

Does patella position influence ligament balancing in total knee arthroplasty?

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Abstract

Purpose In vivo comparative gap measurements were performed in three different patella positions (reduced, subluxated and everted) using offset-type-force-controlled-spreader-system.

Methods Prospectively, 50 knees were operated by total knee arthroplasty using a navigation-assisted gap-balancing technique. The offset-type-force-controlled-spreader-system was used for gap measurements. This commercially available instrument allows controllable tension in patella-reduced position. The mediolateral gaps of knee extension (0°) and flexion (90°) angle were recorded in three different patella positions; reduced, subluxated and everted. Any gap differences of more than 3 mm were considered as a meaningful difference. Correlation between the difference with the demographic data, preoperative radiologic alignment and intraoperative data was analysed. For statistical analysis, ANOVA and Pearson's correlation test were used.

Results The gaps in patella eversion demonstrated smaller gaps both in knee extension and flexion position compared to the gaps of patella reduction position. The amount of decreased gaps was more definite in knee flexion

position. Statistically significant difference was observed for the lateral gap of patella eversion compared to gap of patella reduction in knee flexion position ($p < 0.05$). There were notable cases of variability in knee flexion position. Significant portion of 12 (24 %) knees of patella subluxation and 33 (66 %) knees of patella eversion demonstrated either increased or decreased gaps in knee flexion position compared to the gaps of patella reduction position.

Conclusion The gaps in patella eversion demonstrated smaller gaps both in knee extension and flexion position compared to the gaps of patella reduction position. The amount of decreased gaps was more definite in knee flexion position. Therefore, the intraoperative patellar positioning has influence on the measurement of the joint gap. Keeping the patella in reduced position is important during gap balancing.

Level of evidence I.

Keywords Gap technique · Patella · Subluxated · Everted · Navigation · Total knee arthroplasty

Introduction

Successful outcome of total knee arthroplasty (TKA) is dependent on the accurate implant position, restoration of limb alignment and optimal ligament balancing [2, 6, 11, 25]. Gap balancing affects the final knee kinematics [10], and inadequate correction of soft tissue imbalance is considered an important factor for early TKA failure [7, 15, 21]. For optimum results, surgeons strive for equal and symmetric flexion and extension gaps flexion and extension gaps [28].

Whereas accurate bone cut and implantation can be achieved as a result of the development of guide devices

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such as computer-assisted navigation system [13, 22, 23], and a common difficulty with manually performed TKAs is obtaining accurate intraoperative soft tissue balancing, which surgeons traditionally address gaps through “subjective feel”. In particular, ideal gap balance per se has not been defined [9].

Various techniques and instruments for gap balance measurement or alignment have been suggested e.g. tension jigs, spacer blocks, laminar spreaders, trial components, electrical instruments and navigation systems [9, 19]. However, they can only be used with an everted or sublaxed patella orientation. Recent cadaveric studies have shown that patellar eversion causes increased valgus angle during soft tissue balancing in TKA [14] and significantly affects the mediolateral distribution of the tibiofemoral contact forces [5]. These studies suggest that assessing soft tissue balance in patella non-reduced position may be unphysiological and have poor relevancy with post-operative joint condition.

The aim of this study was to determine whether patella reduction is important during assessment of soft tissue balance in TKA. In vivo comparative gap measurements were performed in three different patella positions (reduced, sublaxed and everted) using an offset-type-force-controlled-spreader-system and computer navigation system. The hypothesis was that the lateral tibiofemoral gaps in patella non-reduced position would be smaller than in patella-reduced position.

Materials and methods

Fifty consecutive osteoarthritic knees (50 patients) were prospectively enrolled for intraoperative gap measurements between May 2012 and April 2013 at which time the study numbers were sufficient to satisfy the power calculation. The sample size was calculated to detect a significant difference in gaps of each medial and lateral gaps of knee joint flexion and extension position with power of 80 % with an α value of 0.05. All patients underwent unilateral TKA. The inclusion and exclusion criteria for this study are summarized in Table 1. The demographic and preoperative knee function characteristics of patients, as well as their knee deformities, are summarized in Table 2. The study protocol was approved by the Institutional Review Board of Veterans Health Service Medical Center and all included patients provided written informed consent.

Surgical technique and gap measurements

All surgeries were performed by single surgeon (JHY) using the navigation system (OrthoPilot™, version 4.0; B.

Table 1 The inclusion and exclusion criteria for this study

Inclusion criteria	Exclusion criteria
Primary osteoarthritis with substantial pain and loss of function	Valgus knees
Varus knees	Previous knee surgery requiring the removal of metallic implants
	Previous knee joint ligament injuries
	Rheumatoid arthritis
	Knee joint infection
	Revision TKAs
	Inability to put the patella in everted position

Table 2 Patient demographics, preoperative functional status and deformities

Male/female patients	4:46
Age (years) ^a	68 ± 2.1
Height (cm) ^a	169 ± 4.1 (males), 153 ± 4.2 (females)
Weight (kg) ^a	68 ± 3.1 (males), 53 ± 3.6 (females)
Preoperative flexion contracture (°) ^a	6.1 ± 5.2
Preoperative full flexion (°) ^a	129.6 ± 11.2
Preoperative mechanical axis angle (°) ^a	Varus -7.8 ± 4.1
Mechanical tibial angle (°) ^a	87.2 ± 3.6
Mechanical femoral angle (°) ^a	86.5 ± 3.4
Preoperative KSS scores ^a	51 ± 5.5
Preoperative WOMAC scores ^a	67 ± 4.6

KSS knee society score; WOMAC Western Ontario MacMaster

^a Mean ± standard deviation

Braun Aesculap, Tuttlingen, Germany). All patients were implanted with cemented type ultra-congruent fixed bearing design (Columbus™ UC, B. Braun Aesculap, Tuttlingen, Germany). None of the patients underwent patellar resurfacing.

All 50 knees underwent the same surgical approach consisting of a midline skin incision and a medial parapatellar approach under an air tourniquet at 250 mmHg. The patellar was sublaxed laterally and the tibia was sublaxed anteriorly. The anterior and posterior cruciate ligaments were sacrificed. The medial meniscus and the osteophytes were removed. The arrays of computer navigation system were set up by means of femoral tracker, mounted to a screw. Screws (1 each) were fixed to the medial aspect of femur and tibia, respectively. The kinematic and anatomic selected points were registered which are required for the system to identify hip, knee and ankle joint centres. After marking all the reference points, the limb alignment was checked by navigation system.

Fig. 1 The offset-type-force-controlled-spreader-system (B. Braun Aesculap, Tuttlingen, Germany). Notice the distractor of offset nature (*arrow 1*) allowing measuring the gaps in patella reduction position and the indicator at the end of spreader handle (*arrow 2*) where the desired amount of force can be applied

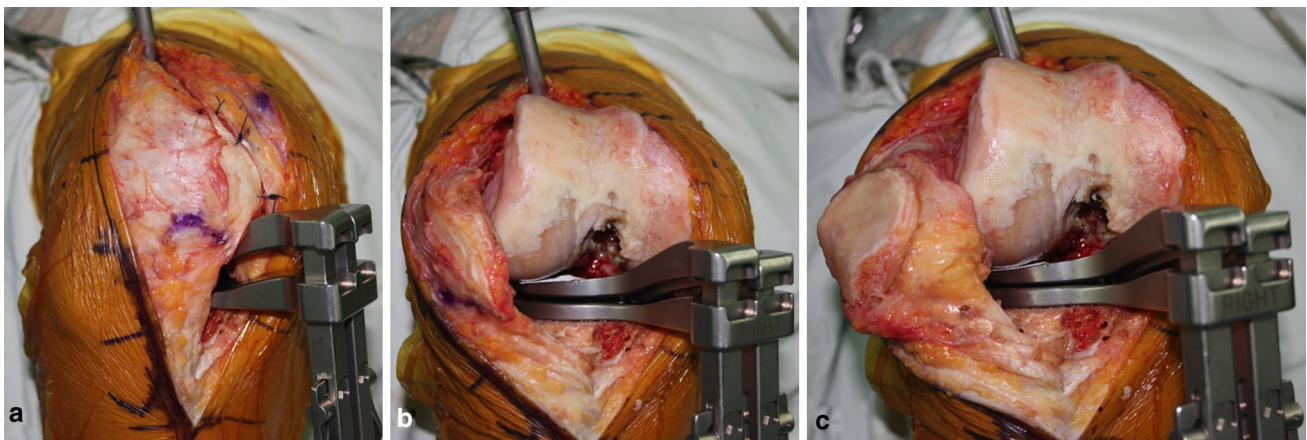


Fig. 2 The mediolateral gaps were measured with three different patella positions; **a** reduced, **b** subluxated and **c** everted for each case. *Rt. knee*

A tibial cut was made perpendicular to the long axis of tibia using a cutting block positioned under navigation guidance. Osteophytes on femoral posterior condyles were removed after cutting the proximal tibia. The offset-type-force-controlled-spreader-system (B. Braun Aesculap, Tuttlingen, Germany) (Fig. 1) was inserted to the tibio-femoral gap at full extension position to identify the overall mechanical alignment. If the alignment was not within 2° from neutral axis, soft tissue release was done accordingly. Once the alignment was within 2° from neutral axis, the mediolateral gaps were measured with three different patella positions; reduced, subluxated and everted for each case (Fig. 2). The mediolateral gaps were measured at full extension (0°) and at 90° of knee flexion. The distraction device used in this study allows measuring the gaps in patella-reduced position with the desired amount of force. The distraction force of the spreader system was set at 150 N. This amount of force was chosen on the basis of previous study regarding intraoperative gap measurements during surgery [17, 24].

The mediolateral extension and flexion gaps were recorded in millimetres by the navigation system and each measurement was done twice and averaged. In previous studies assessing the intraoperative gap measurements during TKA, a difference of 2 or 3 mm in the measurements has been regarded as being clinically relevant [8, 16, 17]. Therefore, any gap difference of more than 3 mm was considered a meaningful value.

Since this navigation system provides the data from registered point of posterior femoral condyles, the relative femoral component rotation position is provided from the posterior condylar axis. Proceeding further, to balance the discrepancies between medial and lateral gaps at 90° of knee flexion, femoral rotation was adjusted to equalize flexion gaps, rotated such that the posterior condyles of the prosthetic femur are parallel to the tibia. However, if the femoral component rotation was beyond 0° – 6° , that is less than -1° or more than 7° , from the posterior condylar axis, further release of the soft tissues were performed. The anteroposterior translation of the femoral component was

adjusted to yield equalized flexion–extension gaps. Once the level and the position of the femoral component have been decided, distal femoral bone cutting was performed. After confirming the distal cut level and the alignment by navigation system, the chamfer cut guide was placed as planned. The remaining femoral bone cuts including the posterior condyles were then performed.

Data about levels of distal and posterior femoral cuts and amount of femoral component rotations were recorded from the navigation system. The estimated joint line was calculated by subtracting the thickness of the resected tibia bone from the thickness of the polyethylene insert. The lowest point of lateral tibia plateau is registered during the initial steps, and the thickness of the lateral part of proximal tibia bone resection could be identified from the monitor of the navigation system. The values were considered as positive if the joint line moved proximally (that is, closer to the hip) and negative if the joint line moved distally (that is, closer to the ankle) [27].

Clinical and radiologic evaluation

Symptom severity was assessed at 3, 6 and 12 months and thereafter until last follow-up using the knee society score (KSS) [12] and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) score [3]. Mechanical limb alignment was checked using a standing radiograph of the entire lower extremity at each follow-up visit. Passive maximum knee range of motion (ROM) was measured using a goniometer. At these evaluations, assessments were performed by a physician assistant not directly involved in the surgical procedures. A KSS of 90 points was considered an excellent outcome, a score between 80 and 89 points was considered a good outcome, a score between 70 and 79 points was considered a fair outcome and a score of less than 70 points was considered a poor outcome. The WOMAC system involves the completion of a twenty-four item questionnaire with three sections, namely pain, stiffness and function [3]. Five response options are possible (none, mild, moderate, severe and extreme), which are scored from 0 to 4 to yield subtotal scores for pain (five items; possible total score range, 0–20), stiffness (2 items; possible score range, 0–8) and function (17 items; possible score range, 0–68).

Statistical analysis

The arithmetic mean, standard deviation and the distribution of values were determined for each gap measurements in the three patella positions. Comparison in each group was done with analysis of variance (ANOVA), Chi square analysis and the two-tailed Student's *t* test. The gaps which demonstrated meaningful difference (more than 3 mm

difference) from the gaps measured in patella reduction position were further analysed with the preoperative demographic and radiologic data using the Pearson's correlation analysis. Intraoperative obtained data (joint line change, femoral component rotation, distal femoral cut thickness, posterior femoral cut thickness of medial condyle, posterior femoral cut thickness of lateral condyle) were also correlated. Correlation coefficient (*r*) ranges from -1 (negative correlation) to $+1$ (positive correlation). If $p < 0.05$ and $0.1 < r < 0.3$, there is a weak correlation between the two variables; if $0.3 < r < 0.7$, there is good correlation; and if $0.7 < r < 1$, there is strong correlation. The Statistical Package for Social Science Version 10.1 (SPSS Inc., Chicago, IL, USA) was used for all analysis, and *p* value < 0.05 was considered statistically significant.

Results

The mean and standard deviations for each gap measurement in three different patella positions are demonstrated in Table 3. The gaps in patella eversion demonstrated smaller gaps both in knee extension and flexion position compared to the gaps of patella reduction position. The amount of decreased gaps was more definite in knee flexion position. Statistically significant difference was observed only for the lateral gap of patella eversion compared to gap of patella reduction in knee flexion position ($p < 0.05$).

The cases of meaningfully different gaps (more than 3 mm) compared to the gaps of patella reduction are demonstrated in Table 4. There were notable cases of variability in knee flexion position. During patella subluxation, there were two (4 %) cases of medial and three (6 %) cases of lateral gaps increased compared to the gaps of patella reduction. Three (6 %) cases of medial and four (8 %) cases of lateral gaps were decreased. In patella eversion position, there were six (12 %) cases of medial and seven (14 %) cases of lateral gaps increased compared

Table 3 Results of distraction gap of each compartment

	Patella reduction	Patella subluxation	Patella eversion
Knee extension (0°)			
Medial gap	11 ± 2	12 ± 2	10 ± 2
Lateral gap	12 ± 2	12 ± 2	12 ± 2
Knee flexion (90°)			
Medial gap	12 ± 1	12 ± 2	11 ± 2
Lateral gap	15 ± 3	13 ± 2	11 ± 3*

Mean ± standard deviation

* The bolded numbers are those with $p < 0.05$ (eversion vs. reduction) significance

Table 4 Cases (%) of meaningfully different gaps (more than 3 mm difference) compared to the gap measurements in patella reduction position

	Patella subluxation	Patella eversion
Knee extension (0°)		
Medial gap	None observed	None observed
Lateral gap	None observed	None observed
Knee flexion (90°)		
Medial gap	2 (4 %) Cases increased 3 (6 %) Cases decreased	6 (12 %) Cases increased 10 (20 %) Cases decreased
Lateral gap	3 (6 %) Cases increased 4 (8 %) Cases decreased	7 (14 %) Cases increased 10 (20 %) Cases decreased

to the gaps of patella reduction. Ten (20 %) cases of medial and 10 (20 %) cases of lateral gaps were decreased.

There were few weak correlations between the incidences of cases with meaningfully different gaps (more than 3 mm difference) compared to the gaps measured in patella reduction position. Weak correlations were observed for preoperative demographic parameters such as height, weight and body mass index. Mechanical tibial angle and joint line

elevation also demonstrated weak correlations. The statistically significant factors are demonstrated in Table 5.

The mean preoperative KSS improved from 51 ± 5.5 to 91 ± 1.0 at latest follow-up. The mean preoperative WOMAC score improved from 67 ± 4.6 to 27 ± 1.0 at latest follow-up. The mean preoperative mechanical axis was $-7.8^\circ \pm 4.1^\circ$. All knees were in varus alignment. The mean postoperative mechanical axis was $0.5^\circ \pm 2.5^\circ$. The mean patella tilt was $1.8^\circ \pm 5.3^\circ$. All patients demonstrated neutral patella tracking position. No patient demonstrated patella alta or baja. There were no other minor or major complications.

Discussion

The most important finding of the present study is that the gaps in patella eversion demonstrated smaller gaps both in knee extension and flexion position compared to the gaps of patella reduction position. The amount of decreased gaps was more definite in knee flexion position. Statistically significant difference was observed only for the lateral gap

Table 5 Significant correlations between the meaningfully different gaps (more than 3 mm difference compared to the gaps measured in patella reduction position) were patient height, weight and body mass index as well as mechanical tibial angle and joint line elevation

Parameters	Patella subluxation				Patella eversion			
	Increased F–M gap	Decreased F–M gap	Increased F–L gap	Decreased F–L gap	Increased F–M gap	Decreased F–M gap	Increased F–L gap	Decreased F–L gap
<i>Preoperative demographics</i>								
Age	0.02	0.05	0.18	0.10	0.15	0.16	0.11	0.22
Gender	0.21	0.21	0.12	0.02	0.17	0.15	0.05	0.21
Height	0.04	0.15	0.16	0.20*	0.02	0.13	0.15	0.18
Weight	0.10	0.13	0.14	0.04	0.20*	0.02	0.11	0.16
Body mass index	0.19	0.16	0.20	0.11	0.18	0.07	0.15*	0.01
Preoperative flexion contracture (°)	0.13	0.12	0.24	0.24	0.19	0.05	0.01	0.23
Preoperative full flexion (°)	0.11	0.11	0.03	0.23	0.27	0.22	0.15	0.22
<i>Radiologic parameters</i>								
Preoperative mechanical axis angle	0.21	0.29	0.21	0.24	0.07	0.01	0.09	0.04
Mechanical tibial angle	0.21	0.04	0.05	0.25	0.15*	0.17	0.14	0.30
Mechanical femoral angle	0.14	0.19	0.21	0.08	0.21	0.05	0.23	0.05
<i>Intraoperative parameters</i>								
Joint line elevation	0.16	0.14	0.18	0.10	0.14	0.01	0.11*	0.06
Rotation of femoral component	0.13	0.07	0.12	0.21	0.22	0.13	0.13	0.19
Distal femoral cut thickness	0.18	0.11	0.03	0.32	0.21	0.12	0.06	0.21
Posterior femoral cut thickness (medial condyle)	0.19	0.13	0.12	0.13	0.05	0.12	0.13	0.21
Posterior femoral cut thickness (lateral condyle)	0.22	0.07	0.12	0.03	0.24	0.19	0.07	0.14

Significant parameters demonstrating weak correlation ($0.1 < r < 0.3$) are marked in bold

F–M flexion–medial, F–L flexion–lateral

* $p < 0.05$

of patella eversion compared to gap of patella reduction in knee flexion position ($p < 0.05$). One other finding was that significant portion; 12 (24 %) cases of patella subluxation and 33 (66 %) cases of patella eversion demonstrated either increased or decreased gaps in knee flexion position compared from the gaps of patella reduction position. Therefore, placing the patella in reduced position is important during gap measurements in TKA.

The results of this study support the hypotheses that patellar positioning has influence on the intraoperative joint gap measurement. Patellar eversion decreased the lateral joint gap more than medial joint gap, both in knee extension and flexion. These effects could be attributed to the lateral shift and external rotation of the tibia with patella eversion [14]. This was also supported by prior studies demonstrating that patellar eversion increases the valgus alignment of the knee during soft tissue balancing with a tensor device [14, 20]. These effects were greater in knee flexion, which is also supported by a previous study using intact cadaveric knees that showed that patella eversion decreases the flexion gap [18]. This may also be explained by the fact that the projected vector of the patellar tendon after patella eversion is more vertical and therefore more parallel to the tibial axis in the sagittal plane in extension.

Everting the patella is known with negative impact to clinical outcome after TKA. Bonutti et al. [4] noted the 20 % increased tension in quadriceps tendon. Walter et al. [26] described the detrimental effects of patellar eversion on the short-term outcome on the quadriceps strength in TKA. It has been assumed that traction on the extensor mechanism in combination with excessive hyperflexion of the knee can lead to micro-trauma in the extensor mechanism. These micro-traumas can cause subsequent fibrosis of the quadriceps and patellar tendon. Moreover, from this study, patella-everted group demonstrated much more gap difference from the patellar-reduced/subluxated group. It can be recommended not to evert the patella during TKA.

Proper soft tissue balance is one of the keys of long-term success in TKA [21]. For this purpose, recent commercially available tensor has been used for this study. The offset-type-force-controlled-spreader-system allows measuring the gaps in reduced patellar position with the desired amount of force. Most other tensor systems have been used only in patella subluxated or everted positions, which neglects the force through the patello-femoral joint from the extensor mechanism. Soft tissue balance in patella-reduced position is important in clinical setting, and further investigation should be done for intraoperative soft tissue balancing and clinical outcomes.

In the literature, there is a general lack of references to physiologic data on tibiofemoral gap tensions. The force that should be applied to generate the gaps is unclear. Asano et al. [1] consider 80–160 N a suitable distraction

force. Luring et al. [14] used 150 N for extension as well as 90 N per side for flexion. Matsumoto et al. [17] establish that 40 lb (≈ 178 N) of joint distraction force correspond most closely to the insert thickness in the preliminary clinical study. Based on these studies, the distraction force to measure the gaps in this study was set to 150 N.

Limitations of the study should be noted. First, all patients were in varus alignment with majority of patients were females. This fact could have a bias in analyzing the results. Second, the tourniquet was inflated throughout surgery under anaesthesia. The application of tourniquet may have influence in quadriceps extensor mechanism affecting the tibiofemoral gaps. However, these effects were not evaluated. Third, during flexion gap measurements, the knee was flexed to 90° with gentle holding of the thigh to minimize the effect of thigh weight. This variable-holding power had not been considered. And lastly, since there is general lack of references to physiologic data on intraoperative gap tensions, the measured gaps may not represent the state of knee after TKA, thereby having limitations to apply clinically.

Conclusion

The gaps in patella eversion demonstrated smaller gaps both in knee extension and flexion position compared to the gaps of patella reduction position. The amount of decreased gaps was more definite in knee flexion position. Therefore, the intraoperative patellar positioning has influence on the measurement of the joint gap. Keeping the patella in reduced position is important during gap balancing.

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