

# Rotational Alignment Landmarks in Primary Total Knee Arthroplasty

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## ABSTRACT

**Purpose:** We hypothesized that the anterior tibial surface curvature is a more reliable landmark for correct tibial component rotational positioning in TKA respect to the 'Akagi' line and the medial third of the tibial tubercle.

**Methods:** Three independent investigators reviewed 124 knee MRI scans, identifying independently the femoral transepicondylar axis (TEA), the femoral posterior condylar axis (PCA), a line connecting the middle of the posterior cruciate ligament and the medial edge of the patellar tendon attachment (Akagi's line), the medial third of the tibial tubercle and the anterior tibial surface curvature. The most appropriate tibial baseplate tracing for the NexGen Total Knee System (Zimmer, Warsaw, USA) was superimposed matching the anterior tibial cortex with its anterior surface. At this point, the rotation of the tibial plate tracing was calculated in respect to the TEA, the medial third of the tibial tubercle line, the Akagi's line and the PCA. Customized software was created and used for analysis of the MRI datasets.

**Results:** The investigators agreed on the localization of the Akagi's line in 64% of the cases within 3° and in 85% of the cases within 5° (minimum -16°, maximum -7°): this landmark might lead to internal rotation of the tibial component. The observers agreed on the localization of the medial third of the tibial tubercle in 29% of the cases within 3° and, in 70% of the cases, within 5° (minimum -4°, maximum +4°): this landmark might lead to external rotation of the tibial component. The investigators agreed on the localization of the anterior tibial surface curvature in 89% of the cases within 3° and in 99% of the cases within 5° (minimum -1°, maximum +4°): component alignment along the anterior cortex guaranteed full matching  $\pm 3^\circ$  to the epicondylar axis in 75% of the knees.

**Conclusion:** Alignment of the tibial component, when based on the anterior tibial surface, was more reliable and easier identifiable than either the Akagi's line or the medial third of the tibial tubercle.

**Level of evidence:** Level 3 (Retrospective cohort study).

**Keywords:** TKA, Alignment, Bone landmarks, MRI.

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## INTRODUCTION

Restoration of the mechanical axis and soft tissue balancing are well established key factors for a successful total knee arthroplasty (TKA), which remains an operation with a considerable rate of failure. Many studies related a poor functional outcome to femoral and tibial components rotational malalignment.<sup>1-3</sup> Rotational malalignment may lead to patellar maltracking, anterior knee pain, flexion instability and premature wear of the polyethylene inlay. The rotational alignment of the femoral component has been extensively studied and useful reference axes for setting proper femoral rotation have been established, including the posterior condylar axis, the midtrochlear line (Whiteside's line) and the transepicondylar axis.<sup>4-6</sup> As a result, many femoral cutting guides use the transepicondylar line as a reference for the rotational alignment of the femoral component.

Less attention has been given to the rotational alignment of the tibial component: a standard reference is still controversial in the current literature. Currently, two techniques are used to determine tibial rotation in TKA. The first method utilizes anatomical landmarks, while the second is a range-of-motion (ROM) technique. Historically, the anatomical landmark technique used conventional extraarticular (i.e. the transmalleolar axis, the second metatarsal axis and the tibial tuberosity) and intraarticular references (i.e. the posterior tibial condylar line the transcondylar tibial line, or the line between the tibial spines). More recently, various sagittal planes have been described including a line perpendicular to the posterior joint surface passing through the medial third of the tibial tubercle<sup>7</sup> and a line passing through the middle of the posterior cruciate ligament perpendicularly to the projected femoral transepicondylar axis (Akagi's line).<sup>8</sup> Unfortunately, many of these references vary among patients are difficult to establish and are, therefore, unreliable. The ROM technique aligns the tibial component according to the rotational alignment of the femoral component during trial

reduction with a 'self-seeking method'. Unfortunately, this method induces the risk of transferring a femoral malrotation to the tibia.<sup>1</sup> None of these methods have been universally adopted.

The aim of this study was to define an easily identifiable landmark and to propose a reliable method for ideal positioning of the tibial component in TKA. We attended to ascertain if there was an optimal way of tibial components orientation in TKA, starting from the fact that a single area would be a better and more easily definable landmark than a single point or a line, as previously described.<sup>6-8</sup> We hypothesized that the anterior tibial surface curvature was a more reliable landmark for correct tibial component rotational positioning in TKA with respect to the Akagi's line and the medial third of the tibial tubercle.

## METHODS

We analyzed 124 magnetic resonance imaging (MRI) knee scans from 124 patients (69 women and 55 men) with a mean age of 42 years (18 to 74 years). All scans were performed utilizing a Siemens Artroskan system, positioning the knee in full extension with the second metatarsal axis in a vertical position: all images were 2 mm in thickness and with 3 mm in reconstructive increments from the distal metaphysis to the tibial tubercle. All scans were done because of a hypothesis of ligamentous or cartilaginous lesion. None of these knees revealed the presence of osteoarthritis, ligamentous lesions, significant meniscal lesions or flexion contracture.

On a single axial scan showing, the femoral transepicondylar axis (TEA), the femoral posterior condylar axis (PCA) (Fig. 1) and the projection of the medial third of the tibial tubercle on the anterior tibial cortex (Fig. 2) were identified. For each knee, the TEA, the PCA and the medial third of the tibial tubercle were reported on a tibial axial cut. The geometric center of the tibial area was also identified (Fig. 3). A line was first drawn from the center of the tibial plate to the medial third of the tubercle (A) and then the perpendicular line to the TEA passing through the tibial plate center (Fig. 4) was identified (B). At this point, the Akagi's line was drawn (Fig. 5). This landmark is made by a line starting at the medial third of the tibial tubercle and ending at the center of the posterior cruciate ligament tibial insertion. The most appropriate tibial baseplate tracing (size 3 to 8) for the NexGen Total Knee System (Zimmer, Warsaw, USA) was superimposed at this time matching the anterior tibial cortex with its anterior surface (Fig. 6). The rotation of the tibial plate tracing was calculated with respect to the TEA, the medial third of the tibial tubercle line, the Akagi's line and the PCA.

Customized software was created and used for analysis of the MRI datasets. All axial images were evaluated



Fig. 1: An MRI axial scan of the distal femur: transepicondylar axis (TEA) and femoral posterior condylar axis (PCA)

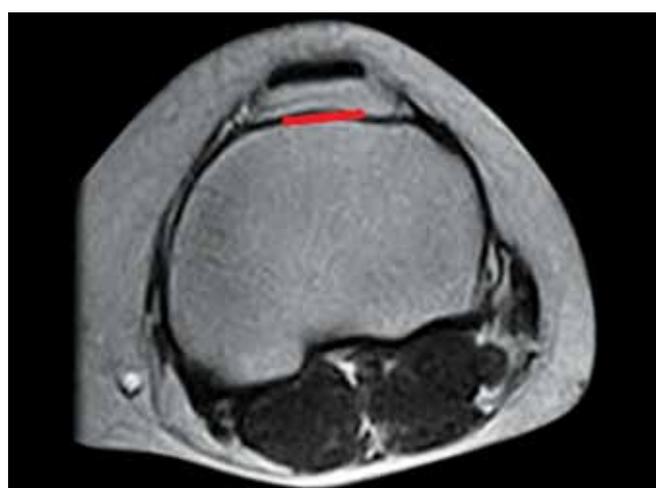


Fig. 2: An MRI axial scan of the proximal tibia: projection of the medial third of the tibial tubercle on the anterior tibial cortex

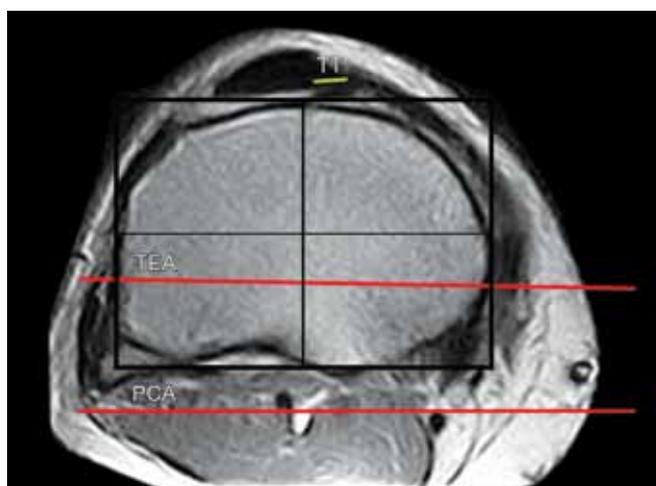
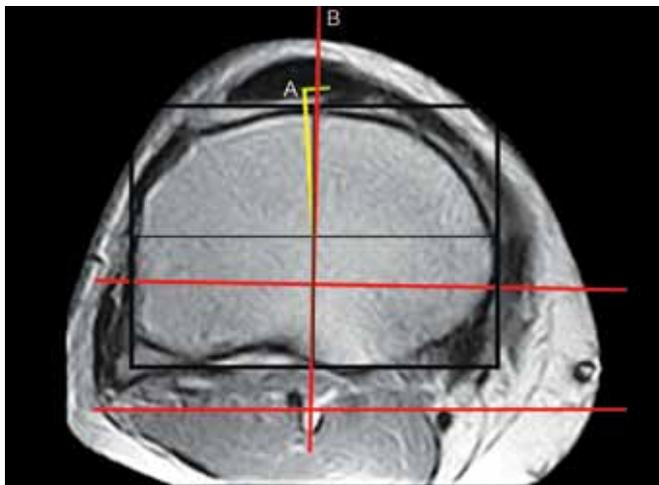
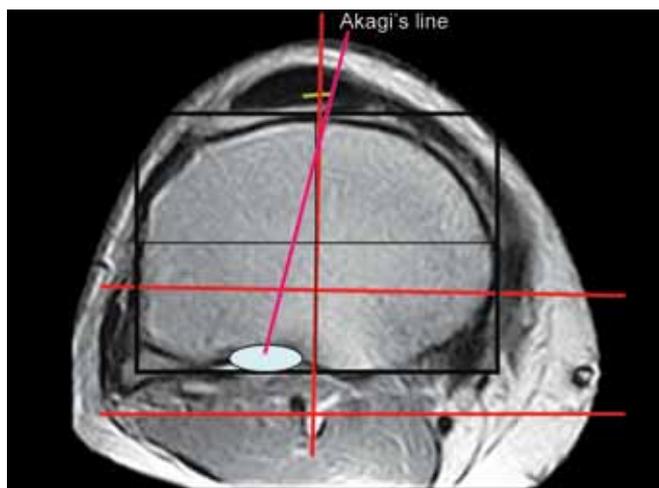


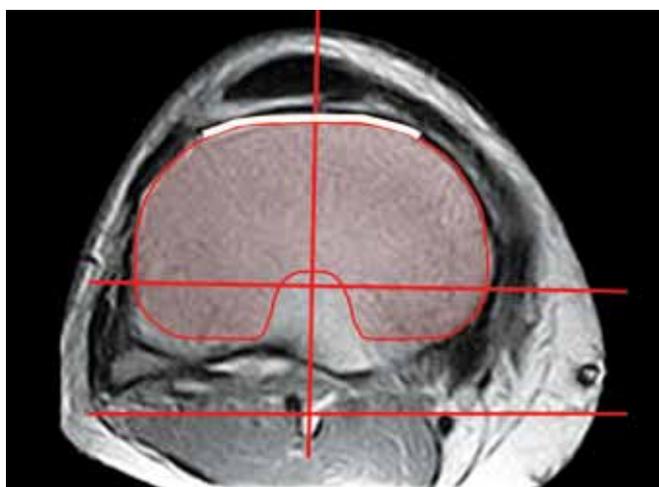
Fig. 3: An MRI axial scan of the proximal tibia: identification of the geometric center of the tibial plate (TT: Projection of the medial third of the tibial tubercle on the anterior tibial cortex; TEA: Transepicondylar axis; PCA: Femoral posterior condylar axis)



**Fig. 4:** An MRI axial scan of the proximal tibia: (A) line A: conjunction between the geometric center of the tibial plate and the projection of the medial third of the tibial tubercle on the anterior tibial cortex; (B) line B: perpendicular conjunction between the geometric center of the tibial plate and the projection of the TEA



**Fig. 5:** An MRI axial scan of the proximal tibia: the 'Akagi's line'. This landmark is made by a line starting at the medial third of the tibial tubercle and ending at the center of the posterior cruciate ligament tibial insertion



**Fig. 6:** Tibial baseplate tracing (NexGen Total Knee System, Zimmer, Warsaw, USA) superimposed matching the anterior tibial cortex with its anterior surface. The posteromedial corner is not covered: this is an indirect sign of a sufficient external rotation of the tibial component

independently by three independent observers (PFI, PCM, AB). They independently repeated the entire process, from point gathering to angles measurement. The reliability of each measurement was then calculated by using Bland-Altman analysis for interobserver agreement: the coefficient value has been reported as an average of multiple pairwise comparisons (PFI vs PCM; PFI vs AB; PCM vs AB).

## RESULTS

### Akagi's Line

The three observers showed an agreement on the localization of the Akagi's line in 64% of the cases within 3° and in 85% of the cases within 5° (minimum -16°, maximum -7°). The average intraclass correlation coefficient was 0.923 (PFI vs PCM: 0.910; PFI vs AB: 0.933; PCM vs AB: 0.927). The use of this landmark might lead to internal rotation of the tibial component.

### Medial Third of the Tibial Tubercle

The three observers showed an agreement on the localization of the medial third of the tibial tubercle in 29% of the cases within 3° and, in 70% of the cases, within 5° (minimum -4°, maximum +4°). The average intraclass correlation coefficient was 0.881 (PFI vs PCM: 0.871; PFI vs AB: 0.897; PCM vs AB: 0.876). This landmark led to an average external rotation of the tibial component of 4.7° (±3.6°) respect to the TEA.

### Anterior Tibial Surface Curvature

The three observers showed an agreement on the localization of the anterior tibial surface curvature in 89% of the cases within 3° and in 99% of the cases within 5° (minimum -1°, maximum +4°). The average intraclass correlation coefficient was 0.949 (PFI vs PCM: 0.940; PFI vs AB: 0.961; PCM vs AB: 0.947). Component alignment along the anterior cortex guaranteed full matching ±3° to the epicondylar axis in extension in 75% of the cases with minor errors in external rotation.

## DISCUSSION

Rotational malalignment has been shown as a major cause of mid-term failure in TKA.<sup>1-3</sup> While the transepicondylar axis is universally recognized as a primary reference for the femoral rotational alignment,<sup>9-11</sup> there is no consensus for the tibial rotational alignment. In fact, many different anatomical landmarks have been suggested from previous studies as the best references for tibial component rotational alignment in TKA.<sup>4-6,8</sup>

Many surgeons prefer a single point as a reference. Incavo et al<sup>12</sup> suggested aligning the mid-axis line of the tibial tray with a point close to the medial third of the patellar tendon. Lützner et al<sup>13</sup> showed a better femorotibial rotational alignment when using the medial third of the tibial tubercle as a landmark. Barrack et al<sup>14</sup> suggested to use the most prominent point of the tibial tubercle for correct tibial component alignment. Unfortunately, Cobb et al,<sup>15</sup> in a cadaveric study, showed that the position of the tibial tubercle center showed a very large variation among the knees studied. Ikeuchi et al<sup>6</sup> indicated the medial border of the attachment of the patellar tendon as the best landmark for tibial rotational positioning. Recently, Rossi et al,<sup>16</sup> in a cadaveric study, validated the posterolateral tibial corner as a reliable reference point: the identification of this point requires a complete exposure of the tibial plateau, which is difficult to obtain in many knees.

Other studies suggest the use of an axis or a sagittal plane in place of a single-point mark for correct rotational alignment. Akagi et al<sup>8</sup> described a line perpendicular to the projected femoral TEA, starting at the medial third of the tibial tubercle and pointing at the middle of the posterior cruciate ligament tibial insertion. Dalury<sup>17</sup> proposed using a line from the mid-point between the tibial spines passing 1 mm medial to the medial border of the tibial tubercle. Luo<sup>18</sup> proposed the use of a line perpendicular to the posterior joint surface passing through the medial third of the tibial tubercle. Many sagittal axes are unfortunately not easily and reliably identifiable at surgery. Graw et al<sup>19</sup> showed high variability of several sagittal axes in relation to different tibial resection levels. Nagamine et al<sup>20</sup> demonstrated that a sagittal antero-posterior axis was less reliable than the posterior condylar axis for use in alignment for TKA.

Some surgeons, including Incavo et al<sup>21</sup> and Westrich et al,<sup>22</sup> prefer the use of an asymmetrical component maximizing tibial cover in order to provide the best stability and load transfer in TKA. In our experience, tibial cover itself is not sufficient to guarantee a satisfactory tibial rotational alignment. Pagnano et al<sup>23</sup> demonstrated that rotational malalignment in TKA is not correctable by the use of a mobile-bearing option.

Siston et al<sup>24</sup> affirmed that neither the axis technique nor the single-point reference technique establishes a correct tibial rotation alignment, suggesting the use of computer-assisted techniques for correct rotational alignment in TKA.

Eckhoff et al<sup>25</sup> suggest the use of the ROM technique for correct components alignment in TKA instead of using anatomical landmarks. They put the knee through a full range of flexion and extension, allowing the tibial tray to orientate itself in the best position relative to the femoral component.

Because the ROM technique is highly dependent on the rotational orientation of the femoral component and the soft tissue balancing, many authors<sup>6,26,27</sup> did not suggest this technique because the risk of positioning the tibial component with an excessive internal rotation.

This study showed that the anterior tibial cortex is a reliable and easily identifiable landmark for correct tibial component positioning. It allows a satisfactory parallelism between the mediolateral axis of the tibial component and the epicondylar axis. This technique also allows determining the correct rotational alignment of the prosthetic components in respect to the extensor mechanism, avoiding many complications related to the patellofemoral joint.<sup>28</sup> Patellofemoral complications after total knee arthroplasty still represent the most cited cause of pain and the most reported reason for revision surgery.<sup>2</sup>

Our study has several limitations. It does not answer the question as to whether there is an overall optimal orientation of the tibial component during TKA. We do provide a reproducible method for a correct tibial component rotational orientation. In this study, we used a symmetrical tibial base-plate tracing (NexGen Total Knee System, Zimmer, Warsaw, USA). It is possible that the use of an asymmetrical tracing might lead to excessive internal rotation of the component, if the 'curve-on-curve' technique is intraoperatively chosen. The use of an MRI as a preoperative planning system may be questionable. We believe that MRI-based preoperative measurements overcome intraoperative limitations while accounting for the individual anatomy of each patient, thus helping optimize component rotation. Finally, the results of our study may not apply to the severely deformed knee. We purposely studied knees without any major malalignment. We hypothesized that the tibial component alignment following an anterior tibial cortex without major osteoarthritic deformity might be appropriate for deformed knees too. Patel et al<sup>29</sup> showed that the degree of preoperative osteoarthritic deformity did not influence the use of the TEA as a reliable rotational landmark in TKA. Rotational malalignment of the components may cause chronic pain or early failure in TKA. Our study showed that the anterior tibial cortex represents an easily identifiable and trustable landmark for a correct rotational alignment of the tibial component when compare to the Akagi's line and the medial third of the tibial tubercle. In fact, tibial component alignment along the anterior cortex guaranteed full matching  $\pm 3^\circ$  to the TEA in 75% of the cases with minor errors in external rotation.

## CONCLUSION

We believe that our study has revealed clinically important information about the rotational alignment of the tibial component in TKA.

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