Aim of study: Recent studies from our laboratory have utilized an infrared fiber optic probe (IFOP) to identify molecular signatures associated with degenerative collagen in harvested osteoarthritic human cartilage (1). In the current study, this research is advanced by the development of methodology to extend the IFOP to a clinical setting to be used as an arthroscopic diagnostic tool to evaluate the chondral surface in vivo. This requires development of a method that can rapidly distinguish classes of cartilage. The use of chemometrics (statistically based pattern-recognition methods used to identify or classify materials based on their infrared spectral characteristics) was investigated as a way to facilitate diagnosis of early-stage degeneration and to automate analyses. The chemometric evaluation of cartilage degeneration was compared to Collins visual grade and histological Mankin score.

Methods: Twenty-six arthritic human tibial plateaus (TP) were obtained during knee replacement surgery and analyzed using the IFOP (RemSpec Corp, Sturbridge, MA) under an IRB-approved protocol. IFOP data was collected from regions of each specimen visually identified and graded as corresponding to Collins Scale grade 1, 1.5, 2, or 2.5 (corresponding to morphology that had swelling of softening, superficially slight fibrillation, deeper fibrillation or serious fibrillation). Tissue regions sampled by IFOP were then extracted by biopsy punch and processed in paraffin for histology. Tissues sections were stained with H&E and Alcian Blue and given a Mankin Score. The histological Mankin score considers structure fissuring, cell clones, loss of proteoglycan and tidemark integrity, where grade 0 represents normal cartilage and grade 14 represents severely degenerated cartilage. Two investigators evaluated randomized and blind-coded samples independently, and the final Mankin score was calculated as a mean of the two evaluations. Infrared spectra contain information on the molecular species present in the tissues, and changes in the spectra can be correlated with degeneration of tissue components. Vibrations arising from the collagen, proteoglycan and water components of cartilage were monitored by IFOP. A chemometric model using partial least square (PLS) regression algorithm based on classification of cartilage degradation was developed using QUANT II OPUS NT software (Bruker Optics, MA). At least 17 spectra from each grade of cartilage were utilized as input to create a model to “teach” the method what characteristics infrared spectra have for that particular Collins grade. For Mankin grading, 37 spectra from 20 biopsy spots were collected. Test spectra were input, and the PLS-predicted grade of cartilage assigned to the test spectra was compared to the actual grade as determined visually or histologically.

Results and Conclusion: Several spectral regions were investigated for data analysis, with the 1582-976 cm⁻¹ range yielding the best results. This region contains absorbances that arise from molecular vibrations from collagen and proteoglycan components. A comparison of the Collins visual scale grade and the PLS-predicted values gave a result of R²=0.7487 and P<0.05 (Figure 1). The correlation between the Mankin histological scale grade and PLS-predicted values gave R²=0.9137 and P<0.05 (Figure 2). This result demonstrates that this algorithm can be utilized to evaluate a spectrum from a region of cartilage, and output the class of degradation. Since spectral acquisition takes only 30 seconds, this newly-developed method, once refined, could provide a rapid, minimally-invasive means of in vivo quantitation of cartilage matrix degradation based on changes in the molecular structure of the tissue.


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