Biocompatibility Study of $CoCrMoSi_k$ Original Alloy Variants

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The study follow the improvement of properties of cobalt base alloys, used in medical applications. This scope targeted the obtaining of alloys with friendly biological interactions to human body. If the original variants of $CoCrMoSi_k$ (k = 4, 5, 6, 7) alloys don't subjected to the criteria of biological acceptance from animal body, these don't be placed in live body, indifferent the adequacy of the biomaterials properties. Realization of the original alloy variants must consider and the possibility to appear the base patho-physiological phenomena, with determine or not their safety on long time (generate of thrombosis, inflammation, infection and / or inducing and causing neoplasms).

Keywords: cobalt alloys, silicon, biocompatibility, microscopy

Once with development of materials engineering with medical destination and, specially, osteo-articullar was described and the principal characteristics necessary for an implant: increased resistance to mechanical requests, do not cause harmful reactions from adjacent tissues, do not be toxic for body [1].

Thus, it is starting to define the materials biocompatibility and the most accepted definition describes the biocompatibility like the capacity of a material to functioning in a specific medical application, producing a favorite reaction in guest body.

In the cementless hip arthroplasty, osteo-integration of components is one of the important processes and by this depend the success of intervention [2-4].

This phenomenon which must be rapid, efficient and for lasting, occurs at the bone-implants interface [5].

Therefore, in the case of metallic biomaterials for implants, it is places special importance on surfaces study, to improve the properties [6-10].

The biological systems can have destructive effects on cobalt base materials, known like the name of biodegradation [11-14].

In the medicine domain, this including the erosion process caused by body metabolism and bacterian activity [15].

This paper present the pathologic and/or physiologic, locally or systemic effects of materials from $CoCrMoSi_k$ original alloy variants.

Experimental part

The obtaining of original variants of $CoCrMoSi_k$ (k = 4, 5, 6, 7) alloys, was made on an arc remelting installation, in vacuum, type RAV, eliminating any disruptive factor in the casting process.

Determination of chemical composition by optical emission spectrometry was made on taken samples after solidification of alloy obtained by casting. The preparation of the samples for optical emission spectrometry was made by polishing on abrasive paper, with rough granulation.

The electronic discharge was made with elimination of a high quantity of energy, fact that determines plasma formation and light emission [16]. The lighting spectrum is divided by an optical diffraction network and the results are processed with specialized software [3].

Because the discharge was made on sample surface and don't enter into sample, it is measured and the contamination of sample surface.

The mass concentrations determinate by elements from cobalt base alloys are specified in the table 1.

Alloying element	CoCrMo	CoCrMoSi4	CoCrMoSi5	CoCrMoSi6	CoCrMoSi7
	(% mass)				
Co	62.10	59.40	58.50	56.70	56.40
Cr	26.79	26.46	26.16	26.23	25.48
Mo	6.00	5.39	5.24	5.29	5.20
Ni	2.90	2.72	2.62	2.84	2.87
Si	0.78	4.64	6.06	7.40	8.45
Mn	0.42	0.38	0.43	0.39	0.38
Fe	0.33	0.43	0.31	0.58	0.43
Other	0.68	0.58	0.68	0.57	0.79

Table 1
CHEMICAL COMPOSITION OF COCRMO ALLOYS, EXPRESSED IN MASS PERCENTS

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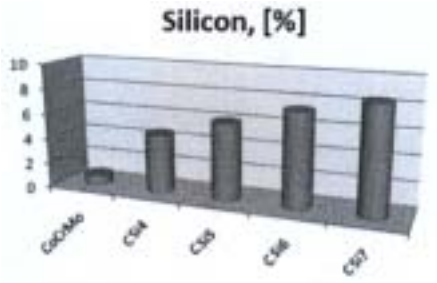

Fig. 1. Variations of silicon percent determinate by optical emission spectrometry for alloys by CoCrMo systems

The researches about the chemical composition highlighted the fact that the principal elements identified on cobalt base alloys are following: Co, Cr, Mo and Si.

By increasing of silicon percent, the alloying elements present small values, a significant modification being at principal alloying element, cobalt. If initially, cobalt was found in 62.1% in CoCrMo commercial alloy, in $CoCrMoSi_7$ alloy cobalt was found in 56.4%.

Samples used at subcutaneous implanting

The samples used at subcutaneous implanting were processed by machining and had a cylindrical shape, with diameter between 6-8 mm and thickness by 2 mm.

It is used outred mice (non-consanguine) from CD1 line (Cantacuzino Institute from Bucharest), females, with weight by 25 g. Before the implantation of testing materials, the animals were anesthetized by locally subcutaneous administration of 0.5% xiline, in three points, 0.5 mL.

After anesthesia installation, it was practiced an incision by approximately 7-8 mm length in dorsal area of mice, and with an anatomical forceps was tunneled the conjunctive tissue to obtain a pocket, in which are introduced the samples from original variants of cobalt alloys.

The skin was sutured with non-resorbable wire (non-resorbable by body) 2-0.

It is evaluated the experiment in the terms of response and/or reactions locally tissues, biological consequences (biocompatibility) it has on live tissues.

The samples used for biocompatible tests had small dimensions (pills) and required a fine processing, by machining.

The mice were maintaining in similar conditions by microclimate and food, for a time by 21 days, after they were euthanized with chloroform. From each mouse was taken the skin and conjunctive subcutaneous tissue, from the area which has come in contact with the implanted alloy, this immersed in formalin 10% for fixing.

After implantation was made a periodical examination, clinical and behavioral of animals; histopathology specimen collection was made at 24, 48 and 72 h intervals and 7 days for all the lots taken into study.

The samples for histopathology exam was made with attention and sent at laboratory in sequestrate conditions.

The experiment on mice followed possible pathologic and/or physiologic, locally and systemic effects of materials from CoCrMo system, intended to medical applications, implanted subcutaneous – reactions which can indicate a possible toxic effect or rejection of implanted materials [16-20].

Results and discussions

The CoCrMo commercial alloy implanted in subjacent area present an adipose tissue with canalicular structures and large vessels, separated by bays of conjunctive tissue with an increased fibroblast population or by islands of conjunctive tissue with similar cell aspect; associated, but and numerous high macrophages, with intracytoplasmic grains (fig. 2).

In subcutaneous tissue (fig. 2a) after 21 days can observe a moderate inflammation with a broadcast distribution, rarely nodular, which present perivascular and perinervous.

In subjacent area of implanted commercial alloy (fig. 2b), the skin present normal aspect, with epidermis, without modifications and a small diminution of the space occupied by dermis, in which are present numerous adipocytes, striated muscle tissue, but and a hypodermis characterized by the presence of a conjunctive tissue richly vascularized, with numerous active fibroblasts.

In lateral area (fig. 2c) of implanted commercial alloy (near pill), the skin have a easy papillomavirus epidermis, dermis is superficial and deep, collagenizated intense and hialinizated.

It can observe in this area, near pill exist a hypodermis and muscular tissue normal striated.

$CoCrMoSi_4$ original variant implanted in subjacent area (fig. 3a), present a densification of conjunctive tissue with collagen fibers, parallel between then and numerous active fibroblasts, realizing a fibrous band which delimit the implanted $CoCrMoSi_4$ alloy. External to this band it is found a moderate inflammatory infiltrate, numerous macrophages with hemosiderin and numerous congested capillaries.

In superjacent area (fig. 3b) of $CoCrMoSi_4$ implanted alloy, the skin present a normal aspect.

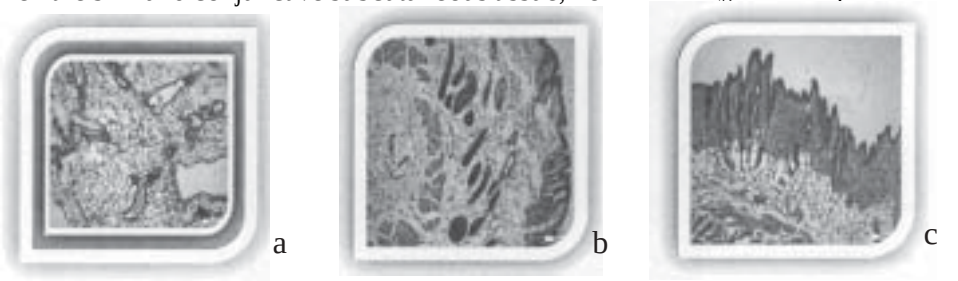

Fig. 2. CoCrMo commercial alloy implanted: a) subjacent area; b) superjacent area; c) lateral area

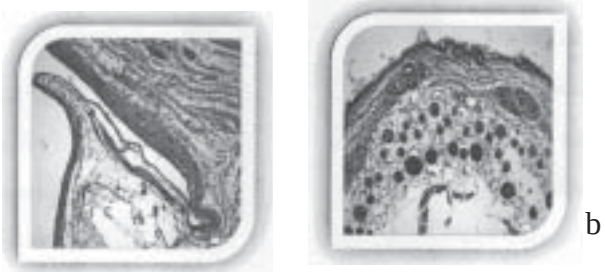

Fig. 3. $CoCrMoSi_4$ implanted alloy: a) subjacent area; b) superjacent area

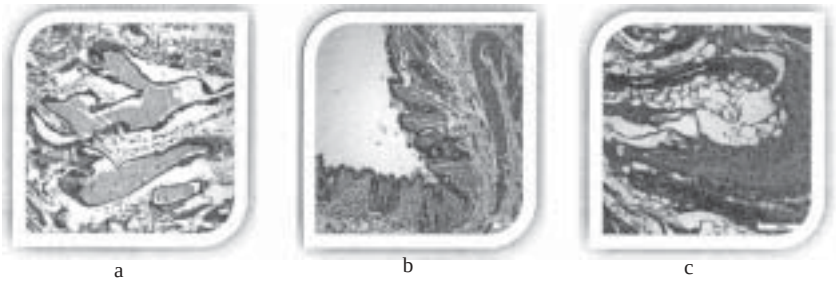

Fig. 4. $CoCrMoSi_5$ implanted alloy: a) subjacent area; b) superjacent area; c) lateral area

Fig. 5. $CoCrMoSi_6$ alloy implanted: a) subjacent area; b) superjacent area; c) lateral area

Fig. 6. $CoCrMoSi_7$ alloy implanted: a) subjacent area; b) superjacent area; c) lateral area

At the $CoCrMoSi_4$ alloy was not taken in lateral area, because the implanted material was surround by a compact film, described at subjacent area.

$CoCrMoSi_5$ original variant implanted in subjacent area (fig. 4a), present a conjunctive tissue with numerous adiposities and expended venules.

The superjacent area of CoCrMoSi5 implanted alloy (fig. 4b) present skin with normal aspect, hypodermis with adiposities and muscular striated tissue.

The skin area is with atrophic epidermis, taking place the diminution of skin axis and dermis have relatively lax aspect.

The $CoCrMoSi_5$ alloy implanted in lateral area (near pill) (fig. 4c), highlight a skin with atrophic epidermis. In hypodermis it is found collagenized and hialinizated areas, with numerous active fibroblasts. In this area appear vascular elements (capillary, arterioles, venules) with reactive endothelium and numerous lymphocytes in lumen.

In comparison with the $CoCrMoSi_4$ experimental alloy, the $CoCrMoSi_5$ alloy don't present a conjunctive tissue organized in delimit band of implanted material.

$CoCrMoSi_6$ original variant implanted in subjacent area of material (fig. 5a), present a hypodermis with adipose tissue separated by bands and/or collagen islands, with numerous fibroblasts. These are infiltrating chronic inflammatory, moderate represented, big macrophages, with grains.

In the case of $CoCrMoSi_6$ original alloy it is found a densification of conjunctive tissue with collagen fibers, parallel between then and numerous active fibroblasts, realizing a fibrous band which delimit the implanted material. The fibrous band obtained at $CoCrMoSi_6$ alloy is thinner than that of $CoCrMoSi_4$ alloy.

In the superjacent area of $CoCrMoSi_6$ implanted alloy (fig. 5b) can be observed that the skin present a normal aspect, a hypodermis with aspect similar with that described at subjacent area – densification of conjunctive tissue, under form of fibrous bands, like a wall organized perimaterial implanted. In the case of this alloy it is found that the lymphatic vessels are much expended.

In lateral area of $CoCrMoSi_6$ implanted alloy (near pill) (fig. 5c), the skin present normal aspect, without modifications.

In subjacent area of $CoCrMoSi_7$ alloy (fig. 6a) have infiltrate inflammatory by massive chronic type, arranged diffusive and/or nodular, perivascullar and perinervous, associating elements by acute type and macrophages.

In superjacent area of $CoCrMoSi_7$ implanted alloy (fig. 6b), the skin present a normal aspect, but not a normal hypodermis.

The $CoCrMoSi_7$ alloy implanted in lateral (near pill) present a densification of conjunctive tissue with collagen fibers, parallel between then and numerous active fibroblasts (fig. 6c).

Due to active fibroblasts was made a fibrous band which delimits implanted material, but is thinner than $CoCrMoSi_4$ and $CoCrMoSi_6$ original variants.

The original variants of alloys present aspect of biocompatibility detected by microscopic studies, conducted in same conditions like in the case of CoCrMo commercial alloy. The original variants of alloys by CoCrMo system don't present major differences in comparison with commercial alloy. The modifications of tissue consist in appearance of one tissue by grain implanted peri-material, who can be interpreted like results of conjunctive organizing and repairing of a consecutive injury.

At original variants of $CoCrMoSi_k$ ($k = 4, 6, 7$) alloys exist supplementary, adjacent to implanted alloy, a densification of conjunctive tissue which formed a delimited structure, type fibrous membrane which are not significant for general state of tested biological organism, because the inflammation is low.

Conclusions

Necessity to increase the lifetime of implants is the motor factor, both to manufacture de new biocompatible materials, also to improve, by different methods, of the quality of existing metallic materials.

The central objective of this study was fulfilled by evaluating improvement of the properties of cobalt alloys, used in medical applications, which can resist a longtime in human body, as well as knowledge development of new biocompatible structures.

In the biocompatibility study it is found that no locally histological modifications are recorded, generated by a possible toxicity of biomaterials, based on cobalt, meaning that these type of alloys can be used successfully in medical applications.

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