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# The adductor tubercle: an important landmark to determine the joint line level in revision total knee arthroplasty

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**Abstract**
*Purpose* The restoration of the physiological femorotibial joint line (JL) is important to obtain a good outcome in revision total knee arthroplasty (RTKA). However, its assessment is challenging. The ratio of the distance between the adductor tubercle (AT) JL (ATJL) and the trans-epicondylar femoral width (FW) was proposed as a reliable method. The purpose of this study was to check whether this ratio is a reliable tool to restore the prosthetic JL height in challenging prosthetic revision cases.
*Methods* Twenty-one patients (mean age 65.8 years) were recruited. During surgery, FW was measured and ATJL distance was calculated using 0.53 (SD 0.03) as the ratio. After implant positioning, the obtained ATJL line was measured to verify the accuracy of the surgical procedure. Thirteen patients presented a healthy contralateral knee: a comparative radiograph examination was performed to verify the appropriateness of the restored JL height.
*Results* The intra-operatively calculated ATJL was not significantly different with respect to the measured ATJL obtained after prosthetic component implantation. The comparative analysis between the restored JL and the JL of the contralateral not operated knee was also not statistically significant, thus confirming the appropriateness of the restored JL height.
*Conclusions* This study shows that the method which uses an AT to JL distance/FW ratio to determine the JL level, previously applied in primary TKA, is valid when using intra-operatively acquired measurements in RTKA. This is clinically relevant since it represents a reliable tool which helps surgeons to restore the JL level in challenging prosthetic revision cases.
*Level of evidence* Case series, Level IV.

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**Keywords** Joint line · Revision total knee arthroplasty · Adductor tubercle · Femoral width · Knee surgery · Ratio

## Introduction

With more than 700,000 interventions a year in the USA, primary total knee arthroplasty (TKA) is having a growing impact in surgical practice [11]. Accordingly, the number of revision TKA required is rising, and the projected increase from 2005 to 2030 is 601 % [11]. Unfortunately, revision procedures remain a surgical challenge, because results are less predictable and satisfactory than primary procedures and survivorship at 12 years is 82 % [23]. Among the key technical requirements to obtain a good outcome, restoration of the physiological joint line (JL) is important because it allows ligament balance and normal knee kinematics to be restored [1, 12, 18]. A deviation in the JL of 5 mm proximally and anteriorly produces instability, which is most evident in mid-flexion [16], whereas a change of 2 mm can reduce knee flexion [2]. Moreover, changes in JL can affect the patello-femoral joint. JL elevation may result in patella baja causing impingement of the patella on the tibial component and resulting in anterior knee pain, increased polywear, flexion limitation and extensor mechanism failure [10, 18], whereas lowering of the JL (distally displaced–distalization) creates patella alta, which can be the cause of dislocation [8]. Furthermore, an elevation of the JL of <5–8 mm is linked to poorer clinical and functional outcomes [18, 19].

Whereas there is agreement in the literature about the importance of the JL for knee function and the negative effects of JL alteration in revision TKA, there is still some debate regarding the most appropriate methodology for the assessment of the femoro-tibial JL position.

In a previous study [6], a new landmark was introduced to assess the femoro-tibial JL. The ratio of the distance between the adductor tubercle (AT) JL (ATJL) and the trans-epicondylar femoral width (FW) was proposed as a method to identify the JL level. Good intra-observer and inter-observer reliability was supported first by a radiographic study and more recently intra-operatively in primary TKA [6, 7]. However, up to now no studies have documented the clinical usefulness of this approach in revision TKA.

The hypothesis is that the previously validated ratio would also be applicable for the determination of the JL in the challenging prosthetic revision cases when the anatomical JL is missing. Thus, the purpose of this study was to check whether this ratio is a reliable tool to restore the prosthetic JL height as closely as possible to the anatomical JL in revision TKA.

## Materials and methods

### Surgical technique: revision by using a constrained prosthesis

The surgical technique is based on the principles of knee arthroplasty surgery developed for the total condylar knee prosthesis at the Hospital for Special Surgery in the early 1970s [9], which allows the surgeon to perform a successful RTKA [25]. With intra-medullary alignment systems, the tibial resection is performed perpendicularly to the tibial axis in the coronal and sagittal planes. In the case of a bone defect, this will be treated by using bone graft or metal augmentations. For medullary fixation, the medullary canal is opened using hand reamers, and a suitable trial rod with a good fitting to the canal is selected and attached to a trial tibial component and put in place. The selected tibial implant should cover the cortical rim of proximal tibia [5, 24]. The distal femoral resection is made at 5° or 7° valgus in reference to the femoral shaft. An intra-medullary cutting guide is usually used for this cut. The size of the femoral component must be selected, and it must be made simultaneously with soft tissue balance as the two issues are intimately related. It is the authors' preference to choose the femoral component size according to the failed component, if it was appropriately sized, or a same-sized component or one-size larger than the size of the selected revision tibial component. After sizing the femur (by adding posterior augments when necessary to compensate for the bone loss and allow a good fitting between bone and prosthesis), the medial and lateral epicondyles will serve as reference for rotational position of femoral component. Once the femoral component is set at the correct rotation with respect to the epicondylar axis, the objective is to restore the JL.

In this study, the FW was measured and multiplied by 0.53, the constant derived from the ratio ATJL/FW validated in a previous study [6], to calculate the JL from the AT (Figs. 1, 2). The appropriate distal femoral augments were used to compensate for the distal bone loss and restore the JL. With the trial components in place, the knee was stabilized in extension and the polyethylene that filled the extension space was inserted. The knee was then fully flexed. If the knee was stable (flexion space equal to the extension space), no adjustments were necessary. If there was a discrepancy between flexion and extension gaps, additional adjustments were performed.

In case of the flexion gap was too large, the first step was to check the sagittal position of the femoral component: if it was too anterior, it was moved posteriorly by using an offset stem and a (thicker) posterior augmentation, and if it was not enough, the next larger size of the femoral component was chosen. Once the appropriate alignment and stability were achieved, the final components were assembled.

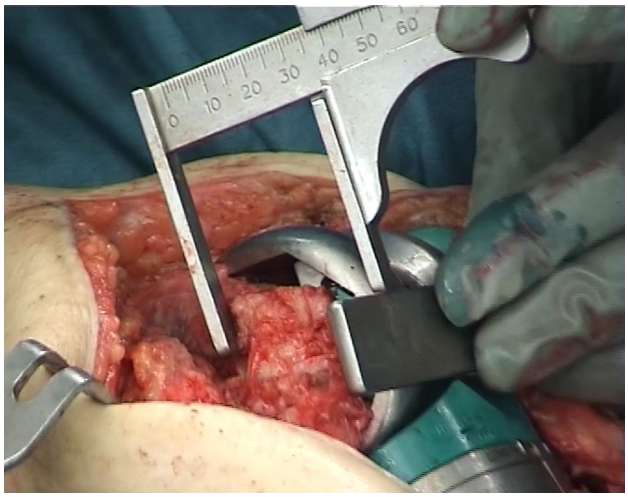

**Fig. 1** Femoral trial component is distally placed in order to restore the JL previously calculated according to FW. The JL from the AT is measured by a calliper. Augments are usually required to fill the gap between the distal femoral bone cut and the prosthesis

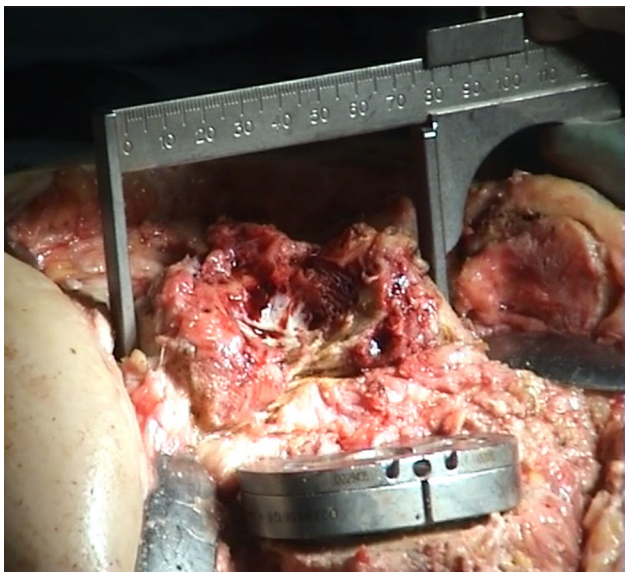

**Fig. 2** Intra-operative measurement of FW. The calliper is placed according to the two most prominent points in the femoral shape to measure the FW, and this value is then multiplied by the coefficient 0.53 to calculate the JL from the AT

### Patient selection, treatment and JL restoration

Twenty-one patients (mean age 65.8 years—range 48–83, mean BMI 29.3—range 20.7–38.3) were recruited for the study (performed at the Rizzoli Orthopaedic Institute, Bologna, Italy). During surgery, FW was measured with calliper (0.05-mm accuracy), and the ideal ATJL distance was calculated using 0.53 as a ratio for all patients. After implant positioning, the ATJL line obtained was then measured to verify the feasibility and accuracy of the surgical procedure to approximate the ideal ATJL.

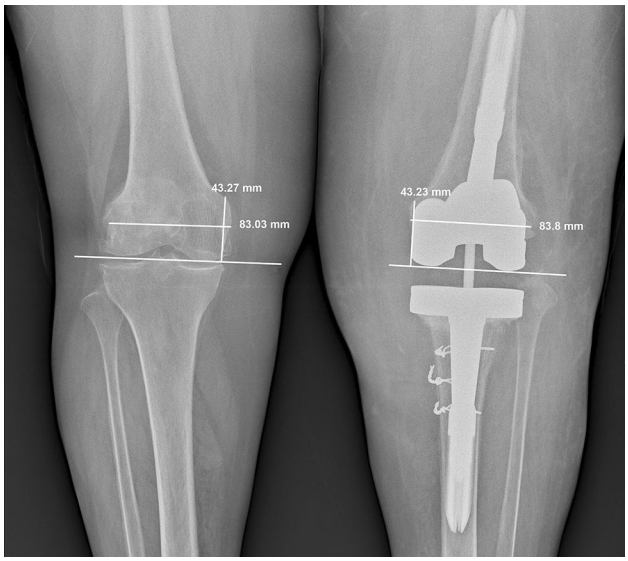


**Fig. 3** Post-operative X-rays in AP view of both knees. A comparison between the ratio measured on the RTKA and the contralateral not operated knee was made to verify the appropriateness of the restored JL height

Thirteen patients presented a healthy contralateral knee (i.e. no previous surgeries, Kellgren–Lawrence below IV) and also underwent radiograph examination. Comparison between the ratio measured on the RTKA and the contralateral not operated knee was made on these patients to verify the appropriateness of the restored JL height (Fig. 3).

### Statistical analysis

Paired Student's *t* test was used to calculate the difference between the ideal ATJL, as calculated from the FW measured intra-operatively, and the real ATJL obtained after implant positioning and to compare the obtained ATJL with the contralateral ATJL of the not operated knee.

Power analysis was a priori calculated on the main goal, to evaluate the accuracy of restoring the ATJL as close as possible to the ideal one calculated with the proposed ratio. Considering a standard deviation of 2.9 mm in ATJL distance and a difference of 5 mm between the obtained ATJL and the ideal ATJL [16], with a set at 0.05 and a power of >0.9, 20 patients were required.

## Results

Intra-tester and inter-observer reliability for ATJL was reported in the authors' previous studies [6, 7].

**Table 1** Difference between the ATJL distance calculated according to ATJL/FW ratio and the ATJL distance measured after surgery with prosthesis in place

| | *n* | Mean | SD |
|---|---|---|---|
| ATJL ideal | 21 | 44.70 | 2.98 |
| ATJL real | 21 | 43.01 | 2.93 |
| Difference (ATJL ideal−ATJL real) | 21 | 1.69 | 2.27 |

The mean difference was 1.69 mm

**Table 2** Difference between the ATJL/FW ratio obtained intra-operatively after prosthesis implant and the same ratio measured on X-rays of native knee

| | *n* | Mean | SD | 95 % CI |
|---|---|---|---|---|
| Operated knee | 13 | 0.53 | 0.03 | 0.51–0.53 |
| Contralateral | 13 | 0.53 | 0.02 | 0.51–0.54 |
| Difference (operated knee −contralateral) | 13 | 0.00 | 0.03 | |

There was no difference (mean difference of 0.00), thus confirming the validity of the method

Among the 21 RTKA performed by applying the proposed ratio, in all but three cases distal femoral augmentations were required to compensate for the bone loss and restore the calculated JL. Laxity in flexion was observed in 12/21 (57 %) of the cases and addressed by moving posteriorly the femoral component using stem offset (with a thicker posterior augmentation). In only one case, the next larger size of the femoral component was required to address persistent flexion laxity. The mean polyethylene thickness implanted in this series was 15 mm, ranging from 12.5 to 20 mm, whereas tibial augmentations were never thicker than 5 mm.

The intra-operatively calculated ATJL was not significantly different with respect to the measured ATJL obtained after prosthetic components implantation (Table 1).

The comparative analysis between the restored JL and the JL of the contralateral not operated knee, performed on the radiograph evaluation and analysed through the FW/ATJL ratio comparison, was also not statistically significant, thus confirming the appropriateness of the restored JL height (Table 2).

## Discussion

The most important finding of this study was that the FW/ATJL 0.53 ratio, previously validated for primary TKA, appears to be a valid tool also for the determination of the JL in challenging prosthetic revision when the anatomical JL is missing. RTKA presents numerous technical challenges and critical decisions for the surgeon facing a knee with a previously failed primary implant and a markedly altered anatomy to restore [17]. The principles involved in knee reconstruction include reestablishment of the anatomical alignment, restoration of the JL, and flexion and extension gap balancing. All these steps must be achieved to obtain a good functional outcome [3, 13, 20]. Among the surgical challenges of RTKA, accurate restoration of the JL is technically difficult because of bone stock loss that makes the identification of relevant bone landmarks difficult [4]. In fact, the most appropriate method to restore the JL as close as possible to the anatomical one is still controversial. Intra-operative landmarks to determine the anatomical JL in a RTKA include the old meniscal scar, one finger width above the fibular head, a mean distance of 3 cm below the medial epicondyle and 2.5 cm below the lateral epicondyle [22]. Maderbacher et al. [15] suggested to assess the JL by measuring the distances from the bony landmarks to the JL of the contralateral knee on the radiographic images. All the proposed methods present important limitations, being subjective and unreliable (the meniscal scar is not always detectable, one finger over the fibular tip is not precise and reproducible, the contralateral knee may be significantly damaged or already replaced), or based on absolute values, which is not a very accurate way of predicting JL position, as this distance is likely to change with the size and morphology of the patient. The use of ratio has been previously suggested to overcome the problem of the large individual variation in size. Some authors proposed using the epicondyles as a reference point, considering the ratio of the distance between the medial epicondyle and JL tangent, to the trans-epicondylar width of the femur (ME/FW ratio) [18, 21, 23]. However, particularly in RTKA, where the anatomy is markedly compromised, the epicondyles are often challenging to identify. The AT has been proposed as an easier and more reliable landmark and has been recently proposed for assessing the femoro-tibial JL. In fact, the ratio of the distance between the AT and JL (ATJL) to the trans-epicondylar FW has been shown to be reliable, without gender specificity, and a lower standard deviation than the ME/FW ratio. A radiographic study showed a linear correlation between the ATJL distance and the FW, thus suggesting its clinical usefulness for guiding implant component positioning to re-establish the JL [5]. The feasibility of this radiographic investigation on the ATJL/FW ratio was then tested in the surgical setting. In a study on 40 patients undergoing primary TKA, this ratio proved to be a feasible option by allowing reliable JL identification [7]. Intra-operatively acquired measurements were found to be comparable to the radiographic ones, whereas avoiding the radiographic limitations due to magnification errors, with a negligible difference.

Thus, 0.53 was found to be an accurate and reliable ratio to determine the most appropriate JL level starting from the AT assessment and the measurement of the FW. This method was further confirmed in a study recently published on a wide case series where 100 patients evaluated radiographically leading to the same ratio [14]. However, no study up to now proved the usefulness and accuracy of this method to have a simple ratio to be used in challenging cases of TKA revision.

The clinical usefulness of this ratio would be maximal in the revision arthroplasty setting. In this study, we tested the ATJL/FW ratio in 21 RTKA. Our results showed the surgical feasibility of JL restoration according to the JL calculated by applying the ratio: in fact, the calculated JL was not significantly different with respect to the intra-operatively measured ATJL obtained after prosthetic component implantation. Moreover, the JL restoration was verified by evaluating radiographs in the subgroup of patients with contralateral not operated knees (Fig. 2). The comparative analysis between the restored JL and the JL of the native knee was also not statistically significant, and the difference was always below 5 mm, which is considered a safe limit for a good functional outcome, thus confirming the appropriateness of the restored JL height.

The JL restoration allowed the flexion and extension gap to be equal and symmetric in 20/21 cases (12 directly and 8 by simply shifting posteriorly the femoral component), thus showing a good ligament balance due to the appropriate JL level. In this way, JL restoration was obtained simultaneously to ligament balancing, another challenging and key aspect in revision arthroplasty, thus markedly simplifying and shortening surgery and further confirming the validity and usefulness of this method.

This study presents some limitations: senior surgeons performed this challenging procedure, whereas the calliper positioning might be troublesome for less experienced surgeons. However, to favour the landmark identification, amplioscopic control can be used to identify the AT precisely. Another weak point is the limited number of cases with contralateral radiographs to compare the restored JL with the anatomical line. However, it is common that complex revision cases belong to patients with bilaterally treated knees for osteoarthritis, our data were still able to show the accuracy of the JL level obtained, and this study was appropriately powered for the main study aim, the demonstration of the accuracy of this method in revision arthroplasty.

The clinical relevance of findings of the present study is the demonstration of the validity of a new, easily detectable and reliable landmark to be used, by applying a simple ratio, to help surgeons to restore the JL and obtain ligament balancing, thus simplifying and shortening surgery in the complex cases of RTKA.

## Conclusion

This study shows that the validity of the method which uses an AT to JL distance/FW ratio to determine the JL level, previously applied in primary TKA, is confirmed when using intra-operatively acquired measurements in RTKA. Thus, this ratio represents a reliable tool to restore the JL level in challenging prosthetic revision cases.

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