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Investigation of high frequency ultrasound transducers and coded signals suitable for cartilage volume imaging

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Background, Motivation and Objective

Cartilage degeneration in joints causing pain and various types of knee problems, is a serious problem affecting people in all ages. Degenerated articular cartilage is also known as a central hallmark of osteoarthritis which is a complex musculoskeletal disorder involving numerous contributory genetic, constitutional and biomechanical factors. As a part of the cartilage degeneration, the volume occupied by the collagen fibers becomes reduced and the cell (chondrocyte) volume increases. Since high frequency ultrasound is capably of resolving individual chondrocytes, ultrasound has been suggested as a promising method for determining the cartilage status. In the current work, the main objective is to compare images taken in vitro with different transducer types, in order to determine their suitability for cartilage imaging.

Statement of Contribution/Methods

Two commercially available PZT and PVDF transducers with similar centre frequency (40 MHz), aperture diameter (6.35 mm), and focal distance (12.7 mm), were used to image a thick (1.25 mm) cartilage sample. In addition, an in-house developed 40MHz P(VDF-TrFE) transducer with a much smaller aperture diameter (1.6 mm) and focal distance (2.6 mm) was investigated on the same sample. All imaging was performed on a customized scanning platform developed around a Leica DMi8 inverted microscope. Three different excitation pulses (Ricker wavelet, Gaussian chirped, and 13-bit Barker code) were implemented on the system, and compared after wave compression.

Results/Discussion

The investigation shows that both commercial transducers were capable of producing high quality images of the cartilage sample in terms of large SNR, high dynamic range, and good resolution. For coded signals however, the PZT transducer had more restrictions on code lengths and excitation repletion frequency due to its built-in delay line. The in-house P(VDF-TrFE) transducer also produced images with acceptable resolution, but suffered from noise due to its much smaller aperture size. However, the low SNR could be significantly increased by using coded signals as illustrated in Fig. 1, where C-scan images from a Ricker wavelet and Gaussian modulated chirp are compared. Our finding therefore suggest that low cost miniaturized polymer transducers can produce high quality images of cartilage with appropriate signal coding.

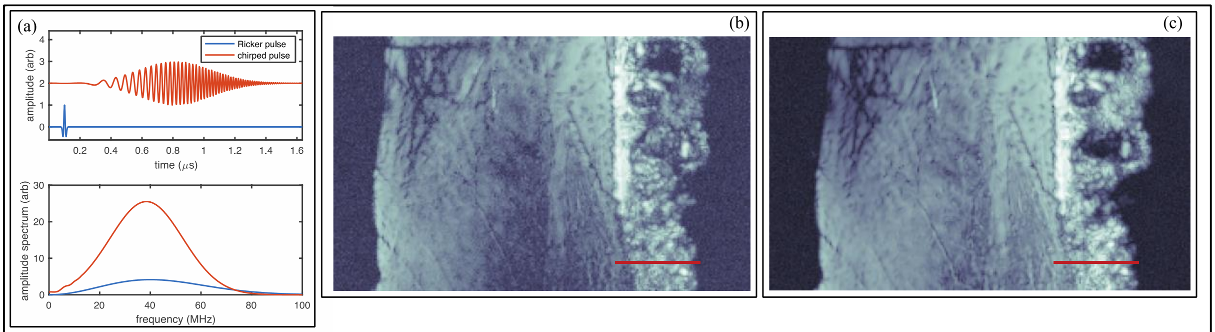

Fig. 1: Comparison of Ricker wavelet and chirped pulse used as excitation pulses for the in-house tranducer. The pulse shapes are shown in Fig. (a) with examples of obtained C-scan images for the Ricker and chirped pulses shown in Fig. (b) and (c), respectively. The chirped pulse was compressed using a matched filter with a shape identical to the excitation pulse. The red scaling bars in Fig. (b) and (c) have length 1.0mm.