

Gap configuration and anteroposterior leg axis after sequential medial ligament release in rotating-platform total knee arthroplasty

Christian Luring¹, Holger Bächis¹, Tobias Hüfner², Christian Grauvogel¹, Lars Perlick¹ and Joachim Grifka¹

Departments of ¹Orthopaedic Surgery, University of Regensburg, ²Trauma Surgery, Medical School, Hannover, Germany

Correspondence CL: c_luring@yahoo.de

Submitted 04-11-12. Accepted 05-02-24

Background Soft tissue management is a major issue in total knee replacement. There have been very few papers dealing with its effect on leg axis and tibiofemoral gap.

Methods In a cadaver specimen study, we analyzed this effect by performing a sequential medial soft tissue release after a mobile-bearing total knee arthroplasty. Measurements were obtained using a CT-free navigation system (Ci navigation system).

Results We found the highest increase in leg axis and medial gap when releasing the anteromedial tibial sleeve of the capsule 6 cm below the joint line, in extension, and after dividing the medial collateral ligament, in flexion, when releasing the medial half of the posterior cruciate ligament. There were differences in amount of change between extension and flexion, especially when releasing the medial half of the posterior cruciate ligament. In extension, the lateral gap remained the same as in flexion.

Interpretation Implementation of computer-assisted surgery has allowed this first navigation-controlled study investigating the effect of soft tissue release in TKR with rotating platform. Each sequential release step has the desired effect on a.p. leg axis and tibiofemoral gaps. It is important that the differences between the effects in extension and flexion be noted.

It is commonly accepted that postoperative coronal malalignment and dysbalance of collateral ligaments may lead to early loosening of prostheses (Lotke and Ecker 1977, Insall et al. 1985, Dorr and

Boiardo 1986, Teeny et al. 1991, Karachalios et al. 1994, Matsueda et al. 1999).

Ligamentous instability or contractures due to bony deformities are well recognized difficulties in primary TKR. Numerous studies focusing on different ligament balancing techniques have been published (Ranawat et al. 1984, Buechel 1990, Stern et al. 1991, Whiteside et al. 1993, Insall 1993, Freeman 1997, Matsueda et al. 1999, Whiteside et al. 2000, Kanamiya et al. 2002, Winemaker 2002, Engh 2003, Mihalko et al. 2003). Some authors have proposed a sequential technique that varies according to the deformity (Clayton et al. 1986, Faris et al. 1994), whereas Insall et al. (1979) suggested release of all medial structures in one single step. These techniques have all been described for a fixed polyethylene insert. In the current literature, little is known about these soft tissue release sequences in total knee replacement with a mobile polyethylene insert.

After the establishment of conventional total knee replacements, mobile bearings were developed in the belief that axial rotation and the greater articular conformity of polyethylene would reduce aseptic loosening due to polyethylene wear (McEwen et al. 2001). The hypothetical advantages of mobile bearings are still being discussed (Callaghan et al. 2000, Kim et al. 2001, Huang et al. 2003, Price et al. 2003, Jacobs et al. 2004, Ranawat et al. 2004). As regards possible displacement and therefore failure of the mobile insert, soft tissue management is important. If the medial or lateral structures (anteromedial-lateral capsule, pes

anserinus, medial/lateral collateral ligament, posterior capsule) are too loose, the mobile insert may become displaced in hyperflexion.

In this cadaver study, we assessed the relationship between a standardized sequential medial soft tissue release modified according to the recommendations of Matsueda et al. (1999), the resulting change of a.p. leg axis and the medial and lateral tibiofemoral gaps in extension and flexion in total knee replacement with rotating platform. Measurements were computer-assisted (DePuy I-Orthopaedics, Munich, Germany).

Material and methods

Material

We investigated 8 fresh human cadavers (4 female). The median age was 69 (64–80) years. All knees were without severe deformities concerning coronal alignment (between 4° varus and 4° valgus), and no specimen had undergone previous operations of the ipsilateral foot, knee and hip. All specimens had full range of movement of the ipsilateral hip and the operated knee. The cadavers were kept at +7°C for up to 36 h following death. They were kept at room temperature for 2 h before testing.

Navigation system

For planning of implant position, size of prosthetic and polyethylene components, bone cuts and for measurement of coronal alignment as well as mediolateral gaps, we used the Ci CT-free navigation system (DePuy I-Orthopaedics, Munich, Germany). This system is based on an optical tracking unit which detects reflecting marker spheres attached to the bone and instruments by an infrared camera system. It allows the measurement of a.p. leg axis (coronal alignment) and the tibiofemoral gaps over the full range of movement in real time. It provides leg axis and gap size with an accuracy of less than 0.5 degrees/mm.

Surgical technique

The study followed our standard operation routine. No soft tissues were removed. Knee replacement surgery was performed using the PFC Sigma RP standard specialist-2 instruments (DePuy Interna-

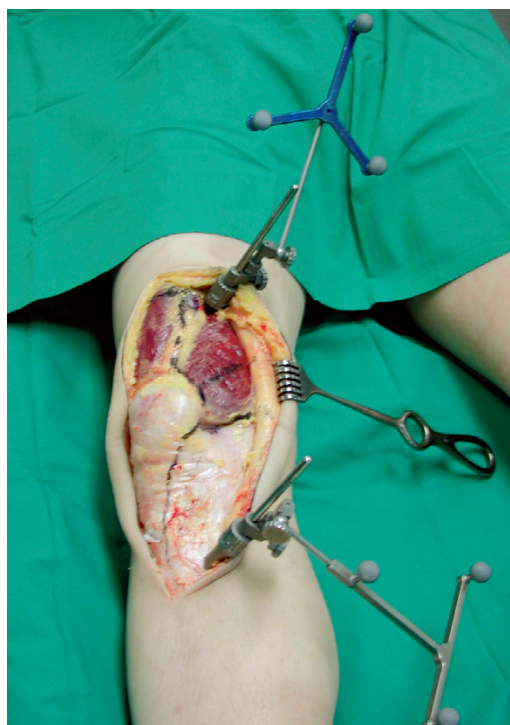


Figure 1. Experimental set-up. The two reference arrays are rigidly attached to the femur and the tibia.

tional, Leeds, UK). Each knee received the correct implant and polyethylene size for the individual anatomy, which stayed the same for the complete release sequence. The PFC Sigma RP implant allows axial rotation, but no a.p. glide. After a standard median skin incision and a medial-parapatellar arthrotomy, two reference arrays with passive marker spheres were rigidly attached to both, the femoral and the tibial bone (Figure 1) and the anatomical contour of the knee was acquired. A first navigation-controlled measurement of the physiological a.p. (coronal) leg alignment and the width of the medial and lateral gap in extension and 90 degrees flexion was carried out. Then the anterior cruciate ligament and the menisci were removed and the implantation (bone cuts, measurement of implant and polyethylene size) was performed, navigation-controlled. Resection of the tibia and distal and dorsal femur was performed, and the tibial slope was set to 3°. The femoral component was rotated parallel to the epicondylar axis. After insertion and fixation of trial components, the patella was set in place and fixed with a sharp clamp. Then a second navigation-controlled mea-

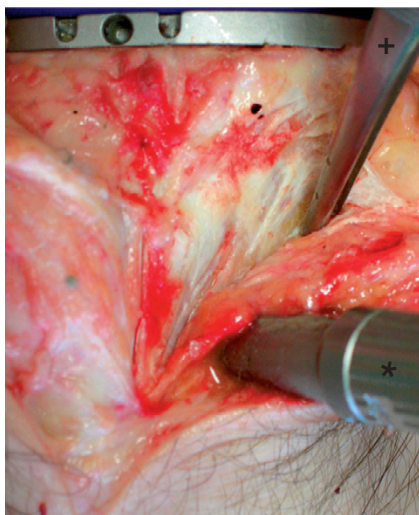


Figure 2. Subperiosteal release of the tibial attachment of the semimembranosus with the trial components and the tibial navigation reference array (*) in situ, and pincette (+).

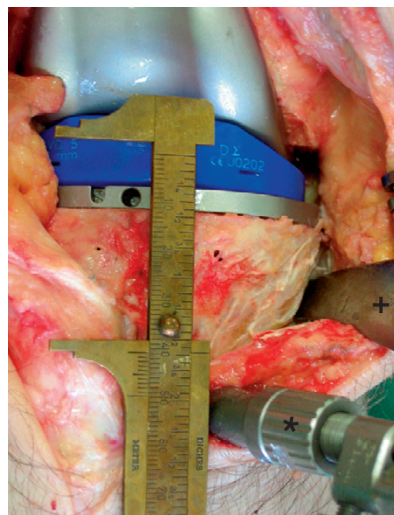


Figure 3. Subperiosteal release of the anteromedial tibial sleeve 4 cm below the joint line with trial components in situ and tibial navigation reference array (*) in situ, and surgical hook (+).

surement of the a.p. leg alignment and the width of the medial and lateral gap in extension and 90 degrees flexion was performed. Then the measurement was repeated with both varus and valgus stress. Each measurement was done three times and averaged. Afterwards, the sequential medial soft tissue release was carried out. After each release step, a.p. leg alignment and mediolateral gap width was checked three times with varus and valgus stress testing.

Sequential medial soft tissue release sequence

According to the recommendation of Matsueda et al. (1999), we performed the sequential soft tissue release using subperiosteal or subligamentous sharp dissection by scalpel or Cobb elevator. The sequence prescribes the release of:

1. the anteromedial tibial sleeve 2 cm below the joint line in horizontal direction posteriorly as far as the popliteus muscle.
2. the posteromedial capsule, as well as the tibial attachment of the semimembranosus (Figure 2).
3. the anteromedial tibial sleeve 4 cm below the joint line (Figure 3).
4. the anteromedial tibial sleeve 6 cm below the joint line.
5. the medial collateral ligament from the femoral condyle (Figure 4).

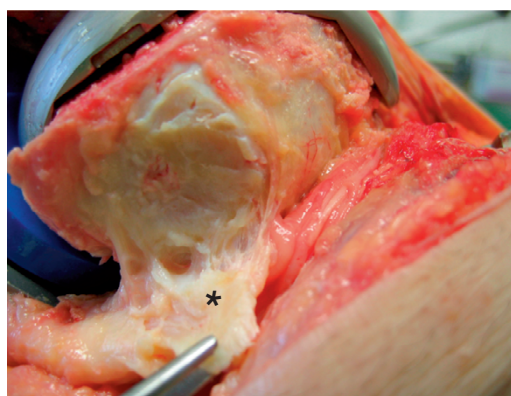


Figure 4. Subperiosteal release of the femoral attachment of the medial collateral ligament with the trial components in situ. (*) medial collateral ligament.

6. the medial half of the posterior cruciate ligament on the tibial side.
7. the entire posterior cruciate ligament on the tibial side.

Statistics

The paired t-test was used. A p-value of 0.05 or less was considered to be significant. The analysis was carried out to determine the effect and possible significance of the different angles and gaps after each release step. For comparison of leg axis and medial gap in extension between each release step, box plots were used. The height of the box is

Table 1. Medial release. Change in the leg axis (in degrees) and in the medial and lateral tibiofemoral gaps (in mm) for extension. Values are mean (standard deviation)

Medial release step	Valgus stress			Varus stress		
	Leg axis	Medial gap	Lateral gap	Leg axis	Medial gap	Lateral gap
Reference	2.1 (1.0)	23 (2.9)	22 (3.1)	3.7 (1.7)	21 (3.5)	24 (3.3)
2-cm anteriomedial sleeve	3.4 (1.8)	24 (2.8)	21 (3.1)	3.8 (1.5)	21 (3.3)	24 (3.4)
Posteriomedial capsule and semimembranosus	5.4 (2.0)	25 (2.7)	21 (3.3)	3.5 (1.6)	21 (3.1)	24 (3.3)
4-cm anteriomedial sleeve	6.8 (1.7)	26 (3.4)	21 (3.2)	3.4 (1.5)	21 (3.3)	24 (3.7)
6-cm anteriomedial sleeve	9.1 (1.5)	28 (3.0)	21 (3.3)	4.4 (1.5)	21 (3.2)	24 (3.7)
MCL	14 (2.8)	32 (3.2)	21 (3.5)	3.4 (1.6)	21 (3.0)	24 (3.4)
Medial half of the PCL	15 (2.6)	32 (3.1)	20 (3.2)	3.5 (3.2)	21 (3.1)	24 (3.4)
Entire PCL	16 (2.4)	33 (2.9)	20 (2.9)	3.7 (1.7)	21 (3.1)	24 (3.3)

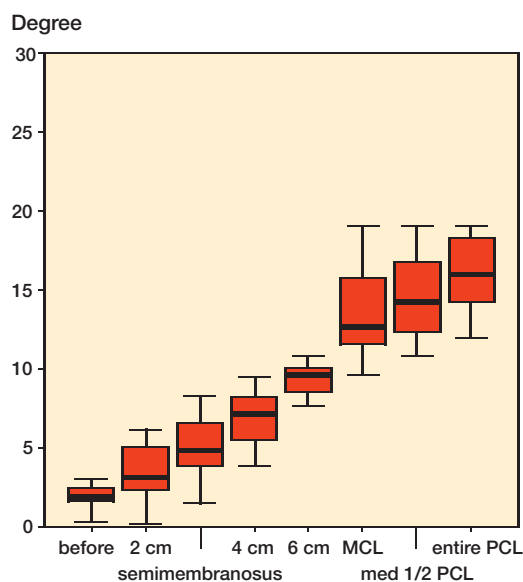


Figure 5. Box plot showing leg axis in extension with valgus stress; mean value with lowest and highest values.

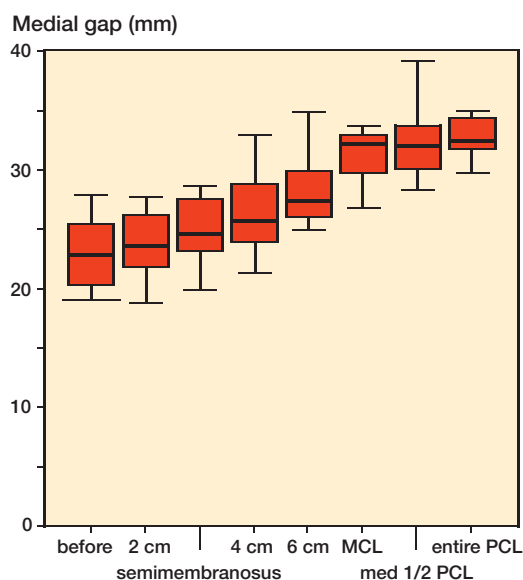


Figure 6. Medial gap in extension with valgus stress; mean value with lowest and highest values.

the interquartile range which represents half of all values. 25% of values are higher and 25% of values are lower than the box. The median is displayed as a horizontal line across each box. The minimum and maximum values are represented by vertical lines.

We used the SPSS statistics package, version 11.5 (SPSS Inc., Chicago, IL).

Results

Anteroposterior leg axis in extension (Table 1)

In extension and with valgus stress, the difference

in the a.p. leg axis was statistically significant with $p < 0.01$ comparing each release step with the following one. The coronal angle increased continuously after each release (Figure 5) in 1.5° – 2° steps from the first to the fourth release step. After cutting the medial collateral ligament, we found the highest increase compared to the angle of the previous release ($p < 0.001$).

Concerning varus stress, no relevant changes could be seen. Mean leg axis was constantly between 3.3° and 3.7° , which can be interpreted as being a result of different varus forces produced by the surgeon.

Table 2. Medial release. Change in the medial and lateral tibiofemoral gaps (in mm) for flexion. Values are mean (SD)

Medial release step	Valgus stress		Varus stress	
	Medial gap	Lateral gap	Medial gap	Lateral gap
Reference	24 (3.6)	19 (4.3)	23 (3.3)	23 (4.9)
2-cm anteriomedial sleeve	24 (3.6)	19 (4.5)	24 (4.4)	26 (3.2)
Posteriomedial capsule and semimembranosus	25 (3.3)	18 (3.7)	24 (3.6)	24 (4.9)
4-cm anteriomedial sleeve	26 (5.5)	17 (3.6)	24 (4.0)	25 (4.0)
6-cm anteriomedial sleeve	29 (5.9)	18 (3.4)	24 (3.5)	24 (5.4)
MCL	40 (6.9)	17 (3.8)	25 (4.0)	24 (4.9)
Medial half of the PCL	45 (9.2)	17 (3.4)	24 (4.4)	25 (3.8)
Entire PCL	75 (9.3)	16 (3.7)	24 (4.2)	24 (4.0)

Gap size (mm)

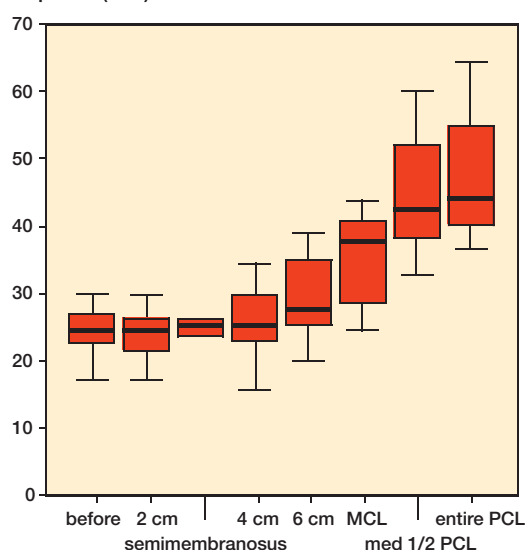


Figure 7. Medial gap in flexion with valgus stress; mean value with lowest and highest values.

Gap size (mm)

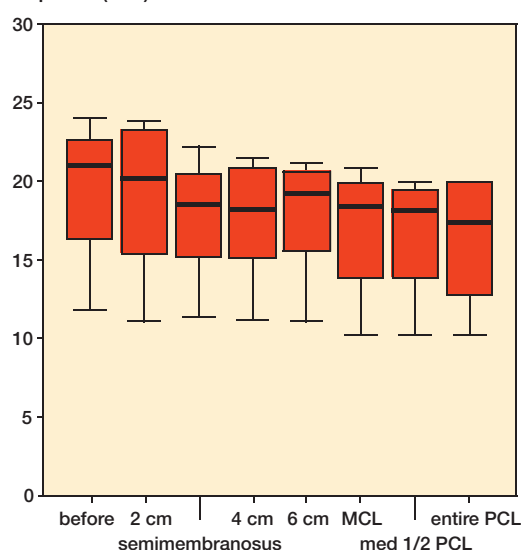


Figure 8. Lateral gap in flexion with valgus stress; mean value with lowest and highest values.

Mediolateral gap in extension

For the medial gap with valgus stress, we found a progression in the gap distance for each release step except the 2 cm release with $p < 0.05$ (Figure 6). The medial gap increased progressively, the highest increase being seen for the 6 cm release ($p = 0.002$, from 26 mm to 28 mm on average) and for sacrificing the MCL ($p < 0.001$, from 28 mm to 32 mm on average). With valgus stress no statistically differences were seen for the lateral gap, the size being continuously in the 20–22 mm range.

The size of the mediolateral gap with varus stress gap was similar (21 mm) during the total release

sequence. We found the same for the lateral gap in extension with varus force application (mean gap size 23–24 mm).

Mediolateral gap in flexion (Table 2)

As the navigation system does not provide a leg axis in flexion, we evaluated only the mediolateral gap sizes. Focusing on gap size with valgus stress (Figure 7), no statistically relevant data were calculated for the 2 cm release, the posterior capsule and the 4 cm release. Statistically significant data were seen for the following release steps: 6 cm, MCL, medial half of the posterior cruciate liga-

ment, and the entire posterior cruciate ligament ($p < 0.05$).

Focusing on the lateral gap in flexion with valgus stress, we found a slight wavering of the gap sizes, which may have been due to the axial rotation of the platform (Figure 8). With varus stress, we found for the medial gap that it varied between 24 and 24 mm over the full release sequence; the lateral gap varied between 23 and 26 mm. No differences were seen between male and female specimens.

Discussion

Since the rotating platform knee prosthesis allows axial rotation to a limited extent, it is necessary to balance the knee carefully. There have been many reports about different soft tissue releases: about their necessity and the clinical results of different techniques (Insall et al. 1979, Stern et al. 1991, Faris 1994, Laskin 1996, Griffin et al. 2000). There has, however, been a lack of experimental procedures focusing on the effect of ligament release techniques in TKR with rotating platform. Few papers have concentrated on soft tissue release techniques and their influence on the leg axis (Krackow and Mihalko 1999, Matsueda et al. 1999, Kanamiya et al. 2002).

We found similar effects to those found by Krackow et al. (1999) with regard to the release of the medial half of and the entire posterior cruciate ligament, which resulted in a stronger increase in medial gap in flexion (mean 5.0 mm compared to the previous release of the MCL) than in extension (mean 0.5 mm compared to the previous release of the MCL). These authors reported that sacrifice of the PCL led to a 4-mm increase in flexion gap, but very little average increase in extension gap in the same knee. We found a homogenous increase in the medial gap in extension over the total sequential release, compared to little change in flexion for the release steps until the MCL. When releasing the medial half of the PCL, a huge increase in the medial gap in flexion could be seen. This effect may result in instability of the knee in flexion and a displacement of the rotating platform becomes possible with hyperflexion.

In an MRI study, Freeman (1997) showed the behavior of the PCL in flexion and extension.

Their findings strengthen the hypothesis that PCL is tightened in 90° flexion but not in full extension. Mihalko et al. (2003) compared two ligament balancing techniques for gaining a balanced flexion and extension gap, and found a similar effect for the medial flexion gap compared to the medial extension gap after releasing the PCL. However, their use of cadaveric knees without hip and ankle joints can be criticized. This criticism also applies to the work of Matsueda et al. (1999), who used cadaveric knees with soft tissues removed, and transected 30 cm from the joint space.

In contrast to Matsueda et al. (1999), who used a fixed platform, we found that release of the medial collateral ligament increased the medial gap substantially in extension and lesser in flexion.

One criticism of our study could be that we used normal cadaveric knees without severe deformities. Thus, the magnitude of changing a.p. leg axis and tibiofemoral gaps may differ from arthrotic knees with varus deformity. The concept of varus and valgus stress testing may also be criticized, but, as other authors (Stern et al. 1991), we tried to simulate the intraoperative situation of a TKR in daily routine with manual tension and without a special pressure device.

Our findings emphasize the fact that each sequential medial soft tissue release step has the desired effect on the a.p. leg axis and the tibiofemoral gaps. With regard to possible displacement of a rotating platform, the surgeon should be aware of the different effect of the PCL release on the extension and flexion gap.

The Ci-navigation system was provided by DePuy I-Orthopedics, Munich, Germany.

No competing interests declared.

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