COMPUTER AIDED EVALUATION OF POROACCESSIBILITY OF POROUS COATINGS OUTER LAYER OF INTRA-OSSEOUS IMPLANTS

Ryszard Uklejewski[1], Mariusz Winiecki[1*], Wojciech Radomski[2]

[1]Kazimierz Wielki University in Bydgoszcz,
Faculty of Mathematics, Physics&Technical Sciences,
Department of Fundamentals of Medical Bioengineering,
Bydgoszcz, Poland
[2]Student of Informatics Master's Course,
Poznan University of Technology,
Faculty of Informatics, Poznan, Poland
*e-mail: winiecki@ukw.edu.pl

The poroaccessibility of intra-osseous implant coating is the ability of the porous coating outer layer to accommodate the ingrowing bone tissue filling its pore space and effective new bone formation mineralizing in the pores to form biomechanically functional bone-implant fixation. The poroaccessibility determines the functional features of intra-osseous implant porous coating which are called its structural-osteoinductive properties [6,8]. The structural-osteoinductive properties can be characterized by the set of three-dimensional parameters of poroaccessibility describing the functional properties of microgeometry of implant porous coatings: the effective volumetric porosity φ_{Vef}, the index of the porous coating space capacity V_{PM}, the representative surface porosity φ_{Srep}, the representative pores size pSrep, the representative angle of the poroaccessibility Ωrep and the bone-implant interface adhesive surface enlargement index ψ [3,7,1].

The original method of stereometric evaluation of the microstructural properties of intra-osseous implants porous coatings by means of the parameters of poroaccessibility [4] is based the 3D roughness profilometry and was preliminary verified during experimental tests performed on the representative examples of porous coated femoral stems and acetabular cups of various hip endoprostheses [2,5,9].

In this paper we present the possibilities of computer aiding for evaluation of the poroaccessibility of porous coating outer layer of intra-osseous implants illustrated by the measurement data from the experimental tests performed on porous coated components of various hip endoprostheses.

The computer aided evaluation of the microstructure of implant porous coatings can be realized by the authoring application software PoroAccess_1.0 elaborated for our purposes in our research team in Java programming language. The screen of the application software is presented in FIG.1. The PoroAccess_1.0 software lets to perform the dynamic analysis of the surface porosity φS in function of the pores depth pd which is showed as the map of porosity situated on the right side of the screen (see FIG.1). The application software imports results from the series of contact profilometry measurements as the 2D matrices in ASCII format and calculates the values of the poroaccessibility parameters of porous coating outer layer according to the mathematical formulas given in [3,11]. The applications software also has the module enabling 3D visualization of measured region of porous coating outer layer as the isometric plot.

The presented methodology provides the characterization of the effective part of porous coating – its outer layer, which is full of pores open for penetrating bone tissue with the diameter of many macro pores surpassing 100 μm. Such size of pores, according to clinical research [1], is beneficial for bone tissue to grow into the coating, so the pore space of the porous coating outer layer participates in creating biomechanically functional bone-porous implant fixation. The set of poroaccessibility parameters characterizes some major aspects of porous coating outer layer features. The parameters describe spatial (φVef, φSrep),

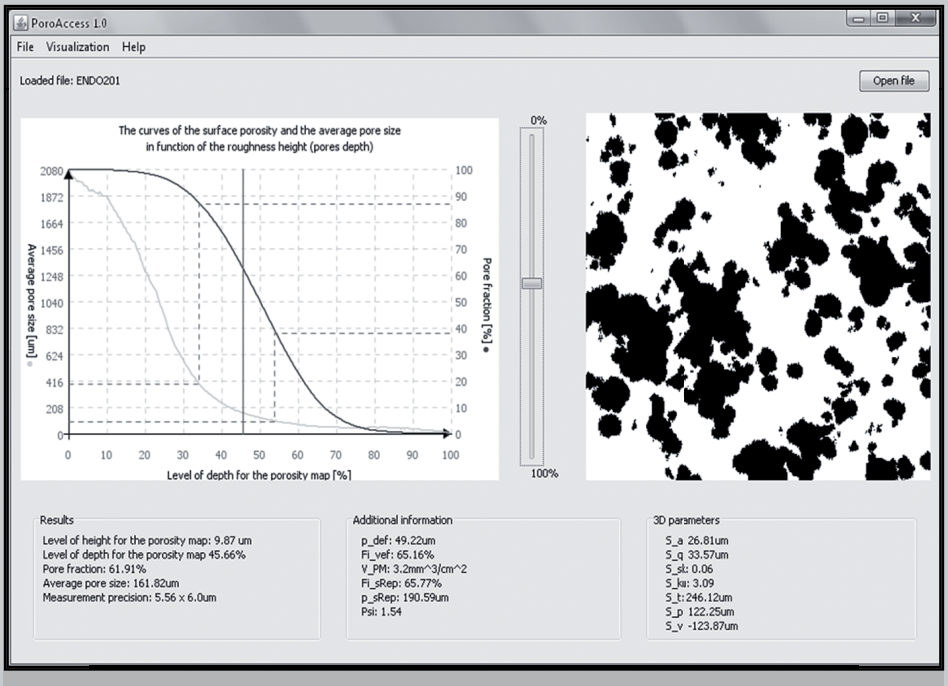

FIG. 1. Screen of the PoroAccess_1.0.

volumetric (V_{PM}), hybrid (pdef, Ω_{rep}) and some functional (physicochemical) properties of implant porous coatings outer layer, e.g. enhancement of the adhesive properties (ψ), which can be indirectly interpreted in the aspect of its structural-osteoinductive properties [10].

The presented methodology of characterization of implant porous coatings with use of the poroaccessibility parameters is going to be applied as a specific tool in research on designing porous coatings with functionally graded pore distribution and designed poroaccessibility. Nowadays, the best potential to manufacture implant porous coatings with designed poroaccessibility have Direct Metal Manufacturing (DMM) technologies like Selective Laser Sintering/Melting (SLS/M) or Electron Beam Melting (EBM), so the next stage of this research is the investigation on the possibilities to manufacture the porous coating with designed poroaccessibility in one of DMM technologies.

The biostructural evaluation of the manufactured in DMM technologies porous coatings together with its biological evaluation in NHOst cultures is expected to provide more information about the representative features of the microstructure of the porous coatings and allow to evaluate the most advantageous poroaccessibility of their pore spaces for potential bone tissue ingrowth to be verified in further in vivo test on animal models.

[Engineering of Biomaterials, 109-111, (2011), 42-43]

References

[1] Brooker A.F., Collier J.P., Evidence of bone ingrowth into a porous-coated prosthesis, J. Bone Joint Surg. Am. 1984, 66, 619-621.
[2] Uklejewski R., Winiecki M., Czapski T., Rogala P., Kochański J., Parametric evaluation of implant porous coatings – the results from representative examples of femoral stems measurements. Inżynieria biomateriałów, 2008, 11(77-80), 101-103.
[3] Uklejewski R., Winiecki M., Mielniczuk J., Rogala P., Auguściński A., The poroaccessibility parameters for three-dimensional characterization of orthopedic implants porous coatings, Metrology MS, 2008, 15(2), 215-226.
[4] Uklejewski R., Winiecki M., Mielniczuk J., Rogala P., Stereometryczna ocena strukturalno-osteoindukcyjnych właściwości porowatych pokryć implantów dokostnych za pomocą parametrów porodostępności. Mechanik, 2009, 82(11), 918-921.
[5] Uklejewski R., Winiecki M., Rogala P., Experimental investigations of porous coatings mictroctructure of model endoosseous implants. Inżynieria Biomateriałów, 2009, 12(89-91), 112-114.
[6] Uklejewski R., Winiecki M., Rogala P., Mielniczuk J, Auguściński A., Stryła W., Structural and biomechanical biocompatibility in bone-porous implant fixation region – on the basis of two-phase poroelastic biomechanical model of bone tissue, Inżynieria Biomateriałów, 2007, 10 (69-72), 93-95.
[7] Uklejewski R., Winiecki M., Rogala P., On the characterization of orthopaedic implants porous coatings with three-dimensional roughness measurement, Proceedings of the 11th International Conference on Metrology and Properties of Engineering Surfaces, Huddersfield, UK, 16-20.07.2007, 2007, pp. 241-245.
[8] Uklejewski R., Winiecki M., Rogala P., On the structural-adaptive compatibility of bone with porous coated implants on the base of the traditional one-phase and the modern two-phase poroelastic biomechanical model of bone tissue. Inżynieria Biomateriałów, 2006, 9(54-55), 1-13.
[9] Uklejewski R., Winiecki M., Rogala P., Radomski W., The characterization of structural and osteoinductive properties of orthopaedic implants porous coatings with the set of 3D poroaccesibility parameters. Proceedings of the 13th International Conference on Metrology and Properties of Engineering Surfaces, London, UK, 12-15.04.2011, 2011, pp. 103-107.
[10] Uklejewski R., Winiecki M., Rogala P., The stereometric characterization of the poroaccessibility of plasma sprayed porous coatings outer layer of intra-osseous implants. Measurement Science and Technology. (zgłoszony do druku).
[11] Winiecki M., The Investigation on the Microgeometrical Constructional Properties of Porous Endoosseous Implants and the Influence of these Properties on the Strength of the Bone-Implant Model Fixation, (in Polish), PhD Thesis (PhD supervisor: R.Uklejewski), Poznan University of Technology, Faculty of Working Machines and Transportations, Poznan, 2006.