Trabecular orientation in the human tibia and the relationship with lower-limb alignment for patients with osteoarthritis of the knee

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Introduction: Wolff’s Law proposes that trabecular bone adapts in response to mechanical loading and that trabeculae align with the trajectory of predominant loads. Sclerosis of subchondral bone is a well-recognized radiographic and surgical feature of osteoarthritic knees. In line with Wolff’s Law, initial research¹ has indicated associations between measurements of the sclerotic area taken from standard anteroposterior radiographs of the knee and both the angle of the load line, as measured by the Orthopilot® (BBraun Aesculap, Tuttingen, Germany) navigation system during surgery, and the mechanical axis of the lower limb calculated from weight-bearing, long leg radiographs². In addition it is thought that the orientation of the trabeculae in the tibia changes in response to altered loading in the joint. The current study therefore aimed to investigate trabecular orientation in the tibia in patients with osteoarthritis of the knee. Consistent with Wolff’s Law, it was hypothesized that orientation would reflect the mechanical loading of the joint and hence that there would be a correlation between the trabecular orientation and the mechanical axis of the lower limb.

Methods: 51 anonymised radiographs from patients with osteoarthritis were analyzed using ImageJ³. Each patient had both a standard anteroposterior radiograph of the knee and a long leg view taken while weight bearing.

For each anteroposterior radiograph, the angle of the femoral shaft and tibial shaft were calculated from the femoral intercondylar point to the mid-point of the femoral shaft and from the tibial interspinous point to the mid-point of the tibial shaft respectively. The femoral shaft – tibial shaft (FS -TS) angle was then calculated as the difference between the two, as described by Sheehy et al. (2011)⁵.

A medial rectangle was selected with the top, bottom, medial and lateral borders being the sclerotic bone, the growth line, the bone edge and the centre of the medial tibial spine. The same rectangle was then moved to the lateral side and lined up with the sclerotic edge and the lateral bone edge. Trabecular orientation of both areas was measured using OrientationJ⁴ (a plug-in for use with ImageJ). In all cases the medial and lateral orientation angles were expressed relative to the angle of the tibial shaft.

The mechanical axis of the lower limb was measured from the full length radiographs by calculating the angle formed by the femoral and tibial axes, as described by Goker and Block⁶. All measurements were done independently by two observers, SAS and SL.

Results: Except where indicated, the results are based on analysis of 51 radiographs.

Inter-tester analysis indicated excellent reliability (ICC = 0.99) for the mechanical axis measurement and preliminary inter-tester analysis (based on 25 radiographs) indicated good reliability for the orientation measurements (ICC = 0.76).
The FS-TS angle calculated from the anteroposterior radiographs was significantly correlated with the mechanical axis calculated from the full-leg views (r = 0.96, p < 0.01), with an average offset of 5.7°, which is consistent with previous research.

![Graph showing correlation between FS-TS angle and lateral trabecular orientation.](image)

**Figure:** Correlation between the FS-TS angle and the lateral trabecular orientation.

There was a significant correlation between the lateral trabecular orientation and both the FS-TS angle measured from the anteroposterior radiographs (r = -0.48, p < 0.01) (Figure) and the mechanical axis measured from the long leg views (r = -0.39, p < 0.01). There was also a significant correlation between the medial trabecular orientation and the FS-TS angle (r = 0.35, p = 0.01).

**Discussion:** There were significant correlations between leg alignment (both the mechanical axis and the FS-TS angle) and trabecular orientation in the human tibia. These findings were consistent with Wolff’s Law, which proposes that trabecular bone adapts in response to mechanical loading.

Previous research aiming to evaluate Wolff’s Law has largely focused on either comparisons between species or 3D modeling. To date, research to test the *in vivo* response of trabecular orientation to mechanical loading has been scarce, particularly in humans. Two recent studies did examine the dynamic response in sheep and guinea fowl who were exercised on an incline and, consistent with the current study, changes in trabecular orientation in the tibia and femur were found to reflect differences in mechanical loading as hypothesized. To the best of our knowledge, the current study is the first to investigate *in vivo* trabecular orientation in the human tibia and to establish a correlation with the mechanical axis of the lower limb.

The findings also suggest that inspection of the trabecular orientation might provide valuable information on leg alignment and mechanical loading prior to surgery.

**References**