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Intentional Femoral Component Flexion – A Method to Balance the Flexion-extension Gap in Navigated Total Knee Replacement

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Learning Point of the Article:

Intentional femoral component flexion is a method to balance the flexion and extension gaps in total knee replacement and also helps to restore sagittal diameter.

Abstract

Introduction: Flexion of the femoral component has been described as a theoretical possibility to balance flexion and extension gap. Computer navigation has made it possible to intentionally flex the femoral component in a controlled fashion to take advantage of the same.

Aim: The aim of this study was to assess whether intentional femoral component flexion is helpful in balancing flexion and extension gaps and in restoring sagittal diameter.

Materials and Methods: One hundred and forty-six total knee replacements performed in a navigated, gap-balanced, and tibia-first technique were included in this study. The femoral component flexion needed to equal flexion to extension gap was calculated based on the navigation data. The sagittal diameter, the anterior, and posterior offset were measured pre- and postoperatively based on the lateral radiographs. Flexion/extension gap differences pre- and postoperatively were analyzed. In addition, pre- and post-operative knee society scores were analyzed.

Results: To achieve equal flexion and extension gap, the femoral component was flexed in 95% of patients showing mean flexion of 3.6°. The sagittal diameter was restored in 89%; however, the anterior offset was significantly reduced by 1.3 mm, and the posterior offset was significantly increased by 1.6 mm. The average knee society score improved from 33 preoperatively to 88 postoperatively.

Conclusions: Flexion of the femoral component is indeed an option to balance flexion and extension gap and to restore sagittal diameter in navigated total knee replacement. At present, it is possible only in a navigated technique, but an addition instrument should be made available in the future to reap the benefits of the same in the conventional technique.

Keywords: Navigation, flexion and extension gaps, intentional flexion of femoral component, balanced TKR, sagittal diameter, gap balance, total knee replacement.

Introduction

One in five patients is not happy with the results of total knee replacement [1]. Probable causes of pain are instability [2]- due to unequal flexion and extension gap, failure to restore sagittal diameter resulting in over stuffing or flexion instability, failure to restore mediolateral diameter resulting in overhang or under hang, anterior femoral notching, and patellofemoral/extensor mechanism issues. Simulation studies have proven that theoretically, flexion of the femoral component is one solution to tackle all of the above issues [3, 4, 5]. Instability due to mismatch between flexion and extension gap is the most common cause for early failure of total knee replacement [6].

The most common scenario for instability is a loose flexion gap (flexion gap is more than extension gap) where the options available to the surgeon are, option one is to either up size the femoral component which in a posterior referencing system [7, 8, 9] it causes over stuffing of patellofemoral joint and results in anterior knee pain, in anterior referencing system up sizing

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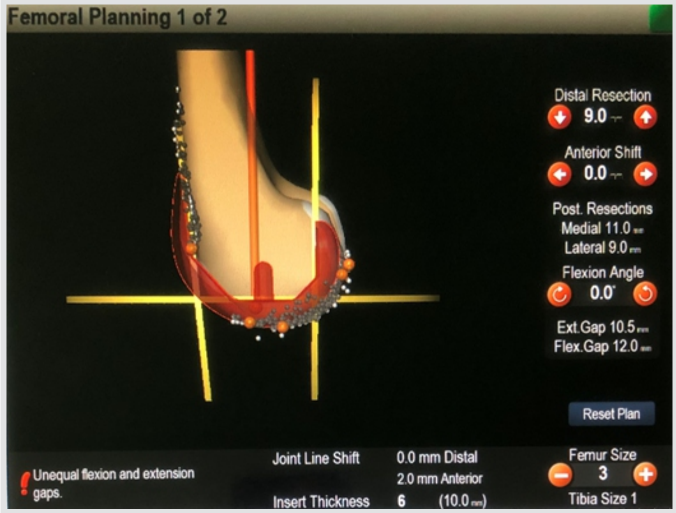

Figure 1: Navigation image of the femoral component planning. The size of the component matches the individual model of this patient knee well. Femoral component is placed at 0° of flexion. Please notice that the flexion gap is 12 mm being 1.5 mm larger than the extension gap and hence showing unequal flexion and extension gaps.

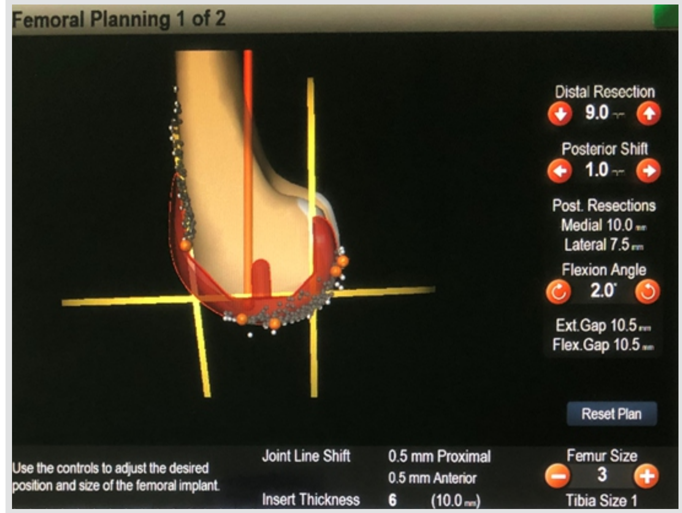

Figure 2: Same picture but after flexing the femoral component by 2°, with that the flexion gap is reduced to 10.5 mm equalizing the extension gap. The joint line is also restored exactly to <0.5 mm.

causes over stuffing of the flexion gap resulting in reduced range of movements and stiffness, in both systems increases mediolateral diameter resulting in overhang and causes irritation of capsule, Ilio-Tibial Band, collateral ligaments resulting in pain. In addition, need for posterior femur augments increases the cost to the patient. Option two is to posteriorize the femoral component, but it can result in femoral notching and can cause periprosthetic fracture. Option three is to increase extension gap too by cutting more distal femur and using thicker poly, but it results in joint line elevation and mid-flexion instability, especially in cruciate retaining knees where posterior cruciate ligament becomes lax or dysfunctions if the joint line becomes elevated [10]. We opted for option four of flexion of the femoral component, which has been proven theoretically in simulation studies [3, 4, 11] to reduce the flexion gap by 1 mm for every 2° flexion of the femoral component.

The purpose of this study was to analyze whether flexion of the femoral component is helpful in adjusting the flexion gap equal to the size of the extension gap, whether it is helpful in restoring the sagittal diameter by applying a navigated, gap balanced technique, how much flexion of the femoral component is ideal in Indian population and to find out the incidence of femoral notching.

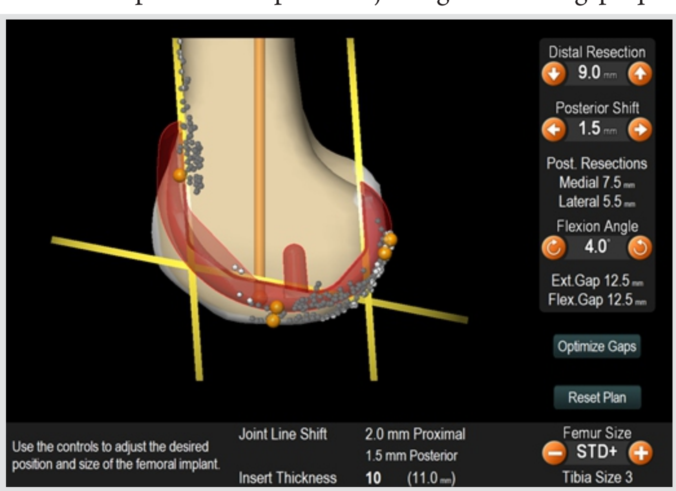

Figure 3: Shows another example of a flexion angle of 4° to equalize flexion and extension gaps.

Materials and Methods

Out of 331 patients who underwent TKA surgery in our hospital between June 2013 and December 2016, 146 TKR in patients were chosen randomly, independent of their clinical result based on the completeness of navigation protocols and register data with minimum 3 years follow-up.

Inclusion criteria were primary total knee replacement for tricompartmental osteoarthritis using Brainlab version 2.6 computer navigated, gap balanced, and tibial first cut technique and the exclusion criteria were limbs where an additional procedure such as an osteotomy was required or where navigation had to be abandoned midway due to any technical hitch.

Implantation was performed in a navigated, gap-balanced, and tibia-first technique by the same primary surgeon (RHG), and all surgeries were performed with the use of computer-assisted navigation using Brainlab version 2.6, Munich, Germany.

The group consisted of 66 female and 47 male patients aged between 50 and 82 (average 62 years), out of which 33 patients had bilateral total knee replacements. In 84 cases, the left side and 62 cases right side primary TKA were performed. One hundred and thirty-six of these knees were classified as varus (>3° of varus alignment) and ten as valgus knees (>3° of valgus alignment). The average varus was 9.77° and the average valgus was 12°. Implants used were Depuy LCS (112 TKR) and PFC Sigma Depuy USA (34 TKR). The minimum follow-up was 3 years after surgery. The mean ability of flexion preoperatively

Table 1: Navigation parameters of flexion and extension gap				
	Mean value±SD Preoperatively	Mean value±SD Postoperatively	Diff. preoperatively Postoperatively	P-value
Extension gap difference mediolateral	–1.2 mm±2.6	–0.3 mm±0.1	0.94 mm±2.5	<0.001
Flexion gap difference mediolateral	–2.3 mm±3	0.4 mm±1.4	–1.9 mm±3.4	<0.001
Extension/flexion gap difference medial	–1 mm±2.9	0.1 mm±1.9	–0.9 mm±3.2	<0.002
Extension/flexion gap difference lateral	–2 mm±3.1	0.5 mm±1.8	–1.5 mm±3.6	<0.001

was 108°.

Surgical technique

In all cases, a cruciate retaining cemented prosthesis was implanted. A standard medial parapatellar approach was used for all cases. A navigated, gap balanced tibia first technique was applied. In this setting, data of the initial and final leg alignment (varus/valgus angle) as well as an intraoperative range of motion (ROM) (flexion and extension angle) were obtained at the beginning and end of surgery. After the tibial cut, a spreader was applied to measure the extension gap medially and laterally. If an imbalance in extension was detected, a soft-tissue release was performed until medial and lateral gaps were equal. After that, the sizes of the medial and lateral flexion gaps were measured. Based on both gap information, a suggestion for the femoral component size and position was offered by the navigation system (Fig. 1). The surgeon then performed the individual, intraoperative planning, checking for femoral component size, femoral rotation, and joint line shift in distal and in anterior/posterior direction. Extension and flexion gap size, as well as the amount of posterior condyle resection, were taken into account. The aim was first to equalize the flexion and extension gaps. Further, the surgeon aimed to restore the sagittal femoral diameter based on the individual femoral model of each patient. As a second option for adjusting the flexion gap to the extension gap, the surgeon flexed the femoral component, with a maximum of up to 8° (Fig. 2). Based on the algorithm of the navigation system, flexion of the component is performed around the anterior cortical contact point of the femur and not around the epicondylar axis. The effect of component flexion on the flexion gap was immediately calculated and presented on-screen (Fig. 3).

Navigation data analysis

The following parameters were analyzed at the beginning of surgery and with the final implant in place varus/valgus angle, pre-operative and post-operative range of movements, amount of distal resection, anterior/posterior shift of femoral component, flexion angle of femoral component, flexion and extension gaps, joint line shift in distal/proximal/anterior/posterior direction, and insert thickness, according to the CAS software data were recorded.

Table 2: Discrepancy between flexion and extension gap		
Discrepancy between Flexion and extension gap of >2 mm	Preoperatively (%)	Postoperatively (%)
Medial	44 (65/146)	18 (26/146)
Lateral	54 (78/146)	21 (30/146)

Clinical analysis

Clinical outcome was assessed using knee society score [12]. Out of the clinical examination, in a particular ROM, pre and postoperatively was analyzed. Varus/ valgus stress tests and anterior drawer test done in 0°, 45°, and 90° flexion was examined to identify instability.

Radiological analysis

In all patients, standard weight-bearing anteroposterior and lateral view of knee joint pre and post-operatively obtained with a minimum of 6 times after surgery (immediate post-operative, 3 months, 6 months, 1 year, 2nd year, and 3rd year). All X-rays were digital X-ray allowing measurement of sagittal flexion of femoral component, which was measured between anterior femoral cortex and inferior aspect of the anterior surface of femoral component [6, 7]. Further, the anterior and posterior femoral offset was calculated according to Bellemans's et al. [13, 14].

Statistical analysis

IBM SPSS software Version 23.0 was used to analyze the statistical data. Outcome measures were assessed in two different ways. First, all alterations between the pre- and post-operative data (ROM, anatomical axis, anterior and posterior femoral offset, patellofemoral alignment, gaps, and joint line shift) were compared using paired t tests. A comparison of differences more or <2 mm pre- and postoperatively was made using the McNemar test. To test the probability of success (deviation <2 mm), we used an exact binomial test. Second, the differences of all the single collected data were correlated with the outcome (knee society score) and ROM in a nonparametric way using Spearman's Rho correlation coefficients. All analyses were done using a two-sided 0.05 level of significance and have not been adjusted for multiple testing.

Results

One hundred and twelve knees were implanted with LCS CR Depuy USA and 34 cases were implanted with PFC Sigma CR Depuy Orthopedics Inc USA. None of the patella were resurfaced.

The mean flexion of the femoral component in the sagittal plane measured by navigation intraoperatively varied between 0° and

8° (mean 3.6°). In 90% of patients (131 out of 146), the femoral component was flexed to equal the flexion and extension gaps. Of which, 69% of femoral components were flexed <5° and 31% were flexed >5°. In average, a femoral component flexion of 5° resulted in a flexion gap reduction of 4 mm, meaning that 1.6° changes the flexion gap by 1 mm. Comparing navigation data with radiographic measurements showed no significant difference. The mean was 3.6° ranging from 0° to 8° of femoral component flexion in the radiological analysis.

Flexion and extension gaps were balanced in 95% of cases with the maximum difference of 0.5 mm between flexion and extension gap.

Distal femoral resection ranged from 6.5 mm to 12 mm, with an average of 8.5 mm resection. The femoral component was shifted anteriorly or posteriorly by 0–4.5 mm with 85% posterior shift average being 1.2 mm. The poly thickness used was 8 mm in PFC and 10 mm in LCS in 94% of the total knee replacements.

The mean sagittal femoral diameter was restored in 95% (139/146) of cases with an alteration of <2 mm (P = not significant). In the remaining (7/146), the sagittal diameter showed an increase of more than 2 mm in four knees and was decreased by more than 2 mm in three knees.

The navigation data were analyzed and discrepancy between the extension and flexion gap on the medial side of more than 2 mm was found in 44 % (65 out of 146 patients) of knees preoperatively (Table 1). Postoperatively, this could be significantly reduced to 18 % (26 out of 146 patients) (P < 0.001) on the medial side. On the lateral side, it could be significantly reduced from 54% (78 out of 146 patients) preoperatively to 21% (30 out of 146) postoperatively (Table 2) (P < 0.001). The distal femoral joint line was restored within 2 mm deviance in 90% of cases (131 out of 146 knees). In anteroposterior direction, a small but significant posterior shift of 0.6 mm was measured, however, still showing in 76% (112 out of 146 knees) a joint line shift of <2 mm.

The amount of external femoral rotation showed an average value of 2.7°, referring to the posterior condylar plane.

The mean flexion was increased from 108° preoperatively to 118° postoperatively.

The mean pre-operative knee society score was 33.26 which improved significantly to 88.45 postoperatively after minimum 3 years follow-up.

Discussion

The most important findings of this study were that flexion of the femoral component is a helpful option to establish flexion-extension balance, flexion helps to restore the sagittal diameter in TKA, and increased flexion of the femoral component was required in Indian knees due to increased distal femoral bowing. This study could show that navigated, gap balanced technique is able to balance the extension gap of a primary TKA in more than 95% of cases within a 2 mm margin.

To achieve balance, the flexion of the femoral component was intentionally performed in more than 90% of cases, to adjust the flexion gap to the extension gap. With this technique in 87% of knees, the sagittal anatomy could be restored within 2 mm.

Flexion of the femoral component required to balance flexion and extension gap was >5° in 31% of the patients, which was a significant finding when comparing to other studies [7, 15], which showed 90% of flexion <5° in other populations. The reason for increased flexion required in Indian population may be due to increased femoral bowing in Indian population.

Flexing the femoral component increases the knee extensors moment arm and reduces the quadriceps and patellofemoral contact forces in posterior-referencing CR-TKA. There seems to be little risk associated with flexing the femoral component in a downsized implant, which could have advantages in terms of preventing mediolateral overhang and anterior notching and would result in similar patellofemoral forces and kinematics as in a neutrally-positioned upsized component [5].

Different authors [3, 4] have described in their models that a component flexion of around 2° leads to a reduction in flexion gap of around 1 mm. In this study, the femoral component was intentionally flexed in more than 90% of patients to reduce the flexion gap. Flexion ranged between 0° and 8°, showing a mean flexion of 3.6°, which was significantly more than other studies [15, 16]. In this study, a flexion of 1.6° lead to a flexion gap decrease of 1 mm, which is almost in the range of the above-mentioned studies.

The navigation technique has proven its technical precision [16, 17, 18]. The maximal difference is 0.5° and 0.5 mm for axis or distances. In this study, it was possible to confirm the advantage of computer navigation by achieving balance in flexion and extension gap in 95% of knees.

Different studies have described that the correlation between the radiological parameters and the clinical and subjective patient outcome is low [17]. In the presented work, the correlation between the radiological parameters, navigation data, and patient outcome (oxford score) was again low. One limitation of this study is the accuracy of the radiological analysis. Although defined positions were chosen and meticulously controlled, the reproducibility is described to be low.

Conclusions

Intentional flexion of the femoral component was required in more than 90% of primary TKA cases to achieve equal gaps in navigated gap balanced technique. At the same time, the sagittal diameter is also restored in 87% of patients. However, the posterior offset is significantly increased by 1.6 mm to achieve equal gaps, and the femoral component is flexed averagely by 3.6°.

Flexion of the femoral component required to balance flexion and extension gap was >5° in 31% of the patients, which was a significant finding when comparing to other studies [14, 15], which showed 90% of flexion <5° in other populations. The reason for increased flexion required in Indian population may be due to increased distal femoral bowing in Indian population. Research on the same is necessary.

Clinical Message

At present, intentional flexion of the femoral component is only possible in a navigated technique. In a conventional technique, an optional instrument should also be available to alter femoral component flexion to reap the benefits of the same. To evaluate the effect of this technique on the clinical outcome, future studies are needed.

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