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Title

Preoperative varus deformity of the knee affects the intraoperative joint gap in unicompartmental knee arthroplasty

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Abstract

Background

It is generally believed that contraction of the soft tissue structures on the medial side may occur in the knee with severe varus deformity. However, the relationship between the severity of varus deformity of the knee and the intraoperative soft tissue balance in unicompartmental knee arthroplasty (UKA) has not been well reported thus far.

Methods

One hundred and three consecutive medial UKAs were enrolled. After the femoral trial prosthesis was placed, the component gap was measured at 10° (extension) and 120° (flexion) of flexion using a UKA tensor. The pre-osteotomy gap was then calculated from the thickness of the bone cut. Paired Student's t-test was used to compare the component gap, as well as the pre-osteotomy gap, in extension and those in flexion. The relationship between the preoperative Hip-Knee-Ankle (HKA) angle and the pre-osteotomy gap was analysed using Pearson's correlation coefficient and simple linear regression analysis.

Results

The component gap in extension was significantly smaller than that in flexion while the pre-osteotomy gap in extension was significantly wider than that in flexion. There was a positive correlation between the severity of varus deformation in preoperative knee and the pre-osteotomy gap in extension, while there was no correlation between the preoperative HKA angle and the pre-osteotomy gap in flexion.

Conclusions

The tension of the medial tightness does not correlate with the degree of preoperative varus deformity in UKA.

Keywords

Unicompartmental knee arthroplasty; varus deformity; intraoperative joint gap; soft-tissue balance; medial stability

1. Introduction

Osteoarthritis is the most common degenerative disease of the joint that affects a large part of the elderly population [1]. In case osteoarthritis is limited to a single compartment of the knee joint, usually the medial compartment, unicompartmental knee arthroplasty (UKA) can be a good option to obtain joint function and relieve knee pain [2]. Theoretically, UKA has some advantages over total knee arthroplasty (TKA), which is considered to be a technically well-established procedure in the treatment of end-stage degenerative joint disease or deformity of the knee over the past 30 years. UKA can preserve the bone stock and the patellofemoral compartments as well as the cruciate ligaments and natural knee kinematics [3], and has been reported to promote faster recovery [4] than TKA.

Although the results of UKA used to be disappointing with revision rates of up to 30% at 5–7 years in the 1970s [5,6], advances in implant design and surgical technique have generated promising survivorship statistics recently. The results of UKA at 10 years are approaching those reported for TKA [7], e.g., a systematic review revealed that the survival rate after medial UKA improved to 93.9% at 5 years, 91.7% at 10 years, 88.9% at 15 years, and 84.7% at 20 years [8]. On the other hand, other studies have shown that UKA survival does not match that of TKA despite current progress in the surgical procedure or implant design [9-11]. In terms of surgical technique, alignment and soft-tissue balance are considered to be essential in UKA for better clinical outcomes and implant survivorship [12-14], as aseptic loosening is the most common reason for failure in the early postoperative period and the progression of lateral osteoarthritis is the most common reason for failure in the midterm and late periods [15].

Knees with limited preoperative varus deformation are considered to have an unaltered soft tissue envelope. However, it can be different in cases where the preoperative varus deformity is more advanced, since it is generally believed that the deformity itself has induced an abnormality in the soft tissue envelope of the knee [16, 17]. Thus, many knee surgeons believe that progressive shortening or contraction of the soft tissue structures on the medial side may occur in the knee with severe varus deformity [17-20]. However, to our knowledge, the relationship between the preoperative alignment of the knee, i.e., the severity of varus deformity of the knee, and the intraoperative soft tissue balance in UKA has not been well reported thus far and little or no data exist on the matter.

Aim of this study is to provide a detailed interpretation of the relationship between the preoperative alignment of the lower extremity and the intraoperative joint gap in patients undergoing UKA. Our hypothesis is that patients with severe varus deformation of the knee showed a narrower intraoperative joint gap.

2. Materials and Methods

The hospital ethics committee approved the study protocol (No. 1510, Data of Approval: 02 Dec 2013), and informed consent was obtained from all patients. One hundred and three consecutive patients were prospectively enrolled and underwent medial UKA using the Persona Partial Knee System (Zimmer Biomet inc., Warsaw, IN, USA) from September 2017 to August 2019. The inclusion criteria for UKA were a radiographic diagnosis of isolated medial compartment osteoarthritis or idiopathic osteonecrosis with an active ROM of > 90°, a fixed flexion deformity of < 10°, and a varus deformity of < 15°. Magnetic resonance imaging (MRI) was performed for all the cases before surgery and the cases without the intact anterior cruciate ligament (ACL) and articular surface of the lateral compartment were excluded from the study. As a result, no case was excluded and a total of 103 UKAs were finally included in the study. Three senior doctors, each with > 15 years of experience, performed the surgery.

After inflating the tourniquet to 250 mmHg, a mini-medial parapatellar approach was performed. Following the macroscopic observation of an intact ACL, the articular surface of the lateral and patellofemoral compartments, the minimal soft tissue release of the medial structures as well as the osteophyte removal was performed. A proximal tibial osteotomy was then performed using an accelerometer-based portable navigation system (OrthAlign Plus®, UniAlign™; OrthAlign Inc., Aliso Viejo, CA, USA), which helps the surgeon to precisely perform tibial osteotomy in UKA with coronal and sagittal alignment. It provides measurement accuracy of ± 0.5° when measuring the angle between the OrthAlign Plus® unit and the reference sensor (manufacturer's data). We examined the accuracy of tibial implant alignment using this system in UKA and reported that it decreased the outliers of tibial coronal and sagittal alignment [21].

The target value of preoperative planning in coronal alignment was set to 1.0° in varus and that in sagittal alignment was set with reference to the original slope. The original posterior tibial slope was measured with reference to the perpendicular line of the sagittal axis, which was defined as the line connecting the anterior one-third of the medial tibial plateau and midpoints of the tibial plafond. The mean posterior tibial slope was 7.4 ± 1.0° (range, 6.0°–10.0°). The sagittal alignment was set to 6.0° and 8.0° when the angle was ≤ 6.0° and ≥ 8.0°, respectively, and the target value was set as the target value of preoperative planning therebetween. Following the tibial osteotomy, a distal femoral osteotomy was performed with spacer block methods referring to the surface of the proximal tibial cut. The femoral rotation was carefully adjusted to the mechanical axis of the tibia, and the remaining (posterior and chamfer part) osteotomies of the femur were performed. The thickness of the tibial and femoral bone cut was measured using a caliper and the actual osteotomies were calculated by adding the thickness of the bone saw blades (1.27 mm).

Following the femoral osteotomies, a trial prosthesis was placed in the distal femur, and the component gap between the medial tibial osteotomy surface and the femoral trial prosthesis was measured using a UKA tensor. Reports on the design and the methodology of the UKA tensor have previously been published [22]. The UKA tensor (Fig. 1) consists of 3 parts - an upper plate, a lower platform plate with a spike, and an extra-articular main body. Upper and lower plates are to be placed at the medial compartment of the knee. By using this device, surgeons can measure the joint component gap while applying a constant joint distraction force. Joint distraction force was exerted between the upper and lower plates through a specially made torque driver. In preliminary in-vitro experiments, an error for joint distraction within ±3% was obtained. During the measurement, the medial parapatellar arthrotomy was temporarily repaired with stitches proximal to the connection arm of the UKA tensor. The thigh and knee were aligned in the sagittal plane to eliminate the external load on the knee. The joint distraction forces were preloaded several times to minimise the error due to the creep of the surrounding soft tissues. After the joint distraction force of 20 lb (9.1kg) was applied, the component gap (in mm) between the centre midpoints of the upper surface of the plate and the proximal tibial cut was measured at 10° (extension) and 120° (flexion) of knee flexion, because the posterior femoral bone cut was designed to be parallel when the knee was 120° of flexion. The pre-osteotomy gap was then calculated and defined from the data of the thickness of the bone cut (Fig. 2). Preoperative and postoperative coronal hip–knee–ankle (HKA) angles were measured based on long-leg standing radiographs.

The data are expressed as means ± standard deviations. Paired Student's t-test was used to compare the component gap in extension and that in flexion. The pre-osteotomy gap in extension and that in flexion was compared using paired Student's t-test as well. The relationship between the preoperative HKA angle and the pre-osteotomy gap was analysed using Pearson's correlation coefficient and simple linear regression analysis. Data analyses were performed using BellCurve for Excel (Social Survey Research Information Co., Ltd., Tokyo, Japan). The sample size calculation was also performed using G*Power 3 (Heinrich Heine Universität Düsseldorf, Germany). Based on our calculations, a minimum sample size of 62 patients was required to observe a moderate correlation between the preoperative HKA angle and the pre-osteotomy gap with a type I error (α) of 0.01, a power ($1 - \beta$) of 0.80, and a correlation ρ H1 of 0.5. Statistical significance was considered at $P<0.01$.

3. Results

Patient demographics are shown in Table 1. Mean HKA angle was 7.7 ± 3.1° (range, 1.5°–15.5°) varus preoperatively and 3.5 ± 2.7° (range, -3.0°–10.0°) varus postoperatively. The mean values of the thickness of the tibial bone cut, the femoral distal bone cut, and the femoral posterior bone cut were 5.0 ± 0.9 mm, 6.1 ± 1.0 mm, and 8.0 ± 0.7 mm, respectively. The mean value of the component gap in extension was 10.0 ± 0.9 mm, which was significantly smaller than that in flexion (10.9 ± 1.6 mm) (Fig. 3a). The mean value of the pre-osteotomy gap in extension was 5.4 ± 1.6 mm, which was significantly greater than that in flexion (4.0 ± 2.0 mm) (Fig. 3b). Summary of results was shown in Table 2. The relationships between the preoperative HKA angle and the pre-osteotomy gap are shown in Fig. 4 (a: extension, b: flexion). There was a positive correlation between the severity of varus deformation in preoperative knee and the pre-osteotomy gap in extension (Fig. 4a, $R = 0.37$, $P < 0.01$), while there was no correlation between the preoperative HKA angle and the pre-osteotomy gap in flexion (Fig. 4b).

4. Discussion

The most important finding of the present study was that the degree of preoperative varus deformation of the knee positively correlated with the pre-osteotomy gap in extension during UKA, which shows that the tension of the medial tightness does not correlate with the degree of preoperative varus deformity. Our hypothesis was shown to be rejected. This result suggests that the contracture of the medial soft tissue structure does not exist even in knees with severe varus deformity. We assume contracture of the superficial medial collateral ligament does not exist after releasing the capsular ligaments with removal of the osteophytes, while osteoarthritic changes might increase stiffness of the medial soft tissue along with osteophyte formation.

Although it is generally believed that the development of medial tightness is correlated with the severity of the varus deformity, little data has existed on the issue. In other words, it is unknown whether the tension of the soft tissue on the medial side, i.e. mainly medial collateral ligament - medial joint tightness depends mostly on the condition of the superficial medial collateral ligament [23] - will increase with the progression of preoperative varus deformity. Therefore, it would be beneficial if we could know the relationship between intraoperative medial tightness and preoperative alignment before surgery.

It was reported by some authors that medial soft tissue contracture did not always exist in knees with varus deformation in TKA. Ushio et al [24] evaluated soft-tissue balance in 151 varus-deformed osteoarthritic knees using preoperative stress radiographs. Preoperative knee radiographs in the anteroposterior view with no stress and with varus/valgus stress in extension were assessed and the absolute joint line angle (an exact angle of the joint line) and the relative joint line angle (the absolute joint line angle minus the joint line angle in the neutral condition) were compared. As a result, they found no significant differences in the numerical values of the relative joint line angle between varus and valgus stresses and concluded that contracture of medial soft tissue did not necessarily exist even in varus knees with osteoarthritis when considering articular cartilage wear, which is not inconsistent with our current result. They mentioned that because joint line tilting in the varus direction under non-stress conditions could cause underestimation of medial soft tissue laxity and overestimation of lateral soft tissue laxity, surgeons should be reminded that underestimating the medial joint laxity might cause excessive medial tissue release and increase the risks of postoperative instability. Okamoto et al [25] retrospectively reviewed 70 patients with varus-type osteoarthritis who underwent 90 TKA and divided them into three groups according to a degree of preoperative alignment (mild varus group (< 10°), moderate varus group (10°–20°), and severe varus group (> 20°)). Then, they compared intraoperative joint gap, amount of resected bone, and intraoperative soft tissue laxity on the lateral and medial sides according to the severity of preoperative varus deformity and found that there were no differences in the medial joint gaps among the groups. They concluded that the medial soft tissue was not shorter with greater varus deformity when taking the resected bone into account, which supports our current result.

The mean value of the pre-osteotomy gap was greater in extension than in flexion. UKA is normally performed to the knee with anteromedial osteoarthritis, which means that the anterior cruciate ligament is intact, thus the tibial anterior subluxation does not occur in the knee. The posterior slope of the medial tibial plateau decreases in the knee with anteromedial osteoarthritis where the anterior cartilage diminishes while the posterior cartilage remains, which might be the reason for the result. On the other hand, the mean value of the component gap was smaller in extension than in flexion. The Persona Partial Knee System is designed to have a feature that the thickness of the femoral posterior bone resection is 2 mm greater than that of the posterior portion of the component (data from Zimmer Biomet inc.) to achieve some laxity in flexion, which could be the reason of the result.

The intraoperative medial compartment stability of the knee resulted in a better post-operative knee flexion angle in UKA. Matsuzaki et al [26] showed that the post-operative knee flexion angle following UKA was negatively correlated with the component gap at 90° of flexion and it was negatively correlated with joint looseness, which was defined as the component gap minus the polyethylene insert thickness, at 90° of flexion as well. In the case of UKA with severe varus deformity where the pre-osteotomy gap in extension tends to be too wide, the component gap can also be wider in extension than in flexion even with the use of the Persona Partial Knee System where the thickness of the femoral posterior bone resection is designed to be 2 mm greater than that of the femoral component. The manufacture, Zimmer Biomet inc., offers a special zig to reduce the thickness of the distal femoral bone cut, and surgeons can take advantage of the zig to achieve a better postoperative soft-tissue balance in such a case.

This study has several limitations. First, our study was limited to the medial compartment of osteoarthritic knees and no knees with valgus deformities or rheumatoid arthritis were included. Also, we did not compare non-arthritic knees with osteoarthritic knees, and these might impact our results, although most knees that are subject to UKA have varus deformity due to osteoarthritis. We trust our data are useful to understand the difference in the soft-tissue balance between mild and severe varus deformities. Second, other factors such as patella alta/baja or contracture of the quadriceps might have influenced the assessment of intraoperative joint gap. In this study, we attempted to focus on preoperative varus alignment and intraoperative joint gap as it would be useful for knee surgeons to predict the intraoperative joint gap simply from the degree of preoperative varus deformity. Third, this study was based only on plain radiographs, which could cause inaccurate measurement of the alignment in the lower extremity and misinterpretation of its effects on the medial tightness. A CT-based study may be more accurate in evaluating the alignment. Fourth, the study did not evaluate clinical outcomes. Further research involving the assessment of intraoperative joint gap and clinical outcomes, ideally subjective outcomes, should be conducted in the future. Fifth, this study is not a prospective cohort study monitoring the longitudinal change that may occur with respect to soft tissue tightness and alignment preoperatively. We have to investigate the progression of preoperative deformity of the knee before drawing a definite conclusion in the future.

5. Conclusion

Surgeons tend to consider the intraoperative joint gap to be tight in the knee with severe varus deformity, however, the present study exhibited the opposite results, i.e., the degree of preoperative varus deformation of the knee positively correlated with the intraoperative gap in extension during UKA. The result implies that the tension of the medial tightness does not correlate with the degree of varus deformity of the knee. We believe the result of the current study is helpful for knee surgeons to achieve better postoperative soft-tissue balance and consequently obtain higher patient satisfaction following UKA.

Conflict of interest

The authors have declared no conflict of interest.

Ethical approval

The study was approved by the Review Board at our institution.

Funding

None declared.

Legends to figures

Fig. 1

The UKA tensor used in this study

It consists of three parts: an upper seesaw plate, a lower platform plate with a spike and an extra-articular main body.

Fig. 2

Definition of the pre-osteotomy gap

The pre-osteotomy gap = the component gap + the thickness of the femoral component - (the thickness of the tibial bone cut + the thickness of distal femoral bone cut (in extension) or posterior femoral bone cut (in flexion))

Fig. 3

The mean component gap and the pre-osteotomy gap in extension and flexion

The mean value of the component gap in extension was significantly smaller than that in flexion (a). The mean value of the pre-osteotomy gap in extension was significantly greater than that in flexion (b).

Fig. 4

The relationships between the preoperative Hip-Knee-Ankle (HKA) angle and the pre-osteotomy gap in extension and flexion

Patients with more varus deformation in their preoperative knee tended to show a wider pre-osteotomy gap in extension (a), while there was no correlation between the preoperative HKA angle and the pre-osteotomy gap in flexion (b).

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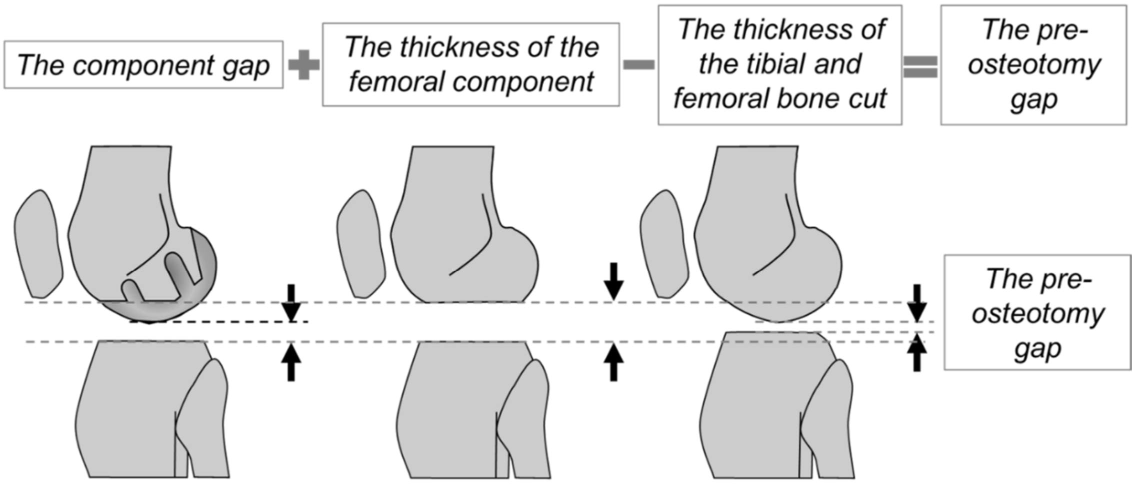
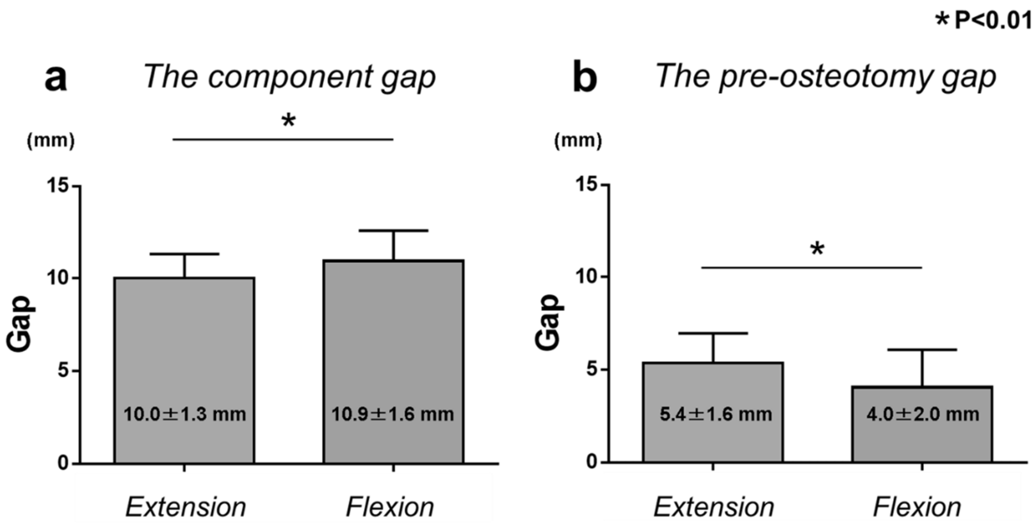
Fig. 1

Fig. 2



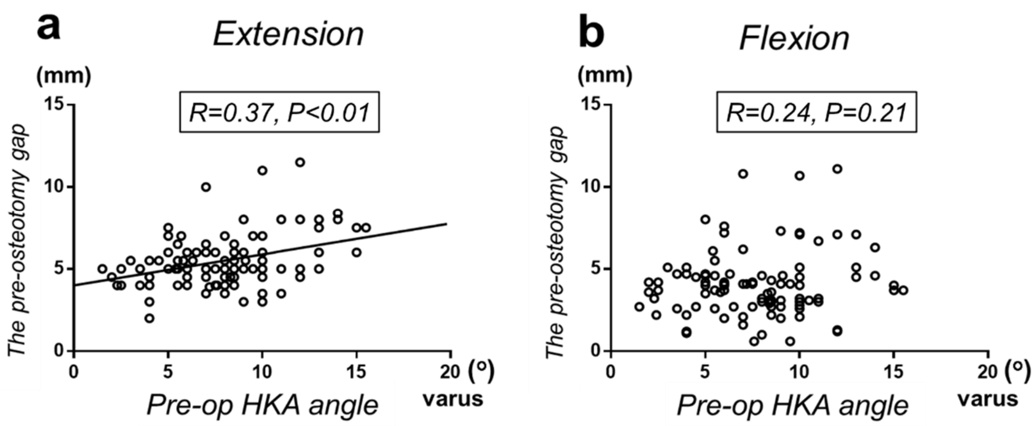
The component gap
The thickness of the femoral component
The thickness of the tibial and femoral bone cut
The pre-osteotomy gap
The pre-osteotomy gap

Fig. 2



* P<0.01
a
The component gap
*
(mm)
15
10
5
0
Gap
10.0±1.3 mm
10.9±1.6 mm
Extension
Flexion
b
The pre-osteotomy gap
(mm)
15
10
5
0
Gap
*
5.4±1.6 mm
4.0±2.0 mm
Extension
Flexion

Fig. 4



a
Extension
(mm)
R=0.37, P<0.01
The pre-osteotomy gap
15
10
5
0
0
5
10
15
20 (°)
varus
Pre-op HKA angle
b
Flexion
(mm)
R=0.24, P=0.21
The pre-osteotomy gap
15
10
5
0
0
5
10
15
20 (°)
varus
Pre-op HKA angle

Table 1

Patient demographics

The values are given as the mean and standard deviation for continuous variables

UKA: unicompartmental knee arthroplasty, HKA: Hip- Knee- Ankle, SD: standard deviation

Age (years)	74.4 (range, 54–95; SD: 8.7)
Gender (male : female)	28 : 75
Side of UKA (left : right)	50 : 53
Preoperative diagnosis	Osteoarthritis: 87, idiopathic osteonecrosis: 16
Preoperative HKA angle (°)	7.7 (range, 1.5–15.5; SD: 3.1)

Table 2

Summary of results

The values are given as the mean and standard deviation

HKA: Hip- Knee- Ankle, SD: standard deviation

Postoperative HKA angle (°)	3.5 (range, -3.0–10.0; SD: 2.7)
Thickness of the tibial bone cut (mm)	5.0 (range, 2.3–6.8; SD: 0.9)
Thickness of the femoral distal bone cut (mm)	6.1 (range, 4.3–9.3; SD: 1.0)
Thickness of the femoral posterior bone cut (mm)	8.0 (range, 6.3–10.3; SD: 0.7)
The component gap in extension (mm)	10.0 (range, 8.0–15.0; SD: 0.9)
The component gap in flexion (mm)	10.9 (range, 8.0–16.0; SD: 1.6)
The pre-osteotomy gap in extension (mm)	5.4 (range, 2.0–11.5; SD: 1.6)
The pre-osteotomy gap in flexion (mm)	4.0 (range, 0.6–11.1; SD: 2.0)