IN VIVO MEASUREMENT OF ARTICULAR SURFACE PROXIMITY

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INTRODUCTION

This paper describes a method to determine the proximity of articular surfaces during movement. This information may be useful in the study of osteoarthritis, in biomechanical modeling, and in identifying normal and pathological joint mechanics. As an example, the distances between the tibia and femur articular surfaces during canine gait before and after anterior cruciate ligament (ACL) transection are presented.

METHODS

Kinematic Data: Kinematic data was collected using a biplane radiographic system capable of tracking implanted radiopaque markers in 3D at a rate of 250 frames/s with a dynamic accuracy of $\pm$ 0.1mm (Tashman, 1995). Four 1.6mm tantalum spheres were implanted into the right tibia and femur of each dog at the beginning of the study. Data was acquired from 0.2s before to 0.3s after paw-strike for 3 trials of treadmill walking at 1.5m/s. 3D marker coordinates were determined using previously described techniques (Tashman, 1999). All animal procedures were approved by our institutional Care of Experimental Animals Committee.

Computed Tomgraphy Data: Computed tomography (CT) data was collected for each dog (1mm slices, 0.488mm x 0.488mm resolution). Custom designed software determined the surface points of each bone from the CT scans.

The relationship between the implanted tantalum markers and surface points was derived from the CT scans. This information was combined with the 3D kinematic data and allowed the surface points of each bone to be determined for every frame of 3D data collected. Minimum distances between bone surface points on the tibia and femur were then calculated at each instant.

Solid Figure Reconstruction: In order to visualize the results, the CT slices were reconstructed into 3D solid figures (Geiger, 1996). Custom designed software animated the solid figure bones according to the 3D kinematic data, and the articular surfaces were color coded according to the minimum distance to the other bone at each instant.

RESULTS

Figure 1 shows the color coded surface of the femur of a representative subject at sequential instants of the stance phase of gait. Each sphere on the surface of the femur represents a two-pixel by two-pixel region (0.976 mm^2). Pictures A, B and C display the minimum distance from the femur to tibia surface prior to ACL transection, while pictures D, E and F display the minimum distances between bone surfaces two years after ACL transection.

Figure 2 shows the same femur with india-ink staining. The india-ink stain is most prominent on areas of full-thickness cartilage loss.

DISCUSSION

There are two major findings to note in Figure 1. First, in both the ACL intact (A, B, C) and post-ACL transection (D, E, F) conditions, the largest area of close joint proximity during paw-strike was on the medial half of the femur. Furthermore, after ACL transection, the imbalance between the size of the areas of close proximity on the medial and lateral condyles had shifted even more toward the medial side. These results agree with the india-ink staining results (Figure 2) that show cartilage loss on the medial femoral condyle. The correspondence between the areas of closest joint proximity and the region of cartilage loss in Figures 1 and 2 was also present in other dogs that experienced cartilage damage two years after ACL transection.

The second feature to note in Figure 1 is the anterior shift in the areas of closest proximity at each corresponding time instant of weight-bearing. At times t=0.000s (paw-strike), t=0.100s, and t=0.200s, the region of close proximity between the femur and tibia was shifted in the anterior direction two years post ACL-transection, relative to ACL-intact. This result agrees with the previously reported finding of a rapid anterior tibial translation relative to the femur after paw-strike in ACL deficient dogs (Tashman, 1999).

These findings suggest that this method may provide useful information regarding *in vivo* articular surface contact areas during dynamic movements.

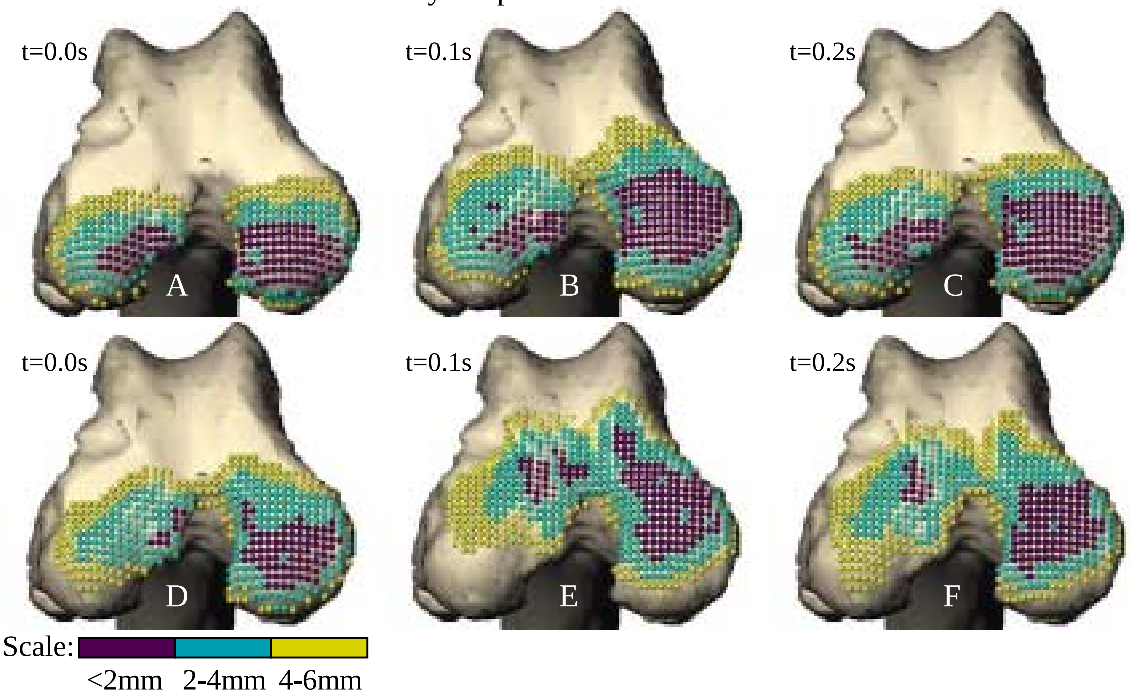

Figure 1: Minimum distance from femur surface to tibia surface. Femur regions closer to tibia are darker, while regions farther from tibia are lighter. A, B and C are ACL intact, while D, E, and F are two years after ACL transection. t is time in seconds after paw-strike.

Figure 2: Femur of dog 2 years post ACL transection with india-ink staining. Note regions of full-thickness cartilage loss on medial condyle.

REFERENCES

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