functional knee scores (patient questionnaire score p=0.43, Oxford Knee Score p=0.78). There was no significant difference in persisting anterior knee pain after one year (34% femur first group; 27% tibia first; p=0.443), and the 1-year results of flexion also showed no significant difference between the two groups (femur first group: 120.9°, range 90° to 145°; tibia first group: 121.02°, range 95° to 135°; p=0.94). Radiographic analysis at 1-year follow-up showed no significant difference in frontal axis malalignment (neither varus nor valgus) between the two groups. The mean inlay thickness was significantly thinner (p<0.001) in the tibia first group (10.37 mm, range 10 to 14 mm) than in the femur first group (11.22 mm, range 10 to 14 mm).

**Conclusion:** Measured resection and gap balancing techniques gave equal clinical and radiographic results after one year. The tibia first technique is more bone preserving and needs thinner inlays.

**Keywords:** Total Knee Arthroplasty; Measured resection technique; Gap balancing technique; Tibia first; Femur first; Femoral component rotation.

## Introduction

Precise soft tissue balancing combined with accurate bone resections determine the correct rotational alignment of the femoral component, with the goal of i) a symmetrical balanced joint in flexion and extension, and ii) stability over full arc or motion and therefore iii) restored normal knee kinematics and iv) improved functional outcome and patient satisfaction after total knee arthroplasty (TKA) [1 -3]. Femoral component malrotation has been associated with numerous adverse sequelae, including patellofemoral and tibiofemoral instability, knee pain, arthrofibrosis, and abnormal knee kinematics [4, 5].

There seems to be much confusion about the concept of 'rotation' of the femoral component. In fact, rotation of the femoral component should be considered an adapted and unnatural situation that arises because the transverse knee axis makes a mean angle of 87° with the mechanical axis of the tibia [6]. Coronal tibial cuts perpendicular to the mechanical axis of the tibia will produce a 3° asymmetrical resection of the tibia, which is compensated by a 3° asymmetrical resection of the distal femur to obtain neutral alignment. The same is true for the posterior condyles [7]. The asymmetrical tibial resection will result in a trapezoidal flexion space, which will be larger laterally. Thus a 3° external rotation of the femoral component is recommended to compensate for the lateral over-resection of the tibia [8]. This rotational adaptation is the main determinant of ligament balancing in flexion, load distribution in flexion, and the patellofemoral and tibiofemoral kinematics.

Controversy exists regarding the best surgical technique for obtaining a balanced flexion gap and a correct rotational alignment of the femoral component.

Many utilize a measured resection technique [9 - 13] in which bony landmarks (femoral epicondyles, anterior-posterior axis, posterior condylar axis) are used alone or in combination to determine femoral component rotation. The osseous referenced measured resection technique is also named femur first technique. Advocates of this technique recommend placement of the femoral component either parallel to the transepicondylar axis [9, 10, 12], perpendicular to the anteroposterior axis [13], or approximately 3° to 4° externally rotated relative to the posterior condylar axis [14]. A wide anatomic variation in the relationship of the posterior condylar axis to the transepicondylar axis (1-10°) [11, 12] must be taken into account.

Relying only on bone surfaces, the femur first technique has several disadvantages. For example, when applied to a valgus knee with hypoplastic lateral femoral condyles the resection will lead to an internal rotation of the femoral component in relation to the transepicondylar axis. Another major problem with the classical measured resection technique is the inconsistency between surgeons in intra-operatively locating the reference axis. It accounts for the wide range of post-operative rotational positions of the femoral component reported in the literature for this method [15].

These facts have led some authors to conclude that bony landmarks are unreliable and a standard 3° external rotation is not a good option in determining the optimal rotational position of the femoral component and should thus be considered an outdated technique [15].

Other authors recommend a gap balancing methodology in which the femoral component is positioned parallel to the resected proximal tibia with both collateral ligaments equally tensioned [15 - 18]. A problem with the gap balancing technique is that it does not take into account the natural laxity on the lateral side of the knee [19]. Applying equal tension to the medial and lateral collateral ligaments will cause more joint space opening on the lateral side, thereby creating a balanced but more externally rotated flexion gap [20]. This is especially evident in combination with a contraction situation on the medial side due to a persisting varus configuration. This external rotation will force the knee to shift to varus in flexion, thus causing overload on the medial side [21]. Furthermore, the tibia first technique depends on the surgeon's ability to make an accurate proximal tibial resection. A varus tibial cut will result in internal rotation of the femoral component and a valgus tibial cut in external rotation of the femoral component.

Many studies (Table 1) have compared the two surgical techniques with a focus on femoral rotation [22], mediolateral tibiofemoral stability tested by varus-valgus stress test [23] or indirectly by femoral condylar lift-off [1], and patient satisfaction [23, 24].

In summary there are many substantial errors that can occur when the femur first method (measured resection technique) is applied, and the review of the literature suggests that the tibia first technique (gap balancing) provides more reproducible flexion gaps and therefore rotational stability that improves functional performance and reduces polyethylene wear [25].

We therefore designed a study to compare the clinical and radiographic outcome of measured resection technique (femur first) versus gap balancing technique (tibia first) in TKA.

## Materials and Methods

### Patient characteristics

Patient characteristics are summarized in Table 2. 111 patients requiring TKA were enrolled in the study from 2009 through 02/2012. 51 patients were allocated to the femur-first technique and 60 patients to the tibial-first technique per surgeon's preference. There were 32 women and 19 men in the femur first group and 39 women and 21 men in the tibia first group. The mean age was 69 years (range 49 to 86) in the femur first and 71 years (50-88) in the tibia first group. The mean body mass index (BMI) was 29.3 kg/m2 (19.3 to 42.7) in the femur first and 28.9 kg/m2 (19.8 to 38.6) in the tibia first group ($p=0.67$). Pre-operatively the mean passive flexion in the femur first group was 116.9° (60 to 140) and 111.05° (70 to 140) in the tibia first group, which was significantly different ($p=0.047$).

Before surgery 34 of 51 patients in the femur first group (67%) and 53 of 60 in the tibia first group (88%) had anterior knee pain, which was significantly different ($p=0.0057$).

Varus and valgus deformity in the coronal plane was defined as more than 5° deviation from the physiological 6°. In the tibia first group 12 patients had valgus and 4 had varus alignment deformity. In the femur first group 11 patients had valgus- and 7 varus alignment deformity.

Pre-operatively there was no significant difference in the clinical subjective scores between the femur fist group and the tibia first group (patient questionnaire score p=0.45, Oxford Knee Score p=0.63).

Of the 114 patients three were lost to follow-up (two from the femur first group and one from the tibia first group). Two patients refused participation after six weeks. One patient died before the one year follow-up.

### Data collection

The patients had a clinical and radiographic assessment of range of motion (ROM) using a goniometer, pre-operatively and at six weeks and one year post-operatively. Flexion and extension, knee stability in sagittal plane and mediolateral stability under valgus-varus stress was assessed.

Radiographic assessment was undertaken pre-operatively and post-operatively at six weeks and one year by one author (RH) and included the anterior-posterior (AP) and lateral views of the knee as well as a long-leg weight-bearing view to assess leg alignment and axial view of the patella.

The subjective evaluation was based on the patient questionnaire score (Appendix 1) and Oxford Knee Score [26]. Each score was determined pre-operatively and at 6 weeks and one year follow-up.

Any intra-operative surgical complications and need of revision surgery in the follow-up were recorded.

### Operative technique

All operations were performed by the same four experienced surgeons (two performed the femur first technique and two performed the tibia first technique). NexGen® LPS-Flex Mobile (Zimmer®, Inc., Warsaw, Indiana, USA) was the used as total knee system, a posterior stabilized design with a mobile bearing inlay and cemented tibia and femur component fixation. Identical components were used for the two different techniques of implantation. Using the tibia first technique the femoral component rotation was determined from the flexion gap tension (gap balancing technique – ligament balancing). Using the femur first technique the femoral component rotation is determined from the osseous surface references of the femur, in our system 3° of external rotation in relation to the posterior condylar axis (measured resection technique – osseous referenced).

All patients received a standard medial parapatellar approach, three with an additional tuberositas osteotomy (all from the tibia first group). The posterior cruciate ligament was resected in all patients. An extramedullary alignment jig was used for the tibial osteotomy and an intramedullary jig for the femur. The arthrotomy and skin were then closed in layers. Drains were inserted intra-operatively and removed at day one or two. The post-operative rehabilitation program was identical in both groups with partial weight bearing of 20 kg for the first 6 weeks and no restrictions of the ROM.

### Statistical analyses

Data was recorded prospectively in case report forms and transcribed into an MS Excel worksheet. Radiographic assessment data were added to the worksheet. WinStat Statistic Package (V. 2007.1, R. Fitsch Software, Bad Krozingen, Germany) was used. To test for significance of difference we used t-test for numerical variables and chi-square test for categorical data. The level of significance was set to $p<0.05$. The statistical part of the study was performed by the biomedical statistician Vilijam Zdravkovic (Kantonsspital St. Gallen).

## Results

The results are summarized in Table 3. There was no significant difference in operating time between the two groups (femur first 114.8 min [90 to 150], tibia first 115.7 min [75 to 206], $p=0.83$). There was no significant difference in any of the clinical outcome scores at any review period in the two groups (patient questionnaire $p=0.43$, Oxford Knee Score $p=0.78$ at 1-year follow-up). The two clinical outcome scores are displayed in Figure 1 and Figure 2. At 1-year the mean patient questionnaire score and Oxford Knee Score had improved significantly compared with the pre-operative scores in both groups (tibia first, $p<0.001$; femur first, $p<0.001$). At 1-year follow-up in the femur first group 17 of 51 patients complained of persisting anterior knee pain (34%), and 16 of 60 in the tibia first group (27%), which was not significantly different ($p=0.443$). The mean range of flexion improved after one year in both groups from the pre-operative value in the femur first group from 116.9° (60° to 140°) to 120.9° (90° to 145°) ($p=0.042$) and in the tibia first group from 111.05° (70° to 140°) to 121.02° (95° to 135°) ($p<0.001$). The 1-year results of flexion showed no significant difference between the two groups ($p=0.94$). There was no significant difference between the two groups regarding the mediolateral stability in extension ($p=0.25$, Table 4). After one year 96% and 92% from the femur first and the tibia first group, respectively, were overall satisfied with the operation result. The mean inlay thickness was smaller in the tibia first group (10.37 mm [10 to 14]) than in the femur fist group (11.22 mm [10 to 14]), which was a significant difference ($p<0.001$). The radiographic analysis showed no significant difference in frontal axis malalignment (neither varus nor valgus) between the two groups. In the femur first group there was one each with varus and valgus malalignment and in the tibia first group there were two patients with varus malalignment and one with valgus malalignment in the frontal plane. Seven intra-operative complications occurred. One fracture of the medial femur condyl (from the tibia first group) which required internal fixation with screws. There were four partial ruptures of the medial collateral ligament, which were sutured (three from the femur first group and one from the tibia first group). One accidental resection of the anterolateral capsule (femur first group), which was covered with a Prolene® mesh. One partial avulsion of the patellar ligament required refixation (tibia first group). One patient from the femur first group needed revision surgery three months post-operatively with debridement, inlay exchange and mobilization due to a persisting extension deficit. One patient from the tibia first group needed a closed knee mobilization under anesthesia due to a flexion deficit. There were no cases of infection or wound dehiscence.

## Discussion

Measured resection and gap balancing are the two most common techniques for knee balancing. Each has its own advantages and disadvantages. Accurate and reproducible assessment of soft-tissue balance throughout the full ROM is paramount to achieving a well-balanced knee with improved longevity [16, 20, 22-24, 27].

We therefore asked whether the gap balancing technique can achieve better ligament balancing than the measured resection technique and whether it will lead to a better joint function, including patella tracking with less anterior knee pain, and a more balanced ligament tension with superior mechanical alignment and varus-valgus stability, and a higher patient satisfaction at short-term follow-up. We also hypothesized that with the tibia first technique thinner inlays can be used than with the femur first technique. Based on these findings a study was designed to compare the functional outcome scores, mechanical axis and clinical results including the ROM, mediolateral stability and inlay thickness in the femur first versus the tibia first group.

The study has several limitations. Patients were not completely randomized prior to surgery. The group assignment was surgeon's choice depending on personal preference of operation technique. The main difference between the two operation techniques is the different adjustment of the flexion gap and rotation of the femur component. Hence, one main issue that distinguishes between these two techniques is to determine the post-operative femur component rotation, e.g. with a post-operative CT-scan, which we did not perform in our series. The follow-up time of one year is short.

The study revealed no difference in the functional outcome scores and the radiographic analysis results of the mechanical axis. Pang et al. [28] reported better outcomes regarding the Knee Society Score (KSS) for function and the mechanical axis, and with less outliers, when the computer assisted gap balancing technique was used in comparison with the conventional measured resection technique. With their findings it remains unclear whether it was the navigation and/or the difference in the surgical technique that caused better outcome in the tibia first group. In the current study, both surgical techniques were performed conventionally and no difference was observed in the outcome scores and the mechanical axis. Becker et al. [23] performed the two different techniques with support by computer assisted surgery and found no difference in the clinical outcome and mechanical axis. Singh et al. [29] compared the two techniques both with computer navigation support and reported slightly better functional scores in the tibia first group, with values for the pre- and post-operative Oxford Knee Score quite similar to those of our study collective.

In the current study patients in both groups achieved a mean ROM of 121° flexion after TKA, despite the tibia first group having a slightly inferior pre-operative flexion (111° versus 117°, p=0.047). In modern prosthetic design one may expect a ROM of more than 120°, which was achieved in our collective, despite a mean BMI of 29 kg/m2. Previous studies have shown that patients with a higher BMI show lower function scores after TKA [30]. There are many other factors with a direct impact on the ROM after TKA, such as the relation between the flexion and extension gap that is influenced by the posterior condylar offset, the femoral rollback and the external rotation [31]. An increased posterior slope of the tibial component from 0° to 7° also has a significant impact on maximal knee flexion [32].

The current study focused on the medial and lateral knee stability in extension and showed no difference between the two groups. Biomechanical studies have shown that tibiofemoral loading during normal walking rises to three times the body weight [33]. Knee flexion during normal walking is limited to 15° and is reduced to 7°–10° after TKA [34]. Thus, one may presume that knee stability during walking is primarily important close to full knee extension as tested in the current study. Becker et al. [23] compared 63 TKAs with measured resection technique to 53 TKAs with gap balancing technique, all performed with computer assistance, and found equal medial-lateral stability with no radiographical differences in joint space opening in varus-valgus stress in extension. Also, Lee et al. [35] compared the medial and lateral extension gap with manual loading during surgery. They compared the conventional measured resection technique and the computer assisted gap balancing technique and found no difference in outcome. In the publication of Matsumoto et al. [24] the gap balancing technique showed slightly superior results in achieving an equalized rectangular gap compared to the femur first group (though not significant). There was, however, no significant difference in the post-operative ROM, KSS or Knee Society Functional Score (KSFS) at a minimum of two year follow-up. Dennis et al. [25] found a better coronal stability in the tibia first group, with less condylar lift-off in fluoroscopically analyzed deep knee bends. The authors believe that lift-off is a major factor in the long term polyethylene wear of TKAs as supported by the experimental work of Jennings et al. [36] using a physiologic knee simulator. In general, achieving a stable well balanced knee in the frontal plane is an important issue considering that an analysis of the histories of failure after TKA revealed 27–29% of early failures to have been caused by ligament instability [38], the second most common cause of failure after infection with 38% [37].

Many details affect the patellofemoral kinematics and may therefore cause anterior knee pain, e.g. patellofemoral maltracking and -overstuffing or malrotation of the tibia or femoral component. Some authors recommend a greater than the historical 3° external rotation of the femoral component to prevent the lateroventral overstuffing and therefore improve patellofemoral kinematics [39]. It is known that the gap balancing technique is associated with a tendency to incorporate more external rotation. Accordingly, better patellofemoral kinematics could be expected in our tibia first group. However, no significant difference in anterior knee pain was found between the two groups.

Our study shows that TKA bone loss was smaller and lead to an overall thinner polyethylene inlay in the tibia first group (10.37 mm inlay thickness), compared with the femur first group (11.22 mm inlay thickness, $p<0.001$).

With the tibia first method, each consecutive bone cut is built on and adapted to the previous one and so bone is maximally preserved. This may explain our findings. Compared with the femur first method, femur and tibia preparation is performed independently and a possible over-resection can finally be corrected with a thicker inlay.

## Conclusion

In our study no difference between the measured resection technique and gap balancing technique was found regarding the functional outcome scores, analysis of the mechanical axis and functional outcome in the clinical evaluation. We recommend that surgeons should use their preferred surgical technique. There is nevertheless a slight tendency with the gap balancing technique towards more bone preserving cuts with consequent thinner inlay use.

More research is needed with long-time follow-up to identify a preferred technique with the potential benefit of less wear in a symmetrical balanced joint and hence less aseptic loosening.

## References


1. **Scuderi GR**, Komistek RD, Dennis D a, Insall JN. The impact of femoral component rotational alignment on condylar lift-off. Clin Orthop Relat Res 2003; 148–54 [PMID: 12771825 DOI: 10.1097/01.blo.0000063603.67412.ca]

2. **Middleton FR**, Palmer SH. How accurate is Whiteside's line as a reference axis in total knee arthroplasty? Knee 2007; 14: 204–7 [PMID: 17428665 DOI: 10.1016/j.knee.2007.02.002]

3. **Whiteside L.** Soft tissue balancing: the knee. J Arthroplasty 2002; 17: 23–7 [PMID: 12068398 DOI: 10.1054/arth.2002.33264]

4. **Berger R,** Crossett LS, Jacobs JJ, Rubash HE. Malrotation causing patellofemoral complications after total knee arthroplasty. Clin Orthop Relat Res [Internet] 1998; 144–53 [PMID: 9917679 DOI: 10.1097/00003086-199811000-00021]

5. **Boldt JG,** Stiehl JB, Hodler J, Zanetti M, Munzinger U. Femoral component rotation and arthrofibrosis following mobile-bearing total knee arthroplasty. Int Orthop 2006; 30: 420–5 [PMID: 16521009 DOI: 10.1007/s00264-006-0085-z]

6. **Moreland JR**, Bassett LW, Hanker GJ. Radiographic analysis of the axial alignment of the lower extremity. J Bone Jt Surg Am [Internet] 1987; 69: 745–9 [PMID: 3597474]

7. **Romero J**, Duronio JF, Sohrabi A, Alexander N, MacWilliams BA, Jones LC, Hungerford DS. Varus and valgus flexion laxity of total knee alignment methods in loaded cadaveric knees. Clin Orthop Relat Res [Internet] 2002; 243–53 [PMID: 11795740]

8. **Worland RL**, Jessup DE, Vazquez-Vela Johnson G, Alemparte JA, Tanaka S, Rex FS, Keenan J. The effect of femoral component rotation and asymmetry in total knee replacements. Orthopedics 2002;25:1045–8 [PMID: 12401010]

9. **Berger R,** Rubash HE, Seel MJ, Thompson WH, Crossett LS. Determining the rotational alignment of the femoral component in total knee arthroplasty using the epicondylar axis. Clin Orthop Relat Res [Internet] 1993; 286: 40–7 [PMID: 8425366 DOI: 10.1097/00003086-199301000-00008]

10. **Griffin FM**, Math K, Scuderi GR, Insall JN, Poilvache PL. Anatomy of the epicondyles of the distal femur: MRI analysis of normal knees. J Arthroplasty 2000; 15: 354–9 [PMID: 10794232 DOI: 10.1016/s0883-5403(00)90739-3]

11. **Mantas JP**, Bloebaum RD, Skedros JG, Hofmann AA. Implications of reference axes used for rotational alignment of the femoral component in primary and revision knee arthroplasty. J Arthroplasty 1992; 7: 531–5 [PMID: 1479373 DOI: 10.1016/S0883-5403(06)80075-6]

12. **Poilvache PL**, Insall JN, Scuderi GR, Font-Rodriguez DE. Rotational landmarks and sizing of the distal femur in total knee arthroplasty. Clin Orthop Relat Res 1996; 35–46 [PMID: 8895617 DOI: 10.1097/00003086-199610000-00006]

13. **Whiteside L**, Arima J. The anteroposterior axis for femoral rotational alignment in valgus total knee arthroplasty. Clin Orthop Relat Res 1995; 77: 168–72 [PMID: 7497664]

14. **Nagamine R,** Miura H, Inoue Y, Urabe K, Matsuda S, Okamoto Y, Nishizawa M, Iwamoto Y. Reliability of the anteroposterior axis and the posterior condylar axis for determining rotational alignment of the femoral component in total knee arthroplasty. J Orthop Sci 1998; 3: 194–8 [PMID: 9662661 DOI: 10.1007/s007760050041]

15. **Benjamin J**. Determining femoral component position using CAS and measured resection. In: Clinical Orthopaedics and Related Research. 2008. page 2745–50

16. **Dennis DA**. Measured resection: an outdated technique in total knee arthroplasty. Orthopedics [Internet] 2008; 31: 940–3 [PMID: 18814622 DOI: 10.3928/01477447-20080901-08]

17. **Fehring TK**. Rotational malalignment of the femoral component in total knee arthroplasty. Clin Orthop Relat Res 2000;72–9 [PMID: 11064975]

18. **Katz M,** Beck TD, Silber JS, Seldes RM, Lotke P a. Determining femoral rotational alignment in total knee arthroplasty: reliability of techniques. J Arthroplasty 2001; 16: 301–5 [PMID: 11307126 DOI: 10.1054/arth.2001.21456]

19. **Whiteside LA**, Kasselt MR, Haynes DW. Varus-Valgus and Rotational Stability in Rotationally Unconstrained Total Knee Arthroplasty. Clin Orthop Relat Res 1985; 147–57 [PMID: 3581564]

20. **Heesterbeek PJC**, Jacobs WCH, Wymenga AB. Effects of the balanced gap technique on femoral component rotation in TKA. Clin Orthop Relat Res 2009; 467: 1015–22 [PMID: 18830793 DOI: 10.1007/s11999-008-0539-2]

21. **Hanada H,** Whiteside LA, Steiger J, Dyer P, Naito M. Bone landmarks are more reliable than tensioned gaps in TKA component alignment. Clin Orthop Relat Res [Internet] 2007; 462: 137–42 [PMID: 17563704 DOI: 10.1097/BLO.0b013e3180dc92e7]

22. **Luyckx T,** Peeters T, Vandenneucker H, Victor J, Bellemans J. Is adapted measured resection superior to gap balancing in determining femoral component rotation in total knee replacement? J Bone Joint Surg Br [Internet] 2012 [cited 2014 Jul 30]; 94: 1271–6 [PMID: 22933502 DOI: 10.1302/0301-620X.94B9.28670]

23. **Becker R,** Malzdorf M, Stärke C, Randolf P, Lohmann C. No difference between tibia-first and femur-first techniques in TKA using computer-assisted surgery. Knee Surg Sports Traumatol Arthrosc [Internet] 2012 [cited 2014 Jul 30]; 20: 2011–6 [PMID: 22366974 DOI: 10.1007/s00167-012-1928-3]

24. **Matsumoto T,** Muratsu H, Kawakami Y, Takayama K, Ishida K, Matsushita T, Akisue T, Nishida K, Kuroda R, Kurosaka M. Soft-tissue balancing in total knee arthroplasty: cruciate-retaining versus posterior-stabilised, and measured-resection versus gap technique. Int Orthop [Internet] 2014 [cited 2014 Jul 28]; 38: 531–7 [PMID: 24146174 DOI: 10.1007/s00264-013-2133-9]

25. **Dennis DA**, Komistek RD, Kim RH, Sharma A. Gap balancing versus measured resection technique for total knee arthroplasty. Clin Orthop Relat Res [Internet] 2010 [cited 2014 Jul 18]; 468: 102–7 [PMID: 19789934 DOI: 10.1007/s11999-009-1112-3]

26. **Dawson J**, Fitzpatrick R, Murray D, Carr A. Questionnaire on the perceptions of patients about total knee replacement. J Bone Joint Surg Br [Internet] 1998; 80: 63–9 [PMID: 9460955 DOI: http://dx.doi.org/10.1302/0301-620X.80B1.7859]

27. **Daines BK**, Dennis DA. Gap balancing vs. measured resection technique in total knee arthroplasty. Clin Orthop Surg [Internet] 2014; 6: 1–8 [PMID: 24605183 DOI: 10.4055/cios.2014.6.1.1]

28. **Pang HN**, Yeo SJ, Chong HC, Chin PL, Ong J, Lo NN. Computer-assisted gap balancing technique improves outcome in total knee arthroplasty, compared with conventional measured resection technique. Knee Surgery, Sport Traumatol Arthrosc 2011; 19: 1496–503 [PMID: 21448662 DOI: 10.1007/s00167-011-1483-3]

29. **Singh VK**, Varkey R, Trehan R, Kamat Y, Raghavan R, Adhikari A. Functional outcome after computer-assisted total knee arthroplasty using measured resection versus gap balancing techniques: a randomised controlled study. J Orthop Surg (Hong Kong) [Internet] 2012; 20: 344–7 [PMID: 23255643]

30. **Samson AJ**, Mercer GE, Campbell DG. Total knee replacement in the morbidly obese: A literature review. ANZ J Surg 2010; 80: 595–9 [PMID: 20840400 DOI: 10.1111/j.1445-2197.2010.05396.x]

31. **Victor J,** Bellemans J. Physiologic kinematics as a concept for better flexion in TKA. Clin Orthop Relat Res 2006; 53–8 [PMID: 16924173 DOI: 10.1097/01.blo.0000238792.36725.1e]

32. **Bellemans J**, Robijns F, Duerinckx J, Banks S, Vandenneucker H. The influence of tibial slope on maximal flexion after total knee arthroplasty. Knee Surgery, Sport Traumatol Arthrosc 2005; 13: 193–6 [PMID: 15824934 DOI: 10.1007/s00167-004-0557-x]

33. **Taylor WR**, Heller MO, Bergmann G, Duda GN. Tibio-femoral loading during human gait and stair climbing. J Orthop Res 2004; 22: 625–32 [PMID: 15099644 DOI: 10.1016/j.orthres.2003.09.003]

34. **Milner CE**. Is gait normal after total knee arthroplasty? Systematic review of the literature. J Orthop Sci [Internet] 2009; 14: 114–20 [PMID: 19214698 DOI: 10.1007/s00776-008-1285-8]

35. **Lee DH**, Park JH, Song DI, Padhy D, Jeong WK, Han SB. Accuracy of soft tissue balancing in TKA: Comparison between navigation-assisted gap balancing and conventional measured resection. Knee Surgery, Sport Traumatol Arthrosc 2010; 18: 381–7 [PMID: 19924399 DOI: 10.1007/s00167-009-0983-x]

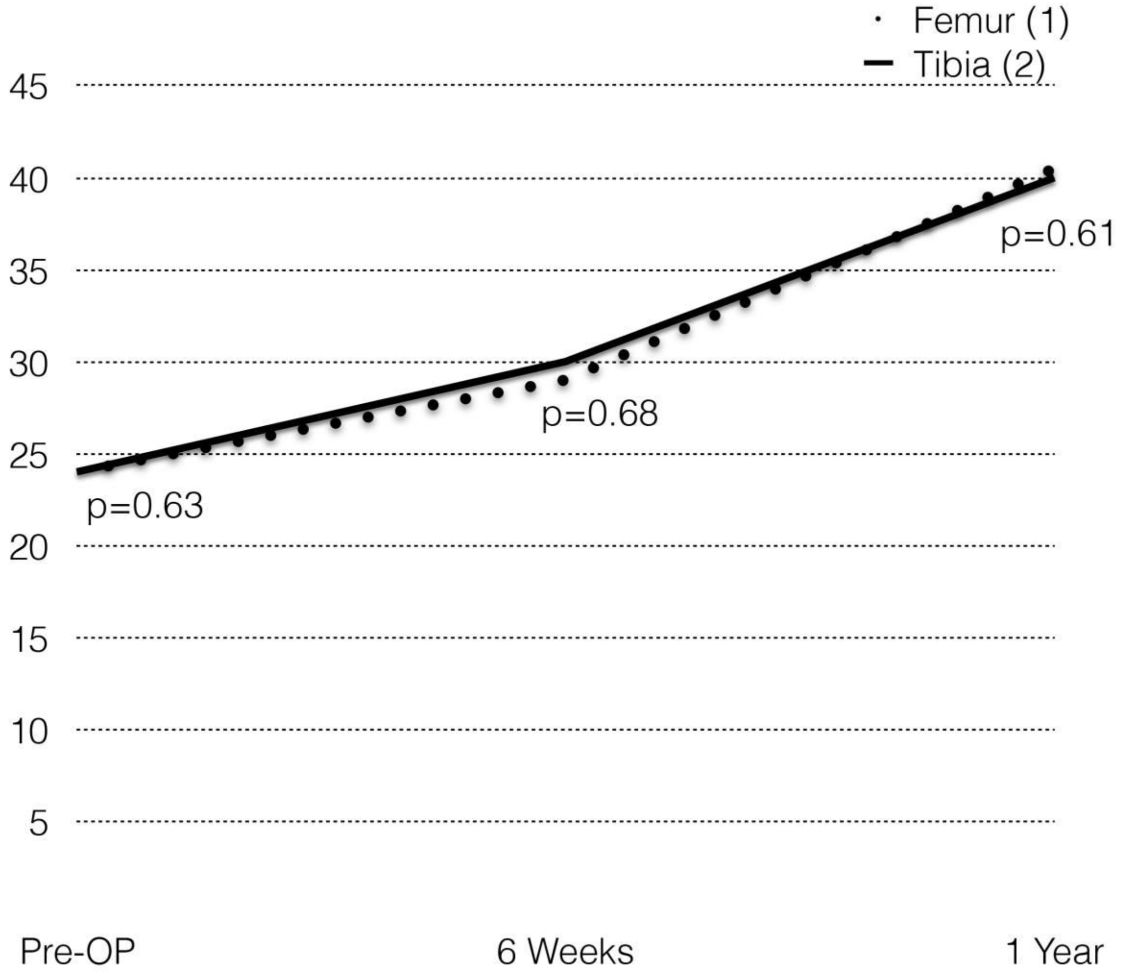
36. **Jennings LM**, Bell CJ, Ingham E, Komistek RD, Stone MH, Fisher J. The influence of femoral condylar lift-off on the wear of artificial knee joints. Proc Inst Mech Eng Part H J Eng Med [Internet] 2007; 221: 305–14 [PMID: 17539585 DOI: 10.1243/09544119jeim215]

37. **Fehring TK**, Odum S, Griffin WL, Mason JB, Nadaud M. Early failures in total knee arthroplasty. Clin Orthop Relat Res 2001; 315–8 [PMID: 11716402 DOI: 10.1097/00003086-200111000-00041]

38. **Mulhall KJ**, Ghomrawi HM, Scully S, Callaghan JJ, Saleh KJ. Current etiologies and modes of failure in total knee arthroplasty revision. Clin Orthop Relat Res 2006; 446: 45–50 [PMID: 16672871 DOI: 10.1097/01.blo.0000214421.21712.62]

39. **Keshmiri A**, Maderbacher G, Baier C, Zeman F, Grifka J, Springorum HR. Significant influence of rotational limb alignment parameters on patellar kinematics: an in vitro study. Knee Surgery, Sport Traumatol Arthrosc 2016; 24: 2407–14 [PMID: 25399346 DOI: 10.1007/s00167-014-3434-2]

**Figure 1:** The mean Oxford Knee Score over time in the femur first (•) and tibia first (—) groups. P-values are indicated for difference between groups.



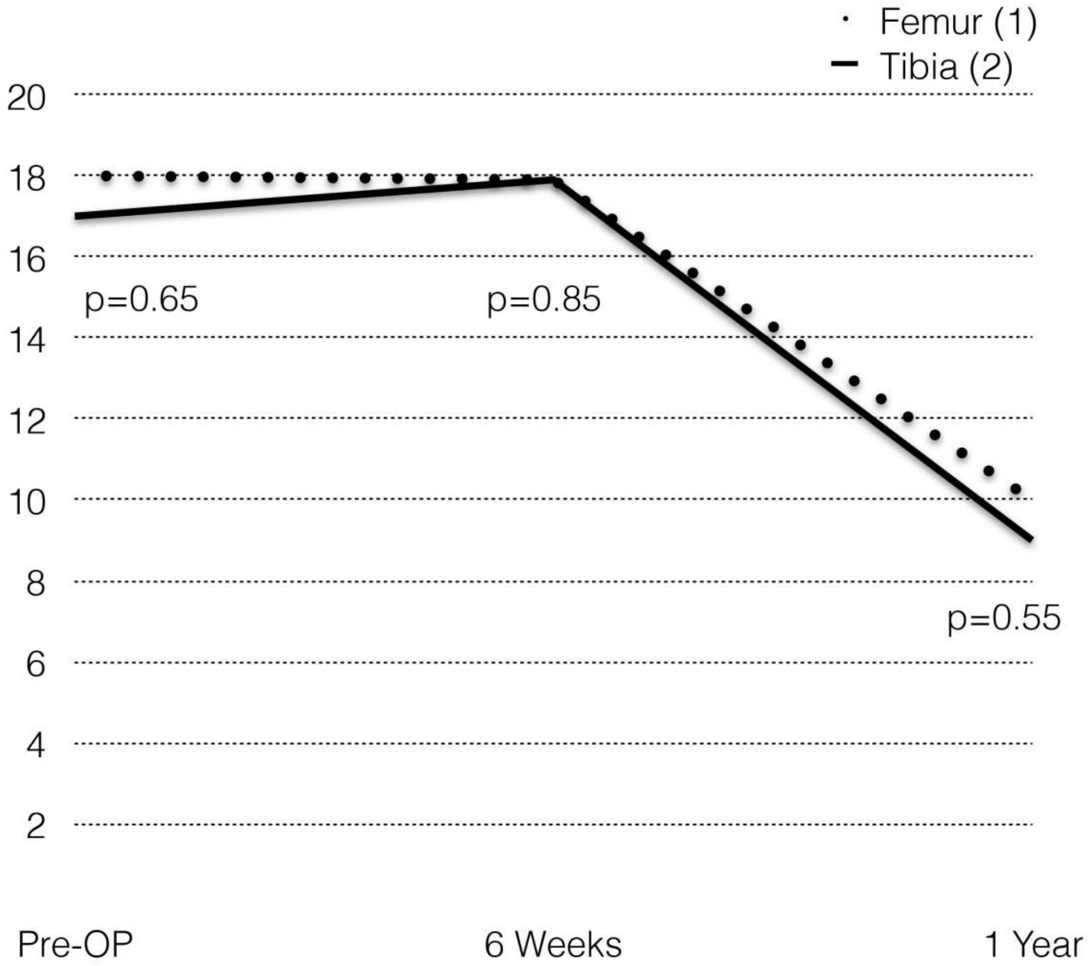



**Figure 2:** The mean patient questionnaire scores over time in the femur first (•) and tibia first (—) groups. P-Values are indicated for difference between groups.

**Table 1** Pertinent Literature

| Author | Patients (n) | Follow-up (months) | Results |
|---|---|---|---|
| Luyckx, 2012[22] | 96 total, 48 'adapted' measured resection, 48 gap balancing | – | No differences in femoral component rotation (Post-op CT), with tendency towards more external rotation in the tibia first group (not significant) |
| Becker, 2012 [23] | 116 total, 63 measured resection, 53 gap balancing | 11 | No differences in mediolateral joint space opening in varus-valgus stress radiographs. No differences in the clinical scores (KSS, KOOS, SF-36) |
| Dennis, 2010 [25] | 60 total, 40 measured resection (20 CR/20 PS), 20 gap balancing (all PS) | – | Better coronal stability in the tibia first group analyzed in the fluoroscopically deep knee bend (less condylar lift off) |
| Matsumoto,2014 [24] | 255 total, 120 measured resection (20 CR/100 PS) (conventional), 135 gap balancing (90 CR/45 PS) (computer assisted) | 24 | The gap balancing technique showed slightly superior results in achieving an equalized rectangular gap (but not significant) compared to the measured resection group in both CR and PS. No differences in the clinical scores (KSS, KSFS) and ROM |
| Singh, 2012[29] | 52 total, 26 measured resection (computer assisted), 26 gap balancing (computer assisted) | 24 | Clinical scores slightly better in the tibia first group (KSS, FKSS, ROKS) |
| Pang, 2011[28] | 140 total, 70 measured resection (conventional), 70 gap balancing (computer assisted) | 24 | Limb alignment and clinical scores better in the computer-assisted tibia first group |

KSS: Knee Society Score; FKSS: functional Knee Society Score; ROKS: revised Oxford Knee Score; KSFS: Knee Society Functional Score; KOOS: Knee Injury and Osteoarthritis Outcome Score; SF-36: Short Form 36 score; CR: crusciate-retaining; PS: posterior-stabilized; ROM: range of motion.

**Table 2** Patient characteristics

| | Measured resection (femur first group) | Gap balancing (tibia first group) | P-value |
|---|---|---|---|
| Number of knees | 51 | 60 | |
| Mean age (years) | 69 | 71 | 0.70 |
| Male:female ratio | 19:32 | 21:39 | 0.67 |
| Mean BMI (kg/m$^2$) | 29.3 | 28.9 | 0.67 |
| Flexion pre-op | 116.9 | 111.05 | 0.047 |
| Anterior knee pain pre-op | 34 (67%) | 53 (88%) | 0.0057 |
| Varus alignment pre-op* | 7 | 4 | 0.11 |
| Valgus alignment pre-op* | 11 | 12 | 0.13 |
| Oxford Knee Score pre-op | 24.3 | 23.7 | 0.63 |
| Patient questionnaire score pre-op | 17.39 | 18.12 | 0.45 |

*more than 5° deviation from the physiological 6° anatomical tibiofemoral angle

**Table 3:** Results by technique (group)

| | Measured resection (femur first group) | Gap balancing (tibia first group) | P-value |
|---|---|---|---|
| Operating time (min) | 114.8 | 115.7 | 0.83 |
| Mean flexion 1 year (flex pre-op) | 120.9° (116.9°) | 121° (111.05°) | 0.94 (<0.001) |
| Anterior knee pain 1 year | 17 (34%) | 16 (27%) | 0.443 |
| Oxford Knee Score 1 year | 40.2 | 39.4 | 0.61 |
| Patient questionnaire score 1 year | 8.8 | 9.38 | 0.43 |
| Varus malalignment post-op* | 1° | 2° | 0.45 |
| Valgus malalignment post-op* | 1° | 1° | 0.5 |
| Mean inlay thickness | 11.22 mm | 10.37 mm | <0.001 |

*more than 5° deviation from the physiological 6° anatomical tibiofemoral angle

**Table 4** Mediolateral stability

| | < 5mm | 6-9 mm | 10-14 mm | > 15 mm |
|---|---|---|---|---|
| **Femur first group (n=51)** | 40 | 11 | | |
| **Tibia first group (n=60)** | 50 | 8 | 2 | |

**Appendix 1:** Patient questionnaire score

International Knee Registry

# Patient Questionnaire

PLEASE COMPLETE ONE FORM PER OPERATIVE SIDE

**Form 4**

☐-☐-☐ Patient Initials (First-Middle-Last)

Case ID

Date of Surgery ☐☐-☐☐-☐☐☐☐ (DD-MM-YYYY)

Investigator ID

Operative Side ☐ Left ☐ Right

Visit Date ☐☐-☐☐-☐☐☐☐

Exam Period: ☐ Preop ☐ 2 Week ☐ 6 Week ☐ 3 Month ☐ 6 Month ☐ 1 Year ☐ 2 Year ☐ 3 Year ☐☐ Year

**1. Knee pain when you are walking?**

- ☐ None/Or you ignore it
- ☐ Mild/Occasional or intermittent
- ☐ Mild/Stairs only
- ☐ Mild/Stairs and level walking
- ☐ Moderate/Pain comes and goes
- ☐ Moderate/Pain each day
- ☐ Severe/Constant, disabling pain

**2. Knee pain when you are at rest?**

- ☐ None
- ☐ Moderate
- ☐ Mild
- ☐ Severe

**3. Do you need assistance in getting out of bed?**

- ☐ I can get out of bed on my own
- ☐ I need the assistance of another person

**4. How do you go up and down stairs?**

- ☐ Normally (one foot on each step)
- ☐ Normally but require use of the rail when going down
- ☐ Normally but require use of the rail when going up
- ☐ I require use of the rail while going up and down
- ☐ I can go up the stairs by using the rail but I am unable to go down
- ☐ I am unable to go up and down stairs

**5. Support when walking?**

- ☐ I walk without any support
- ☐ I use one cane when I go on a long walk
- ☐ I use one cane most of the time
- ☐ I use one crutch
- ☐ I use two canes
- ☐ I use two crutches
- ☐ I use a walker
- ☐ I am unable to walk

**6. How far can you walk without stopping?**

- ☐ I can walk unlimited distances
- ☐ I can walk more than 10 blocks (up to 1 mile / 2 km)
- ☐ I can walk 5-10 blocks (up to 1/2 mile / 1 km)
- ☐ I can walk less than 5 blocks (up to 1/2 km)
- ☐ I can only walk short distances within my home
- ☐ I am confined to a wheelchair or a bed

**POSTOP PATIENTS ONLY:**

**7. Is patient satisfied with the results of the knee replacement surgery?** ☐ Yes ☐ No

22UG-2006
Rev. 4

14334

Reset