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Paper #241

Image Analysis for Quantification of the Pivot Shift Test and Development of an iPad Application

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Summary:
The purpose of this study was to use image analysis for clinical pivot shift testing on patients and to use those results to create an iPad application that provides real-time quantitative assessment of the pivot shift test.

Abstract:
Background:
Clinical grading of the pivot shift test correlates with invasive measurement of tibial translation. Non-invasive measurement of tibial translation with a simple and affordable method could provide an objective clinical evaluation of the pivot shift. We previously proposed a method to quantify the pivot shift with use of readily available equipment and supplies (i.e. stickers and a digital camera). However, the clinical applicability of image analysis is limited due to the time associated with data processing. The purpose of this study was to use image analysis for clinical pivot shift testing on patients and to use those results to create an iPad application that provides real-time quantitative assessment of the pivot shift test.

Material and Methods:
The relative position of the lateral tibia to the femur is identified with 3 skin markers attached to bony landmarks on the lateral side of the knee joint, (i.e. 1. Gerdy´s tubercle, 2. fibular head and 3. lateral epicondyle). By recording a video of a standardized pivot shift test with a digital camera, the position of the tibia in relation to the femur is tracked throughout the entire maneuver in a two-dimensional plane. This video is then converted to a stack of individual frames (.avi file) and subsequently processed into a XY graph with ImageJ software (NIH), which provides coordinates for the centroids of each marker. The coordinates of the centroids of each frame are plotted in a graph that describes the relative movement of the markers throughout the pivot shift test. For an initial validation study of the manual image analysis, 20 knees of unilateral ACL injured patients were examined. Based on the results of that preliminary study we developed a new iPad application prototype to automate that analysis. The iPad records video with a 30Hz camera and the application recognizes and filters the markers from the surroundings based on shape and color and automatically calculates their relative position, providing a translation plot over time.

Results:
All 20 patients had a complete rupture of the ACL. Examination under anesthesia revealed a grade 1 pivot shift in all patients. With the manual image analysis, tibial translation during the reduction of the pivot shift was observed in all 20 patients. Tibial translation was on average 3.6±1.8mm and occurred within 0.12±0.05 seconds. Data processing time was approximately 2 hours per patient. The prototype of the iPad application is able to measure and analyze the pivot shift test within approximately 30 seconds and provide the tester with a graph of translation and clinical grade.

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Discussion:
Quantitative measurement and objective grading of tibial translation during the pivot shift test is consistently possible using manual image analysis. The newly developed iPad application provides the additional advantage of real time quantitative analysis of the pivot shift. Consistency of the iPad application is enhanced when utilizing a standardized pivot shift test. Future studies will involve a multi-center trial of clinical grading and quantification of ACL injured patients.