



## Joint Line Reconstruction in Revision Knee Arthroplasty - Reliability Testing of Radiologic Anatomic Landmarks versus a Novel Defined Landmark

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### Abstract

**Objectives:** Bony landmarks are necessary for intraoperative orientation. Such bony landmarks have been studied before, but no common sense was found about which landmark should be used. Hence, we investigate a novel bony landmark located on the posterior edge of the tibia, which is not changed during primary knee arthroplasty, with regard to its reliability and validity.

**Methods:** In this retrospective study we analyzed conventional radiographs of a total of 100 patients who underwent a primary knee arthroplasty. Measurements were taken by three independent examiners. Marking of the knee joint gap was performed on pre- and post-operative radiographs, thus various bony landmarks have been investigated.

**Results:** The difference between the mean value determined preoperatively and postoperatively is 0.66 mm to 2.41 mm, depending on the point used. For the new measurement point, a distance of 44.8 mm (SD 8.5) is measured preoperatively and 46.9 mm (SD 8.7) postoperatively. Both pre- and post-operatively determined intra- and inter-class coefficients have values mostly >0.85, which corresponds to an excellent agreement. Preoperatively, the new measurement point has an intraclass coefficient of 0.94, and postoperatively 0.92. For the interclass coefficient, the preoperative value is 0.97 and the postoperative value is 0.85.

**Conclusion:** The point in the area of the proximal tibia investigated in this study has a very high reliability and certainly represents another radiological - anatomical landmark for the detection of the joint line in relation to endoprosthetic revision procedures. It represents a safe alternative, especially when the usual bony landmarks are altered or even missing due to the previous, sometimes multiple operations.

**Keywords:** Knee arthroplasty; Revision arthroplasty; Joint line; Anatomic landmark

### Introduction

Physiologic restoration of the joint line in revision arthroplasty of the knee is one of the greatest challenges of surgical orthopedics and also a crucial factor in clinical outcomes of this operation [1,2]. Changes regarding the position of the joint line can have severe consequences in terms of both physiological motion and stability of the knee joint [3-5]. Thus, even a 5-mm shift of the joint line proximally leads to instability in the range of mid flexion (30°-60°), which can cause problems, especially when climbing stairs. In addition, anterior knee pain may occur [6]. Hofmann et al. postulated in 2006, after a clinical - radiological analysis, that the best functional outcome - independent of age, gender or cause of revision - can be expected if the joint line can be reconstructed within  $\pm 4$  mm of the original anatomical joint line [7]. Unlike primary arthroplasty procedures, where accurate resection of the distal femur and proximal tibia can be used to reconstruct the joint line, revision procedures must be guided by alternative bony landmarks, since the bony structures necessary for intraoperative detection of the original joint line have already been removed by the previous procedures [8]. In the past, many authors and research groups have already addressed the functionality and reliability of such bony landmarks, but without being able to establish bony landmarks defined in guidelines.

The aim of this work was to investigate a predefined bony landmark located on the tibia, which is not changed during primary knee arthroplasty, with regard to its reliability in terms of radiological detection of the knee joint gap in the context of endoprosthetic procedures on the knee and to test

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it for validity.

## Methodology

The present study is a retrospective study. Conventional radiographs of a total of 100 patients who were surgically treated with a primary knee arthroplasty at the Department of Orthopedics and Trauma Surgery at the University Hospital Cologne between 2012 and 2015 were analyzed.

In total, 66 (66%) female and 34 (34%) male patients were included. In 52 cases the measurements referred to the left knee, in 48 cases to the right knee. In ninety-seven patients (97%) arthroplasty was performed because of primary gonarthrosis, in three cases (3%) it was performed because of post-traumatic arthrosis. The mean age of patients at the time of primary implantation was 67 years (range 29-87). The P.F.C. Sigma<sup>®</sup> prosthesis from DePuy was used implanted in 86 patients, five patients received a prosthesis from Implantcast and Aesculap, and three patients received a prosthesis from Corin. A positive vote was given by the medical ethics committee of the University of Cologne (ethics number 13-196).

### Sequence of the radiological measurement procedures

Conventional, standardized a.p. radiographs of the knee in standing position, taken preoperatively and postoperatively, as well as conventional strictly lateral radiographs of the knee were used for radiological measurement. Measurements were taken by three independent examiners in three measurement runs each. The IMPAX EE R20 XII SU1 digital report processing system from Agfa HealthCare was used for measurement.

### Measurements on preoperative images

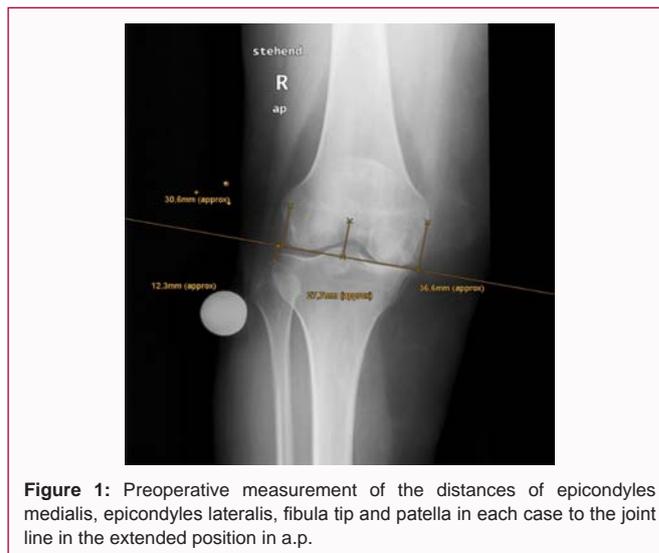
The radiological marking of the knee joint gap in the extended position was performed with a connecting line between the medial femoral condyle and the lateral femoral condyle. Subsequently, orthogonal measurements of the distances from the tip of the caput fibulae to the knee joint space, the lower edge of the patella to the knee joint space, and the epicondylus medialis and lateralis femoris to the knee joint space were performed. The measurements were given in millimeters in each case (Figure 1).

Furthermore, the distance from the inferior patellar pole and the tip of the caput fibulae to a line drawn through the femoral condyles corresponding to the knee joint space in the extended position was also measured in the lateral image, and the respective distances were determined in millimeters. The lateral image was also used to determine the new landmark to be tested for reliability in this study. Using the measurement tools, a straight line was drawn along the tibial cortex and the point at which the tibial edge deviates posteriorly in its proximal diaphyseal region was determined (PPTE). From this point, the distance to the knee joint gap was also recorded in millimeters (Figure 2).

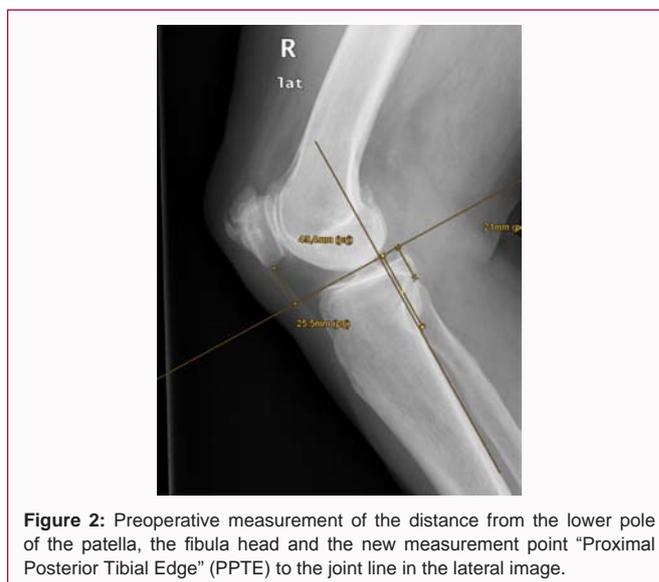
### Measurements on postoperative radiographs

Radiographic marking of the knee joint gap was also performed on postoperative radiographs by drawing a line connecting the medial condyle of the femur to the lateral condyle of the femur. Due to the radiopacity of the inserted prosthesis, only the measurement of the distance of the tip of the caput fibulae, epicondylus lateralis and medialis from the joint line could be reliably determined in the a.p. images used postoperatively (Figure 3).

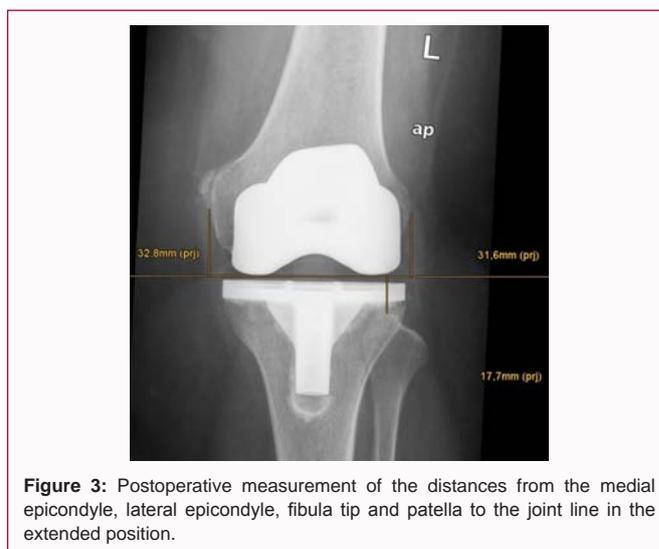
In the postoperative lateral images, both the measurement of the new landmark (PPTE) already determined preoperatively and the



**Figure 1:** Preoperative measurement of the distances of epicondylus medialis, epicondylus lateralis, fibula tip and patella in each case to the joint line in the extended position in a.p.



**Figure 2:** Preoperative measurement of the distance from the lower pole of the patella, the fibula head and the new measurement point "Proximal Posterior Tibial Edge" (PPTE) to the joint line in the lateral image.



**Figure 3:** Postoperative measurement of the distances from the medial epicondyle, lateral epicondyle, fibula tip and patella to the joint line in the extended position.

measurement of the distance from the tip of the patella to the knee joint space were successful (Figure 4).



**Figure 4:** Postoperative measurement of the distance from the lower pole of the patella, the fibula head and the new measurement point "Proximal Posterior Tibial Edge" (PPTe) to the joint line in the lateral image.

**Statistical evaluation**

The researched and digitally recorded data were converted into analyzable data sets using the statistical program IBM® SPSS Statistic Version 22. The normal distribution of the data was checked using the Kolomorov - Smirnov test. To check the internal consistency of the measurements, a reliability analysis was performed. The Intraclass Correlation Coefficient (ICC) is determined as an indicator of reliability. An ICC between 1.00 and 0.81 is considered (almost) perfect, 0.8-0.61 corresponds to substantial agreement, 0.6-0.41 to moderate agreement, 0.4-0.21 to sufficient agreement, and 0.2-0.0 to low agreement. To determine the differences between the collected distances, a one-factor Analysis of Variance (ANOVA) was used to analyze the mean of the collected measurements of the three investigators. Differences in each group were localized using the Scheffé procedure as a post-hoc test. In addition, the absolute differences of the averaged measurements were compared. The significance level was set at  $P < 0.05$ .

**Results**

Overall, the measurements for both pre- and post-operatively determined intraclass and interclass coefficients have values mostly  $> 0.85$ , which corresponds to an excellent agreement. Preoperative measurements tend to have a higher ICC compared to postoperative measurements. Preoperatively, the new measurement point (PPTe) has an intraclass coefficient of 0.94, and postoperatively, 0.92 (Table 1). For the interclass coefficient, the preoperative value is 0.97 and the postoperative value is 0.85 (Table 2).

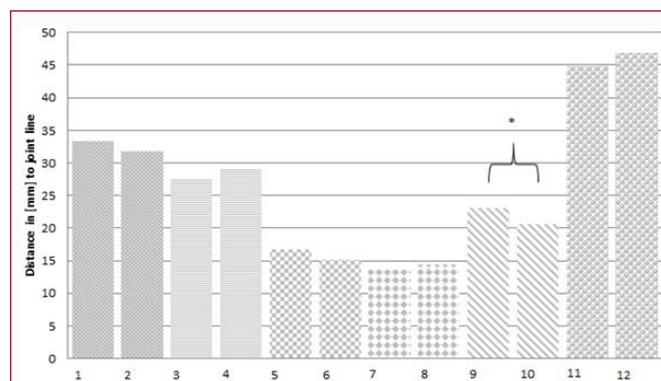
The values obtained for the individual radiologic-anatomic landmarks are shown in Table 3. The difference between the mean

**Table 1:** Intraclass correlation coefficient of the pre- and post-operative measurements between the three independent examiners.

	Preoperative	Postoperative
Epicondyles medialis	0.85	0.84
Epicondyles lateralis	0.85	0.83
Fibular head a.p.	0.94	0.86
Fibular head lateral	0.96	0.94
Patella tip lateral	0.93	
PPTe	0.94	0.92

**Table 2:** Interclass correlation coefficient of the means of three repeated measures and three independent observers.

	Preoperative	Postoperative
Epicondyles medialis	0.86	0.86
Epicondyles lateralis	0.75	0.86
Fibular head a.p.	0.97	0.84
Fibular head lateral	0.98	0.91
Patella tip lateral	0.98	0.91
PPTe	0.97	0.85



**Figure 5:** Comparison of the absolute mean values between pre- and postoperative distance measurement of the individual anatomical-radiological landmarks.

\*Significant difference  $p < 0.05$ . Comparing PPTK to all other landmarks, there is a significant difference both pre- and postoperative  $p < 0.05$ .

value determined preoperatively and postoperatively is 0.66 mm to 2.41 mm, depending on the point used.

For the new measurement point (PPTK), a distance of 44.8 mm (SD 8.5) is measured preoperatively and 46.9 mm (SD 8.7) postoperatively.

A significant difference can be determined between pre- and post-operatively measured values of the measuring points patellar tip and joint line ( $P < 0.05$ ) (Figure 5 and Table 3).

**Discussion**

The aim of this study was to define a bony landmark that allows an easy intraoperative detection of the height of the knee joint space - independent of the examiner - in the event of revision arthroplasty, in order to be able to restore its height physiologically. As described, revision arthroplasty will present a major challenge to orthopedic surgeons [2]. Unlike primary knee arthroplasty procedures, bony landmarks such as the tibial plateau and femoral condyles are usually no longer, or not sufficiently, available in revision procedures, so alternative bony structures must be reported in order to optimally maintain the position of the knee joint space postoperatively, even in revision procedures [9]. The importance of physiologic reconstruction of the joint line becomes clear when considering the consequences already mentioned, such as pain or instability, when the joint line is displaced only 5 mm proximally, which may be the case in up to 36% in revision arthroplasties [3,10].

Various bony landmarks, which are necessary for intraoperative orientation, have been repeatedly investigated in the past with regard to their validity and reliability. However, which radiologic-anatomic landmarks are considered to be superior is currently still inconsistent

**Table 3:** Presentation of the pre- and post-operative measurements related to the respective anatomical-radiological landmark. MV: Mean Value; SD: Standard Difference; MIN: Minimum; MAX: Maximum

	Preoperative				Postoperative				Difference of mean values
	MV	SD	MIN	MAX	MV	SD	MIN	MAX	
Epicondyles medialis	33.4	3.5	23.17	44.9	31.7	4.5	17.1	49	1.67
Epicondyles lateralis	27.5	4.3	16.3	41.3	29.2	4.5	15.6	44.9	1.62
Fibular head a.p.	16.7	5.2	1.93	30.6	15	4.2	4.6	26.6	1.7
Fibular head lateral	13.7	5.9	0.2	26.9	14.4	5.4	2.9	28.9	0.66
Patella tip lateral	23	7.6	0	46	20.6	7.2	6.2	43.2	2.41
PPTE	44.8	8.5	26.43	78.1	46.9	8.7	28	93	2.05

and subject to controversial discussions [9,11-14].

In 2015, Maderbacher et al. published measurements of bony landmarks on the contralateral knee in each case - assuming symmetry of the human body. They concluded that the distance of the fibular head to the joint space at the contralateral knee was the most precise parameter to measure and that any confounding variables such as age, sex, or the extent of osteoarthritis did not affect the measurement of the contralateral knee. As described, a bony landmark located on the fibula can be easily detected intraoperatively. In addition, Maderbacher et al. describe the advantage of using the commonly used "tibia-first" method, in which, after determining the correct tibial height, the joint line can be reconstructed with distal femoral elevation in extension, while the flexion gap can be balanced by dorsal elevation. Due to proximalization of the joint space in the course of balancing the extension and flexion gap by higher insertion and reduction of the femoral component with negative effects on the postoperative result, a bony measuring point in relation to the tibia would be desirable [9]. In the present study, the tip of the fibular head also lends itself with a very high reliability as a bony landmark for the detection of the knee joint gap; in particular, it can be reliably detected even with the knee endoprosthesis in place.

Ozkurt et al. published a study with measurements on a total of 40 cadaveric knees to test the reliability and validity of epicondylus medialis and lateralis as bony landmarks in revision arthroplasty. They concluded that the epicondyle medialis and lateralis are suitable as bony landmarks and epicondylar width to account for sex- and size-specific differences, especially as a simple, reliable intraoperative orientation [11].

However, also in our review, a frequently limited identification possibility of the epicondyles on conventional radiographs is shown. This is also criticized by Maderbacher et al., especially when osteophytic overlays still complicate detection on degeneratively altered knees [9].

Due to the high range of the individual values, as confirmed again by our measurements, the use of ratio representations instead was discussed. In contrast of absolute values, Servien et al., in a study of 200 MRI images of healthy knees, related the distance from the fibular head, epicondyles, and tibial tubercle to the joint line to the femoral and tibial width, respectively, and formed a ratio to account for different body sizes of the subjects. The average distance between the lateral epicondyle and the joint line was 23 mm, and between the joint line and the medial epicondyle this distance was 28 mm, but there was a significant intersexual difference and a large variability regarding the distances. In contrast, the average distance between the fibular head and the joint line was 14 mm (4.1-22.13 mm) with no

intersex difference but a large variability in terms of individual body size, hence it is not considered a reliable landmark [12]. Our results also show high ranges for the individual measurement points, so that the use of absolute values cannot be advocated here either.

In 2013, Iacono et al. found a linear correlation between femoral width and the distance from the adductor tubercle to the joint line in measurements on conventional radiographs before primary arthroplasty procedures. They found greater reliability compared with similarly designed measurements from the medial epicondyle to the joint line [13]. In 2015, they conducted a study to verify whether the relationship drawn from the distance of the adductor tubercle to the joint line and femoral width could also be applied in revision arthroplasty. From measurements on 21 patients who underwent revision arthroplasty, in only 13 patients the height of the joint line was physiologically restored postoperatively, when compared with the healthy contralateral knee [14]. This leaves every third patient with an insufficiently corrected joint line after knee revision arthroplasty.

As demonstrated above, using the epicondyles or the adductor tuberosity as a bony landmark in revision arthroplasty cannot be considered as reliable. The surgeon may struggle to identify these landmarks after primary knee arthroplasty. Furthermore, when using these landmarks, in a significant number of cases the joint line was not restored physiologically. Therefore, an anatomic-radiologic landmark that is easy to identify even after primary knee arthroplasty, is necessary. The novel landmark described (PPTE) matches these requirements. By using the point on the tibia measured during this study, proximalization of the joint space could thus be prevented in the future. In addition, preoperative radiological examinations of the contralateral knee could be omitted, which on the one hand would have organizational advantages, and on the other hand would prevent a further radiation exposure of the patient.

## Conclusion

Physiologic reconstruction of the joint line in revision knee arthroplasty represents a critical factor in clinical outcomes of this surgery. The point in the area of the proximal tibia investigated in this study has a very high reliability and certainly represents another radiological - anatomical landmark for the detection of the joint line in relation to endoprosthetic procedures. It represents a safe alternative, especially when the usual bony landmarks, including in some cases the fibular head, are altered or even missing due to the previous, sometimes multiple operations.

## Limitations

Overall, the study presented here has some weaknesses: First, it is an analysis of radiographic images, without subsequent detection of

the patient's outcome.

Second, the measurements were performed only on the affected side, which precludes the investigation of any interindividual differences that may occur.

In addition, the study included only patients who received a primary prosthesis, so that further measurements regarding the reliability of the measurement point with regard to the representation of the joint line, even in revision surgeries, are not possible.

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