Image Analysis on the Structure of the Achilles tendon

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PAIN in the lower backside of the leg is a common ailment for a large part of the population. This pain is often related to the Achilles tendon. Swelling due to different internal damages of this is called Achilles tendonitis. A specific kind of tendonitis is calcific tendonitis. This is pain of the tendon specifically related to the growth of calcified pieces within the tendon tissue. These pieces are called *heterotopic ossification* (Greek: 'misplaced' and Latin: 'formation of bone'), shortened HO, and the reasons for these formations is still somewhat unclear.

To understand the human physiology of the Achilles tendon an animal model, such as rats, can be very informative. In this project two different previously conducted animal studies were the basis for the data. The first animal experiment focused on if limiting the leg movement in rats by injecting Botox into the adjacent muscles and using a metallic boot to further restrict the movement. The second study introduced small punctures, microinjuries, into the rat tendon tissue by inserting a needle into the tendon. The tendons were then imaged using X-ray computed tomography from a synchrotron light source. This imaging method produced high resolution 3D visualization of the data which was possible thanks to synchrotron tomography. This provides a way for examining the interior structure of the samples non-destructively. To further improve the visualization of the tendons the images were acquired in phase contrast enhancement conditions which allows better imaging of weakly absorbing material such as tendon soft tissue.

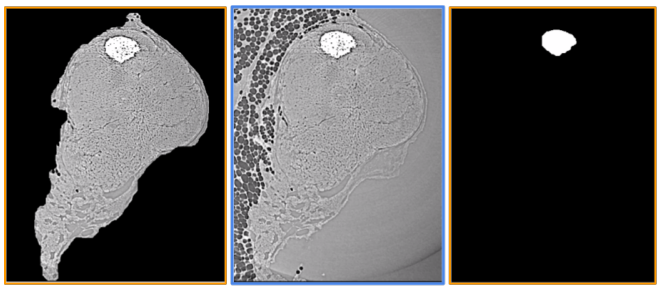

Figure 1. Example of the imaged tendon as well as the segmented tendon (left) and heterotopic ossification (right) taken as a cross section from the top (z-direction).

The goal of the project was to separately segment the HO and the tendon. To do this, some different concepts of image analysis were used. In the images the tendon and HO appear very different. With X-rays, the high density tissues (such as HO) appears very bright, and the lower density tissue (tendon tissue) is grey (fig.1).

The methods had to be tailored to the specific tissue. One of the key concepts for performing the segmentation was binarization thresholding. This makes all pixels above a specific threshold value white, and anything under black. For example a manually chosen high binarization threshold is effective for isolating the HO which is very bright, but a choosing the point based on statistical data of the image is more appropriate for the tendon tissue. Besides this, the order of operations is also very important. For the HO the binarization can be applied as the first step. When it comes to the tendon it is beneficial to first remove noise (by using image filters) and adjusting the images with other image processing techniques before the thresholding is done.

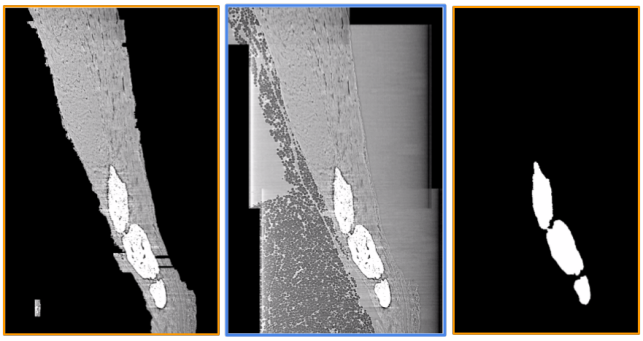

Figure 2. Example of the imaged tendon as well as the segmented tendon (left) and HO (right) taken as a cross section from the side (x-direction).

From the segmentational process, the HO and tendon volumes were extracted as well as the HO deposit location in relation to the tendon length. In general the differences between the groups were not large enough to come to any clear consensus. The data may indicate that micro injuries led to a larger volume of HO, but because the small number of samples the differences could not be statistically shown.

An interesting discovery was that a number of samples, that had multiple HO deposits, looked as if these had grown together by thin connecting bridges of HO tissue or where the ends were pointing at each other as if they were going to merge (fig. 2). This phenomenon could be an interesting continuation for further investigation.

In summary, the processes developed were effective in segmenting the tendon and the heterotopic ossification. More studies on this are needed to establish the reason and prevalence of their presence.