MECHANICAL AND BIOLOGICAL ASSESSMENT OF CARBON FIBER-REINFORCED PEEK COMPOSITE MATERIALS INTENDED FOR LARYNGEAL PROSTHESES

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Introduction

The Larynx cancer is the most common squamous cell carcinoma in the head and neck area (Head and Neck Squamous Cell Carcinoma - HNSCC). It is the seventh most frequently occurring malignant tumor in the male population in Poland [1]. In the treatment of patients with high clinical advance of larynx cancer, the most common procedure is total laryngectomy. It is a mutilating procedure, as a result of which the larynx is completely removed. A patient with laryngectomy is deprived the basic organ involved in creating the voice. For many years, voice prostheses have been used to rehabilitate the speech of laryngectomized patients. The implantation of such a prosthesis involves the creation of a fistula communicating the trachea with the esophagus, which enables the development of tracheo-esophageal speech. Within the obtained fistula a voice prosthesis is placed. In Poland, the most commonly used silicone prostheses are Provox Atos Medical AB, Hörby, Sweden) and Blom-Singer (InHealth Technologies, Carpinteria, CA, USA). According to literature data, the average pot life of an implanted prosthesis is 3-6 months [2,3,4]. The objective of the study was to manufacture and assess the mechanical durability under dynamic loading conditions and biological behavior of composites manufactured from PEEK and selected carbon fibrous reinforcements. In our experiments, such composites are to be used as materials for voice prostheses.

Materials and Methods

The following components were used to manufacture the composite samples consisting of carbon fiber and PEEK polymer: Polyether ether ketone (PEEK 150PF,) delivered by Victrex was the matrix, (2D) carbon fiber cloths delivered from Porcher Industries Composites, code named Pi preg® 3106-P17, multiwalled carbon nanotubes (CNT) provided by NanoAmor, USA. The nanotubes had diameters in the range of 10–30 nm and were 1–2 μm long. The PEEK/CF composites manufactured from by hot compression molding out on a hydraulic press and a heated mold [5]. Three types of composite samples were manufactured:
PEEK/2D/CF - samples made of 2D carbon fiber cloths;
PEEK/2D/CF/CNT- samples made of 2D carbon fiber cloths modified with CNT;
PEEK/MD/CF made of chopped carbon fibers- reinforced PEEK;
The composite samples were obtained by hot molding of PEEK/CF prepregs. Mechanical durability of the samples was studied by aging them in Ringer's solution at 37°C and dynamically loaded under bending up to 10^6 cycles. The ultrasonic wave propagation method was applied to study changes in the composites. Biological tests were carried out in the presence of hFOB-1.19-line human osteoblasts and HS-5-line human fibroblasts. The level of collagen I produced by the cells was determined by ELISA test.

Results and Discussion

FIG. 1 shows changes in the dynamic elastic modulus of the CNT modified-composite plates and without CNT subjected to dynamic bending up to 10^6cycles.

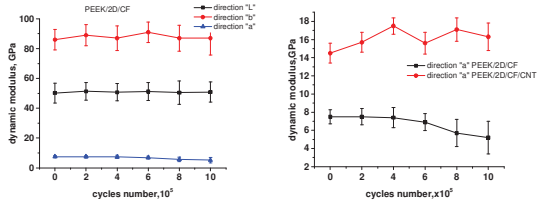

FIG. 1. Variations of dynamic elastic modulus of composite samples with and without CNT in function of cyclic bending loads; a denotes direction perpendicular to composite plate, b- along the width, L- along the length of the plate.

FIGs 2-5 show results of biological tests of composites with two types of carbon fibers and for the pure polymer. Cell viabilities were determined after 7 days cells culture.

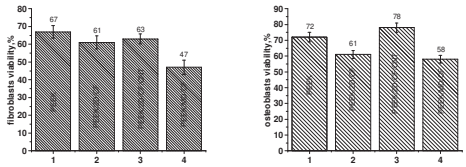

FIG. 3.Viability of fibroblasts and osteoblasts on composite surfaces on day 7 after seeding; TCPS as control.

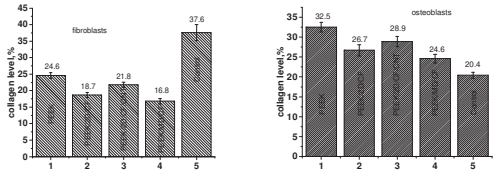

FIG. 4. Levels of collagen I produced by fibroblasts and osteoblasts on PEEK-based sample surfaces, normalized to the level of control (TCPS).

Conclusions

The changes in the mechanical stability of the composite samples were not significant after fatigue testing up to $1*10^6$ cycles. The tests showed differences between the samples in cells viability and levels of the produced collagen I.

Acknowledgments

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References

[1] http://onkologia.org.pl/nowotwory-zlosliwe-krtani-c32/
[2] J.S.Lewin, L.M.Baumgart, M.P.Barrow, K.A.Hutcheson, JAMA Otolaryngol Head Neck Surg. 143(1) (2017) 65-71
[3] A.Krishnamurthy, S.Khwajamohiuddin, Indian J Surg Oncol. 9(1) 2018 39-45.
[4] O.Choussy, R.Hibon, N.Bon nanotubes had, Dehesdin D, Eur Ann Otorhinolaryngol Head Neck Dis. 2013 Apr;130(2) (2013) 49-53.
[5] M. Dworak, S. Blazewicz, Acta of Bioengineering and Biomechanics 18(2) (2016) 71-79.