Image processing as a facile method to determine pore size distribution in porous scaffold

Scaffold for tissue engineering are porous devices which allows the regeneration of living tissues such as bone, cartilage or other tissues. Some studies demonstrated that the regenerative properties of the scaffold are strongly dependent both on the simple porosity, i.e. the ratio between the empty volume and the total volume, and by the pore size distribution. The pore size distribution is usually measured by mercury intrusion porosimeter that use strong fluid pressure in order to evaluate the pore dimension. The biomaterials are often very soft and can be significantly deformed or damaged under strong pressures thus modifying the actual pore size. Moreover, if the pore's interconnection channels are much smaller than the pore itself, the intrusion methods do not allow getting the correct pores distribution. In latter case, methods based on image processing are definitely more effective. The method is based on the elaboration of micrographic images of the porous device. A software should be able to measure the porosity and, above all, the dimension of pores sections, visible on the 2D fracture surface. In our work, we developed a digital imaging procedure able to recognize pores of any geometry and able to measure the pore size distribution in a semi-automatic way. In order to test the effectiveness of the procedure, we carried out an analysis of the complex structure of a home-made polymer based scaffold for bone-cartilage regeneration.

The procedure for the segmentation of the images was developed using the Matlab® programming language; it consists in four steps:

1) pre-processing of the image (a),

2) assisted procedure for threshold determination,

3) binarization and morphological analysis,

4) verification procedure.

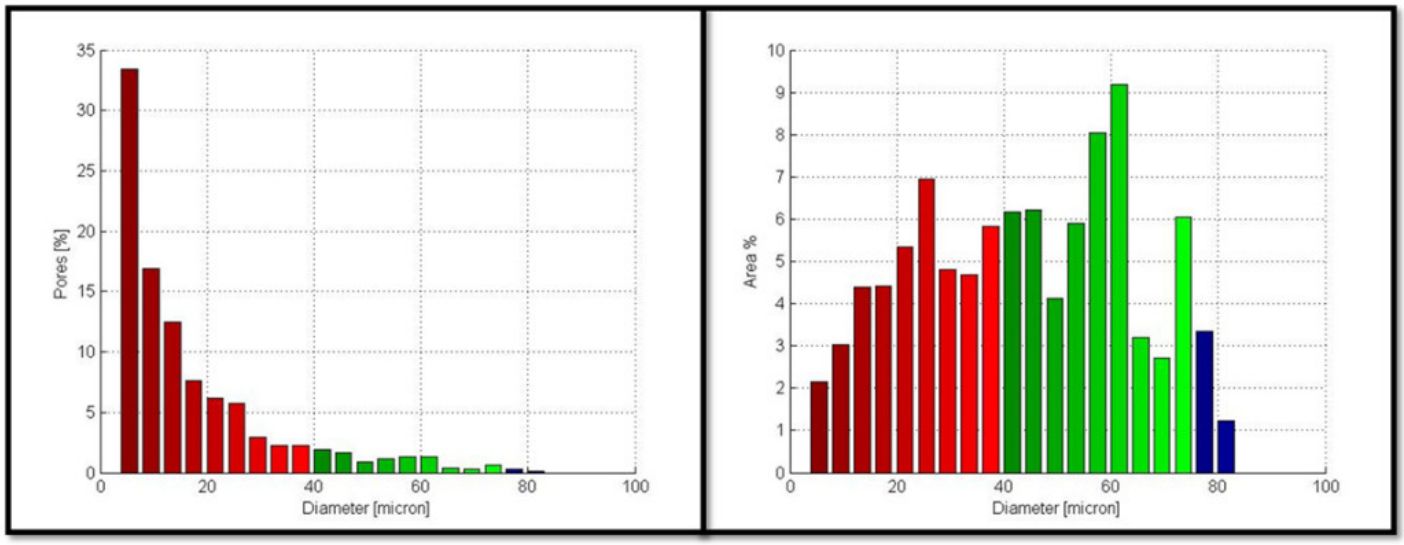

Fig. 1.

The results obtained by the analysis are summarized in two histograms (Fig. 1). The first one represents the pore size distribution; it reports the number of pores having diameters in a given interval. The second histogram represents the Pores Area Distribution; it reports the percentage of the total area occupied by the pores having diameters in a given interval. The red, green and blue colours are assigned to three increasing intervals of the size of the pores;

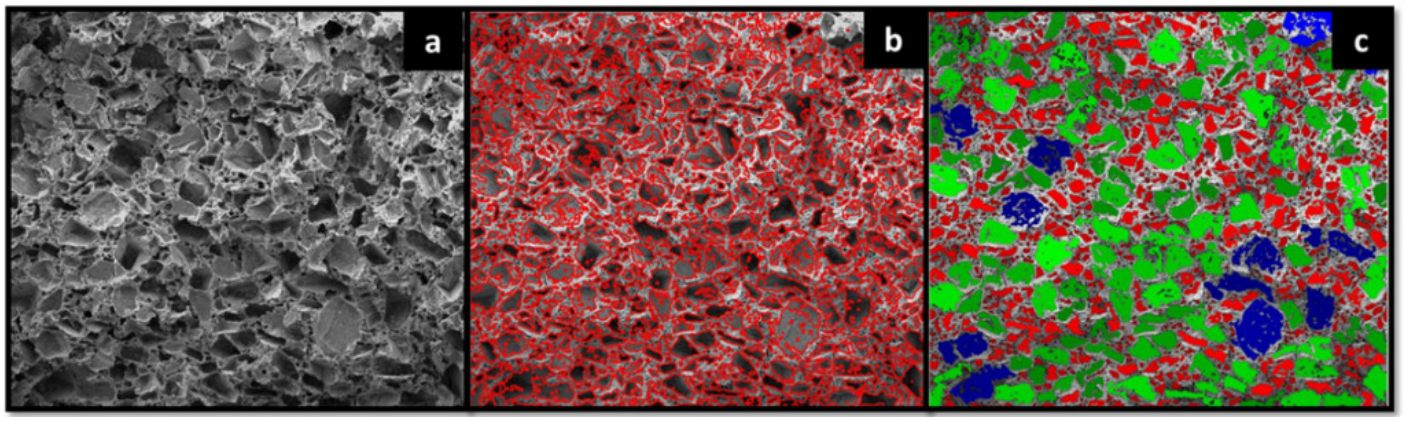

Fig. 2.

In order to verify if the parameters selected in the previous steps lead to a correct identification of the pores in the image, the original SEM micrograph (Fig. 2a) and two images respectively with the

boundaries and the areas of the pores superimposed to the original image (Fig. 2b, 2c) are for comparison. Also in this graphical form, the red, green and blue colours are assigned to three increasing intervals of the size of the pores, in order to facilitate the analysis of the results (Fig 2).

If they are not satisfactorily the operator, can modify the pre-processing parameters and/or the threshold level until the best compromise is achieved.

The software that we developed was able to recognize pores and provide information about pore size distribution of the porous devices requiring a limited interaction with the user. Furthermore this procedure does not interact with the pores morphology and evaluate the real pore dimension of the device.

Publication

A facile method to determine pore size distribution in porous scaffold by using image processing.
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