THE EFFECT OF WEIGHTBEARING ON KNEE JOINT KINEMATICS IN THE ANTERIOR CRUCIATE LIGAMENT DEFICIENT PATIENT

INTRODUCTION:

Many factors have been associated with the destruction of articular cartilage of the knee; however, only trauma such as that associated with the disruption of the anterior cruciate ligament (ACL) has been shown to predispose the knee to arthritis. Abnormal kinematics and kinetics are thought to produce these arthritic changes. Thus, it is important to understand the alterations in knee joint kinematics that result from an ACL deficiency.

Compressive loading of the knee joint, such as occurs during weightbearing, has been shown to reduce anterior-posterior laxity and increase the stiffness of the tibiofemoral joint in comparison to the non-weightbearing knee 1. This has led to the popular belief that compressive load stabilizes the knee and may serve as a protective mechanism for the ACL deficient knee or healing ACL graft. In a recent cadaveric study, Torzilli measured the reduction in anterior-posterior laxity when a compressive load was applied to the knee, however, he documented that the tibia shifted anterior relative to the femur as the load was first applied to ACL deficient knees 2. This finding potentially contradicts the popular belief about compressive loading. To our knowledge, this “anterior neutral shift” has not been documented in vivo. The objective of this study was to determine if the anterior neutral shift occurs in human subjects as the knee transitions from non-weightbearing to weightbearing. Both ACL intact and ACL deficient knees were tested.

METHODS:

Eleven subjects (9 males, 2 females) with a chronic ACL deficient knee and a normal contralateral knee participated in the study. All ACL deficient knees were diagnosed as grade 3 tears by clinical exam, MRI, or arthroscopy. In addition, five normal subjects were also recruited to serve as a control group. The study was approved by the Institutional Review Board and all subjects granted their informed consent prior to participating.

The anterior translation of the tibia relative to the femur was measured using planar stress radiography 3 in conjunction with a custom designed knee laxity testing device (the Vermont Knee Laxity Device; or VKLD) 4. Previous work has shown that the VKLD produces laxity values similar to the KT-1000 and stress radiography, however, it has the added capability of evaluating knee joint kinematics during weightbearing 5. For this study, both techniques were used to document the tibial shift during compressive loading. No anterior-posterior shear loads were applied.

The VKLD was used to apply the compressive loads to the knee joint while stress radiography measured the resulting sagittal plane translations of the tibia with respect to the femur. In the VKLD, subjects were supine with their knees flexed to 20°. Each foot was supported by open boots that could independently move in the horizontal plane. By locking and unlocking this motion, the weightbearing and non-weightbearing loading conditions were controlled. For weightbearing, compressive forces equal to 40% body weight were applied to each leg via the foot supports using free weights and pulleys. During the test, the loads were applied to both knees producing a total compressive load of 80% body weight. Thus, the loads were similar to those produced at the knee during two legged stance. A counterweighting procedure, based on geometrical models of the limb segments 5, was used to predict the mass and mass center locations of the thigh and lower leg. Digital photographs of the subjects were taken using a digital camera and digitized using a computer program that located anatomical landmarks on the femur and tibia. In addition 2 reference points were placed in the field during testing to correct magnification error. This allowed us to establish the position of the tibia relative to the femur during non-weightbearing and weightbearing, and by calculating the difference between these two conditions, the corresponding anterior tibial shift was determined. A paired t-test was used to compare the mean anterior neutral shift of the tibia relative to the femur in the ACL intact and ACL deficient knees. For the normal control group, a paired t-test was utilized to compare the anterior translation values of the right and left knees.

RESULTS:

For the ACL deficient knee, the transition from non-weightbearing to weightbearing produced significantly greater anterior translations of the tibia relative to the femur (p<0.01) compared to the contralateral normal knee. On average (± 1 s.d.), the ACL deficient knee produced anterior translations of 3.4 ± 2.6 mm while the contralateral normal knee translated only 0.8 ± 2.2 mm. No significant difference was found between left and right knees of the normal control group (L = 1.36 (± 3.8) mm, R = 1.06 (± 3.7) mm; p=0.6).

DISCUSSION:

A significant anterior neutral shift of the tibia relative to the femur was observed in the ACL deficient knee as the knee transitioned from non-weightbearing to weightbearing. This result supports the cadaver study of Torzilli et al 2. The translations in the ACL intact knee were much smaller indicating that the ACL is a primary restraint to this shift. Studies measuring the load 6, or strain 7 in the ACL during weightbearing support this hypothesis.

There are two potential causes for the anterior neutral shift. Since the compressive load vector is directed between the ankle and hip joints, it is located posterior to the knee joint producing a moment that must be equilibrated by the extensor mechanism 7. Thus, the quadriceps muscles are dominant. In the ACL intact knee, the ACL prevents the quadriceps from pulling the tibia anterior relative to the femur. In the ACL deficient knee, the tibia shifts forward until other structures resist the load. Second, the compressive force can provide an anterior directed component at the point of tibiofemoral contact since it is applied to an inclined tibial surface. This component may cause the tibia to slide anterior relative to the femur when the knee is near extension 8, 9. In this study, the knee flexion angle was 20°, and the tibial angle with respect to the line of action of the compressive load was 10°, the threshold angle at which the second loading mode becomes relevant due to the 10° to 15° posterior tilt of the tibial surface.

These data question the protective role that weightbearing may have in both the ACL deficient and ACL reconstructed knee during graft healing. Further work is necessary to determine the threshold at which the anterior neutral shift may accelerate joint arthrosis.


ACKNOWLEDGEMENT: This project was funded by the Bauerfeind Corp, Zeulenroda, Germany.