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The medial tangent of the proximal tibia is a suitable extra-articular landmark in determining the tibial anteroposterior axis



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Abstract

Background: Tibial rotational alignment in total knee arthroplasty (TKA) is generally determined based on intra-articular structure, and can be difficult to ascertain in some cases. The aim of this study was to investigate whether the medial tangent angle of the tibia (MTAT) could be useful in determining the anteroposterior axis of the tibia.

Methods: This study was performed on 103 lower limbs in 53 patients who underwent primary total hip arthroplasty. The selection criteria for our study were based on the assumption that knees in patients undergoing THA exhibit fewer degenerative changes than knees in patients undergoing TKA. Using computed tomography images, the MTAT, comprising the medial tangent of the proximal tibia and the anteroposterior (AP) axis of the tibia, was measured on three horizontal planes: at the distal edge of the tibial tubercle (A), at 5 cm distally (B), and at 10 cm further distally (C). The tibial medial surface was grouped into three classes according to shape: valley type, flat type, and hill type. The percentage at which these shapes were observed in each group was also calculated. Measurement reliability was calculated using the intraclass correlation coefficient.

Results: The angles were 45.2° (interquartile range: IR 43.0–47.7) at A, 42.7° (IR 38.7–45.9) at B, and 42.4° (IR 38.2–45.9) at C. Intra-rater reliability and inter-rater reliability was 0.982 and 0.974 at A, 0.810 and 0.411 at B, and 0.940 and 0.811 at C, respectively. Regarding the tibial medial surface, the valley type was observed in all cases at A, and the hill type was observed in the highest percentage of cases at B and C.

Conclusions: The MTAT was approximately 45° at level A, and reproducibility was the highest among the three groups. The two points forming the valley on the tibial medial surface were bony ridges. Therefore, the medial tangent of the tibia at level A could be easily determined. Because the distal edge of the tibial tubercle exists at the surgical area and the extra-articular area, it can be a suitable intraoperative, extra-articular landmark in determining the tibial AP axis, even for revision TKA.

Keywords: Tibia, Rotation, Reference, Total knee arthroplasty, Joint revision

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Background

Total knee arthroplasty (TKA) is an effective procedure for painful knee osteoarthritis [1, 2]. However, it has been reported that 10 to 20% of patients who undergo TKA are dissatisfied with their surgical outcomes [3, 4]. Malrotation of the tibial component causes wear on the polyethylene tibial inserts which results in patellofemoral complications after TKA [5–8]. Therefore, tibial rotational alignment in TKA is an important factor for positive surgical outcomes. Rotational positioning of the tibial component in TKA is generally determined based on intra-articular structure [9–13]. However, this determination is often difficult in cases with severe deformity or inflammation, in which there are osteophytes or degenerative changes in the posterior cruciate ligament (PCL). Moreover, in revision TKA the intra-articular structure has already been resected. Consequently, other extra-articular landmarks for determining tibial rotational alignment are required for such cases. However, the potential extra-articular landmarks investigated to date have been reported to be unreliable [14].

The medial surface of the tibia is flat and smooth [15], and the cortex is often used for bone graft [16]. Therefore, it was hypothesized that the cortex surface could be used as a landmark for tibial rotational alignment. This area is an extra-articular area, and can be used as a reference even in revision TKA. The aim of this study was to investigate whether the medial tangent angle of the tibia (MTAT), comprising the medial tangent of the proximal tibia and the anteroposterior (AP) axis of the tibia, could be useful in determining tibial rotational alignment in TKA in general, and revision TKA in particular.

Methods

Study population

A cross sectional study was performed on 103 lower limbs in 53 Japanese patients scheduled to undergo primary total hip arthroplasty (THA) at our hospital from April, 2018 to March, 2019 (70 lower limbs in 36 female patients and 33 lower limbs in 17 male patients). The selection criteria for our study were based on the assumption that knees in patients undergoing THA exhibit fewer degenerative changes than knees in patients undergoing TKA. In addition, computed tomography (CT) data were obtained from all subjects during routine preoperative planning for the hip arthroplasty. Patients with rheumatoid arthritis, patients who had a history of previous surgery in the lower limbs, and patients with osteoarthritis (OA) of the knee equal to or higher than Kellgren-Lawrence classification grade 2 were excluded [17], because measurement of the MTAT was likely to be affected by the deformities inherent in such knees. The median age was 65.0 years (interquartile range: IR

57.0–71.0 years), the median body height was 157.2 cm (IR 150.7–164.3 cm), the median body weight was 55.0 kg (IR 50.9–62.0 kg), the median body mass index was 22.3 kg/m² (IR 20.5–24.3 kg/m²), and the median femorotibial angle was 176.0 ° (IR 174.0–178.0 °).

The Institutional Review Board (IRB) of Nihon University School of Medicine granted ethical approval (approval number: RK-200714-8). All patients of our study gave their informed consent for participation and publication of their anonymized data. All procedures performed in studies involving human participants were in accordance with the 1964 Helsinki declaration.

Measurement of the angle between the medial tangent of the proximal tibia and the anteroposterior axis of the tibia using computed tomography images

The tibia model was created using three-dimensional template software (ZedKnee[®], LEXI, Japan). Coordinate axes were as follows. Origin: the intersection point between the Z-axis and the perpendicular line running down from the middle of the PCL to the Z-axis, Z-axis: the line passing through the center point of the medullary cavity at the proximal one third and the center point at the distal one third, Y-axis: the line that is perpendicular to the Z-axis and passing through the origin, and is on the plane formed by the Z-axis and the line segment parallel to the tibial AP axis and intersecting the Z-axis, X-axis: the line passing through the origin and perpendicular to both the Z-axis and the Y-axis. The tibial AP axis was defined as the line connecting the middle of the PCL and the medial edge of the patellar tendon attachment [11, 18]. The MTAT, comprising the medial tangent of the proximal tibia and the anteroposterior (AP) axis of the tibia, was measured on three horizontal planes (X-Y planes): at the distal edge of the tibial tubercle (A), at 5 cm distally (B), and at 10 cm further distally (C) (Figs. 1, 2). The distal edge of the tibial tubercle was defined as the inflection point on the downslope of the tibial tubercle. Differences in the MTAT value between the three levels, between the right and left lower limbs, and between females and males were calculated. The tibial medial surface was grouped into three classes according to shape: valley type (bimodal shape), flat type, and hill type (Fig. 3). The percentage at which these shapes were observed in each group (A, B and C) was also calculated. In addition, the distance between the top of the tibia tubercle and the distal edge of the tibial tubercle was also measured (Fig. 2).

Statistical analysis

Data analysis was performed using IBM SPSS software, version 25. The Friedman's test was used to investigate the differences in the MTAT value between the three groups (A, B and C). The Wilcoxon's signed rank test

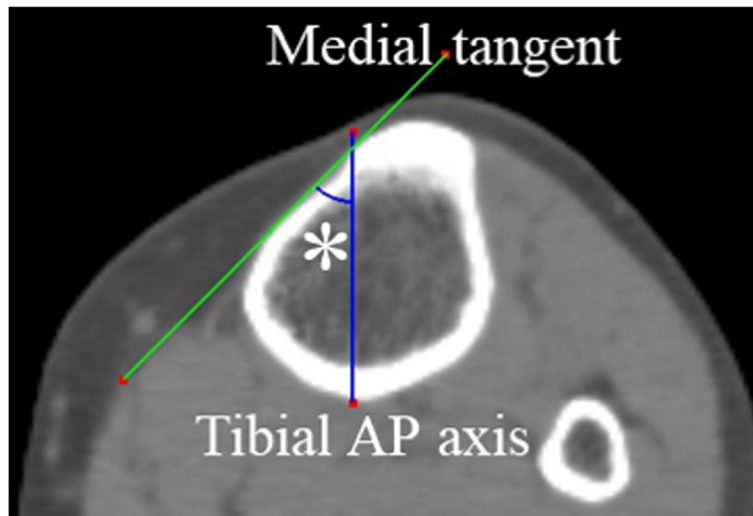


Fig. 1 The medial tangent angle of the tibia on the horizontal plane. AP, anteroposterior. An asterisk indicates the medial tangent angle of the tibia (MTAT), comprising the medial tangent of the proximal tibia and the anteroposterior axis of the tibia

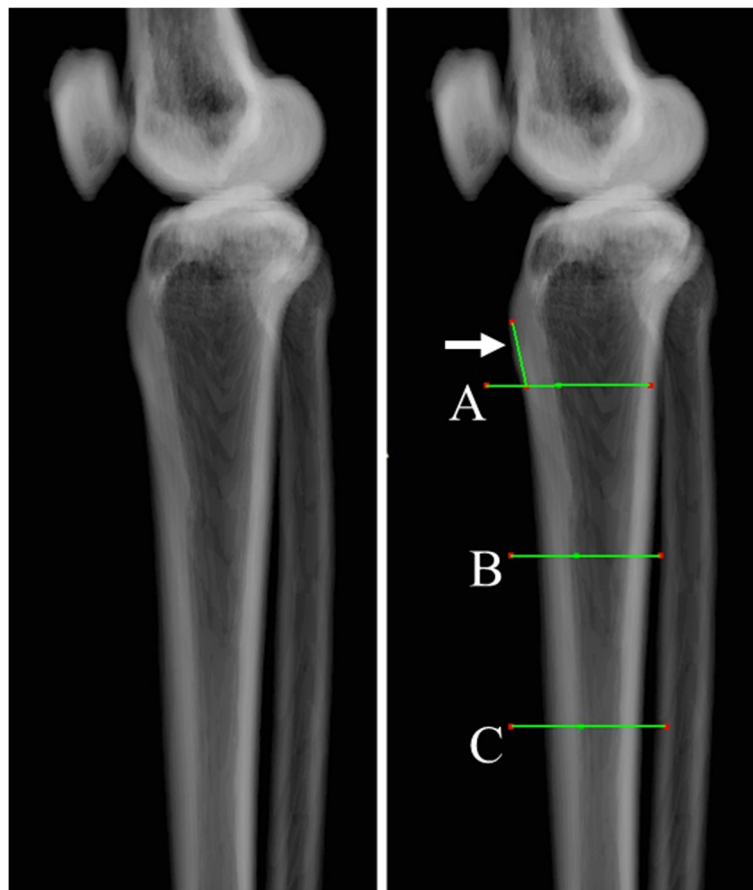


Fig. 2 Levels of the three horizontal planes in measuring the medial tangent angles of the tibia. **a** the level of the distal edge of the tibial tubercle; **b** the level at 5 cm distal to **(a)**; **c** the level at 10 cm further distally. The distal edge of the tibial tubercle was defined as the inflection point on the downslope of the tibial tubercle. A white arrow indicates the distance between the top of the tibia tubercle and the distal edge of the tibial tubercle

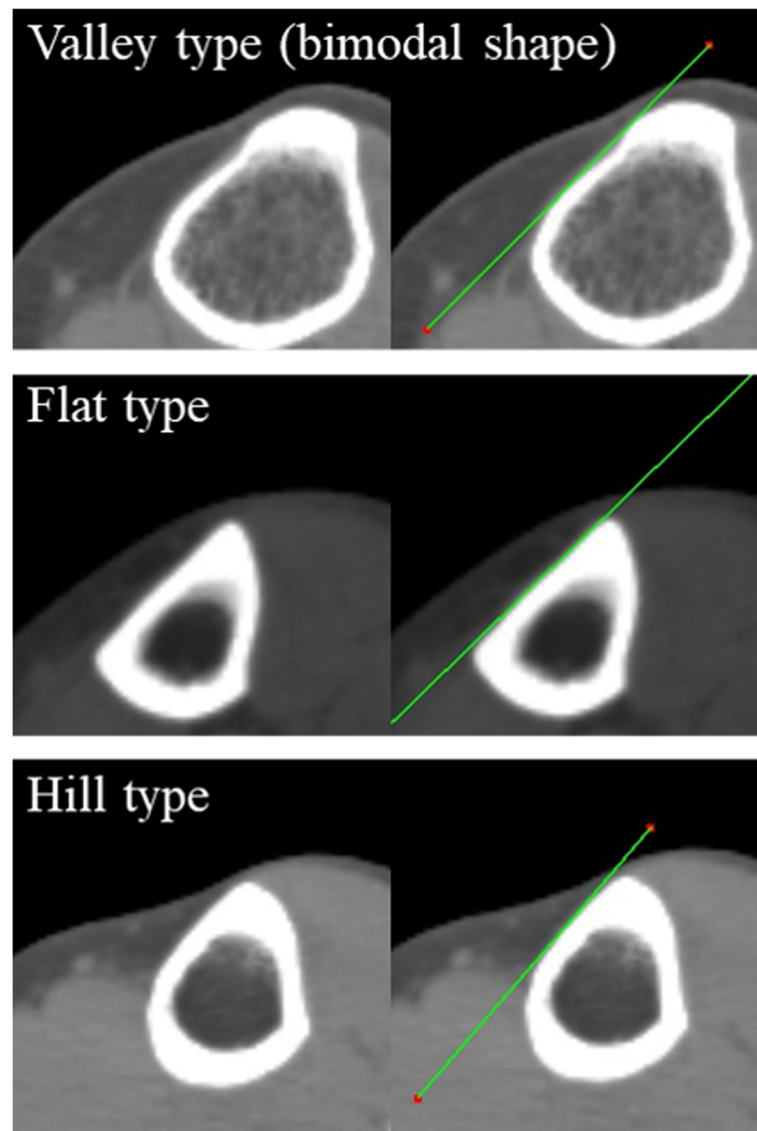


Fig. 3 Classification according to shape of the medial surface on the horizontal plane. The tibial medial surface was grouped into three classes according to shape: valley type (bimodal shape), flat type, and hill type

was performed to investigate the differences between the right and left lower limbs. The Wilcoxon's rank sum test was performed to investigate the difference between females and males. The Fisher's exact test was used to investigate the differences in the percentage at which the three shapes were observed between the three groups (A, B and C). *P* values of less than 0.05 were considered significant. Intra-rater and inter-rater reliability for measuring the MTAT at the three horizontal planes was calculated with the intraclass correlation coefficient. The MTAT at each of the three horizontal planes was measured two times with an interval of 6 weeks by two investigators on ten knees randomly selected from the study subjects.

Results

The median MTAT was 45.2° (IR 43.0–47.7) at A, 42.7° (IR 38.7–45.9) at B, and 42.4° (IR 38.2–45.9) at C (Table 1). Significant differences were noted between the values at A and B, and between the values at A and C. Intra-rater reliability and inter-rater reliability for measuring the MTAT was 0.982 and 0.974 at A, 0.810 and 0.411 at B and 0.940 and 0.811 at C, respectively (Table 1). No significant differences between right and left lower limbs or between females and males were noted (Tables 2 and 3). Regarding the tibial medial surface, the valley type was observed in all cases at A, and the hill type was observed in the highest percentage of cases at B and C (Table 4). Significant differences in the percentage at which the three

Table 1 Measurement of the medial tangent angle of the tibia and reliability calculated with intraclass correlation coefficients

	Level	Median	interquartile range	Inter-rater reliability	Intra-rater reliability
Whole (n = 103)	A	45.2 ^{***, †††}	43.0–47.7	0.974	0.982
	B	42.7 ^{***}	38.7–45.9	0.411	0.810
	C	42.4 ^{†††}	38.2–45.9	0.811	0.940

A, the level of the distal edge of the tibial tubercle; B, the level at 5 cm distal to A; C, the level at 10 cm further distally
 Data are presented as degrees, intraclass correlation coefficients
 An asterisk indicates significant difference between the values at A and B. ^{***}*P* < 0.001. A dagger indicates significant difference between the values at A and C. ^{†††}*P* < 0.001

shapes were observed were noted between group A and B, and between group A and C. The median distance between the top of the tibia tubercle and the distal edge of the tibial tubercle was 17.8 mm (IR 15.7–19.8 mm).

Discussion

The most important finding of the present study was that the medial tangent of the proximal tibia was a suitable extra-articular landmark in determining the tibial anteroposterior axis for TKA, and the MTAT was approximately 45° at level A.

In the past, tibial rotational alignment in TKA had been determined in reference to the medial one third of the tibial tubercle [12]. However, there was no strong theoretical justification for this method. Akagi et al. demonstrated that the line connecting the middle of the PCL to the medial edge of the patellar tendon attachment was perpendicular to the surgical epicondylar axis, and this line has since been used as the tibial AP axis for primary TKA [11, 18, 19]. Since then, variants of this line have been reported [20, 21]. Kim et al. reported that the line connecting the anterior border of the proximal third of the tibia to the middle of the PCL was also perpendicular to the surgical epicondylar axis, and could also be used as the tibial AP axis [22]. These lines are very useful for primary TKA in which the PCL is recognized directly. For primary medial unicompartamental knee arthroplasty, Tsukamoto et al. showed that the line connecting the medial border of the patellar tendon at

Table 2 Measurement of the medial tangent angle of the tibia in the right and left lower limbs

	Level	Median	interquartile range	<i>P</i> value
Right (n = 50) / Left (n = 50)	A	45.3/45.3	42.2–48.0/43.0–47.2	0.224
	B	43.0/42.0	38.7–46.0/39.1–45.4	0.772
	C	42.9/42.1	39.0–46.0/37.9–45.2	0.069

A, the level of the distal edge of the tibial tubercle; B, the level at 5 cm distal to A; C, the level at 10 cm further distally
 Data are presented as degrees or *P* values

Table 3 Measurement of the medial tangent angle of the tibia in females and males

	Level	Median	interquartile range	<i>P</i> value
Females (n = 70) / Males (n = 33)	A	45.3/45.1	43.0–48.0/42.9–46.9	0.611
	B	41.1/43.5	38.3–45.4/40.7–45.9	0.159
	C	42.8/42.1	38.9–46.0/37.5–45.4	0.360

A, the level of the distal edge of the tibial tubercle; B, the level at 5 cm distal to A; C, the level at 10 cm further distally
 Data are presented as degrees or *P* values

the articular surface level and the medial intercondylar tubercle was suitable as the tibial AP axis [23]. However, the above lines cannot be used for knees in which the PCL disappears due to severe inflammation or for revision TKA in which joint structures have already been resected. Additional landmarks for tibial rotational alignment independent of intra-articular condition are needed for such cases.

In techniques referencing the extra-articular structure, the transmalleolar axis of the ankle and the second metatarsus bone axis of the foot have been used to determine the tibial AP axis conventionally [12]. However, it has been reported that these techniques exhibit individual variability [14, 24, 25]. Though reproducibility of the MTAT value at level C in the present study was high, the interquartile range of the MTAT at level C was the largest among the three groups (Table 1). Individual variability of the tibial torsion was suggested even in the present study. This shows that extra-articular reference in the determination of the tibial AP axis should be close to the knee. Therefore, the medial tangent of the proximal tibia was determined to be a suitable landmark. However, it was also considered that the MTAT at a level more proximal than level A would also vary between individuals because of the individual variability that exists in the protrusion of the tibial tubercle. In addition, medial bony defect or spur was often observed at levels more proximal than level A. Therefore, the MTAT was evaluated at three levels (A, B and C) in the

Table 4 Percentage of cases exhibiting each tibial medial surface shape at the three levels

	Valley type	Flat type	Hill type
A (n = 103)	100%	0%	0%
B (n = 103)	5.8%	17.5%	76.7%
C (n = 103)	13.6%	20.4%	66.0%

Significant differences in the percentage at which the three shapes were observed were noted between group A and B (*P* value < 0.001), and between group A and C (*P* value < 0.001)

A, the level of the distal edge of the tibial tubercle; B, the level at 5 cm distal to A; C, the level at 10 cm further distally
 Data are presented as percentages

present study. The median distance between the top of the tibia tubercle and the distal edge of the tibia tubercle was 17.8 mm (IR 15.7–19.8 mm), or about one finger in the present study. Therefore, if it is difficult to identify the distal edge of the tibia tubercle, the MTAT at a level one finger distal to the top of the tibia tubercle may be used as a reference.

Even when the identification of the lines illustrated above is easy, it is difficult to confirm whether such lines do in fact match the preoperatively planned tibial axis of rotation. Mitsuhashi et al. showed that the number of outliers for rotational alignment of the tibial component was significantly higher in conventional TKA than in TKA using a navigation system [26]. However, because TKA using a navigation system involves higher costs, there are some hospitals at which such systems are not used. In addition, the tracker pins in such systems have been known to cause infection and fracture, although incidence rates are low [27, 28]. Therefore, intraoperative landmarks not involving a navigation system are more practical for the determination of tibial rotational alignment.

The distal edge of the tibia tubercle exists at, or very close to, the surgical area. The main medial anatomical structure on the horizontal plane at level A is the just inferior portion of the pes anserinus, which inserts into the tibia tubercle 6 ± 5 mm distally [29, 30]. Therefore, by inserting a wire along the surface of the cortex through the thin portion of the pes anserinus, reproduction of the medial tangent of the tibia during surgery can be achieved (Fig. 4). In addition, because the MTAT at level A was found to be approximately 45° in the present study, the value can be easily used as an

intraoperative reference for the tibial AP axis. Even in conventional TKA not involving a navigation system, the MTAT at level A can be a very useful landmark.

The medial surface of the tibia was smooth, but not completely flat (Table 4). In all lower limbs, the tibial medial surface at level A was found to be of the valley type due to the fact that the distal edge of the tibia tubercle is still slightly prominent at this level (Table 4). In addition, the two points forming the valley were bony ridges. Therefore, the medial tangent of the tibia at level A could be easily determined. As a result, the reproducibility of the MTAT value at level A was the highest among the three groups (Table 1).

There are some limitations to the present study. First, individual variability existed, even at level A. However, because the interquartile range of the MTAT at level A in our study was small, we believe that a value of 45° may be used by surgeons intraoperatively. Surgeons may also choose to reproduce the accurate MTAT intraoperatively, using the value of the MTAT at level A measured on preoperative CT scans. In revision cases in which the MTAT cannot be measured in preoperative CT, the MTAT on the contralateral side may be used as a reference since no significant difference between the right and left lower limbs was noted in our study (Table 2). Second, the patients in the present study were patients scheduled to undergo total hip arthroplasty. However, some patients with dysplasia of the hip have been reported to have lower limb rotational alignment abnormalities [31]. Therefore, although patients with moderate to severe OA in the knee were excluded due to the fact that degenerative changes were considered likely to affect the identification of the tibial AP axis on

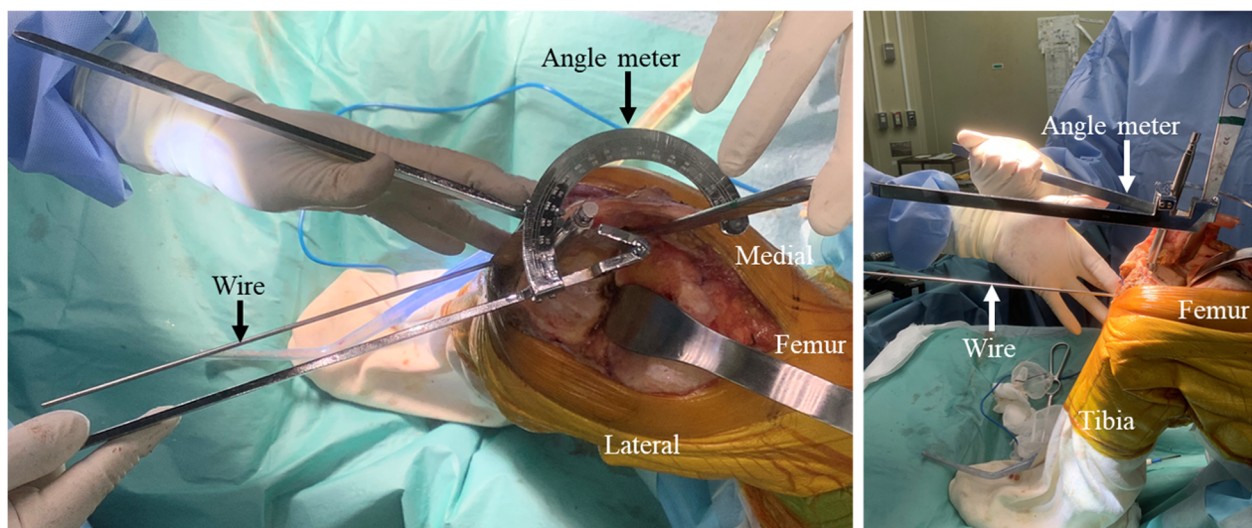


Fig. 4 Intraoperative reference for the tibial anteroposterior axis with the medial tangent angle of the tibia. The medial tangent of the tibia can be reproduced by inserting a wire along the medial surface of the tibia. Intraoperative confirmation of the anteroposterior axis of the tibia can be performed with the medial tangent angle of the tibia

CT images, future studies should focus on patients scheduled to undergo knee arthroplasty. Furthermore, since the aim of our study was to investigate the MTAT using CT images, we deemed it unjustifiable to expose healthy subjects to unnecessary radiation exposure, and selected patients already scheduled to undergo lower limb CT scans. Third, the patients in the present study were all Japanese. Although the median MTAT at level A was approximately 45° in the present study, it is possible that different bony shapes in the lower limbs exist in different ethnicities. In the future more research involving subjects with osteoarthritic knee and in other ethnic groups should be conducted.

Conclusions

The MTAT was approximately 45° at the distal edge of the tibial tubercle with high reproducibility. In addition, because this level exists at the surgical area and the extra-articular area, it can be a suitable intraoperative, extra-articular landmark in determining the tibial AP axis, even for revision TKA, in which the PCL has already been resected.

Abbreviations

AP: Anteroposterior; CT: Computed tomography; IR: Interquartile range; IRB: Institutional review board; MTAT: Medial tangent angle of the tibia; OA: Osteoarthritis; PCL: Posterior cruciate ligament; THA: Total hip arthroplasty; TKA: Total knee arthroplasty

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Authors' contributions

HL designed the study and analyzed the data. HL, NE, YC and HF performed the measurements. HL wrote the manuscript in consultation with TS (Takanobu Sumino) and TS (Takashi Suzuki). YS, KR and KN have contributed to data collection, and critically reviewed the manuscript. The final version of the manuscript was approved by all authors.

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Availability of data and materials

The datasets generated and/or analyzed during the current study are not publicly available due to our institutional policy but are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The Institutional Review Board (IRB) of Nihon University School of Medicine granted ethical approval (approval number: RK-200714-8). All patients of our study gave their informed consent for participation and publication of their anonymized data. All procedures performed in studies involving human participants were in accordance with the 1964 Helsinki declaration.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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