Dramatic Changes in the ^{23}Na Signal in Cartilage of Excised Human Osteoporotic Femoral Heads

K. Keinan-Adamsky[1], H. Shinar[1], S. Shabat[2], Y. S. Brin[2], M. Nyska[2], and G. Navon[1]

[1]School of Chemistry, Tel Aviv University, Tel Aviv, Israel, [2]Sapir Medical Center, Meir Hospital, Kfar Saba, Israel

Introduction: It has long been shown that molecules and ions, interacting with collagen fibers, tend to partially align along the fibers so that their motion is anisotropic. In such cases the ^{23}Na quadrupolar interaction is not averaged to zero, leading to splittings of the spectral lines. These splittings can be clearly observed by using multiple quantum filtered NMR and MRI techniques (1). In osteoarthritis (OA) it has been demonstrated by NMR that the amount of sodium ions is reduced (2,3). We have recently reported that concomitantly with the decrease in the amount of sodium ions in proteoglycan (PG) depleted cartilage there is a significant increase in the ^{23}Na residual quadrupolar interaction, ν_Q (1,4,5). **We report here the observation of a dramatic increase in the ^{23}Na residual quadrupolar interaction in cartilage of excised osteoporotic (OP) human femoral heads**. We are not aware of any report of changes in the micro-structure of cartilage of OP bones.

Methods: Cartilage-bone plugs, 8 mm in diameter, were excised from femoral heads of OA and OP patients undergoing a hip replacement surgery, from control human femoral heads obtained from the bone transplantation center and also from mature bovine femoral condyles. For NMR measurements the plugs were equilibrated in saline and immersed in fluorinated oil. PG depletion plugs was done by incubation with 1mg/ml trypsin and decalcification by incubation with formic acid. ^{23}Na one-dimensional spectroscopic images were obtained by 1D single-quantum quadrupolar echo (SQ-QE) spectroscopic imaging (5). ^{23}Na ν_Q was also determined from the triple quantum filtering (TQF) sequence (1). Since ^{23}Na is not observed from the bone, the values obtained represent the average ν_Q in the cartilage.

Results: The effect of the PG depletion on the ^{23}Na quadrupolar splitting in bovine cartilage-bone plugs was measured by ^{23}Na SQ-QE imaging as a function of the incubation time (Fig. 1). The quadrupolar splitting, measured in the central region of the plug, where the integrated intensity was the highest, increased by 68% from approximately 1000 Hz in the intact plug to 1700 Hz after 8.5 hours of incubation. Concomitantly a significant decrease in the amount of sodium is clearly seen. Since the amount of sodium can not be assessed from this imaging sequence, the effect of trypsin on the total amount of sodium was measured from ^{23}Na gradient echo images (Fig. 2). After 8.5 h of degradation there is a loss of 65% in the intensity observed in the center of the plug.

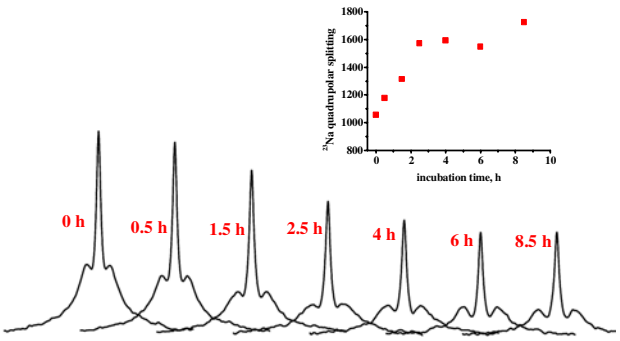

Fig. 1. ^{23}Na spectra extracted from one-dimensional SQ-QE images of bovine cartilage at locations with maximum intensities. as a function of the incubation

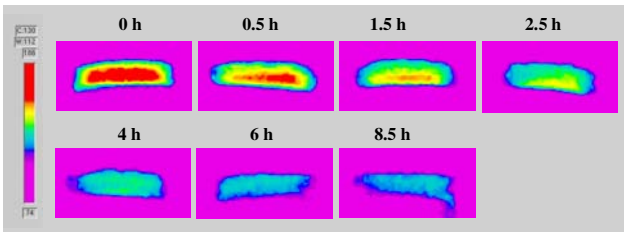

Fig. 2. Gradient echo images of bovine cartilage-bone plug as a function of the incubation time in trypsin

	ν_Q (Hz)
Control (n=11)	834 ± 192
OA (n=10)	1008 ± 284
OP (n=11)	1246 ± 191

Average ^{23}Na ν_Q of human control, OA and OP cartilage-bone plugs.

^{23}Na ν_Q was measured in control, OA, and OP human cartilage-bone plugs by ^{23}Na TQF NMR (Table). An increase in the average splitting of 23% was observed in the OA plugs relative to the control. A dramatic increase of 60% was observed for the OP plugs. The OA plugs are expected to have a lower amount of PG and thus a diminished concentration of sodium ions. This result is in line with the average ν_Q values obtained for trypsinized bovine plugs which were larger by 23 %(n=5) than those obtained for the intact cartilage. OP bone is characterized by a diminished amount of Ca^{+2} ions and we hypothesize that there may be a reduced amount of Ca^{+2} also in the cartilage. We have checked the ^{23}Na ν_Q in decalcified human control samples and found an increase of 29% as a result of the decalcification. Thus the large increase in the ^{23}Na ν_Q in the cartilage of OP samples can be explained, at least in part by the decrease in the calcium concentration.

Discussion: We have found that the ^{23}Na quadrupolar splitting is sensitive to the integrity of the cartilage matrix in human femoral head cartilage. For OP samples, the observed ^{23}Na splittings are larger in the OA group relative to controls and are much larger in the OP group. Only part of the increase in the ^{23}Na can be explained by the diminished amount of Ca^{+2} ions in the OP cartilage. There may be other changes in the cartilage matrix that we are not yet aware of.

References: 1. G. Navon et al., NMR Biomed. 14, 112 (2001). 2. A.J. Wheaton et al., Acad Radiol. 11,21 (2004). 3. A. Bashir et al., Magn Reson Med. 41, 857 (1999). 4. O. Danzige et al., In Proc 7th Annual Meeting ISMRM. 1522 (1999). 5. H. Shinar et al., NMR Biomed. 19, 877 (2006).