A DEVICE FOR TESTING OF THE TRIBOLOGICAL PROPERTIES OF INTERVEREBRAL DISC ENDOPROSTHESIS – SBT-03.1 SIMULATOR

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Abstract

As a result of research conducted in the Metal Forming Institute in Poznan, SBT-03 simulator for friction and wear testing of human intervertebral disc endoprostheses was modernized. The structure of the device allows reflecting of the range of mobility and loads present in the natural spine. Moreover, the device allows recording and measurement of such parameters as axial compression force, moment of friction, temperature in the friction loop and number of operation cycles. This enables an evaluation of the intensity of wear processes of different designs of structures of a lumbar spine intervertebral disc endoprostheses depending on the type of materials used and production method.

Keywords: *intervertebral disc endoprosthesis of the spine, friction and wear tests, SBT-03.1 simulator, friction coefficient*

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Introduction

Statistics indicate that 80% of adults, regardless of their sex, experienced spinal pains [1]. This is, in particular, a problem of inhabitants of highly developed industrial countries, where considerable limitation of physical activity, prevalence of sitting position and obesity are observed.

Spondyloarthrosis begins frequently in the area of an intervertebral disc – degenerative disc disease [1]. Then it affects other structures of the mobile segment, which is the basic functional unit of the spine. As degenerative disc disease develops, it leads to dehydration of the nucleus pulposus. The process results in a decrease in the height of the intervertebral disc (deteriorating its shock absorption properties), a decrease in the physiological mobility of the mobile segment and disturbance of intervertebral joint loads. A progressing degeneration of the intervertebral disc may lead to a decrease in the surface of the cross-section of the spinal canal (stenosis). This may result in pressure on the dural sac, spinal roots and vascular network causing chronic pains in the spine, including root-type pains or the neurogenic claudication.

A relatively new invasive procedure for the treatment of patients suffering from discogenic back pains is intervertebral disc arthroplasty. This method is an alternative to the patients who have been treated with arthrodesis, i.e. fixation of a damaged segment with adjacent healthy discs [3]. Contrary to arthrodesis, intervertebral disc arthroplasty, in the long run, will not cause disturbance of biomechanics of the spine and, thus, will not lead to a degeneration of the mobile segments adjacent to the operated segment [3].

Presently, the clinical practice uses several types of intervertebral disc endoprostheses. Depending on materials used and the type of structure, intervertebral disc components are exposed to wear as a result of friction between the components. Thus, the basic requirements for friction elements include ensuring of low friction resistance, high resistance to wear and minimum quantity of generated wear products [4]. Getting into perimplantal tissues, the particles may cause toxic, allergic and even carcinogenic reactions. The friction and wear tests conducted with special simulators provide an opportunity for preclinical determination of the tribological properties of the friction coponents of the intervertebral disc endoprosthesis both as regards a short, medium and long period of time.

Materials and methods

Before the commencement of the design works, the authors explored the scope of mobility of the individual mobile segments of the spine and values of loads to which particular intervertebral discs are subject. The mobility of discs in relation to one another is limited by the influence of the support triad components on a given mobile segment and it may be found in three anatomical planes, i.e. sagittal plane – bending to the front and rear (bend and hyperextension), frontal plane – lateral and traverse bending – rotating movements. From the combination of the above-mentioned movements, a circumduction movement originates. For instance, for the L4-L5 mobile segment the total of flex and reflex movements is 15o and the values of the unilateral lateral bend and unilateral axial twist are 5o and 3o respectively [5].

A healthy intervertebral disc constitutes a hydraulic device, which is subject to permanent influence of compression forces. In the lumbar spine, the value of the compression force exerted on the intervertebral disc in a standing man of average height ranges within approx. 700 to 800 N [6]. The source of the force is muscle tension, body mass above the muscle and external forces.

The main goal of the research conducted on the simulator SBT-01.1 is to determine the impact of friction pair and endoprosthesis construction on the frictional resistance, wear as a function of the number of cycles, changes in surface roughness and study the amount and chemical composition of wear products.

Results and discussion

A simulator allowing friction and wear testing of the intervertebral disc endoprostheses was modernized for laboratory tests. The simulator is equipped with two servomotors reproducing the basic types of movements and loads that occur in the spine, i.e. bending in the sagittal or frontal plane or axial twisting. In the bottom part of the simulator there is a tightening system, which allows an application of the compression force.

The basic technical parameters realized with the use of the simulator include:

- compression force in the spine axis 0÷3000 N;
- deflection angle at bend: +10°,
- deflection angle at extension: -5°;
- deflection angle at lateral bending: ±7,5°;
- unilateral axial bending angle: ±3°;

Special handles for fastening of the external metal plates allow a stable fixation with the possibility of adjustment of the axial position. FIGURE 1 presents an image of the SBT-01.1 simulator. The simulator is equipped with an automatic measurement system allowing the recording and the measurement of such parameters as axial compression

force, moment of friction, temperature in the friction loop and number of operation cycles.

Conclusions

The structure of the SBT.03.1 simulator for the friction and wear testing of the intervertebral disc endoprostheses allows a reflection of the scope of mobility and loads occurring in a real spine. This provides an opportunity for preclinical determination of the tribological properties of the friction loop of the intervertebral disc endoprosthesis as regards a short, medium and long period of time. During the testing the endoprosthesis is immersed in a greasing and cooling liquid, which simulates bodily fluids. The presently published papers relating to the issues connected with the wear of the friction elements of the intervertebral disc endoprosthesis are mostly limited to determining of the changes in heights of the individual components. Insufficient attention has been devoted to determining of such parameters as the values of moment of friction, the friction force and the friction coefficient.

FIG. 1. SBT-03.1 simulator.

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CYTOTOXICITY OF HYDROXYAPATITE COATINGS MODIFIED WITH SILVER NANOPARTICLES

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Abstract

Application of nanosized particles with antibacterial properties is of great interest in the development of new biocompatible products. Due to the excellent antibacterial activity Ag NPs and Ag NPs containing composites are widely used in many bactericidal applications. The objective of the present research is to characterize the cytotoxity properties of plasma sprayed hydroxyapatite coating (HA) modified by sedimentation of Ag NPs on its' surface. The present research was carried out in the frame of European FP7 NANOMINING Project "Development of New Nanocomposites Using Materials from Mining Industry" (NMP4-CP-2011-263942).

***Keywords**: plasma spraying, hydroxyapatite, silver nanoparticles, cytotoxicity*

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Introduction

The percentage of knee, hip and elbow infections is estimated as 0.5-12%; 1-2%; 1-2.5% and 7-9% respectively [1]. Approximately a million people are operated and have implants inserted annually. A small number of the infections may cause serious complications in dozens of patients. An implant surface is susceptible to infections for two main reasons: the formation of a biofilm on the implant surface and a reduced resistance on the implant and tissue interface [2]. The infections are caused mainly by Staphylococus ureus and Staphylococus epidermidis. The bacteria create a biofilm on the implant surface and become extremely resistant to antibiotics. The infection may cause an exhausting pain and long-term disability for the patients.

Presently, hydroxyapatite is widely used in orthopedics, as it shows perfect biocompatibility owing to its similar chemical properties and the bonelike crystallographic structure. The porous structure of hydroxyapatite causes that a strong chemical bonding is created with the natural bone. Moreover, hydroxyapatite is bioactive, which means that it becomes reabsorbed after some time and is replaced by the natural bone. However, low mechanical properties of HA limit its application in implants under high loads [3]. On the other hand, commonly used titanium and its alloys have good biocompatibility, high strength and low density. Apart from that, it shows low resistance to friction wear and release of titanium alloy particles to the surrounding tissues. The combination of HA and its good biotolerance with very good mechanical properties of the titanium seems to be a good solution, which enables a creation of near-perfect biomaterials [4].

Silver-doped HA (Ag+HA) coatings show decreasing toughness with increasing quantities of silver ions. Silver is known for its strong bactericidal properties. Due to the toxicity, compounds based on silver have been widely used