Validation of Micro-CT: Experimental Protocol for Porous Materials

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Introduction
In order to quantify the internal structure of porous materials, X-ray microfocus computed tomography (micro-CT) can be applied. For cancellous bone-like structures, micro-CT has already proven its accuracy for the imaging of the 3D internal architecture, but how accurate and reliable is micro-CT for the characterisation and screening of non-bone porous materials? This study proposed an experimental validation protocol which renders validation parameters to quantify the error made by applying normal micro-CT.

Materials and Methods
As a proof of principle, the proposed protocol was applied to titanium bone scaffolds with a global porosity of about 70-80 %. Based on optimal acquisition parameters, determined by means of a micro-CT simulator, micro-CT images were acquired. The samples were embedded in resin, cut physically into slices and digitized via optical light microscopy after grinding and polishing. Due to the possible deviation between the physical cutting angle of the optical images and the scanning angle of the micro-CT images, interpolated micro-CT images that are inclined under the same angle as the cutting angle were reconstructed. The threshold plays an important role in the analysis as well as the validation of micro-CT images. Hence, a novel thresholding method was added to the protocol based on the overlap and mismatch between the micro-CT and the optical images. Both the binarized, interpolated micro-CT and optical images were registered and matched by overlay. The percentage overlap, micro-CT mismatch, optical mismatch and total mismatch were determined from the overlay images. Also, for both the optical and the micro-CT images, the surface fraction (2D) was calculated.

Results
For micro-CT images with a voxel size of 13.5 µm, acquired on a Philips HOMX 161 X-ray system with AEA Tomohawk CT software, a match of about 82 % was found. This match was however incorporated with a total mismatch of about 60 %. Also, it was also determined that micro-CT overestimated the surface fraction by about 5 % absolute to the real surface fraction. The surface fraction decreased by about 2.6 % for 5 % increase in the threshold.
**Discussion and conclusion**
An experimental protocol was developed that defines not only validation criteria to evaluate the errors introduced by using *normal* micro-CT for the characterisation of porous materials, but also the ‘optimal’ threshold value for binarizing the micro-CT images. By applying the protocol, it was shown that titanium bone scaffolds, i.e. highly porous materials with a complex and variable internal structure, could be analysed with sufficient accuracy by means of *normal* micro-CT. However, a large error was induced due to the limiting resolution of both the micro-CT device and the micro-CT images, and the high attenuating character and complex structure of the material.