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# Reliability evaluation of inter-eminence line, Akagi and Dalury lines for intraoperative tibial rotation: An osteology-based study

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ABSTRACT

*Background:* This large osteology study examined the reliability, reproducibility and correlation between previously described tibial tray rotation alignment lines (including Akagi and Dalury lines). In addition, it described a novel inter-eminence line utilising the tibial plateau inter-condylar eminences as a landmark.
*Methods:* A total of 214 post-medieval (18–19th centuries) skeletal tibia were examined. The inter/intra-observer variation and correlation between reference lines were measured.
*Results:* Inter-observer reproducibility was excellent and there were no differences between Akagi, Dalury, and inter-eminence lines. Similarly, intra-observer reliability was excellent for Akagi, Dalury, and inter-eminence lines. Qualitative review of tibial inter-condylar eminences suggested that these could be easily identifiable. When taking the medial angle from a medial–lateral reference line, the Akagi line showed a mean of 96.90° (±10.27), inter-eminence line 94.52° (±12.84), and Dalury line 88.06° (±11.75). The angle produced by the Dalury line was significantly different from both the Akagi and inter-eminence lines ($P \leq 0.001$). The Akagi line and inter-eminence line showed a strong correlation ($r = 0.74$). The Dalury line showed a weaker correlation with both the Akagi line ($r = 0.69$) and inter-eminence line ($r = 0.40$).
*Conclusion:* This study suggested that tibial rotation lines showed excellent intra/inter-observer reliability and reproducibility. The novel and easily drawn inter-eminence line showed strong correlation with the Akagi line and could be used for tibial tray rotational alignment in total knee arthroplasty.



## 1. Introduction

Total knee arthroplasty is considered to be one of the most cost-effective interventions in orthopaedic surgery due to its ability to restore function and quality of life. However, in a small percentage of patients this can cause persistent pain and failure, which can lead to revision arthroplasty surgery, with significant personal and socio-economic implications. The recorded causes of aseptic failure include instability, fracture, tibia and femur component loosening, and polyethylene wear [1,2]. Technical factors, including proper

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component alignment, can affect the patient-reported outcome and survival following total knee arthroplasty [3]. Component malalignment leads to alteration of joint kinematics, patella maltracking, premature polyethylene wear and knee instability [4].

Several bony anatomical landmarks have been described to aid adequate component alignment. On the femoral side, gold standards include the transepicondylar axis and the anteroposterior axis (Whiteside's line), which are assumed to be closely associated with the flexion–extension axis of the knee [5,6]. Similarly, on the tibial side, several bony and soft tissue anatomical landmarks have been described to achieve proper rotational and transverse plane component alignment [7]. These include the medial third of the tibial tubercle, the medial border of the tibial tubercle, the transverse axis of the tibia, and the projected femoral transepicondylar axis [8]. In addition, a combination of the above has been described as alignment lines, including Dalury and Akagi lines [9,10]. However, in comparison to the femoral alignment guides, none of the latter has achieved gold standard status due to paucity of research in the area.

This large osteology study aimed to examine the reliability, reproducibility and correlation between the most commonly utilised tibial tray rotation alignment lines (including Akagi and Dalury). In addition, it described a novel inter-eminence line utilising the tibial plateau inter-condylar eminences as a landmark.

## 2. Materials and methods

This was an osteological survey analysing selected individuals from the St Bride's Church crypt in Fleet Street, London, UK. The Centre for Human Bioarchaeology (CHB), Museum of London, assists the church with the curation of the individuals and provides access to the skeletal remains for research purposes. The 227 skeletal individuals available for research were post-medieval in date, with the osteological analysis recorded for each individual onto the Oracle platform Wellcome Osteological Research Database (WORD). The skeletal remains of those curated were of individuals interred in lead coffins in the crypt of the church from the late 1670s until the crypt was closed in 1853. The association of coffin plates with the skeletal remains provides invaluable biographical information and enables other documentary sources to be researched, so that more can be learned about them and the time in which they lived. The individuals in St Bride's crypt are a significant and large biographical skeletal collection, and contemporary with the biographical skeletal collection at Christ Church, Spitalfields. The skeletal remains from St Bride's crypt provide an important insight into a post-medieval population of London. Their well-documented background – including age and date of death, socioeconomic status, demographics, cause of death and occupation – makes this population ideal for comparative social studies between osteological assemblages. Permission was granted, by the church and Centre for Human Bioarchaeology, for photography and handling of the skeletal remains for research purposes.

All 227 available skeletal remains were analysed; 13 were excluded due to post-mortem damage to the proximal aspect of the tibia or extensive wear to the tibial plateau. The final sample consisted of 214 tibiae: 200 paired (100 left and 100 right, same individual) and 14 unpaired. There were a total of 108 left and 106 right tibiae. The tibiae were placed on an osteometric board and digital images were taken using a standardised system (Figure 1). The images where then analysed with ImageJ software (version 1.50, National Institute of Health, USA). Measurements included the following: (1) Akagi line: a line was drawn connecting the mid-point of the posterior cruciate ligament (PCL) attachment to the point one-third from the medial border of the tibial tuberosity [9]. (2) Dalury line: a line was drawn from the point one millimetre medial to the medial border of the tibial tuberosity and passing to the deepest groove between the tibial spines [10,11]. (3) Inter-eminence line: the four inter-condylar eminences were marked, and lines were drawn connecting the posterior (medial and lateral) tibial eminences; similarly, parallel lines were drawn connecting the anterior tibial eminences. A perpendicular line was drawn to the parallel lines between the inter-condylar eminences to the anterior plateau, this formed the inter-eminence line (Figure 2). The angle formed between these lines and the transverse axis (medial–lateral reference line) connecting the widest part of the plateau was measured. Qualitative assessment of the tibial eminences was undertaken and scored from poor (1) to excellent (4) as follows: 1, unable to identify inter-condylar eminences; 2, able to identify at least (2/3)/4 inter-condylar eminences with (1/2)/4 being damaged or harder to identify; 3, at least three inter-condylar eminences very prominent and easily identifiable, with one being harder but present to a good quality; and 4, all inter-condylar eminences very prominent and easily identified. Measurements on a

**Figure 1.** The tibiae were placed on an osteometric board and digital images were taken using a standardised system.

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