Importance of Maintaining Tibial A/P Slope

A Technical Overview of the Biomechanical Importance of Tibial Slope in High Tibial Osteotomy

Definition of A/P Slope

Tibial A/P slope is defined as the angle between the line representing the posterior inclination of the tibial plateau and the line perpendicular to the line through the center of the diaphysis of the tibia (tibial axis)[1]. Under fluoroscopy, the line representing the posterior inclination of the tibial plateau can be visualized and is made up of both the lateral condylar plateau and the medial condylar plateau, superimposed (see Figure 1).

a

b

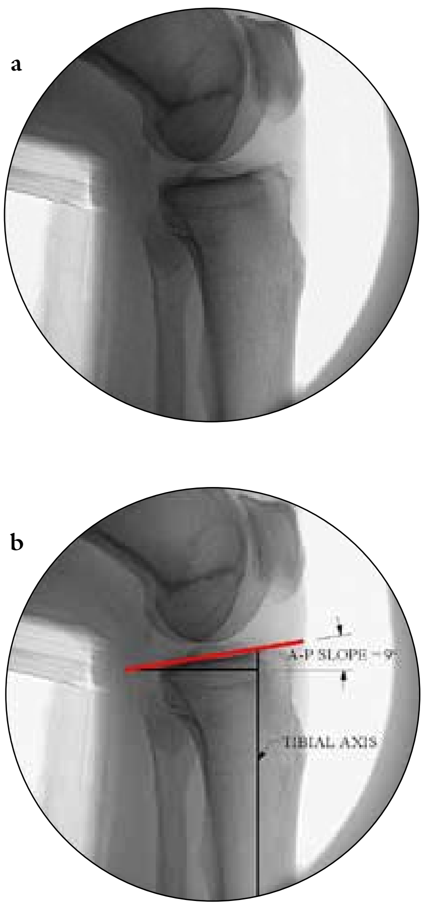


Figure 1. (a) Fluoroscopic sagittal view of the tibia. (b) Fluoroscopic sagittal view of the tibia with A/P slope depicted.

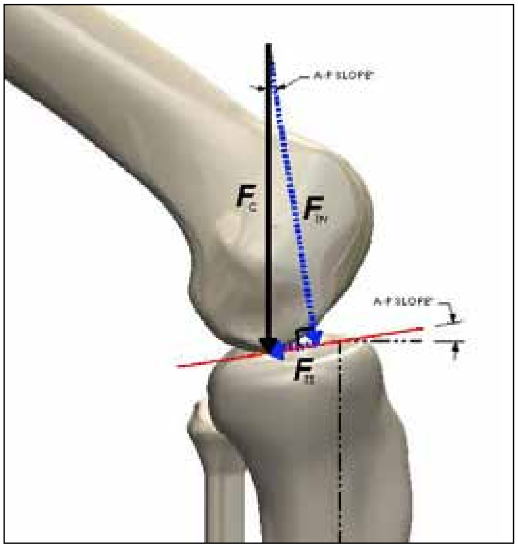
The biomechanical importance of A/P Slope can be mathematically demonstrated using a simplified model. During weight-bearing there is a downward compressive force that is depicted in Figure 2(a) as FC. This force is not normal to the A/P slope of the proximal tibia, given an A/P slope greater than zero, and therefore can be broken into two components; a component normal to the A/P slope, depicted in Figure 2(a) as FTN, and a force component parallel to the A/P slope, depicted in Figure 2(a) as FTS. For the purpose of this model, the slope parallel to the A/P slope, FTS, or the shear force component of FC is the force component that the soft tissue anatomy must counteract to maintain stability in the knee. Using the geometry to form an equation with the shear force, FTS, as a function of the A/P slope and assuming that the compressive force, FC, is constant, we can see how the change in A/P slope affects the internal loading of the knee.

$$F_{TS} = F_C * sin\ (A/P\ Slope)$$

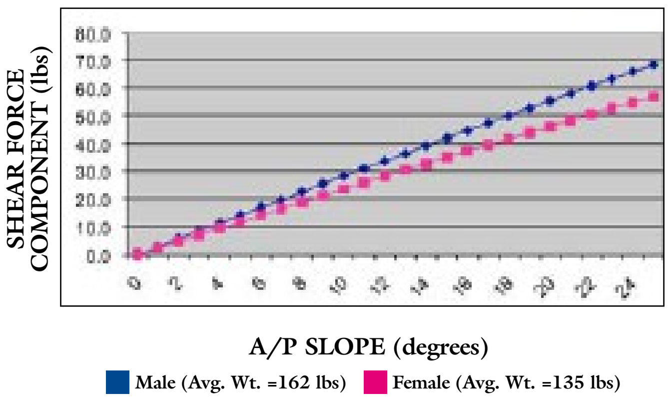
To determine potential loads in the knee we can apply values to the equation and chart those values (see Figure 2). The constant FC can be approximated based on research done by Zeni JA, et al[2], to determine the contact forces in the knee as a function of body weight. The maximum derived knee contact force derived ranges from 1.7*BW to 3*BW with a mean of 2.1*BW (BW=body weight). These values correspond with experimental values published by Taylor et al. (2001). Furthermore, according to Isaac Asimov's The Human Body[3], the average body weight for males is 162 lbs and for females is 135 lbs. With these numbers we can calculate a reasonable estimate for the contact force in the knee as 340 lbs and 284 lbs respectively. A/P slope values in the human knee range from -3° to +10° according to Hashemi J, et al, with the potential for unintentional slope modification up to 15° with some procedures. This demonstrates what the potential loads are in the knee, as well as the effect A/P slope has on the loads. These simplified calculations show that a deviation of 1° in A/P slope changes shear loading by 2 to 3 lbs. in this simplified model. In the case where A/P slope is significantly changed, the loading in the knee is also significantly

continued

a



b. A/P SLOPE vs SHEAR FORCE COMPONENT



A/P Slope	Male	Female
1°	2.8 lbs	2.4 lbs
5°	14.2 lbs	11.8 lbs
10°	28.1 lbs	23.4 lbs

Figure 2: (a) A simplified representation of the forces depicted through a free body diagram showing how the vertical compressive force (F_C) in the knee is broken down into its directional components as defined normal to the A/P slope (F_{TN}) and parallel to the A/P Slope (F_{TS}). (b) A graph showing how the shear force component increases as the A/P slope increases.

changed. The structures in the knee may not be prepared for this change in loading which could lead to instability and further injury of the soft tissues. In addition to affecting the internal loading of the knee, the slope of the tibial plateau has a direct relationship with anterior tibial translation of the knee as it transitions from nonweight-bearing to weight-bearing conditions. Application of compressive load to the knee produces an anteriorly directed shear force that results in an anterior neutral position shift of the tibia relative to the femur. The amount of anterior translation produced during the transition from nonweight-bearing to weight-bearing is not only produced by the orientation of the patellar tendon relative to the tibial plateau, but is also influenced by the magnitudes of the compressive joint load and the posteriorly directed slope of the tibial plateau.

The component of force, FTN must then be stabilized by soft tissue (ligaments). The Arthrex iBalance HTO System is designed to maintain the A/P slope angle, which in turn should maintain the natural loading of ligaments.

REFERENCES:

1. Hashemi J, Chandrashekar N, Gill B, Beynnon BD, Slauterbeck JR, Schutt RC, Mansouri H, Dabezies E, *The Geometry of the Tibial Plateau and its Influence on the Biomechanics of the Tibiofemoral Joint,* J Bone Joint Surg Am 2008; 90:2724-34.
2. Zeni JA, Higginson JS, *Estimation of Knee Joint Compression Force in Subjects with Medial Compartment Knee Osteoarthritis,* American Society of Biomechanics Conference 2007, Poster P9-21.
3. Asimov, Isaac. *The Human Body, New rev. ed.,* p. 314; Diagram Group Staff, *Comparisons*, pp. 72-73.