Introduction  Early detection of articular cartilage degeneration is a significant challenge. While macroscopic, later-stage damage such as fibrillations can be recognized via existing technology (1), early stages of degeneration that involve disruption of the molecular components of cartilage but no obvious visual damage are much more difficult to identify. Recently, we described the use of an infrared fiber optic probe (IFOP) as a potential diagnostic tool for early non-destructive detection of chondral degradation (2). While Fourier transform infrared (FTIR) spectroscopy has been used frequently in the past for the analysis of protein structure in biological tissues (3), the use of this technology in conjunction with fiber optics is relatively new in the biomedical field. In the current study, we demonstrate IFOP detection of spectral changes in articular cartilage associated with degradation in human osteoarthritic tissues and in a rabbit model of OA.

Methods  Human Tissues: Tibial plateaus (n = 12) were obtained immediately after knee replacement surgery (under an IRB-approved protocol) and stored in saline at 4°C until analysis. Rabbits: Under an IACUC-approved protocol, surgery was performed on the right knee of 6 month old female New Zealand white rabbits to create osteoarthritic changes similar to that described in the Hulth-Tehlag Model (4). The surgery involved transection of the anterior cruciate ligament and the posterior cruciate ligament and excision of the meniscus: sports injuries to articular cartilage. In Orthopaedic sports medicine principles and practice. W.B. Saunders Company, Philadelphia. 82-107.

IFOP Analysis  For the human tissues, the fiber optic probe was placed in contact with sites visually identified as grossly normal (no obvious macroscopic damage) and degraded (fibrillations, clefts or fissures present), corresponding to Mankin Scale grade 1 and grade 3 respectively. For the rabbits, the medial side of the right (surgical) and left (control) tibial plateaus were sampled. The IFOP consists of a flexible fiber optic cable composed of the mid-infrared-transmitting glass “chalcosilicate” (RemSpec Corp, Sturbridge, MA) equipped with an MCT detector coupled to a Mattson Cygnus 25 spectrometer (Mattson Instruments, Madison, WI). The fiber optic is 1 meter in length and transmissive over the infrared region of 4000 - 900 cm⁻¹. A flat tip ZnS ATR crystal with a 1-mm area of surface contact was attached to the end of the cable. Spectral data was obtained for all specimens and comparisons in peak heights and areas made between normal (or control) and degraded sites. The areas and intensities of the type II collagen absorbances (amide I, II&III) were monitored in the 1590-1720 cm⁻¹, 1590-1480 cm⁻¹ and 1300-1200 cm⁻¹ infrared regions respectively (Fig. 1).

Results  IFOP Analysis  In the 12 human tissues, consistent spectral changes were found between grade 1 and grade 3 sites (Fig. 2). The intensity ratios of the 1238 cm⁻¹/1227 cm⁻¹ peak decreased (p = .018 , paired T-test), and the ratio of the amide II area to the area of the 1338 cm⁻¹ absorbance increased with degradation for (p = .034, paired T-test). In the rabbit tissues, spectral changes similar to those in the human cartilage were noted between control and surgical cartilage for the 1238/1227 cm⁻¹ ratio (Fig. 3). Histological Evaluation of Cartilage of the Rabbit Tibial Plateau. All sections were obtained from the middle of the medial compartment of the tibial plateau. For the surgical (degraded) tibial cartilage, at 4 weeks-post surgery there was clefting on the superficial layers, although part of the normal layers were still evident. By 8 weeks post-surgery, the clefts were deeper and the superficial layers were almost totally deteriorated. There was no obvious change with time in the control sides.

Discussion  Infrared spectral changes arise from alterations in molecular structure of tissue components. In intact cartilage, the infrared spectrum obtained from the articular surface arises primarily from type II collagen (5). Thus, it is likely that changes in this spectrum arise from alterations in either quantity or quality (i.e. breakdown) of this component. Overall, these data demonstrate that the IFOP is sensitive to cartilage degradation, and use of this new technology in conjunction with arthroscopy may facilitate the diagnosis and treatment of OA and other joint diseases.