Chapter 1

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THE TOYOTARITY AS AN ELEMENT TO PROPER SELECTION OF Co ALLOYS IN DENTISTRY

Abstract: The paper presents the characteristics and systematics of commercial cobalt-based alloys. The focus is mainly on the alloy, which are widely used in prosthetic dentistry in many dental laboratories. Cobalt alloys, various manufacturers were ranked based on the content of the main component (Co), mechanical properties, applications. The aim of this work was to facilitate the selection of the cobalt-based alloys in the course of construction and prosthetic work.

Key words: dental alloy, Co-alloy, dentures, toyotarity

1.1. Metals used in dental technology

In dental technique the metals, both noble and base metal are very often used. Noble metals as defined those that exhibit substantial resistance to corrosion in air or even in high humidity. Moreover, they are resistant to all acids (except a mixture of nitric acid and hydrochloric acid). Base metals and does not exhibit corrosion resistance and there are easily react with environment, but in some case there are selected as corrosion resistant metals, to this group could be included e.g. titanium, aluminum, niobium and tantalum metals. In metallic materials used in dentistry to preparation of prostheses very popular are the base metals typically cobalt, nickel, chromium, molybdenum, titanium, iron, vanadium, niobium, aluminum, tantalum, and tungsten. However, pure metals are relatively rarely used in the manufacture of dental restorations because of the unsatisfactory mechanical properties and the susceptibility to corrosion in the mouth environment. Only titanium and platinum due to its good me-

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chanical properties and corrosion resistance are considerable use as pure base materials but platinum due to the high price and high melting point is used only in prosthetic addition to noble metal alloys (COMBE E.C. 1997, KORDASZ P., WOLANEK Z. 1983, MAJEWSKI S. 2000, MARCINIAK J. 2002, SWIECZKO-ŻUREK B. 2009).

The properties of the alloy depends on many factors, among others, the casting conditions, chemical composition, crystalographic structure, methods of thermal treatment and mechanical treatment, etc. The alloys, which are characterized by good mechanical and physical properties and good castability, used in dental technology can be divided into those that are the base material of dentures made up and supportive alloy. The basic alloys include all types of gold alloys, stellite alloys, steels and cobalt, molybdenum, chromium alloys. These alloys belong to the homogeneous systems. They are characterized by high resistance to prevent electro-chemical corrosion in the oral environment. The second group consists of supportive alloys, which are used in the performance of dentures but not included in the finished prosthesis (COMBE E.C. 1997, MARCINIAK J. 2002, SWIECZKO-ŻUREK B. 2009).

There are many divisions of alloys. They accept as a criterion for the distribution of such microstructure - alloys homogeneous multi-phase alloys, melting point - high-melting, low melting alloys. The most famous is the division based on the chemical composition of the alloy, that is, the content of each metal in the alloy.

It should be noted, however, that even the alloys of similar chemical composition significantly differ in the properties among themselves and use.

Alloys used in dental prosthetics divided by the ANSI-ADA in 1984 into three groups:

- base alloys - contain in its composition primarily metals, and noble metals is less than 25%;
- noble alloys - in which charge of metal metal is at least 25%; high-noble alloys those which contain at least 60% of the noble metals and at least 40% of gold (COMBE E.C. 1997, MARCINIAK J. 2002, SWIECZKO-ŻUREK B. 2009).

Constantly increasing prices of gold and other noble metals have made it even semi-noble alloys cannot be a long-term substitute for

standard gold alloys, as they proved to be too costly in clinical use. This increased interest in non-noble alloys, which was promoted as a substitute materials. Among introduced the new alloys have enjoyed great popularity nickel-chromium and cobalt-chromium alloys, which, despite the absence of noble metal elements showed considerable resistance to blackening in the mouth, due to forming on their surface a thin layer of chromium oxides.

1.2. Metallic materials used in denture production process

The technique of dental restorations performing is aimed at the reconstruction of defects in the permanent dentition. These deficiencies are eliminated by means of additions movable, permanent or both at the same time. To perform restorations such as, for example, crowns, bridges, restorations, dentures, dental implants or acrylic dentures, there are used three basic materials: metals and their alloys, ceramics and plastics. During the design prosthetic constructions is very important knowledge of metals and their alloys, because metallic materials, in addition to ceramics and plastics are widely used for the manufacture of dentures. It must therefore be familiar with the characteristics of the physical, chemical and mechanical allowing optimum use of their property. In addition, knowledge of the capabilities the application of metallic materials have great potential for improving the manufacturing process of such prostheses. Appropriate choice of material factors and knowledge of the physical and chemical parameters by workers involved in the production process creates favorable conditions for improving prosthetic services. Metallic materials can build the entire supplement such as cast metal crowns, inlays, or may form a skeleton framework such as dentures, which determines the strength of movable or fixed partial denture. Very few dentures are made entirely of non-metallic materials only (porcelain, composite materials) such as veneers, inlays or crowns uniform ceramic, after all they subside strength similar constructions, made with metal. Prosthetics has many modern metallic materials with different mechanical properties, but still none

of the metals and alloys is not universal and combines all the features, which is required of these materials. As a result, we are often forced to introduced into the oral cavity two or even more of the metallic materials, which differ in composition and physicochemical properties. Such proceedings carries a high risk of corrosion on metal parts of the prosthesis, and may adversely act on the human body. Therefore the physician must choose the material for the restoration, which will meet the relevant requirements.

1.3. Commercial cobalt alloys as basic materials used in dental technology - an overview

Cast alloys whose diversity is very large, and the number of different species of alloys is perhaps even several thousand, enable the production of high strength components in different operating conditions, such as in the mouth. A special place in the production of casting alloys occupy a special purpose, such as with high biocompatibility, corrosion resistance, proper thermal expansion, etc. These alloys are generally known as special alloys. Each alloy consists of several metal elements (minimum of two) and other additives having more or less influence on the physical and chemical properties of the alloy (COMBE E.C. 1997, MARCINIAK J. 2002, SWIECZKO-ŻUREK B. 2009).

Alloys whose main component is cobalt, the dental materials most commonly used to perform partial dentures, crowns and bridges. Among the many varieties of cobalt alloys, the most commonly used commercial materials include cobalt derivatives: Biosie F, HERAENIUM CE (EH), Magnum H 40, Micronium Exclusive, Remanium GM 800, Remanium GM 700, Remanium GM 380, Remanium 2000, Supercast, WIROBOND C, WIRONIT, WIRONIT LA. The basic properties of these alloys are presented in the following section. All of these commercial cobalt alloys are characterized by a similar chemical composition, but it should be noted that small differences in the contents of alloying elements have a crucial effect on both the properties of these alloys, but also on the possibility of their use in dentistry.

1.3.1. Commercial cobalt alloy - Biosie F

Biosie F alloy is an alloy of cobalt-chromium-molybdenum (Co-Cr-Mo), both chemical composition and manufacturing technology and processing makes the possibility of the use of skeletal dentures preparing. In its chemical composition are present: Co 64.8% at., Cr 28.5% at., Mo 5.3% at. and Si, Mn, C (as rest). In accordance to the manufacturer's informations alloy has the springy type and is characterized by:
Density - 8,4 g/cm^3.
Hardness HV 10 - 360 HV10.
Melting point range -1320÷1380°C.
The casting temperature - 1500°C.
Elongation at break - 5%.
Tensile strength - 900 N/mm^2.
The yield strength 700 N/mm^2.

Considered to be as the greatest advantages of Biosie F alloy are primarily exceptionally high elasticity and high resistance to cracking;

1.3.2. Commercial cobalt alloy - Remanium GM 380

Remanium GM 380 alloy is an alloy of cobalt-chromium-molybdenum (Co-Cr-Mo), both chemical composition and manufacturing technology and processing makes the possibility of quite universal use. In its chemical composition are present: Co 64.6% at., Cr 29% at., Mo 4.5% at. and Si, C, Mn, N (as rest). In accordance to the manufacturer's materials, this alloy is characterized by:
Density - 8.2 g/cm^3.
Hardness HV 10 - 420 HV10.
Solidification temperature - 1300°C.
Melting temperature - 1370°C.
Tensile strength - 900 N/mm^2.
The yield strength - 640 N/mm^2.
Elastic modulus - 225.000 N/mm^2.

Elongation at break – 4.5%.

Considered to be as the greatest advantages of Remanium GM 380 alloy are the possibility welding with laser, a very good castability, despite good alloy elastic properties characterized by high hardness.

1.3.3. Commercial cobalt alloy - WIRONIT

WIRONIT alloy is an alloy of cobalt-chromium-molybdenum (Co-Cr-Mo), both chemical composition and manufacturing technology and processing makes the possibility of skeletal dentures preparing. Stop ten nie zawiera berylu. In its chemical composition are present: Co 64% at., Cr 28% at., Mo 5% at., C max. 0,35% at. and Si, Mn. In accordance to the manufacturer's materials, this alloy is characterized by:
Density - 8,2 g/cm^3.
Hardness HV 10 - 350 HV10.
Melting temperature range - 1350-1320°C.
Casting temperature 1460°C.
The yield strength 600 N/mm^2

1.3.4. Commercial cobalt alloy - Supercast

Supercast alloy is an alloy of cobalt-chromium-molybdenum (Co-Cr-Mo), both chemical composition and manufacturing technology and processing makes the possibility of skeleton denture porforming. In its chemical composition are present: Co 63.6% at., Cr 29% at., Mo 5.5% at. and others. In accordance to the manufacturer's materials, this alloy is classified as hard alloy and characterized by:
Density: 8.2 g/cm^3.
Hardness HV5 - 340 HV5.
Melting temperatura range - 1334-1371°C.
Casting temperature - 1482°C.
The yield strength - 670 N/mm^2.
Tensile strength - 840 N/mm^2.

Considered to be as the greatest advantages of Supercast alloy are high yield strength, high conductivity, extraordinary susceptibility to deformation.

1.3.5. Commercial cobalt alloy - WIRONIT LA

WIRONIT LA alloy is an alloy of cobalt-chromium-molybdenum (Co-Cr-Mo), both chemical composition and manufacturing technology and processing makes the possibility of partial denture performing. In its chemical composition are present: Co 63.5% at., Cr 29% at., Mo 5% at., C max. 0,25% at., (Si, Mn, N) as a rest, and this alloy do not contain any Ni additives. In accordance to the manufacturer's materials, this alloy characterized by:
Density – 8.2 g/cm^3.
Hardness HV 10 - 360 HV10.
Melting temperature range - 1340-1300°C.
Casting temperature - 1420°C.
The yield strength - 640 N/mm^2
Elastic modulus 200.000 N/mm^2

1.3.6. Commercial cobalt alloy - Remanium GM 800

Remanium GM 800 alloy is an alloy of cobalt-chromium-molybdenum (Co-Cr-Mo), both chemical composition and manufacturing technology and processing makes the possibility of its universal use.

In its chemical composition are present: Co 63.3% at., Cr 30% at., Mo 5% at., and rest Si, C, Mn, N. According to the manufacturer's materials, this alloy characterized by parameters:
Density - 8.2 g/cm^3.
Hardness HV 10 - 360 HV10.
Melting temperature - 1410°C.
Tensile strength - 930 N/mm^2.
Yield strength - 710 N/mm^2.

Elastic modulus - 230.000 N/mm^2.
Elongation at break - 5%.

Considered to be as the greatest advantages of Remanium GM 800 alloy are high gloss surface, ease of processing, high resistant to cracking.

1.3.7. Commercial cobalt alloy - HERAENIUM CE (EH)

The HERAENIUM CE (EH) alloy is an alloy of cobalt-chromium-molybdenum (Co-Cr-Mo), as well as its chemical composition and manufacturing technology and processing makes the possibility of its use during the performance of skeleton denture. In its chemical composition are present: Co 63% at., Cr 27.8%, at. Mo 6.5% at., Mn, Si, C, N< 2% at. According to the manufacturer's materials card, this alloy is classified as very hard material and characterized by parameters:
Density - 8.0 g/cm^3.
Hardness HV5 - 380 HV5.
Casting temperature - 1530°C.
Melting temperature range 1330-1380°C.
Yield strength - 580 N/mm^2.
Tensile strength - 890 N/mm^2.

The greatest advantages of HERAENIUM CE (EH) alloy are high strength of casted elements and the good of their elasticity, as well as the lack of nickel addition in the chemical composition of alloy.

1.3.8. Commercial cobalt alloy - Micronium Exclusive

Micronium Exclusive alloy is an alloy of cobalt-chromium-molybdenum (Co-Cr-Mo), both chemical composition and manufacturing technology and processing makes the possibility of its use in denture creation, to casting the skeleton of denture. In its chemical composition are present: Co 62% at., Cr 30.7% at., Mo 5.7% at., Si 0.6% at.,

Mg 0.5% at., C 0,5% at. According to the manufacturer's materials card, this alloy is characterized by parameters:
Density - 8,3 g/cm^3.
Hardness HV5 - 389 HV5.
Tensile strength - 980 N/m^2
Meling temperature 1385ºC.

1.3.9. Commercial cobalt alloy - Remanium GM 700

The Remanium GM alloy is an alloy of cobalt-chromium-molybdenum (Co-Cr-Mo), both chemical composition and manufacturing technology and processing makes the possibility of its use in denture creation, to casting the skeleton of denture, making of bridges and veneers. In its chemical composition are present: Co 61% at., Cr 30% at., Mo 5% at. and rest Si, C, Mn, N. According to the manufacturer's materials card, this alloy is characterized by parameters:
Density . 8.2 g/cm^3.
Hardness HV 10 - 390 HV10.
Casting temperature - 1400°C .
Melting temperature - 1370°C.
Yield strength - 740 N/mm^2.
Elastic modulus - 225.000 N/mm^2.
Elongation at break 4%.

The greatest advantages of Remanium GM alloy to be considered the possibility of laser welding, lower hardness, ease of processing, good castability.

1.3.10. Commercial cobalt alloy - Remanium 2000

The Remanium 2000 alloy is an alloy of cobalt-chromium-molybdenum (Co-Cr-Mo), both chemical composition and manufacturing technology and processing makes the possibility of its use for skeleton of partial dentures, base on bridges and veneers. In its chemical

composition are present: Co 61% at., Cr 25% at., Mo 7% at., and rest Ce, C, Mn, N. In accordance to the manufacturer's materials, this alloy characterized by parameters:
Density – 8.6 g/cm^3.
Hardeness HV 10 - 340 HV10.
Melting temperature - 1415°C.
Tensile strenght - 900 N/mm^2.
Yield strenght - 600 N/mm^2.
Elastic modulus - 200.000 N/mm^2
Elongation at break 7%

The greatest advantages of Remanium 2000 alloy to be considered the possibility of laser welding, ease of processing, good castability and oxidation resistance.

1.3.11. Commercial cobalt alloy - WIROBOND C

WIROBOND C alloy is an alloy of cobalt-chromium-molybdenum (Co-Cr-Mo), both chemical composition and manufacturing technology and processing makes the possibility of its use for veneering with porcelain, do not contain Ni and Be. In its chemical composition are present: Co 61% at., Cr 26% at. , Mo 6% at. , W 5% at., Si 1% at., Fe 0.5% at., Ce 0.4% at., C max. 0.02% at.
In accordance to the manufacturer's materials card, this alloy is classified as very hard Co-alloy and characterized by parameters:
Density – 8.5 g/cm^3.
Hardness HV 10 - 310 HV10.
Melting temperature range - 1380-1270°C
Casting temperature - 1470°C.
Yield strenght 480 N/mm^2.
Elastic modulus - 210.000 N/mm^2.
Elongation at break - 6%.

1.4. Properties comparison of commercial cobalt alloys including toyotarity theory

The toyotarity theory is based on the s multi-faceted assessment of a range of both businesses and production, and in particular the organization and operation of the production system. In this method emphasizes the importance of such resources in the production of material and intangible resources. Process improvement based on the information gathered, abilities, use of knowledge and experience in creating products, and thus in creating the identity of the company (BORKOWSKI S. 2012a, BORKOWSKI S. 2012b, BORKOWSKI S. 2012c).

The issues and their analysis shows that the quality is very interesting for every customers. If it is a primary mission of the company and subject to improvement, the client is assured that the purchased product by the producer meets the highest declared by him, standards. It is a subconscious influence. Supporting factor may be the cost of that transfer directly to the price of the product. As the execution of prosthetic work is quite responsible, as customers pay particular attention to the product that is in direct contact with the living tissues, including toyotarity theory is applicable in this regard. In terms of performance restorations should pay particular attention to the types of materials used in dental laboratories. Differentiation of dental materials market allows easy selection of materials for a particular application. However, an important factor in this regard is the experience and knowledge of dental technician. The question is whether each dental technician, who takes an active part in the design of dental prostheses have sufficient knowledge to make the right selection of materials. Among many textbooks and books used by dental technicians are still missing databases that easily enable both look for suitable materials, but also to compare them, along with the ability to submit an offer to the patient.

1.5. Summary

This chapter presents and characterized a group of metallic materials used in dental technology. Special attention is paid on cobalt alloys, which have a very a large interest during the manufacture of prostheses. It is noted that the comparison of commercial alloys of the same family of materials can create a picture of the quite extensive use of similar alloys in various aspects. Moreover, it can be seen that cobalt alloys with similar chemical composition characterized by a fairly diverse characteristics and are used for different types of work, thus to improve the process of material selection and design of dental restorations extremely important to review the materials available on the market of dental materials.

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