Diffusion Tensor Imaging in Cartilage

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Introduction

Diffusion tensor imaging (DTI) [1] has been suggested as a means of monitoring the architectural state of the collagen network in cartilage. However, little data are available on DTI of normal and degenerated cartilage. In this study, we performed DTI measurements on normal and enzymatically-degenerated lamb cartilage and on human cartilage in various stages of disease.

Methods

DT-MRI was performed on a water sample and an agarose sample to determine the error in the DTI measurement. DTI was then performed on two lamb patellae and four human knee cartilage-bone samples in a Bruker 8.45T MR scanner (Bruker Instruments, Bellerica, MA) and a 30 mm rf coil. The lamb patellae were imaged pre and post partial trypsinization (overnight at 25 mg/mL). One human sample was from an individual without OA history, which we refer to as nominally "normal", and three were patients who underwent knee replacement surgery for OA. All samples were scanned using the same FOV (3×3 cm^2), slice thickness (3 mm), matrix size (128×128) and number of averages 1. The in-plane resolution was 235×235 μm^2. Other imaging parameters for DTI were as follows: Spin Echo pulse sequence, TR/TE=1000/17 ms, δ/Δ=2/10 ms, 6 non-collinear diffusion gradient directions, 4 diffusion gradient strength levels (200, 250, 300, 350 mT/m) in each direction, corresponding b values (91.1, 142.3, 204.9, 278.9 s/mm^2). Total imaging time for one cartilage sample was about an hour. Data analysis and visualization was conducted with an in-house software package using MATLAB (MathWorks, Natick, MA). Diffusion anisotropy indices, including mean diffusivity (mean D) and fractional anisotropy (FA) were computed on a pixel-by-pixel basis across the whole cartilage for each sample.

Results and Discussion

The FA for water and agarose samples were 0.057±0.008 and 0.065±0.006 respectively. The color scale on the FA images was set with 0.065 at black. Tables 1 and 2 and representative DTI maps for a pre and post-trypsinized sample (Fig 1) and human samples (Fig 2) revealed that mean D was higher for the post-trypsinized and OA sample relative to the pre-trypsinized and normal samples. The values for mean D and the differences between normal and degenerated tissue were within the range previously reported based on other measurements [2], and the FA was in the range previously reported on bovine cartilage [3]. In general FA was higher for the post-trypsinized samples relative to pre-trypsinized ones, but lower in OA samples relative to normal human cartilage. This implied that loss of GAG in intact cartilage may increase collagen structural organization, while cartilage degradation including GAG loss in human tissue involves over-riding damage to the collagen structural integrity.

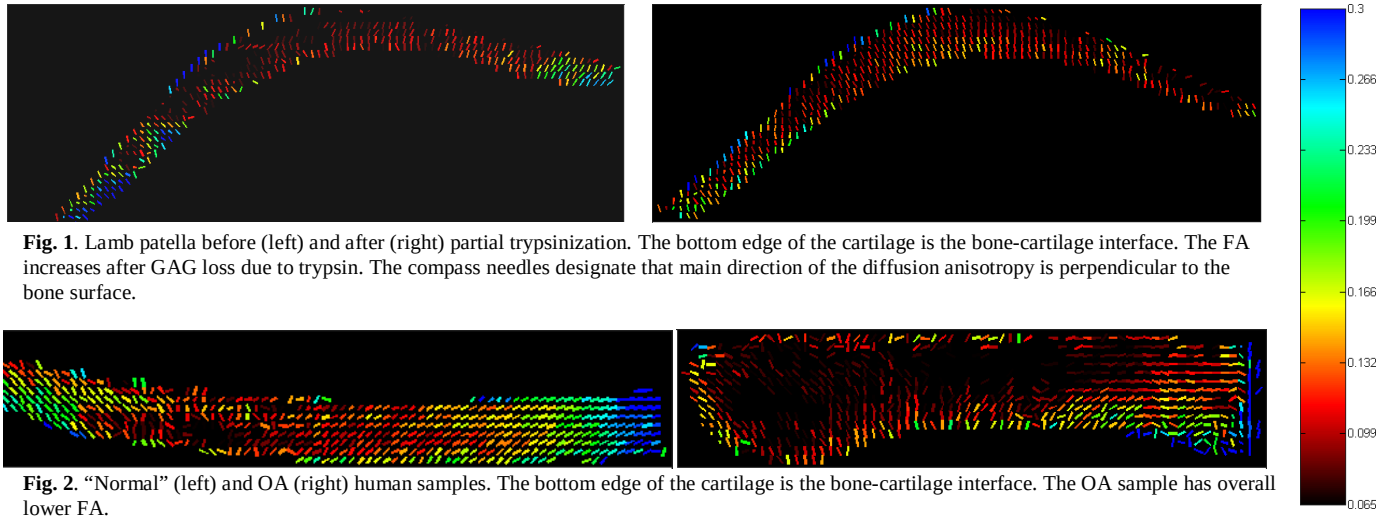

Fig. 1. Lamb patella before (left) and after (right) partial trypsinization. The bottom edge of the cartilage is the bone-cartilage interface. The FA increases after GAG loss due to trypsin. The compass needles designate that main direction of the diffusion anisotropy is perpendicular to the bone surface.

Fig. 2. "Normal" (left) and OA (right) human samples. The bottom edge of the cartilage is the bone-cartilage interface. The OA sample has overall lower FA.

Conclusion

We provide here new data on DTI in human cartilage. The range of mean diffusivity is comparable to expected values. FA is significantly different from water, and varies considerably throughout the tissue. Future work is aimed at increasing the number of samples, both normal and degenerated, and at uncovering the underlying basis for differences in FA in terms of macromolecular organization.

Table 1. Mean±SD of mean diffusivity (mean D), fractional anisotropy (FA) for two pre and post trypsinized lamb patella.

	Trypsinized patella 1		Trypsinized patella 2	
	Pre	Post	pre	Post
Mean D ($10^{-3}mm^2/s$)	1.52±0.15	1.61±0.14	1.48±0.17	1.66±0.14
FA	0.11±0.06	0.12±0.04	0.12±0.05	0.15±0.06

Table 2. Mean±SD of mean diffusivity (mean D), fractional anisotropy (FA) for four human samples

	Non- OA	OA1	OA 2	OA 3
Mean D ($10^{-3}mm^2/s$)	1.30±0.10	1.37±0.19	1.52±0.27	1.53±0.28
FA	0.15±0.06	0.10±0.04	0.10±0.05	0.11±0.05

References

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