E-Appendix

Details of the Imaging Methods

The segmented data from the high-resolution scan were used to create a three-dimensional geometric model of each participant's femur, tibia, and patella with use of the surface extractor module in Analyze. This module uses a mass-spring model in an iterative fashion to approximate the surface of the bones. The segmented data from the five low-resolution scans were used to obtain the Cartesian coordinates of the outlines of each bone for the five imaged loaded positions. The geometric model and the five sets of bone outlines were imported into MATLAB (The MathWorks, Natick, Massachusetts), and each outline set was registered to the geometric model with use of the iterative closest points algorithm[31].

Coordinate systems, with sign conventions based on the modified joint coordinate system[14,32], were defined in the geometric models describing each bone with lateral, anterior, and proximal directions defined as positive. The origin of the femoral coordinate system was defined as the most superior point on the intercondylar notch, the femoral flexion axis was defined as the vector joining the most posterior points on the femoral condyles, the femoral long axis was defined as the vector joining the origin of the femoral coordinate system and the centroid of a transverse slice through the most proximal imaged part of the femur, and the femoral third axis was the cross product of the femoral flexion axis and the femoral long axis. The origin of the patellar coordinate system was defined as the most posterior point of the mid-axial slice through the patella, the patellar flexion axis was defined as the vector joining the origin of the patellar coordinate system and the most lateral point on the mid-axial slice through the patella, the patellar long axis was defined as the vector joining the superior and inferior points on the mid-sagittal slice through the patella, and the patellar third axis was the cross product of the patellar flexion axis and the patellar long axis. The attitude of the patella with respect to the femur was determined with use of the conventions of the joint coordinate system[19] as a rotation about the femoral flexion axis (fixed in the femur), a rotation about the patellar long axis (fixed in the patella), and a rotation about a third axis defined as the cross product of the femoral flexion axis and the patellar long axis. The position of the patella with respect to the femur was determined by the distance between the origins in the medial, anterior, and distal translation directions. These distances were not normalized for knee size so that direct comparisons with previous results obtained with use of this method could be made[20].

Details of the Statistical Analysis

The statistical analysis was carried out with use of maximum likelihood hierarchical random-effects modeling statistical software (MLwiN, version 2.0, 2004; University of London, London, United Kingdom). In this method, linear regressions are carried out within each participant's patellar kinematic data (explanatory variable: patellar tilt, spin, flexion, lateral translation, anterior translation, or proximal translation; independent variable: knee flexion). The weighted regression results are pooled for the two groups. Knee flexion was considered to be a fixed variable as were the two groups, while subjects nested within the two groups were random. Nonlinear main effects as well as interaction effects were tested in each case and were included when significant. Results were considered significant when $p < 0.05$ (two-tailed test).

The hierarchical linear-random-effects model assumes that the data are normally distributed, that subjects are independent, and that subjects are randomly selected. All kinematic parameters are normally distributed, as demonstrated by results obtained for seventy subjects who have undergone assessment with this method to date[21]. Normality was assessed at approximately 30° of knee flexion since data were available for all individuals at this angle and it is commonly used for radiographic assessments of alignment of the patellofemoral joint[33]. Subjects were independent and were randomly selected. We carried out the same analysis using a quadratic random-effects hierarchical model but found that the coefficients of the higher-order terms were not significant; therefore, for the number of subjects studied over the specific flexion range observed, the linear model was an appropriate description of the data.

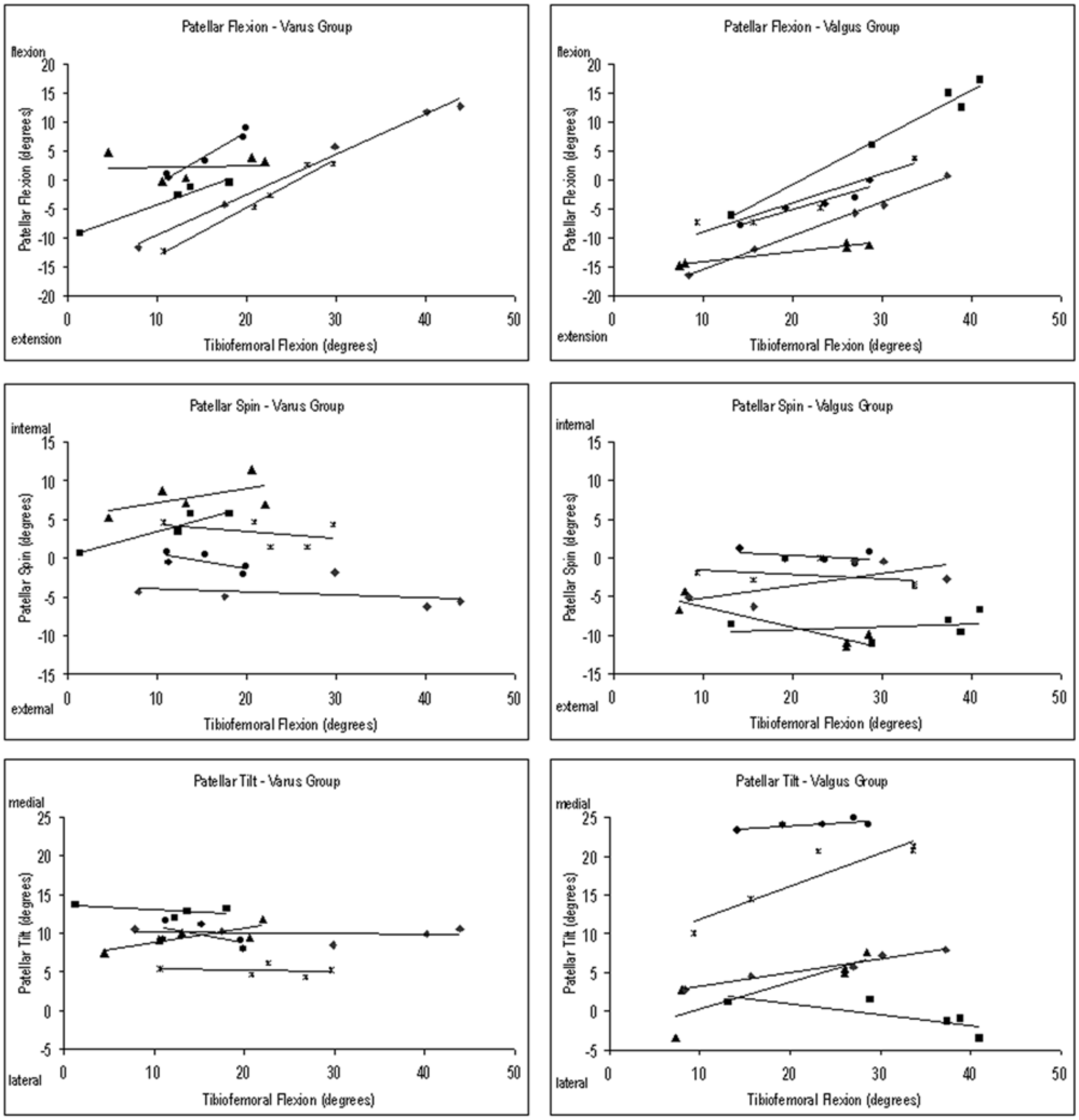

Fig. E-1

Raw data for patellar flexion, spin, and tilt for the varus (left) and valgus (right) groups. A linear regression was fit to each individual's kinematic data. Note that some data points overlap.

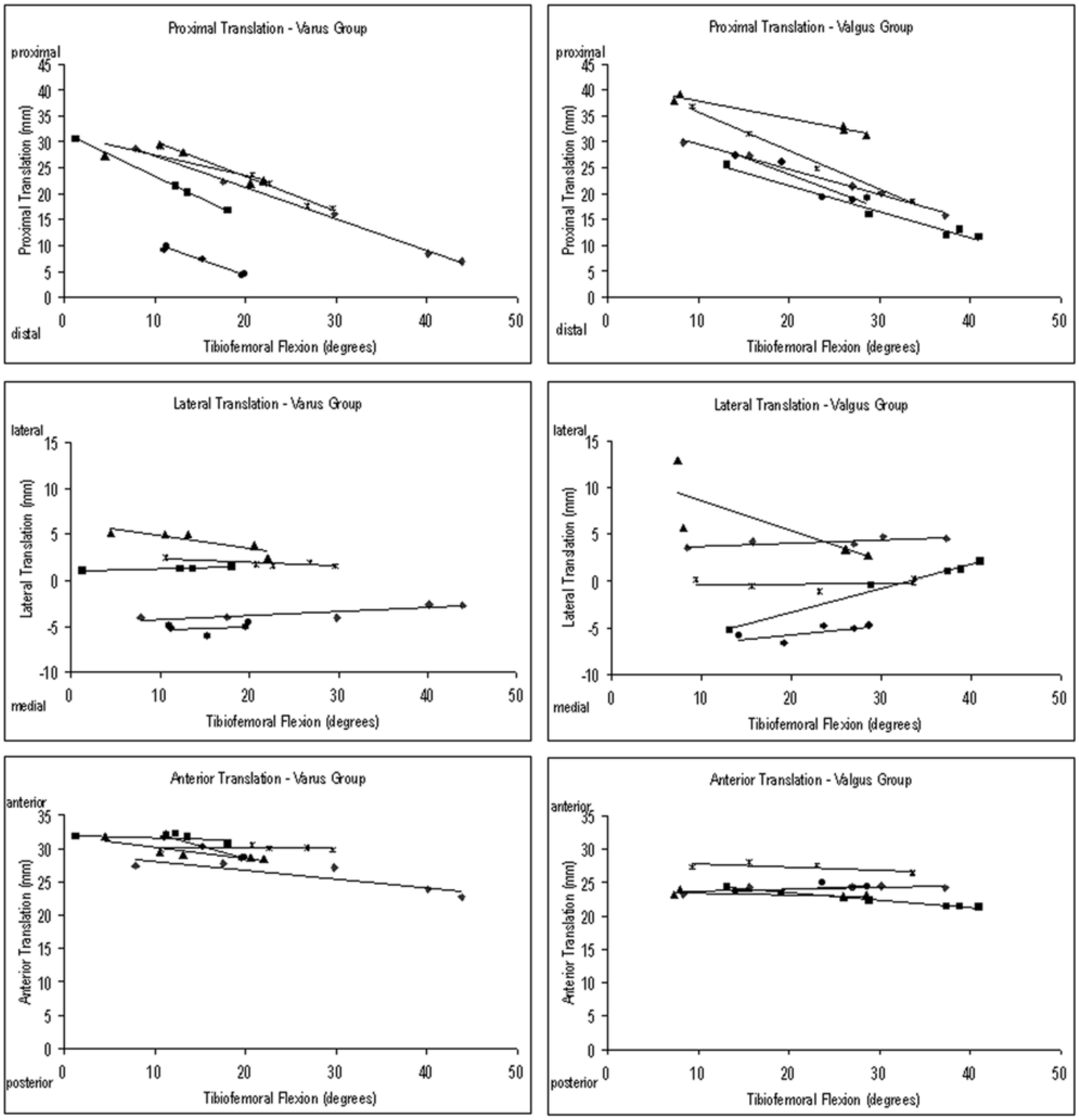

Fig. E-2

Raw data for proximal, lateral, and anterior patellar translation for the varus (left) and valgus (right) groups. A linear regression was fit to each individual's kinematic data. Note that some data points overlap.