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Wear abrasive resistance of intracorporeal prosthesis of oesophagus

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ABSTRACT

Purpose: The main aim of the work is investigation of abrasive wear resistance of evaluated oesophageal prosthesis internal layer, considering its long-term exploitation possibility and extreme option of food consumed by patient after implementation.

Design/methodology/approach: In the work, methodology of wear abrasive investigations of oesophageal prosthesis, made of long-fibre composite material based on medical silicon, internal surface is presented. The measurements have been done on equipment designed and made in Division of Materials Processing Technology, Management and Computer Techniques in Materials Science of Institute of Engineering Materials and Biomaterials.

Findings: The volume of obtained samples mass loss have been determined from approximate calculations of wear trace to simple geometrical figure mapping this loss, ant then the volume of this figure haves been calculated. The CAD software has been used to verify approximation method, which allows to precisely determine mass loss.

Research limitations/implications: Developed constructional model of modern, internal prosthesis of the human oesophagus will be used to design the manufacturing technology and to manufacture given prosthesis.

Originality/value: Worked out construction is the part of the research project realized by authors, that will result in cognitive, constructional and technological effects, but first of all, it will enable the real help very sick people.

Keywords: Oesophagus prostheses; Oesophagus cancer; Materials; Composites; Engineering polymers

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Properties

1. Introduction

In the case of damage and dysfunction of the oesophagus caused by disease, chemical burning or mechanical damage, it is necessary to replace it by a substitute. Nowadays, the moste often reason os thus type of dysfunction is the cancer indication - the cancer of oesophageaus. In the Poland and all over the world, there are using different solutions depending on the cancer

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progress: stents (to expand narrowed oesophagus), natural "prostheses" (to reconstruct the lack of digestive system the vital tissues of the patients are used - e.g. stomach), and extracorporeal probe (used in the case of considerable lack of digestive system fragment i.e. resection of oesophagus, stomach or duodenum). As in the first and second case of disease the patient can eat normally, in the third case the position of incoming of the food as well as its consistency are strictly determined. Possessing this kind of probe is associated with additional health issues, and patient mobility limitation and high discomfort and social exclusion. The solution for this problem is fully biocompatible synthetic prosthesis of oesophagus, that fulfils the features and functions of natural human oesophagus.

From the mechanic point of view, the human oesophagus can be compare to some kind of tubular pipe, that transport the food to the stomach by peristaltic movements (the muscles contractions). The food movement is controlled by so called constrictor muscles, which prevents regurgitation of consumed alimentConsidering the lack of possibility to recreate peristalsis in artificial oesophagus there is need to emphasis its construction and internal surface features facilitating free movement of food in the stomach direction using its consistency and gravity.

Nevertheless, in the case of long-term consuming the food with improper consistency tribological damages (caused by friction) of internal layer of prosthesis can occur. In this case abrasive wear is strictly connected with material particles separating caused by food hard particles microcutting, scratching, grooving. Resistance of internal layer friction region and their operation mechanism decides on abrasive wear resistance degree. Any damage of mentioned surface leading to its unsealing can bring disaster effect for the patients with implement prosthesis.

The main aim of the work is investigation of abrasive wear resistance of evaluated prosthesis internal layer, considering its long-term exploitation possibility and extreme option of food consumed by patient after implementation

2. Materials

Components of composite material used to obtain intracorporeal prosthesis of oesophagus are as follows:

- medical silicon Dow Corning MDX4-4159, consisting of silicone (50%) and co-soluble system: mineral spirits and isopropanol (iPA) with concentration respectively 70% and 30% (Table 1), was used as a matrix;
- para-aramid fibre type 2200 1610 produced by DuPont with properties arranged in Table 2, was used, the fibre was used in continuous form (roving) was used as a reinforcement.

The construction and particular constructional stages of internal oesophageal prosthesis are described in following literature [3 - 5].

Table 1.
Chemical and physical properties of medical silicone Dow Corning MDX4-4159

CHEMICAL AND PHYSICAL PROPERTIES				
Boiling point/range [°C]	Flash-point [°C]	Specific density [g/cm^3]	Viscosity [cSt]	Apperance: form, colour,odour
>82	13.3 (closed crucible Pensky-Martens)	0.865	132 (at the temp. 25°C)	liquid, yellow (straw) solvent-like

Chemical characteristic of the substance:
an amine functional polymer with reactive methoxy- group

Table 2.
Properties of aramid fibre 2200 1610 produced by DuPont

ARAMID FIBER PROPERTIES					
Type	Density [g/cm^3]	Young modulus [GPa]	Tensile strength [MPa]	Elongation at break [%]	Breakdown temperature [˚C]
2200	1,44	105	3053	2.70	490

Hot air shrinkage (15 min at the temperature 190˚C) => 0,1 [%]
Heat stability (48h at the temperature 200˚C) => 90 [%

3. Experimental methods

The abrasive wear resistance has been measured by the use of device designed and made in in Division of Materials Processing Technology, Management and Computer Techniques in Materials Science of Institute of Engineering Materials and Biomaterials (Fig. 1). Station is dedicated for abrasive resistance investigations of different type engineering materials and layers. The measurements have been realized on samples from investigated material and counter-sample with or without the presence of abrasive material during abrasion. As a counter-sample steel ball with diameter 8,7mm has been used. The measurements for a given series of samples have been conducted with the same work conditions which are sliding movement velocity v and load F.

On the basis of preliminary investigations minimal load and the number of cycles have been determined. Samples were placed on specially prepared table, guarantying stable motion during measurement. The measurements have beendone with constant number of cycles equal to 30000 (300m) under load 2 and 10N with or without abrasive material simulating food consumed by the patient. The sample before and after measurement have been cleaned with compressed air to remove improvements arising during abrasion, and then measurements of wear track width and length have been done on stereoscopic microscope Stereo Disscovery.V12 by Zeiss Company coupled to the software for image analysis Leica-Qwin with 20x magnification.

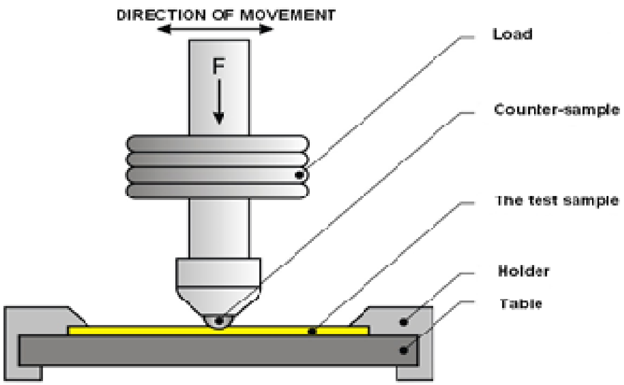

Fig. 1. Diagram of testing abrasive wear resistance equipment

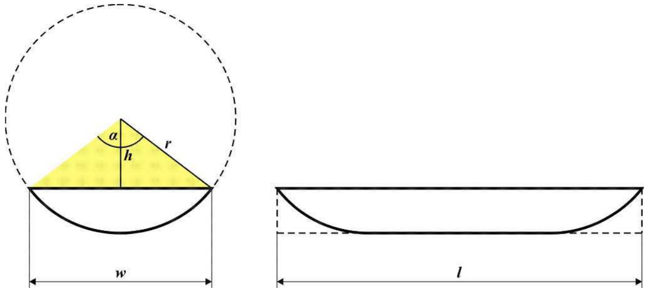

Fig. 2. The approximation of a trace of wear to a simple geometric figure which was used in the work

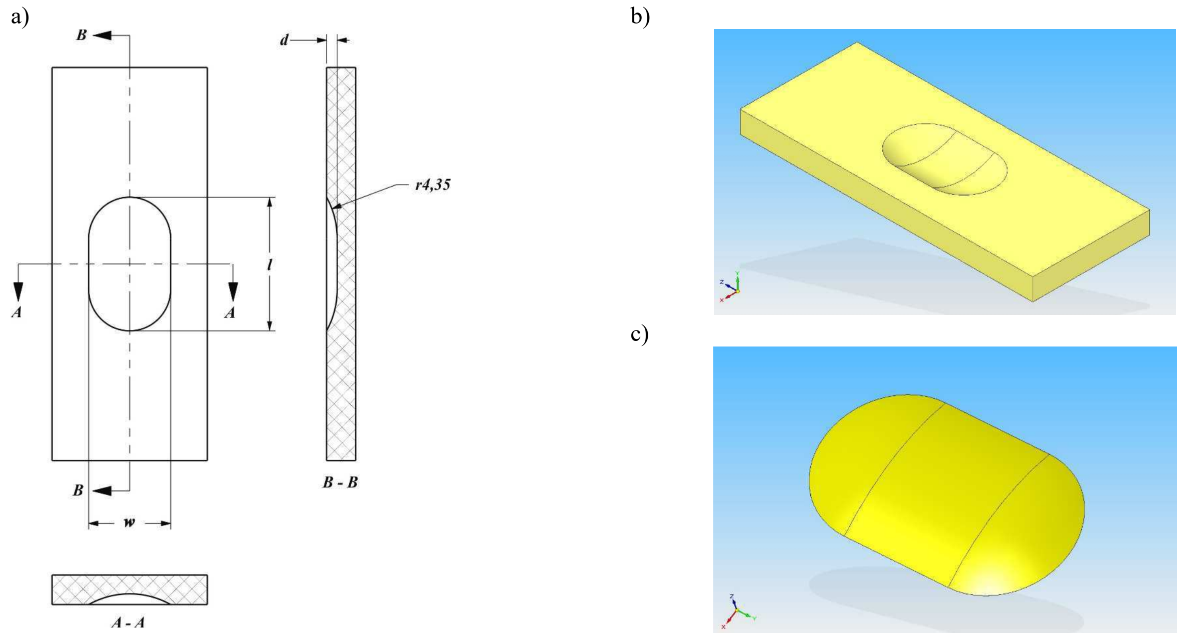

Fig. 3. An example of a trace model wipe samples made in CAD program after the test of resistance to wear: a) size; b) the model; c) weight loss

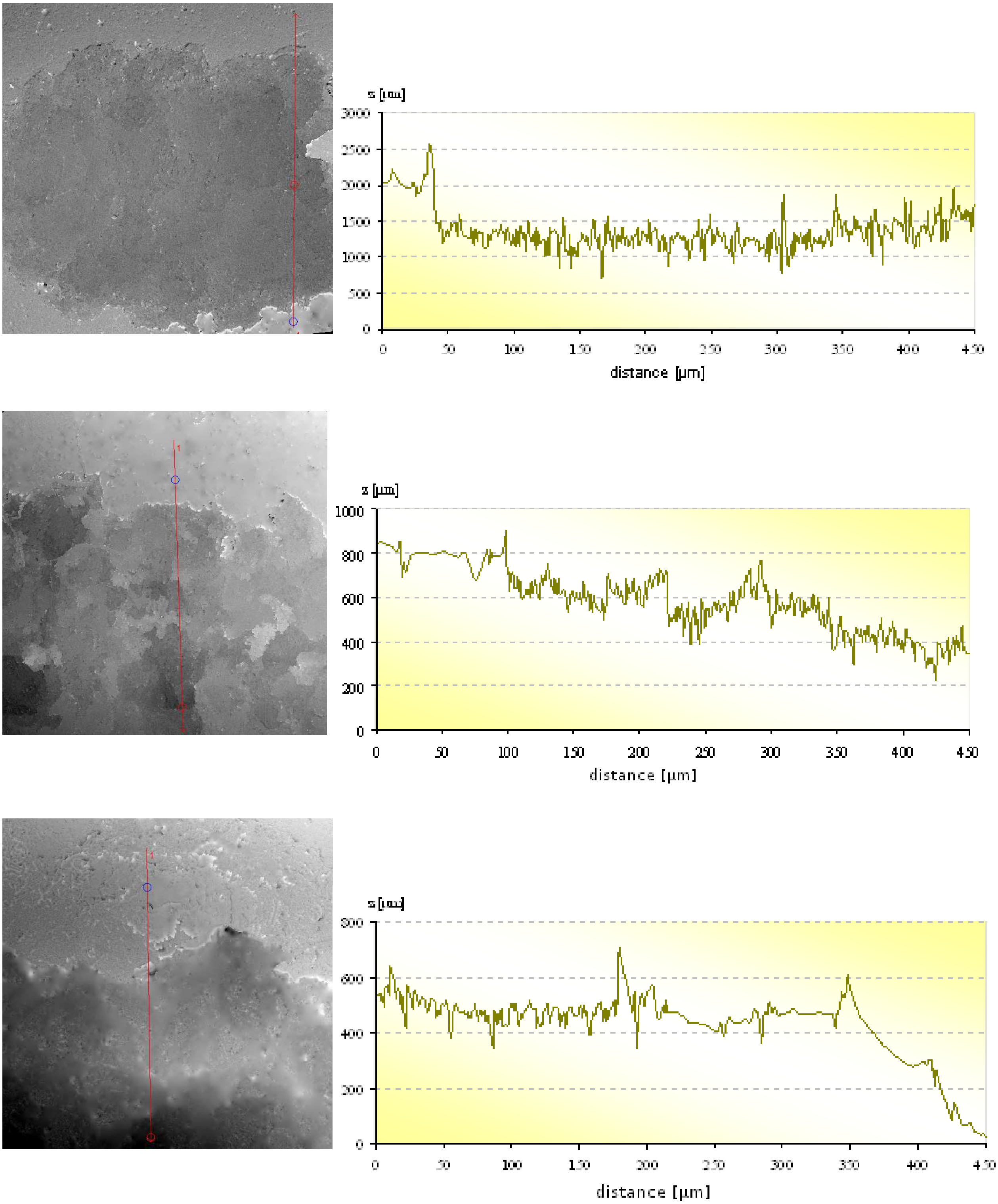

Fig. 4. Representative images and profiles of wear trace of samples after testing abrasion resistance under a load 1000 g

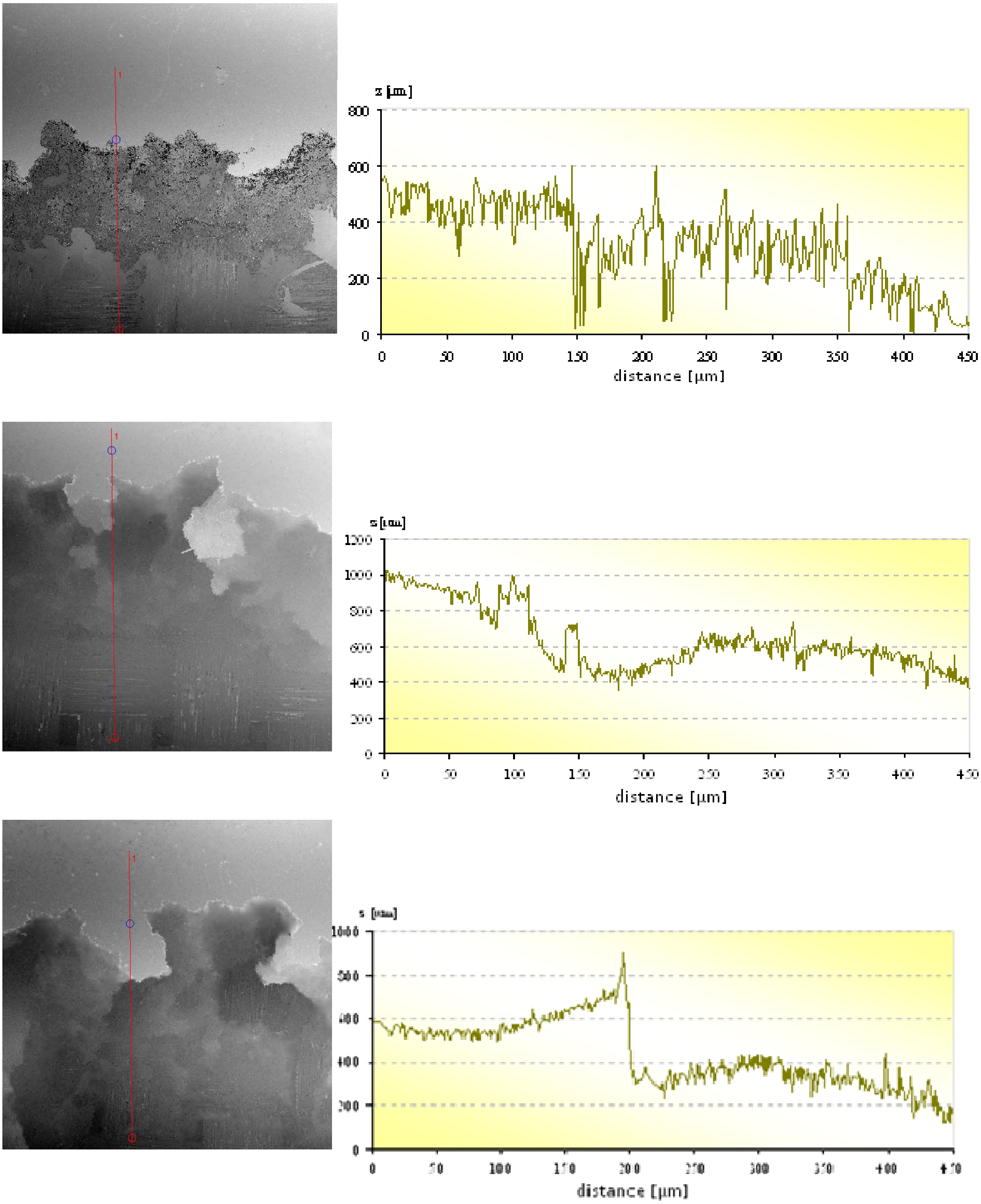

Fig. 5. Representative images and profiles of wear trace of samples after testing abrasion resistance under a load 1000 g, and the addition of a suspension

The volume of mass loss have been determined on the basis of approximation of wear track to as simple as possible geometrical figure mapping this loss (Fig. 2) and then the volume of this figure where calculated using following equations:

$$P_{WYT} = P_{WYC} - P_T \quad (1)$$

where:
P_{WYT} – area of wear,
P_{WYC} – section of circle,
P_T – area of triangle

$$V_{WYT} = P_{WYT} l \quad (2)$$

where: V_{WYT} – volume of wear,l – length of wear. The CAD software has been used to verify approximation method, which allows to precisely determine mass loss. The wear model have been done for each case and ist volume have been determined in the programme (Fig 3). However, profiles of wear, essential for calculations, have been determined using confocal microscope LSM 5 EXCITER by Zeiss under 5x magnification. The surface of the samples have been scanned using diode laser with wavelength 450nm and power 25mW and with interference-proof filter transmitting light with wavelength 405/488nm.

4. Results

The results of abrasive wear resistance measurements of intracorporeal oesophageal prosthesis internal surface are presented in the table 3. The examples of wear trace fragments of samples and their profiles arisen during abrasive measurement of mentioned prosthesis are showed in the Figures 4 and 5. On the basis of obtained results, it have been determined that there are no damages observed on stereoscopic microscope under load 2N (no wear trace). This is probably related to elastic strain of base during measurements, which is not leading to clear damage under given number of cycles. However, addition of abrasive material, imitating possible (extreme) version of food consumed by the patient, initiate mass loss of sample effect (0,0169±0,0028mm^3). Changing load into 10N increase mass loss for the samples without abrasive material to 4,0531±1,0362mm^3 and with abrasive material to 8,0671±1,9587mm^3. When the abrasive material is not used, the samples are damaged with the number of cycles about 20000. However, introduction of additional abrasive factor leads to sample damage after 10000 cycles.

Table 3.
Volume mass loss of the samples after abrasion of internal surface of oesophageal prosthesis

Load type	Wear volume [mm^3] calculated	Wear volume [mm^3] Mean value	Standard deviation	Confidence half-interval	Confidence interval -95%	Confidence interval +95%
2N + suspension	0,017	0,0147	0,0017	0,0014	0,0133	0,0160
	0,012					
	0,015					
	0,015					
	0,016					
	0,013					
10N	2,244	2,9952	0,4877	0,3965	2,5986	3,3917
	3,239					
	3,244					
	3,125					
	3,658					
	2,461					
10N + suspension	6,377	5,6590	0,8012	0,6514	5,0076	6,3104
	5,531					
	5,665					
	4,661					
	6,919					
	4,801					

5. Summary

Measurements of abrasive wear resistance of internal surface of prosthesis prototypes made from composite materials have allowed to determine possibility of prosthesis damage during passing by food consumed by the patient. Abrasive wear resistance of intracorporeal prosthesis if oesophagus, and the evaluated composite material, has indicated that damages are not possible during natural and proper exploitation. It has been determine that to initiate the process of abrasion the mechanical or chemical damages have to occur. Consuming of mushy food or solid one intensively drunk, what is recommended by doctors, should not initiate abrasion of prosthesis leading to its damage. It is undoubtedly related with elasticity of used base (medical silicon), which elastic deforms in the contact with hard food particles avoiding applied material crush dressing.

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