Rigid matching of two 3D patellae data sets for voxel based comparison

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Introduction Osteoarthritis (OA) entails a global socio-economic burden. Degradation of articular cartilage is considered to be an entry point in the process of irreversible joint degradation. An early diagnostic and a close follow up are very important in order to determine the progression of disease and potential effects of therapy. Cartilage degradation can be well detected with MRI, since alterations of its matrix induce variations on the relaxation time T2 [1]. Another indicator of cartilage damage, which can be quantified with MRI, is cartilage thickness [2]. In this work we asses the question of how different 3D MRI (T2 relaxation time and thickness) datasets can be compared at a voxel basis.

Methods A rigid geometrical matching of the 3D MRI images is necessary before comparing any parameter. Matching is performed in two steps. First, both images are transformed to their principal inertial axis. Second, optimal rotation and translation parameters are calculated, which maximize the overlap between both images. After matching, parameters were compared in a voxel basis after first neighbors averaging. The robustness of this method was tested both with repeated images acquired on healthy volunteers (n=7) at 7 different times and with simulations. Images were acquired in a 1.5T scanner (Magnetom Sonata; Siemens, Erlangen, Germany). Anatomical images were acquired with a FLASH sequence (TR/TE=20/8 ms; flip angle 25°, FOV=16×16 cm^2, matrix=256×256, voxel size=0.3×0.3×3 mm^3, 9 slices), and T2 maps were calculated with a self developed interleaved multi-slice multi-echo sequence (TR/TE=3000/13.6 ms, 8 echoes, other parameters as before) [1].

Results The application of this method to all of the different 21 pairs built up with the 7 repeated measurements of each volunteer consistently shows a mean overlap of (99.1±0.5) %. Most of the unfitted points lay at the cartilage surface. This may be a consequence of possible uncertainties in the segmentation in the cartilage surface (CS). Since the bone cartilage surface (BCS) is the last part of cartilage to be affected by OA, it is also interesting to study how the different BCS match with each other. The mean overlap of BCSs was (98.2±1.1) %, which is surprising due to the small number of voxels in the BCS (typically of 500), and may indicate the reliability of the segmentation at the BCS. Overlap of the CS shows a clearly worse mean overlap (92.9±4.9) %. After matching, T2 and thickness were compared (see Fig. 1). T2 values showed a mean relative error of (11.9±0.1) %. Great T2 differences are usually located at the CS.

Simulations of MRI data on two mathematical models of a patella with different grade of symmetry were matched (Fig 2.A). An example of a measurement is shown in Fig. 2B. The second data is moved while keeping fixed first data (magenta) from its initial position in principal axis (light green) to an end position (dark blue) very near of its exact position (light blue). Calculated overlap had a deviation from exact overlap which is slightly dependent on the asymmetry of the model. In Fig 2C symmetric models (blue points) show a higher deviation from exact value than measurements made with a more asymmetric model (red points). The values of the calculated rotations correlate with the exact angle with a Pearson's correlation coefficient of 0.978 (slope 1.04).

Conclusions We have demonstrated that a simple rigid matching is able to position corresponding MRI data sets in space so that short time comparisons of measurements can be made on a voxel basis with good accuracy.

References

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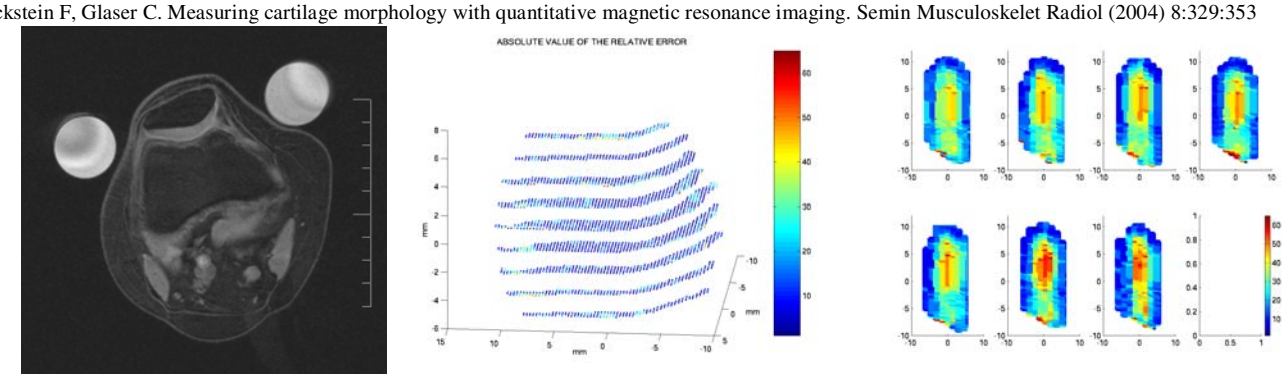

Figure 1: A. Anatomic image of a patella. B. T2-relative error after matching (in %). C. Thickness calculation (scale 0 to 2.8mm).

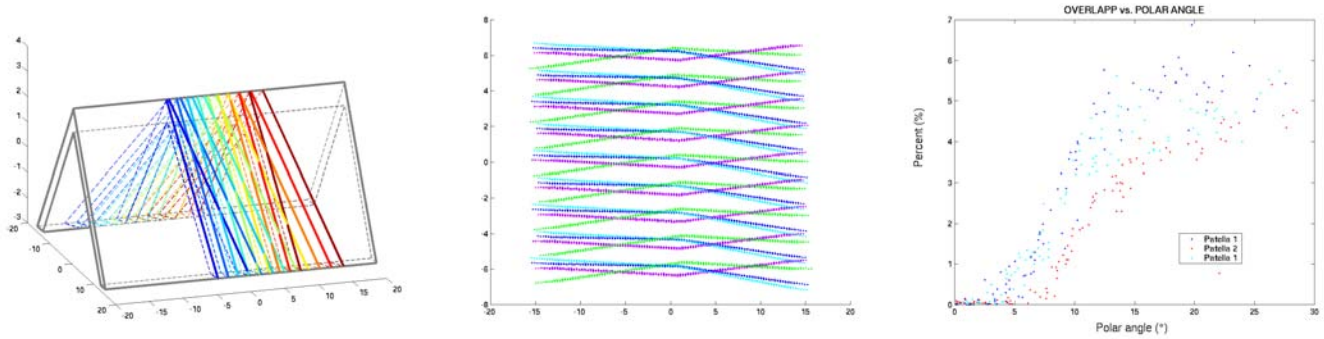

Figure 2 A. Patella model with two sets of slices. B. Results of a matching. C. Calculated minus exact overlap as a function of angle.