Patellar tendon and tibial cartilage viscoelastic properties are inversely related in osteoarthritic knees

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INTRODUCTION: It is currently well-accepted that osteoarthritis is a disease not limited to cartilage and bone but rather affects the whole joint [1]. However, periarticular structures have received less attention in osteoarthritis, although degeneration of periarticular tendons can be evident around osteoarthritic joints [2,3]. The patellar tendon (PT) inserts onto the tibia, and thus the two structures are inherently coupled. With osteoarthritis being a whole joint disease, it is plausible that, as the disease progresses, the PT and tibial cartilage undergo adaptations that are not independent from each other. Cartilage material properties, which are altered in osteoarthritis [4], are currently difficult to assess in living humans [5]. Thus, the material properties of the PT being potentially related to those of tibial cartilage may be of clinical benefit as a supportive assessment tool given tendon material properties can be assessed non-invasively with more accessible methods [6,7,8]. Therefore, we explored the potential relationship between the material-level viscoelastic properties of the PT and tibial cartilage from histology-confirmed osteoarthritic knees.

METHODS: The Research Ethics Committee of the Northern Savo Hospital District gave a favourable opinion towards the study protocol (134/2015). Whole PTs and tibial cartilage plugs (n = 60) were extracted from eight cadaver knees (five female; mean age = 65 ± 8 yr; mean height = 1.72 ± 0.15 m; mean mass = 83 ± 23 kg). Data from PTs were presented at last year's meeting [9]. Briefly, PTs were divided into six regions (three mediolateral × two anteroposterior). Each PT region underwent sinusoidal tensile testing including 0.1, 0.5, and 1.0 Hz using a 0.5% strain amplitude after 30 minutes of relaxation at 8% strain. Twenty sinusoidal cycles were performed at each frequency. Cartilage plugs of 8 mm diameter were extracted from up to eight locations (four medial + four lateral) of the tibial plateau for each knee (Figure 1). Cartilage samples could not always be extracted for all locations of a given knee due to excessive degeneration of some regions. For each sample, sinusoidal indentation testing included the same frequencies as for PT (4 cycles per frequency) and was performed at 2% strain amplitude after 15 minutes of relaxation at 15% compressive strain. For both PT and tibial cartilage, phase angle and dynamic modulus were obtained from the sinusoidal data. As no systematic mediolateral or anteroposterior differences were found for PT viscoelastic properties [9], PT data were averaged across the six regions to provide one overall value per knee for each parameter. Likewise for tibial cartilage, one overall value for each parameter was obtained by averaging all samples from a given knee regardless of OARSI score (determined by three independent observers). The phase difference and dynamic modulus of tibial cartilage was compared with the corresponding PT parameter using Pearson's r correlation coefficients. Statistical significance was set at $p > 0.05$.

RESULTS:

Of the 60 extracted cartilage plugs, eight samples from four knees were considered healthy (OARSI grade 0-1; range: 0-3 per knee, median 0.5 per knee). Early osteoarthritic samples (OARSI grade 2-3) were available from seven of the eight knees (n = 25; range: 0-6 per knee; median 3 samples per knee), whereas advanced osteoarthritic samples (OARSI grade 4-5) were found in all knees (n = 27; range: 1-6 per knee; median 3.5 samples per knee). Significant inverse correlations were found between the PT and tibial cartilage for phase difference ($r \leq -0.889$; $p \leq 0.003$), but not for dynamic modulus ($r \geq -0.575$; $p \geq 0.136$), at all frequencies (Figure 2).

DISCUSSION:

In this exploratory investigation, we found strong, inverse relationships in the phase difference of the PT and tibial cartilage samples from knees with osteoarthritis. Lower tendon viscosity is associated with worse functional outcomes in tendinopathic patients [7,8]. As patients with knee osteoarthritis typically have reduced knee function and use, PT viscosity may also decrease as osteoarthritis develops, potentially inducing the inverse relationship between PT and tibial cartilage phase difference as osteoarthritic tibial cartilage is more viscous than healthy cartilage [4]. Although all knees could be considered osteoarthritic given the paucity of healthy tibial cartilage samples, the distribution of datapoints based on the number of advanced osteoarthritic samples (Figure 2) suggests there may be a diagnostic role for PT viscosity on the state of tibial cartilage health. Overall, this study provides a foundation for larger, more focused investigations of the mechanism(s) behind the connection between PT and tibial cartilage mechanics and its potential clinical value.

SIGNIFICANCE/CLINICAL RELEVANCE:

A strong relationship was found between PT and tibial cartilage viscoelasticity in osteoarthritic knees. Further work is needed to determine if measuring PT biomechanics may be a feasible, non-invasive proxy for monitoring tibial cartilage and joint health.

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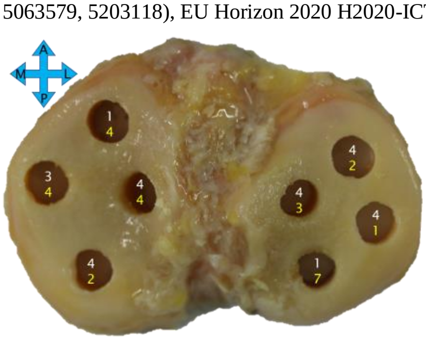

Figure 1. Example tibial plateau of a right knee. Holes indicate osteoarthritic cartilage sample locations, with the number of available samples per location that were early (white) and advanced (yellow) osteoarthritic. The compass on the *upper left* specifies anteroposterior and mediolateral sides.

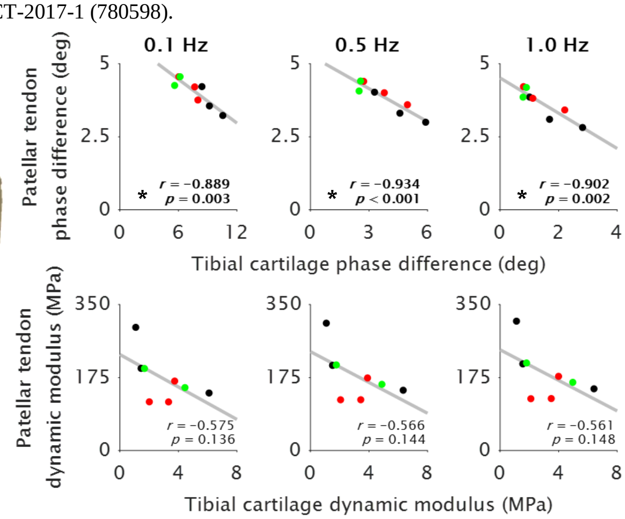

Figure 2. Pearson's r correlations between patellar tendon and tibial cartilage phase difference (upper) and dynamic modulus (lower) at 0.1 (left), 0.5 (middle), and 1.0 Hz (right). Individual dots represent knees with 1-2 (green; n = 2), 3-4 (red; n = 3), and 5 or more (black; n = 3) advanced osteoarthritic samples. Significant correlations ($p < 0.05$) are marked with an asterisk.