

**N. M. POLONEITCHIK, D. V. GARABURDA,
K. I. METELITSA**

**METALS AND ALLOYS OF METALS
IN DENTISTRY. TECHNOLOGICAL
PROCESSES USED FOR PRODUCTION
OF DENTAL PROSTHESES
OF METAL ALLOYS**



Minsk BSMU 2018

ISBN 978-985-21-0091-5



9 789852 100915

Результаторий БГМУ

МИНИСТЕРСТВО ЗДРАВООХРАНЕНИЯ РЕСПУБЛИКИ БЕЛАРУСЬ
БЕЛОРУССКИЙ ГОСУДАРСТВЕННЫЙ МЕДИЦИНСКИЙ УНИВЕРСИТЕТ
КАФЕДРА ОБЩЕЙ СТОМАТОЛОГИИ

Н. М. Полонейчик, Д. В. Гарабурда, К. И. Метелица

**МЕТАЛЛЫ И СПЛАВЫ МЕТАЛЛОВ В СТОМАТОЛОГИИ.
ТЕХНОЛОГИЧЕСКИЕ ПРОЦЕССЫ, ПРИМЕНЯЕМЫЕ
ПРИ ИЗГОТОВЛЕНИИ ЗУБНЫХ ПРОТЕЗОВ
ИЗ СПЛАВОВ МЕТАЛЛОВ**

**METALS AND ALLOYS OF METALS IN DENTISTRY.
TECHNOLOGICAL PROCESSES USED FOR PRODUCTION
OF DENTAL PROSTHESES OF METAL ALLOYS**

Учебно-методическое пособие

2-е издание



Минск БГМУ 2018

УДК 616.314-77(075.8)-054.6
ББК 56.6я73
П52

Рекомендовано Научно-методическим советом университета в качестве
учебно-методического пособия 21.02.2018 г., протокол № 6

Рецензенты: д-р мед. наук, проф. Т. Н. Манак; канд. филол. наук, доц.
М. Н. Петрова

Полонейчик, Н. М.

П52 **Металлы и сплавы металлов в стоматологии. Технологические процессы, применяемые при изготовлении зубных протезов из сплавов металлов = Metals and alloys of metals in dentistry. Technological processes used for production of dental prostheses of metal alloys : учебно-методическое пособие / Н. М. Полонейчик, Д. В. Гарабурда, К. И. Метелица. – 2-е изд. – Минск : БГМУ, 2018. – 40 с.**

ISBN 978-985-21-0091-5.

Изложены основные сведения о металлах и сплавах металлов в стоматологии, основных технологических процессах, применяемых при изготовлении зубных протезов с использованием металлов. Первое издание вышло в 2017 году.

Предназначено для иностранных студентов 1–2-го курсов, обучающихся на английском языке по специальности «Стоматология».

УДК 616.314-77(075.8)-054.6
ББК 56.6я73

ISBN 978-985-21-0091-5

© Полонейчик Н. М., Гарабурда Д. В., Метелица К. И., 2018
© УО «Белорусский государственный медицинский университет», 2018

INTRODUCTION

The production of metallic restorations, such as crowns, bridges, inlays, cast posts and cores and partial dentures, in the dental laboratory is carried out by the *lost wax casting* technique. This method of casting has been around for a considerable time, and is much used by craftsmen to produce intricate jewellery and ornaments. Its history can be traced back beyond 3000 BC, but it was not used in dentistry until the 1890s.

The basic principles are simple. A wax model is produced of the desired shape, and this model is invested in a material resistant to high temperatures. The wax is then removed by melting and burning, leaving behind a cavity of the desired shape. This can now be filled with molten metal, so that the metal assumes the shape of the original wax carving.

When the lost wax casting technique was first developed by Taggart in the early 1900s, the alloys of choice were gold alloys. For the construction of removable partial dentures, the gold alloys were gradually replaced by cobalt-chromium (Co-Cr) alloys during the 1950s and, to a lesser extent, Co-Cr-Ni alloys. In the latter part of the 20th century, titanium made its appearance as a fixed and removable partial denture casting alloy.

It is responsibility of the dentist to request the most suitable alloy for a particular application when instructing a dental laboratory to produce a prosthesis. This requires a knowledge of the types of alloys available, and their compositions and properties. This choice should not be left to the dental technician.

After all it is the dentist who will be placing these materials in the patient's mouth.

METALS AND ALLOYS OF METALS, USED FOR PRODUCTION OF DENTURES AND APPLIANCES

Metals are opaque substances, with "metallic" gloss, which in normal conditions are good electrical and thermal conductors, have good ductility and other properties which are determined by a large number of moving electrons which are not connected with the atoms' cores in their crystal lattice (electron cloud alloys).

CLASSIFICATION OF METALS

All metals are divided into ferrous and nonferrous metals.

Ferrous metals are usually dark-grey, highly dense (except alkaline metals), have high fusion temperature, relatively high hardness. A typical ferrous metal is iron (Fe), the other ferrous metals are cobalt, nickel, manganese, titan, vanadium, chrome, zirconium, niobium, molybdenum, tungsten (wolfram), technetium, hafnium, rhenium; uranic metals, rare earth metals and alkaline earth metals as well.

Nonferrous metals are of red, yellow and white colour. They are more plastic, less hard, possess lower melting temperature. A typical nonferrous metal is copper

(Cu). Gold, silver, palladium, platinum, beryllium, magnesium, aluminum, ruthenium, rhodium, osmium, iridium, zinc, cadmium, mercury, gallium, indium, thallium, germanium, tin, lead, arsenic, antimony, bismuth belong to nonferrous group as well.

According to the risk of corrosion metals are divided into noble and base metals.

Noble metals are metals, which are chemically stable, not prone to oxidation and corrosion, and have beautiful look. They all are precious metals due to their rareness. Main noble metals are gold, platinum, silver, and metals of platinum group (palladium, iridium, ruthenium, osmium and rhodium).

Base metals — are metals, which interact with environment easily and are prone to darkening and oxidation during their contact with air or moisture.

According to density metals are divided into light metals (density till 5 g/cm³) and heavy metals (density more than 10 g/cm³). In the interval between 5 and 10 g/cm³ there are metals with middle density.

According to fusion temperature metals are divided into low-fusion metals (fusion temperature is lower than fusion temperature of tin — 232 °C) and high-fusion metals with fusion temperature higher than that of iron (1535 °C). In the middle interval there are metals with middle fusion point.

Metals, used in dentistry.

Aluminum (Al) is a light metal of silver-white colour. In dentistry it's used as an alloying element (α -stabilizator) in titan-aluminum-vanadium alloys. Aluminum is always a basic element in duraluminum alloy and is included into alloy on the base of copper (aluminum bronze). Aluminum wire is used in clinic for splintage of broken jaws and in laboratory for reinforcement of wax bases of dentures.

Beryllium (Be) is a relatively hard metal of light-grey colour. It is used in dentistry as a component of cobalt-chrome and nickel-chrome alloys. It improves casting properties of alloys and increases binding strength between alloys and ceramics. Dental materials manufacturers don't add beryllium into alloys composition nowadays because of its high toxicity and accumulation in organism. In Russia its application in dental alloys is forbidden.

Vanadium (V) is a plastic metal of silver-grey colour, which resembles steel. In dentistry it is used as an alloying element (β -stabilizator) in titan-aluminum-vanadium alloys. *It increases strength, and viscosity of alloys.*

Bismuth (Bi) is a metal of silver-white colour. It is used in dentistry as a component of low-fusible alloys. It increases corrosion stability and hardness.

Tungsten (wolfram) (W) is a light-grey, high-fusible metal (melting point = 3422 °C). In dentistry it is used for *optimization of mechanical properties of cobalt-chrome alloys*. Besides, it is used for alloying of steel during manufacturing of metal-bladed cutting instruments, containing 8–20 % of tungsten. For production of dental cutting rotating instruments hard alloys on the base of tungsten carbide, bonded with a metallic cobalt binder are used (85–95 % tungsten carbide and 5–15 % cobalt).

Gallium (Ga) is a soft, low-fusible (melting point = 29.75 °C), plastic metal of light-grey color with bluish shade. It is a component of many low-fusible solders and palladium-copper-gallium alloys. It is also used for silver-plating of mirrors.

Iron (Fe) is a glossy, silver-white metal. It's used in dentistry as the main component of steel alloys. Addition of iron into cobalt-chrome alloys increases their flowability and improves casting quality.

Gold (Au) is a yellow metal, which is used in dentistry as a component of noble alloys.

Indium (In) is a malleable low-fusible (melting point = 156.6 °C), very soft metal of silver-white colour. It's a component of many low-fusible solders and alloys. Indium orthophosphate is used as an addition to dental cements. It's used also as alloying element in gold alloys.

Cadmium (Cd) is a low-fusible (melting point = 320 °C) metal of silver-white color with bluish shade. It's used in dentistry as a component of solders and low-fusible alloys. It decreases melting point of the alloy. Cadmium is a severe contaminant of the environment and it has an adverse influence on human body. In many countries solders which contain cadmium are forbidden to use.

Cobalt (Co) is a silver-white metal. It's used in dentistry as a main component of cobalt-chrome alloys or as a component of nickel-chrome alloys and steel alloys. Cobalt provides good mechanical properties of the alloy.

Magnesium (Mg) is a metal of pale-grey color, which is used in dentistry as a component of a solder for steel alloys. It is inserted into numerous alloys composition as a deoxidant and purifier.

Manganese (Mn) is a metal of silver-white colour. It is used in dentistry as a component of steel alloys. It increases strength and hardness of steel, decreases plasticity, improves flowability parameters, decreases melting point and helps to remove the adverse sulfur compounds from the alloy, provides necessary nitrogen concentration in steel.

Copper (Cu) is a red metal. It is used in dentistry as a component of gold-containing alloys and solders. It increases viscosity and mechanical strength of alloys. Copper is used as a basic element of aluminum bronze and brass.

Molybdenum (Mo) is a light-grey metal. It's used in dentistry as a component of cobalt-chrome and titan-molybdenum alloys, and in alloying of Co-Cr and Ti-Mo alloys. 5 % alloying of Co-Cr alloy with molybdenum significantly increases strength of the alloy, improves its casting properties.

Nickel (Ni) is a metal of silver-white color. It is used in dentistry as a main component of Ni-Cr and Ni-Ti alloys, a component of Co-Cr and steel alloys. Introduction of nickel into alloy increases its plasticity, decreases shrinkage and provides its corrosion stability.

Niobium (Nb) is a shining metal of steel-grey color. It is included into alloys on the base of zirconium and titan-aluminum alloys. Niobium increases strength and corrosion stability of alloys.

Tin (Sn) is a white, low-fusible (melting point = 232 °C), shining metal. It's used in dentistry as a component of low-fusion alloys. It's the component of dental palladium alloys.

Palladium (Pd) is a metal of silver-white colour, which is used in dentistry as a main component of alloys, alloying element of gold-containing and silver-palladium alloys. It increases corrosion stability and strength of alloys.

Platinum (Pt) is a metal of greyish color, which is used in dentistry as a component of noble alloys.

Lead (Pb) is a metal of bluish-grey color. It is used in dentistry as a component of low-fusion alloys.

Silver (Ag) is a white metal, which is used in dentistry as an additional component of noble alloys and solders. It is included into composition of silver-palladium and gold-containing alloys, and some solders.

Tantalum (Ta) is a heavy, high-fusible (melting point = 3017 °C), very hard (HB = 800 MPa), well ductile, well processable metal of platinum-grey colour with slight lead shade. It is used as ligature of Ni-Cr alloys. Thanks to its high biocompatibility tantalum has received a wide application in medicine. Thin tantalum plates and tantalum wire for bone suturing are used in maxilla-facial surgery. Tantalum clips are used for connecting blood vessels. Tantalum as well as nickel and chrome is widely used as an anticorrosion coverage. In dentistry tantalum pentoxide is used extensively (Ta_2O_5). Usage of implants covered with Ta_2O_5 prevents inflammatory processes, decreases terms of engraftment of the implant. In prosthodontics the usage of acrylic dentures covered with tantalum pentoxide eliminates all possible pathological reactions caused by acrylates intolerance.

Titanium (Ti) is a silver-white metal. It is used in dentistry as a constructional metal (Ti 99.5 %), main component of Ti-Al-Va and Ti-Mo alloys, a component of Ni-Ti alloys. It gives to steel a fine-grained structure, decreases brittleness, removes steel tendency to intercrystalline corrosion. Titanium nitride (titanium and nitrogen compound) is used for creation of multilayer composite decorative coverages of steel dentures with films of light-yellow to dark-yellow color (coverage thickness makes from 2 to 5 mkm).

Chrome (Cr) is a metal of white shining colour with bluish shade. It's used in dentistry as a component of Co-Cr, Ni-Cr alloys and steel alloys. It increases hardness of alloys, decreasing their plasticity and viscosity at the same time. It provides anticorrosive protection.

Cerium (Ce) is a chemical element from lanthanide group, silvery metal. Alloying of constructional materials with cerium increases their strength significantly.

Zinc (Zn) is a metal of bluish-white colour. It is used in dentistry as ligature component of solders. It increases the flowability of alloys.

Zirconium (Zr) is a silvery-white, hard (HB = 650 MPa), high-fusible metal (melting point = 1855 °C). Its anticorrosive properties overcome such steady

metals as niobium and titanium. In dentistry it's used as a main component of zirconium niobium alloys for manufacturing of implants.

PROPERTIES OF CONSTRUCTIONAL METALS AND THEIR ALLOYS

Biological properties of metals and their alloys.

Biocompatibility is an ability of nonbiological materials used in medicine to provide interaction with biological system (not to produce negative influence on alive tissues and not to change their own properties after their back response). Biocompatibility of materials depends on their biological and physical-chemical properties, such as toxicity, ability of substances of different origin to cause allergy, stimulation of tumorigenesis, affecting blood etc.

Physical properties of metals and alloys of metals.

Density is the ratio of body mass to its volume. Density unit in SI (fr. = Le Systeme International d'Unites.) is 1 kg/m^3 , in CGS system (a metric system based on the Centimeter as the unit of mass, the Second as unit of time and Gram as the unit of mass) — 1 g/cm^3 . Density of different metals, used in dentistry, is shown in table 1.

Table 1

Density of different metals, used in dentistry

Metals	Pt	Au	Mo	Ag	Cu	Ni	Co	Fe	Cr	Ti	Al
Density, g/cm^3	21.45	19.32	10.22	10.49	8.95	8.9	8.9	7.87	7.19	4.5	2.7

Specific gravity (γ) is a rate of weight of the substance to the volume taken by it (in SI specific gravity is measured with N/m^3).

Melting, solidification is the transition of crystalline substance from solid phase into liquid phase and vice versa. The temperature, at which solid crystalline body transits into liquid phase, is called *melting temperature*. Alloys of metals transit from solid crystalline phase into liquid phase not at a melting point but at a *temperature transformation range*. Melting of an alloy starts at a *solidus point* (one of border temperatures of alloy crystallization) and finishes at a *liquidus* temperature point (full melting of solid phases, at which substance fully transits into liquid state). Between *solidus and liquidus points* there is a melting range. For pure substances (elements) temperatures solidus and liquidus are the same. Melting temperatures of some metals, used in dentistry, are represented in table 2.

Table 2

Melting temperatures of some metals, used in dentistry

Metals	Mo	Cr	Pt	Ti	Fe	Co	Ni	Cu	Au	Ag
Melting temperature, $^{\circ}\text{C}$	2620	1903	1769	1668	1535	1480	1455	1083	1064	960.5

Specific heat capacity is a quantity of heat which can rise the temperature of metal mass unit for 1°C .

Thermal conductivity is the ability of metal to conduct heat (transfer some quantity of heat from warmer sites to colder ones). It is defined with a thermal conductivity coefficient.

Linear Coefficient of Thermal Expansion is changing of linear sizes of solid body during changing of temperature. The rate of body lengthening during 1 °C heating to its original length is defined as a coefficient of linear thermal expansion (α_{exp}). Coefficient of thermal expansion (CTE) of some metals which belong to dental alloys, are shown in table 3.

Table 3

Coefficient of thermal expansion of some metals in composition of dental alloys

Metals	Ag	Au	Ni	Co	Fe	Pd	Ti	Pt	Cr
CTE, $\times 10^{-6} \text{ K}^{-1}$	19	14	13	12.8	12	11.7	9.6	8.7	8.1

Alloys of metals, which are used for fabrication of cermet (ceramic fused on metal) dentures should have CTE close to the CTE of ceramic facing. Averagely, CTE of all types of alloys which are used for facing with ceramic, varies between $13.8 \times 10^{-6} \text{ K}^{-1}$ and $15.2 \times 10^{-6} \text{ K}^{-1}$.

Colour is a qualitative subjective characteristic of electromagnetic radiation of optic range, which is determined on the base of appearing physiological phase. Metals have different colour shades of almost all spectrum, but as a rule, for nonprecious metals it is grey, bluish of different degree of saturation and their various combinations. For precious metals yellow-orange and white-silver shades are typical.

Chemical properties of metals and alloys of metals.

Oxidation is a chemical interaction or processes, during which the connection of metals with oxygen and producing of oxides occur.

Corrosion is a chemical or electrochemical interaction between metal or alloy and their environment, leading to its full or partial destruction or changing of its properties.

Corrosion resistance is an ability of metals or alloys to withstand corrosion in the corresponding conditions.

Mechanical properties of metals and alloys of metals are the properties, defining the ability of a metal to withstand deformation and destruction under the influence of outer powers (loads). Outer power (load) causes **stress** in a solid body (the value of the load related to the square unit of cross-sectional surface of tested sample) and **strain** (changing of sizes and shapes of the body under the influence of applied outer powers). Outer powers (loads) can be static, dynamic or cyclic (recurrent). Tensile, compressive, and shear strains appear along the load direction. In practice, dentures are exposed not to single acting loads but their combinations.

Deformations are divided into elastic deformation and plastic deformations, depending on the value of acting load. If the deformation disappears after termination of the load which has caused it, it is called *elastic*. If after the termination of the load the body doesn't recover its original sizes and shape, and we observe residual deformation, such deformation is called *plastic*.

Elasticity is the ability of a metal to recover its original shape and sizes with termination of outer load action which caused its deformation. The biggest

tension, under which the material doesn't gain residual deformations, is called **elastic limit**. After this limit there happens elongation of a sample with the permanent load (growth of deformation without growth of tension). This phenomenon is called flowing of the material. **Flowability** is an ability of bodies to deform in a plastic or viscous way under the tension influence. Solid bodies demonstrate it only at tensions which exceed flowability limit. There is so called **conventional yield strength** — the tension, at which residual lengthening gains 0.2 % of the original sample length. **Elasticity modulus (Young's modulus)** characterizes the resistance of the material towards extension/compression during elastic deformation, or an ability of the object to deform along the axis of load action. Elasticity modulus of some metals from the composition of constructional dental alloys, are shown in table 4.

Table 4

Elasticity modulus of some metals from the composition of constructional dental alloys

Metals	W	Mo	Cr	Fe	Co	Ni	Pt	Cu	Zn	Ag	Au
Elasticity modulus (GPa)	411	329	279	211	209	200	168	110–128	108	83	78

The tensions which were described characterize strength properties of the material (**strength (toughness)** is an ability of metal to withstand the influence of outer destructive powers). The conventional tension, corresponding to the maximal load which is followed by destruction of the sample, is called **tensile strength, or breaking point**. Tensile strength of metals from composition of main constructional dental alloys, is shown in table 5.

Table 5

Tensile strength of metals from composition of main constructional dental alloys

Metals	Ni	Co	Cr	Fe	Pd	Pt	Ag	Au
Tensile strength, MPa	500	260–480	450	180–250	210	160	140	122

If the load exceeds elastic limit, after removal of the load the shape of the sample doesn't recover, and the sample remains elongated. Such deformation is called plastic deformation. Plasticity is an ability of metal or alloy of metals to deform under outer loads influence without destruction and show residual deformation (which remains after removal of load). This property is used in processing of metals with pressure. During extension plastic properties of metal are characterized with relative elongation and narrowing of the sample, which are interconnected, because elongation of the sample is followed with decreasing of its cross-sectional surface square. **Relative extension** is a rate of newly appeared length of the sample to its original length, expressed in %. Relative extension of metals from composition of dental alloys are shown in table 6.

Table 6

Relative extension of metals from composition of main constructional dental alloys

Metals	Fe	Ag	Au	Pt	Pd	Ni	Cr	Co
Relative extension, %	50	48–50	40–50	40	35	35	6–7	5

Hardness is a resistance, which is performed by metal during pressure of solid bodies. The most used methods of hardness measurement are methods of Brinell, Vickers and Rockwell. Hardness of metals from composition of constructional alloys, is shown in table 7.

Table 7

Hardness of metals from composition of main constructional dental alloys

Metals	Cr	Co	Ni	Fe	Pt	Pd	Ag	Au
Hardness, HB, kgf/mm ²	217–236	132	70	60–70	50	49	26	18.5

Hardness of alloys is usually higher than average hardness of metals, contained within them.

Resilience is characterized as resistance of metal or alloy of metals against impact. Resilience is determined as quantity of power, which can destroy sample by impact bending load on Charpy impact testing machine, divided into cross-sectional square of the sample, and expressed in kg/cm².

Fatigue, Endurance in materials science there is known a process of permanent collecting of defects in metal under the influence of cyclic tensions, which leads to changing of its properties, appearing and growth of cracks, and destruction of the material during certain period of time. The reverse property of material is called endurance (ability of the material to accept cyclic loads without destruction in a period of time).

Technological properties of metals and alloys of metals.

Flowability is an ability of metal or alloy of metals to fill cavity of casting molds in liquid phase and accurately reproduce its shape.

Durability ability of metal or alloy of metals to resist abrasion, destruction of the surface or changing sizes under the rubbing action.

Malleability is an ability of metal or alloy of metals to deform under pressure without destruction (to be processed by malleation, pressing etc.) **Ductility** is the ability to deform plastically under the tensile stress, during drawing of metal into long thin wires. These properties depend on metal's plasticity. Plastic metals possess good malleability and ductility.

Processability is an ability of metal or alloy of metals to be processed with the help of cutting instruments.

Shrinkage is a property of metals to decrease its linear sizes and volume during solidification (cooling).

REQUIREMENTS FOR METALS AND ALLOYS OF METALS, USED IN DENTISTRY FOR FABRICATION OF DENTURES

- biocompatibility;
- high corrosion resistance in the oral cavity;
- good mechanical properties (strength, hardness, elasticity, plasticity etc.);
- good technological properties (should be easily cast, soldered, welded, stamped, ducted, processed, grinded and polished);

– should have necessary physical properties (colour, low shrinkage, low melting temperature etc.).

There are additional requirements for the alloys which are used for fabrication of metal-ceramic dentures:

– melting temperature of the alloy should be higher than baking temperature of ceramic;

– thermal expansion coefficient of alloys should be equal or almost equal to the CTE of ceramic;

– alloys should have chemical and mechanical bonding to ceramic.

CLASSIFICATION, COMPOSITION OF CONSTRUCTIONAL ALLOYS

Alloys of metals it's a combination of two or more metals, in result of which a metallic substance is created, which possesses new properties, untypical for any of the components of the alloy. Alloys consist of mixture of basic metallic elements (prevailing by mass), elements of the alloy (metallic or nonmetallic elements, added or saved with a main metal, adding specific properties to the alloy) and additives (metallic or nonmetallic elements which are present in the alloy but don't have to be specially added or kept within the metal).

CLASSIFICATION OF METAL ALLOYS

According to the final aim of use there are distinguished constructional alloys (metals and metal alloys, which are used directly for fabrication of dentures and appliances) and auxiliary alloys (alloys which are applied in different technological processes during laboratory producing of dentures and for fabrication of appliances and devises used on technological steps).

Constructive alloys of metals are classified into 3 groups according to their chemical composition:

Classification by international standards organization ISO, 1993

Highly noble alloys	At least 75 % gold (by mass)	Au+
Noble alloys	Containing 25–75 % gold or metals of platinum group	Au + Pd + Pt
Base alloys	Not containing noble metals. On base of cobalt, nickel, iron, titanium, zirconium	Co+ Ni+ Fe+ Ti+ Zr+

Classification by American dental association ADA, 2004

Highly noble alloys	At least 60 % of noble metals (and at least 40 % gold by mass)	Au ≥ 40 % + Pd Au ≥ 40 % + Pt Au ≥ 40 % + Ag
Noble alloys	Containing at least 25 % of noble metals	Au + Ag, Cu, Pd Pd + Cu, Ga Pd + Ag Ag + Pd
Base alloys	Containing not more than 25 % of noble metals or on base of nickel, cobalt and titanium	Noble ≤ 25 % Co+ Ni+ Ti+

According to the technological process, which is used for fabrication of dentures from metal alloys and according to the properties of constructional metals (plasticity, flowability in casting etc.), the alloys are classified into groups for processing of metals by pressure (deformable), for casting (castable), for sintering (powder), for milling (CAD/CAM technology) and for soldering (solders).

According to the type of fabricated denture construction among castable alloys there are distinguished groups of alloys, which are meant for fabrication of metal-ceramic dentures and fully cast removable dentures. The alloys for fabrication of full cast removable dentures, have to possess high strength and elasticity. In accordance to the requirements of International standard of ISO, the alloys of this group should have yield strength at least 500 MPa and relative extension more than 1.5 %. For fabrication of metal-ceramic construction highly noble, noble and base alloys with Co, Ni, and Ti are used. The alloys for metal-ceramic should have thermal expansion coefficient which excludes load stresses in ceramic, leading to fractures or cracks in the facing (check *thermal expansion on heating*).

Classification of cast constructional alloys of metals on the base of physical properties:

Classification by American dental association
(ADA, 2004)

Classification by ISO1562: 1993

Type	Characteristic of hardness	Yield strength (MPa)	Relative extension (%)
I	Soft	< 140	18
II	Middle	140–200	18
III	Hard	201–340	12
IV	Superhard	≥ 340	10

Type	Characteristic of hardness	Yield strength (MPa)	Relative extension (%)
I	Soft	> 80	16
II	Middle	> 180	10
III	Hard	> 270	15
IV	Superhard	> 360	3

CONSTRUCTIONAL METALS AND ALLOYS OF METALS (COMPOSITIONS)

Alloys of noble metals with high content of gold (highly noble) are the alloys containing at least 75 % of gold by mass. Typical composition: gold — 85 %, platinum — 12 %, zinc — 1 %, silver (in several trademarks).

Alloys of noble metals containing 25–75 % of gold are the alloys containing from 25 till 75 % of gold or metals of platinum group (palladium, iridium, ruthenium, osmium and rhodium). Total weight of gold, platinum group metals and silver must make up not less than 70 % of the alloy weight. Typical composition: gold — 45 %, copper — 15 %, palladium — 5 %, silver — 25 %.

Alloys of noble metals on base of palladium are the alloys, in which palladium is the main element. There are known 2 types of alloys: palladium-copper-gallium alloy (typical composition: palladium — 79 %, copper — 7 %, gallium — 6 %) and palladium-silver alloy (typical composition: palladium — 61 %, silver — 24 %, in some trademarks tin is contained).

Alloys of noble metals on base of silver are the alloys, in which silver is the main element, palladium is another component of the alloy. Typical

composition of silver-palladium alloy: silver — 66 %, palladium — 23 %, gold (in some trademarks).

Alloys on base of cobalt are the alloys in which the main element is cobalt, and other components are chrome (at least 25 % of the mass), nickel and molybdenum (at least 4 % of the mass). Total weight of cobalt, nickel and chrome should make not less than 85 % of the alloy weight. Considering the risk of allergic reaction caused by nickel, manufacturers of the materials don't include it into composition of cobalt-based alloys lately.

Alloys on base of nickel are the alloys, in which main element is nickel and the other components are chrome (at least 20 % by mass) and molybdenum (at least 4 %). Total weight of nickel and chrome should make up not less than 85 % of the alloy weight.

Alloy of nickel and titanium (titanium nickel) it's an alloy of 55 % nickel and 45 % titanium (mass fractions). Melting temperature is 1240–1310 °C, density 6.45 g/cm³. Another name of this alloy which is spread abroad — is NiTiNOL, where NOL is an abbreviation of **naval ordnance laboratory** in USA where this material was invented in 1962. In 1963 it was discovered that nitinol samples which are easily deforming at cooled state, can recover their initial form while heating, therefore making useful effect during a thermodynamic cycle and performing excellent shape memory effect. Titanium nickelid is extensively used in orthodontics for production of arches. They are soft enough for bending but always tend to their initial shape on activation by body temperature. Endodontic instruments are made of titanium nickelid.

Alloys on base of titanium — in dentistry pure titanium (99.5 %) can be used as well as alloys of titanium (90 %) aluminum (6 %) and vanadium (4 %), and alloys on base of titanium (87 %) aluminum (6 %) and niobium (7 %). They are used as cast alloys and for milling CAM. The alloys containing titanium (75 %) vanadium (15 %) and aluminum (10 %) are used for fabrication of orthodontic arches.

Alloys of stainless steel are the alloys on base of iron, containing 0.022–2.14 % of carbon. Carbon is represented in steel as cementite and increases hardness, elasticity, stiffness, decreases plasticity and resistance against impact loads. Alloying means adding of significant quantities of other metals to main combinations of metals to improve their mechanical properties (hardness, elasticity etc.) Alloying is made in metallurgy as introduction into melt or batch of additional chemical elements which improve mechanical, physical and chemical properties of the alloy. Steel alloys, having good anticorrosive properties and containing more than 12 % chrome are called stainless. In dentistry alloyed stainless steel on the base of iron (70–72 %) carbon (0.1–0.3 %), chrome (17–19 %), nickel (8–11 %), silica, magnesium and titanium are used (1Cr18Ni9Ti, 2Cr18Ni9 etc.). Melting temperature is 1450–1500 °C, hardness by Brinell 1550–1600 HB, elasticity modulus 182 MPa·10³, toughness 625–650 MPa, shrinkage 2.7 %. They are meant for fabrication of fixed dentures by stamping, casting of intermediate part of soldered bridges. For orthodontic reasons arches

with round, flat and square profile are produced of steel, as well as braided arches (3- and 6-threaded), brackets, rings, locks, buttons, ligatures etc.

Alloys of stainless steel (marking) it's a characteristic of steel composition expressed with letters and numbers. If in front of the mark, 2 digits appear, they mean the average content of carbon in hundredth part of percent. One digit in front of the mark shows the average content of carbon in tenth part of percent. If in front of the mark there is no digit it means there is no carbon in steel, or 1 % or more than 1 %. Letters mean chemical elements in the composition of steel (Cr-chrome, Ni-nickel, Ti-titanium etc.) Digits which follow these letters, mean average content of corresponding element in percent. If there is no digit following the letter means content of this element is around 1 % but not more than 1.5 %.

Iron-nickel-chrome alloys are cast alloys, containing $\times 3$ more nickel than steel and +5 % more chrome. They are developed as an alternative to alloyed stainless steel.

Zirconium-niobium alloy it's an alloy of zirconium (97 %) and niobium (2.6 %). In dentistry it is used for manufacturing of implants. This material possesses perfect biocompatibility and high toughness to withstand mastication loads.

FORMS OF PRODUCTION OF METALS AND THEIR ALLOYS FOR FABRICATION OF DENTURES AND OTHER AIMS

Dental bushings are standard stainless steel patterns (1Cr18Ni9Ti), which are produced within methodic of cold stamping of steel plates of 0.3 mm thickness and meant for fabrication of artificial crowns by pressure (stamping). They are produced in 23 sizes.

Temporary crowns (provisionals) standard kits of preformed crowns are industrially produced for making of provisional (temporary) dentures. Crowns are made of stainless steel, on the base of tin/silver alloy and alloy of aluminum with galvanic coating of gold.

Wire is a metallic thread, usually with round, rarely — with square, hexagonal, trapezoidal or oval cross-section of steel, aluminum, copper, nickel, titanium, zinc, their alloys and other metals. Wire is received with the help of drawing (dragging) it through holes which have smaller diameter step by step.

Aluminum wire is a wire with size 1.5–2.2 mm, produced of aluminum. It's used in clinic for splinting of jaws fractures and in dental laboratory for temporary strengthening of wax bases of dentures.

Ligature wire it's a thread, used during ligaturing of blood vessels (in medicine). In dentistry the name ligature is used for various bondings and fixations.

Ligature bronze-aluminum wire it's a wire of 0.3–0.5 mm diameter, made of aluminum bronze alloy. The alloy has increased mechanical toughness, good plasticity. Bronze-aluminum wire is used in dentistry as ligatures for temporary fixation of arches in treatment of jaws fractures and temporary splintage of teeth.

Ligature steel wire it's a wire of 0.2–0.3 mm diameter, made of alloyed stainless steel. Steel wire is used in dentistry as ligatures for temporary fixation of arches in treatment of jaws fractures, for temporary splintage of teeth and for fixation of wire arches directly on teeth or on brackets during orthodontic treatment.

Clamp wire is a wire which is used for producing of bent retentive elements of removable partial dentures (clasps).

Clamp wire from golden alloy of 750 probe (purity) is a wire of 1.0, 1.2, 2.0 mm diameter, containing 75 % gold, 9 % platinum and 8 % silver.

Clamp wire from alloyed stainless steel is a wire of 25–32 mm length, 1.0 or 1.2 mm diameter, made of alloyed stainless steel (1Cr18Ni9Ti).

Orthodontic steel wire is a wire of 0.6–1.5 mm diameter made of alloyed stainless steel (1Cr18Ni9Ti, Cr19Ni10), which is used for producing of fixating and active elements of orthodontic apparatus. Cross-section is round or semiround (0.65×1.3 mm and 0.75×1.5 mm).

Orthodontic wire from titanium nickelid is a wire of 0.6–0.8 mm diameter made of nickel/titanium alloy (read *alloy of nickel and titanium*).

Alloy of metal in blocks it's the patterns of constructional cast alloys with mass 5–30 gr, maximal linear size is 20 mm, diameter is 8–15 mm, they are designed for fabrication of dentures by casting.

Alloy of metal in discs it's standard patterns of flat profile, received in result of rolling of golden (AuAgCu 900–40) or silver-palladium (Pd 250; AgPdZn 736–250) alloys with diameter 18.0, 20.0, 23.0 and 25.0 mm; and thickness of 0.28–0.31 mm and meant for fabrication of artificial crowns by pressure (stamping). Bushings (patterns for stamping) receive their shape during drawing under press.

Alloy of metal in granules it's a form of industrial production of large powders of metal alloys in granules. Granulating occurs during pouring of molten metal into liquid. Granulated alloy is used in casting technology. Melting of granules goes on faster than melting of metallic blocks. Granulated alloys are more easily dozed and allow saving of material.

Alloy of metal in powder is a form of industrial production of metals and their alloys. Powders which contain particles of same size are called monodisperse, those powders where particles have different sizes — are polydisperse. Powders are classified on base of fractional composition into large (particles size 150 mkm till 1 mm), middle (40–150 mkm), thin (1–40 mkm), disperse (0.1–1 mkm), ultrathin (< 0.1 mkm) and ultradisperse (< 25 – 30 nm). Powdered materials are used in technology of selective laser sintering (SLS) of metals with the help of CO₂ laser (polydisperse powders with grain size < 85 mkm) and in the technology of baking of formed powders.

Alloy of metal in bands is a form of industrial production of metal alloys for denture fabrication with the help of casting. Bands are supplied with a thickness of 1–3 mm and size 10×10 mm.

Alloy of metal in milling blocks it's the patterns of cobalt-chrome, nickel-chrome, titanium-aluminum-vanadium alloys and titanium (99.5 %), with diameter till 100 mm and thickness of 10–30 mm. They are used in technology of dentures fabrication by computer milling.

AUXILIARY ALLOYS OF METALS

Bronze is an alloy of copper usually with tin as the main alloying element, but the alloys with aluminum, silica, beryllium, lead and other elements are used as well. In dentistry aluminum bronze is used. It is an alloy with copper (till 90 %), aluminum (5–11 %) and some other metals. Aluminum bronze is produced as wire with diameter 0.4–0.5 mm and is used for ligatures during splintage of jaws fractures.

Duraluminum is an alloy of aluminum (95 %), copper (4 %), manganese (0.5 %) and magnesium (0.5 %). Duraluminum is used for producing of some devices of dental laboratory (flasks, articulators etc.).

Brass is a dual or multicomponent alloy on base of copper, where the main alloying element is zinc, sometimes with addition of tin, nickel, lead, manganese, iron and other elements. Brass is used for production of pins for split stone models.

Magnaly is an alloy of aluminum (70 %) and magnesium (30 %). Its properties are similar with duraluminum. Magnaly is used for producing of some devices of dental laboratories (flasks, articulators etc.).

Low-fusion alloy is a metal alloy, which fusion point is lower than melting temperature of tin (232 °C).

Low-fusion alloy of Wood is an alloy with melting temperature 68 °C, (bismuth — 50 %, lead — 25 %, tin — 12.5 %, cadmium — 12.5 %). It's used for production of stamps in technology of processing of metals by pressure (stamping of artificial crowns).

Low-fusion alloy of Melloth is an alloy with melting temperature 63 °C, (bismuth — 50 %, lead — 20 %, tin — 30 %). It's used for production of stamps in technology of processing of metals by pressure (stamping of artificial crowns).

INSTRUMENTAL ALLOYS OF METALS

Instrumental carbon steel is steel which contains 0.7 % carbon and more. This steel performs high hardness and toughness (after final thermal processing) and is used for producing medical instruments. Alloying of carbon steel with tungsten, molybdenum, vanadium and cobalt provides receiving of so called fast-cutting steel, which shows big cutting strength on high speeds. Fast-cutting steels are meant mainly for production of thermally stable instrument, which can work on high speeds (burs, cutters etc.). Nowadays for fabrication of metal-bladed rotating instruments chrome and chrome-nickel fast-cutting steels are used with high anticorrosive resistance. They are alloyed with silica, molybdenum,

vanadium, manganese for improving of plastic deformation. Metallic instruments are protected against corrosion with the help of nickel coating.

Tungsten carbide is a chemical combination of carbon and tungsten, ceramic. It's one of the hardest ceramics known. Hardness is comparable with diamond. Besides hardness, tungsten carbide is outstanding with its high melting temperature, wear resistance, good antioxidation stability. Tungsten carbide is widely used in dentistry as a material for production of burs. Working part of these burs is manufactured by baking or hot pressing of the tungsten carbide powder (90 %) and cobalt (10 %) in vacuum. Cylinder patterns are cut into fragments and soldered to steel shanks. Afterwards the working part receives necessary shape with the help of diamond discs, and metal blades are milled on its surface.

Titanium nickelid — read alloy of nickel and titanium.

SOLDERS

Solders (filler material) are the alloys, meant for soldering parts of dentures.

Soldering is a process of tough connection of metallic parts of denture with the help of molten solder (filler material).

Compositions of some types of solders, meant for different alloys.

Table 8

Comparative characteristic of properties of some metal alloys, used in dentistry
(the tables are taken from specifications of manufacturing companies)

Alloy	Base	Density g/cm ³	Melting range (°C)	Casting temperature (°C)	TEC, $\alpha \times 10^{-6} \text{ K}^{-1}$	Elasticity (MPa)	Hardness (HB)	Yield strength MPa	Relative extension	Usage
AuAgCu 900–40	Au	17.5	944–956				100	200	20	Stamp
AgPdZn 736–250	Ag	10.8	1085–1150				125	300	20	Stamp
25Cr18Ni9Si2	Fe	7.8	1390–1430	1550				250	5	Cast
1Cr18Ni9Ti	Fe	7.8	1390–1430							Stamp
Cellit-K	Co	8.4	1380–1410	1500	14.2	400	400	370	5	Cermet
Wiron	Ni	8.2	1200–1280	1350	14.1	360	260	470	10	Cermet
Wironium plus	Co	8.4	1310–1345	1440		650	340	700	10	CRD
Ti (99.5 %)	Ti	4.5	1668	1700	8.9		200	295–410	20	Cermet, CRD
Ti-Al-Va	Ti	4.5	1670	1700			200	900		Cermet, CRD
Wirobond	Co		1020–1150							Solder
Wiron	Ni		1020–1150							Solder
ИСР-37	Ag		850							Solder
AuAgCdCu	Au		800							Solder

Abbreviations: Stamp — stamping, Cermet — ceramometallic, CRD — fully cast removable dentures.

Golden solder: alloy of gold (75 %), cadmium (12 %), copper (10 %) and silver (3 %), which has melting temperature 800 °C and is used for soldering of parts of dentures, made of golden and silver-palladium alloys.

Silver solder “TICP-37” (Cytrin’s sold): an alloy on base of silver (37 %), copper (38 %), nickel (4 %), cadmium (0.5 %) and other metals (till 20 %), which has melting temperature 850 °C and is meant for soldering of parts of dentures, made of stainless steel.

Solder for nickel-chrome alloys (Wiron): nickel (66 %), chrome (19 %), molybdenum (5.5 %), iron (5 %), silica 3.5 %), boron (1 %). Melting temperature of the solder is 1020–1150°.

Solder for cobalt-chrome alloys (Wirobond): cobalt (60.5 %), chrome (28.5 %), silica (4.5 %), molybdenum (3 %), iron (1.5 %), boron (1.5 %), carbon (0.5 %). Melting temperature of the solder is 1020–1150°.

TECHNOLOGICAL PROCESSES OF MANUFACTURING DENTURES OF METAL ALLOYS

PROCESSING OF METALS BY PRESSURE

Dentures are manufactured of constructional materials with the help of various technologies (technological processes). *Technology* is a complex of actions directed onto creating of a certain object, each of these actions is based on natural (chemical, physical etc.) processes and human activity.

Technologies of manufacturing of dentures and their details with the help of processing metals by pressure. Auxiliary devices and apparatuses, used for processing.

Processing by pressure is a process of receiving patterns or details by force action of an instrument onto the original pattern with its original material.

Drawing is a process of drawing metal wire through a hole in the matrix with less diameter than the one of the original wire. Orthodontic wire, clasp wire and other wires with different cross-sectional diameters (fig. 1, *a*) are manufactured with drawing.

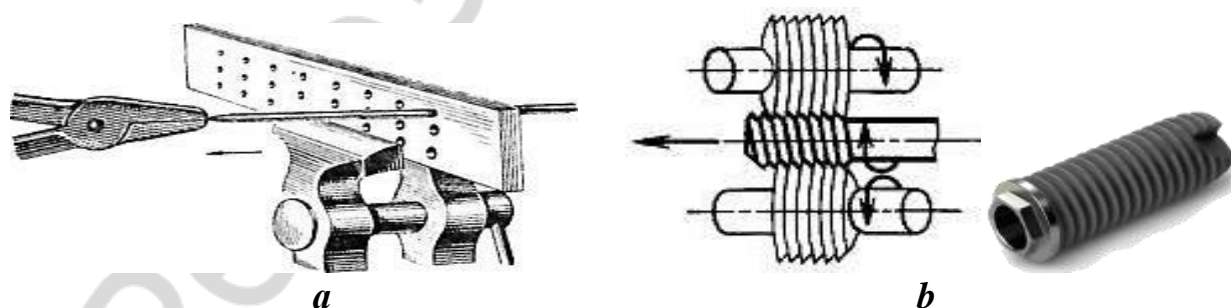


Fig. 1. Processing of metals by pressure:
a — drawing of metal wire; *b* — knurling of ribbed surface on rolling pattern

Knurling is a technology of mechanical processing of metals by pressure for receiving a ribbed, notched surface, conducted on a rolling pattern which is

pressed by two discs with notches (fig. 1, *b*). Knurling is used in manufacturing of titan implants. Implants are products of medical purpose, used for implantation into bone tissues of maxilla and mandible. Implants supply fixation of dentures which restore defects of dental arches.

Rolling is a process of pressing metal by two rolling cylinders of the rolling device (fig. 2, *a*). In prosthodontic dentistry rolling is used in manufacturing of tape strips with 0.3 mm thickness (fig. 2, *b*) of golden and silver-palladium alloys in an original form of 1–3 mm thickness plates.

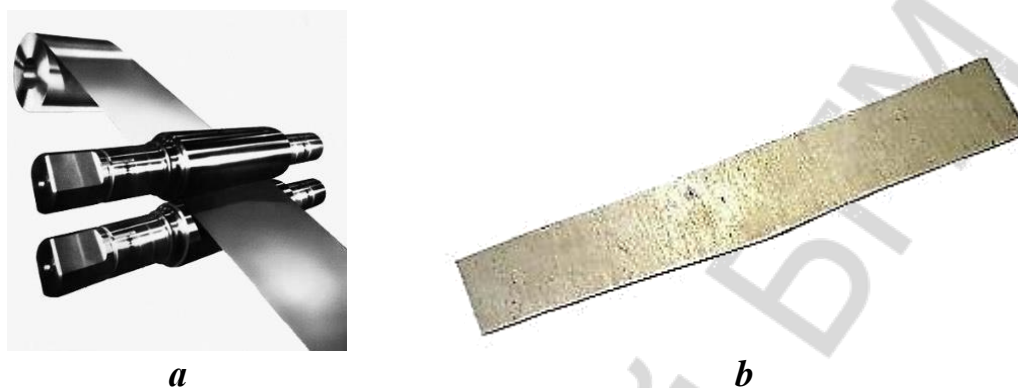


Fig. 2. Two rolling cylinders of a rolling device press a plate (*a*) to produce tape strips of flat profile with 0.3 mm thickness (*b*)

Cutting is a full detachment of a detail from the original pattern by full contour by inserting an instrument (fig. 3, *a*). Cutting is used for fabricate discs out of tape strips of golden or silver-palladium alloy (fig. 3, *b*), which are drawn into bushing afterwards.



Fig. 3. Cutting by full contour (*a*) of discs (*c*) out of the original tape pattern (*b*)

Drawing out — creating of a hollow product out of flat plate original pattern (fig. 4). Drawing out is used during manufacturing of standard bushings of stainless steel, during their warping and for manufacturing bushings out of golden and silver-palladium discs with the help of “Samson” and Sharp’s apparatus.

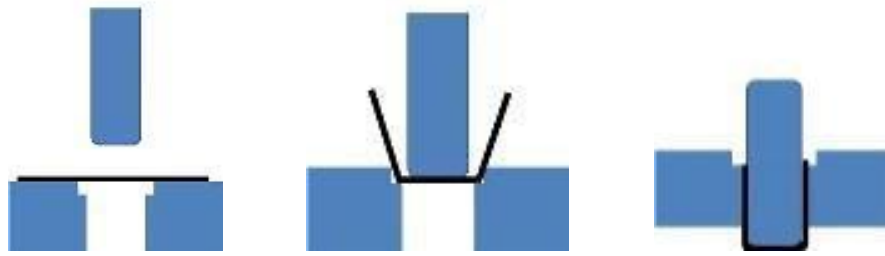


Fig. 4. Making of a hollow product out of flat plate original pattern

«*Samson*» apparatus is a press for manufacturing bushings out of discs of golden and silver-palladium alloys and drawing of steel dental bushings *with decreasing their sizes* (fig. 5, a). Apparatus is constructed as a manual press and consists of metallic plates with holes of different diameter, which are called matrix, and a movable plate with cylinder pins fixed on it — the punches. Diameter of the punch is smaller than the diameter of the corresponding hole in matrix, and the difference between them is equal to the thickness of disc or bushing. To receive a bushing of certain diameter a standard bushing or disc are placed into the corresponding hole of matrix and the punch is carried out to motion. Punch draws the disk through the hole, giving it a cup shape (bushing). After drawing the bushing several times through the holes of decreasing diameters, the necessary diameter of the bushing is received.

Sharp apparatus is a press for producing bushings of golden and silver-palladium discs and redrawing of steel dental bushings to decrease their sizes (fig. 5, b). It consists of a steady frame, two discs secured in it, and a screw with a handle. Lower disc has holes of diameters ranging from 24 to 3 mm. Upper disc contains punches which number is equal to the number of holes on lower disc. When screw is turned with a handle, the punch directs metallic bushings, drawing it through the holes of lower disc.

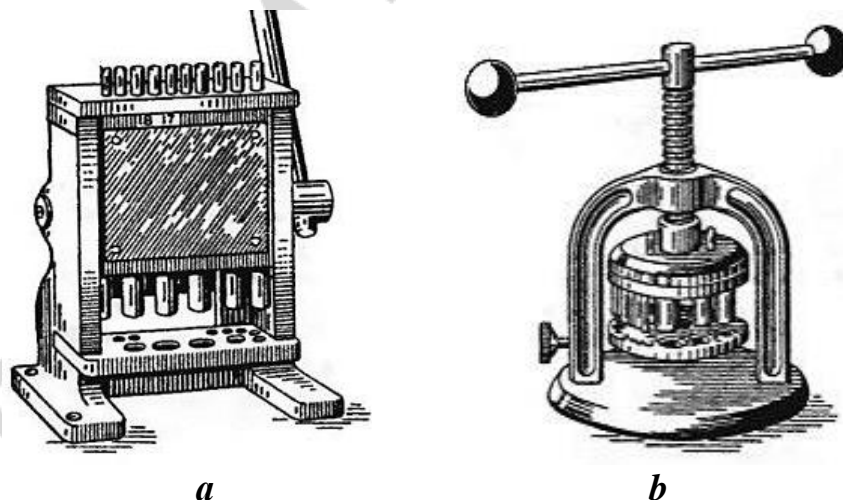


Fig. 5. Apparatus «Samson» (a) and Sharp (b)

Flexing (bending) of metal is an operation of giving to the pattern or its part a needed configuration. In dentistry flexing of a clasp wire leads to creating of

retentive elements of removable dentures (clasps), flexing of orthodontic wire forms active and retentive elements of orthodontic apparatus etc. Crampon pliers, round nose pliers and other tools are used for flexing of wire.

Pliers (tongs) is a general name of tools which are constructed as two flat or half-round working edges with handles which are drawn apart on hinges. Pliers are manufactured of stainless or carbon steel. When carbon steel is used, the nickel coating is applied onto the tongs. Pliers are used for pressing or bending (flexing) of wire. Crampon pliers are universal pliers, used to hold, bite through, bend or press different metal materials used in laboratory fabrication of dentures (fig. 6, *a*). Round nose pliers are the pliers with round cross-section edges, which are used for bending of vestibular metal arches, clasps (fig. 6, *b*). Beak pliers are a type of flat nose pliers, in which edges come into contact in spherical plane (fig. 6, *c*). Beak pliers are used for forming of edges of stamped crowns.

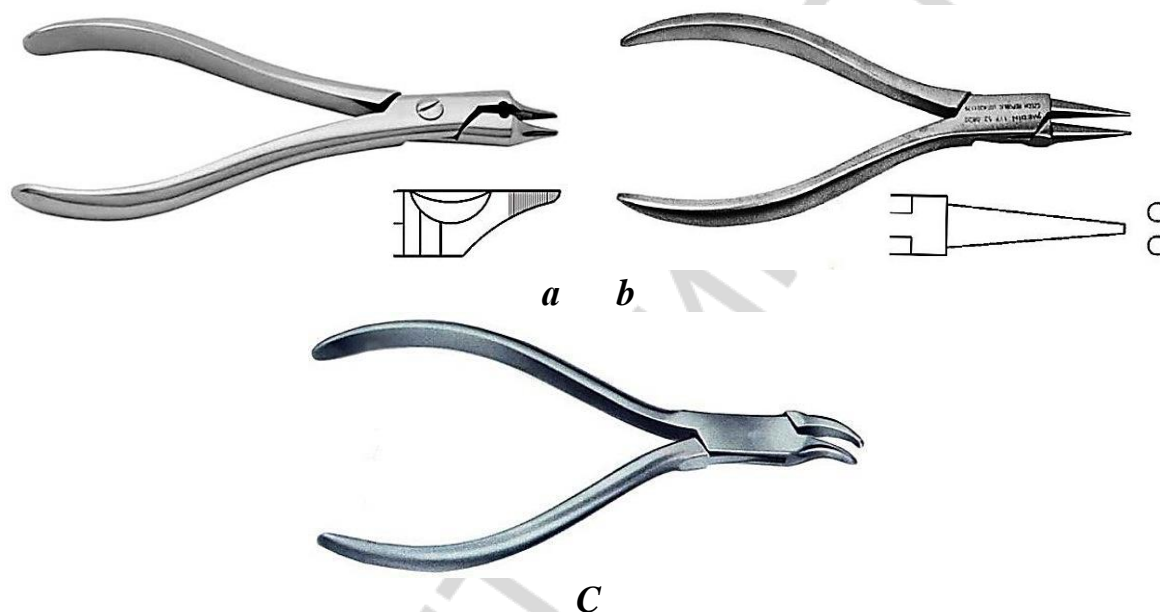


Fig. 6. Crampon pliers (*a*), round nose pliers (*b*), beak pliers (*c*)

Twisting — means turning of pattern's part around longitudinal axis. Multiple turning for 360° gives to the pattern a winding character. Some endodontic instruments are made by twisting as well as orthodontic wires, by twisting 3 or 6 slim steel wires (fig. 7).



Fig. 7. Orthodontic wire, made by twisting of 7 slim steel wires

Forging is a method of processing of metal alloys by gradual deformation of the material by pressure without using any molds. A process of forging usually

precedes the process of stamping. In dental laboratory forging takes place during manufacturing metal crowns, during flattening of clasp wire, arches of orthodontic apparatus etc. Such tools as dental anvil and dental hammer are used for forging.

Dental anvil is a tool, constructed of massive round metal support, which has in the centre a round rack of 10 cm height and is secured in the support with a screw-thread (fig. 8, *a*). Metal pins (mandrels) of various shapes (conoid, rounded, screwdriver-like etc.) are pressed horizontally and with angle inclinations onto the rack and support. Forging of crown is done on the mandrels for its preshaping or for fixing a fold on the crown.

Dental hammer is a tool, used for producing impact during forging of metals in dental lab (fig. 8, *b*). The main part of the hammer is the lightweight hitting part, fabricated of steel or brass. The hitting part is set onto wooden or plastic handle for convenient producing of impact.

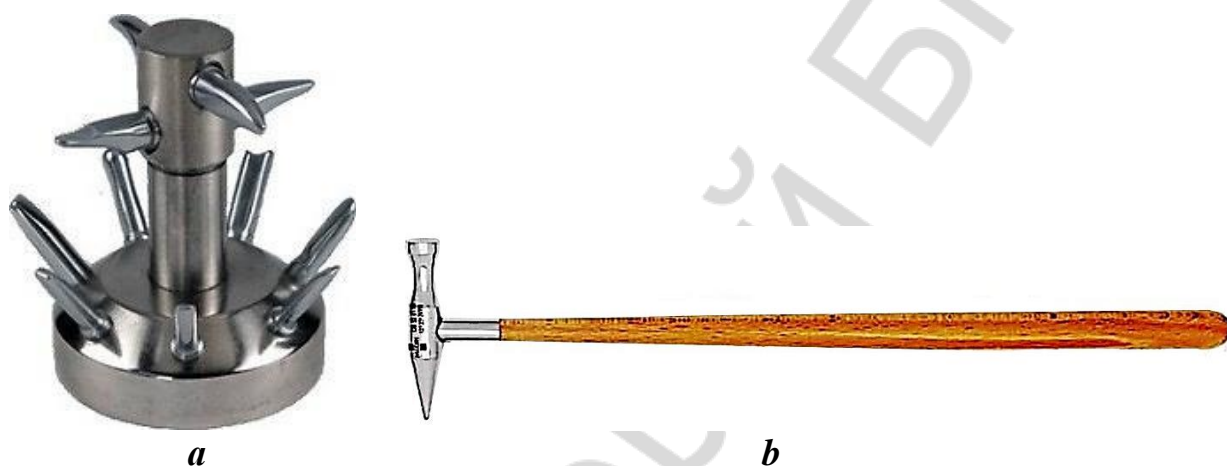


Fig. 8. Dental anvil (*a*) and hammer (*b*)

Stamping is a method of processing of metal alloys by pressure relatively to the walls of previously prepared mold, which fully determines configuration of the future product. Stamping technology is used in fabrication of artificial crowns of golden, silver-palladium alloys and stainless steel, and titanium bases of removable partial dentures as well.

Stamping of artificial crowns is a method of processing of metal alloy patterns (bushings) by pressure relatively to the walls of previously prepared mold (stamp) of low-fusible metal alloy. Such methods as external stamping and combined stamping are distinguished.

External stamping of artificial crowns is a method of producing of artificial crowns of stainless steel or noble alloys of metals with the help of Parker apparatus by pressing onto the external surface of metal bushing and giving it the configuration which will fully correspond to the mold, prepared of low-fusible alloy (fig. 9, *a*).

Parker Apparatus is an apparatus for external stamping of artificial crowns. It consists of hollow base and a cylinder entering it. The base is filled with moldin (mixture of white clay and glycerine) or vulcanized rubber. A bushing on the stamp is placed into this mass, its crown part has to be placed deeper into

the mass (fig. 9. *b*). Hammer's impact or action of the press proceed the stamping. Under impact the mass is getting more dense, passing the pressure equally onto the external surface of the bushing. Therefore moldin presses the bushing around stamp tightly. Final stamping can be done in special mechanic, hydraulic presses (fig. 9, *c*), which produce in the cylinder pressure of 2–3 atm.

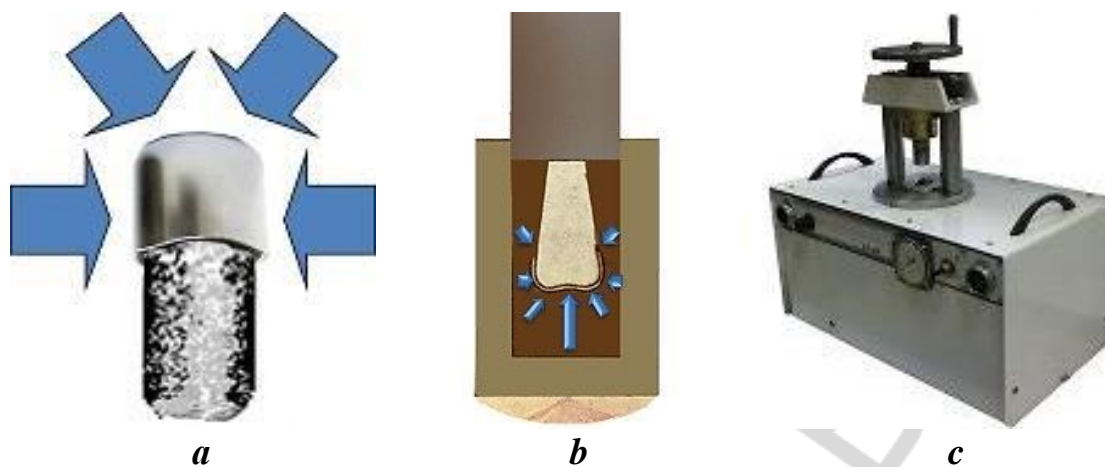


Fig. 9. Scheme of external stamping of artificial crowns (*a*) in Parker apparatus (*b*) with the use of hydraulic press (*c*)

Combined stamping of artificial crowns is a method of producing artificial crowns of stainless steel or noble alloys with the use of Bromstrom apparatus by pressing onto external and internal surfaces of metallic bushing for giving it the configuration which fully corresponds to the prepared molds of low-fusible alloy (methodic of Moscow medical dental institute — MMDI).

Bromstrom apparatus (methodic of MMDI) is a device for combined stamping of metal crowns, in which stamp and contra-stamp are made of low-fusible metal alloy (fig. 10).

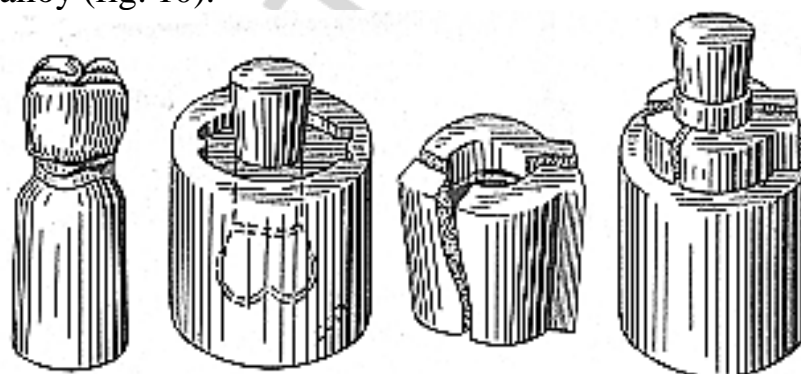


Fig. 10. Bromstrom apparatus (methodic of combined stamping)

THERMAL PROCESSING OF METAL ALLOYS

Thermal processing of metal alloys is a conduction of controlled heating and cooling of metal or metal alloy for receiving a modification of its mechanical or physical characteristics without changing chemical composition. In a result of thermal processing internal tension and distortions of crystal structure disappear in

the alloy, physical-mechanical properties are restored: hardness decreases, plasticity and viscosity increase. *Plastic deformation* leads to changing of physical properties of the metal. All internal changes, which occur under plastic deformation, induce strengthening of the metal. Strengthening characteristics (temporary resistance, yield strength, hardness) increase, and plastic ones — decrease. Strengthening of metal under plastic deformation influence is called *cold-hardening*. Metals with cold-hardening are more inclined to corrosive destruction during their application. The metals are processed with recrystallization annealing for full removal of cold-hardening. Recrystallization — is a process of appearance and growth of new undeformed crystal grain of polycrystal at the expense of other grains. Recrystallization is applied practically for giving to the material maximal plasticity. And it occurs more intense with high temperature in the materials which were plastically deformed. Temperature of recrystallization has an important practical meaning. To restore structure and properties of cold-hardened metal (for example, to continue stamping of the crown under press after previous forging of the bushing on low-fusing metal stamp), it should be heat above temperature of recrystallization.

Annealing is a thermal processing of materials, which means their heating till certain temperature, keeping it and slow cooling down. Its purpose is to improve structure and processability, remove internal tensions etc. Open flame is used for thermal processing of metal alloys. Annealing is used during stamping of crowns from steel and golden bushings. Thermal processing of stainless steel details for removal of cold-hardening and increasing of mechanical properties is carried out by heating of the detail till 1000–1100 °C with the following cooling on air. Thermal processing of golden alloys is reached by heating of disc or detail in the flame of soldering device till red color with the following slow cooling on air.

Chilling (hardening) is a type of thermal processing of metal details, which means their heating above critical temperature (temperature when the type of crystal cell changes) with the following fast cooling, as a rule, in liquid (water or oil). The material after chilling receives bigger hardness, but becomes fragile, less plastic and viscose. As a method of thermal processing of metal alloys chilling *is not used in dentistry*.

Dross is an oxide film, which appears on the surface of metallic dentures during their thermal processing. For chemical removal of the dross, bleach solutions are used.

CASTING OF METAL ALLOYS

Melting of metals and their alloys is a technological process of receiving “liquid melt” for its following casting into molds. Heating temperature, at which the alloy starts melting, is called “solidus point”. On the further heating the alloy gets more and more fluid, until the melting of last crystal grains occurs, and finally becomes liquid. This moment is called “liquidus point”. For reaching optimal flowability and maximal fine structure, the alloy should be overheated

before casting but not more than 100–150 °C above melting temperature. The state of the alloy between liquidus point and the moment of pouring is called “liquid melt”. Pouring point can't be exceeded, otherwise the melt will be excessively heat, and during its cooling down the disorders in crystalline structure will occur.

Methods of melting metals and their alloys — to receive “liquid melt” in dentistry such methods as melting by open flame, melting in arc furnaces and induction furnaces, melting in electrical furnaces of resistance are used.

Melting of metals and their alloys with open flame is a method of melting the metal with the help of torches (devices for maintaining the burning process of liquid, gas or dusty fuel).

Acetylene torch is a device, meant for manual welding, soldering and heating of metals, using mixture of oxygen and acetylene as the combustible. Oxygen and acetylene are produced in balloons at oxygen-acetylene fabrics. Acetylene device for welding, cutting and melting metals consists of two balloons (acetylene and oxygen) with reducers on balloons' valves, rubber hoses and acetylene torch, made by principle of gasoline soldering torch. To melt the metal, the valves of gas balloons are opened, gas comes to the torch by hoses, and the inflammable mixture is created. Torch is regulated till neutral flame (reddish colour) and directed onto the metal in crater-like widening of the flask. Oxygen-gas mixture during burning provides combustion temperature of 2500–3000 °C.

Gasoline torch is a device for mixing of air (oxygen) with fluid fuel (gasoline), meant for soldering, annealing of steel bushings and melting of some golden alloys by open flame. Burning of air with gasoline provides temperature of 1100–1300 °C. Such temperature can allow melting of gold-containing alloys.

Gas torch it's a torch, which has injector, installed in the metal tube with holes for air income, which is secured on the base with side delivery of gas. During work process stream of gas goes out of injector orifice with big speed, creating underpressure in the tube. Thanks to this underpressure, the surrounding air is injected (sucked) into the torch through holes in the tube, and during moving up along the tube it is mixed with the gas, making inflammable mixture, which is fired on the exit of torch. The torch is used for soldering of details with low-fusible solders, heating and melting of materials. It is used in dental laboratories, when open flame with average heat power is needed (till 1300 watts). Natural (methane) or liquefied gas (propane-butane mixture) are used as a fuel for the torch. Combustion temperature of the mixture reaches 2000 °C.

Spirit torch (spirit lamp) it's a torch, in which spirit is used as fuel. Laboratory spirit lamp consists of a capacity for spirit and a cap, through which a wick pass (fig. 11, a). In dental laboratories spirit lamp is used for melting of low-fusible alloys, during modelling and other works. Spirit lamp flame provides temperature till 900 °C.

Melting of metals and their alloys in arc furnaces is a method of melting metals and metal alloys with the use of electric arc.

Electric arc (voltaic arc, arc) is a physical phenomenon, one of types of electric discharge in gas. Electric arc appears between two electrodes with direct

current. Electric arc is used in dentistry for melting of base alloys of metals in arc melting devices.

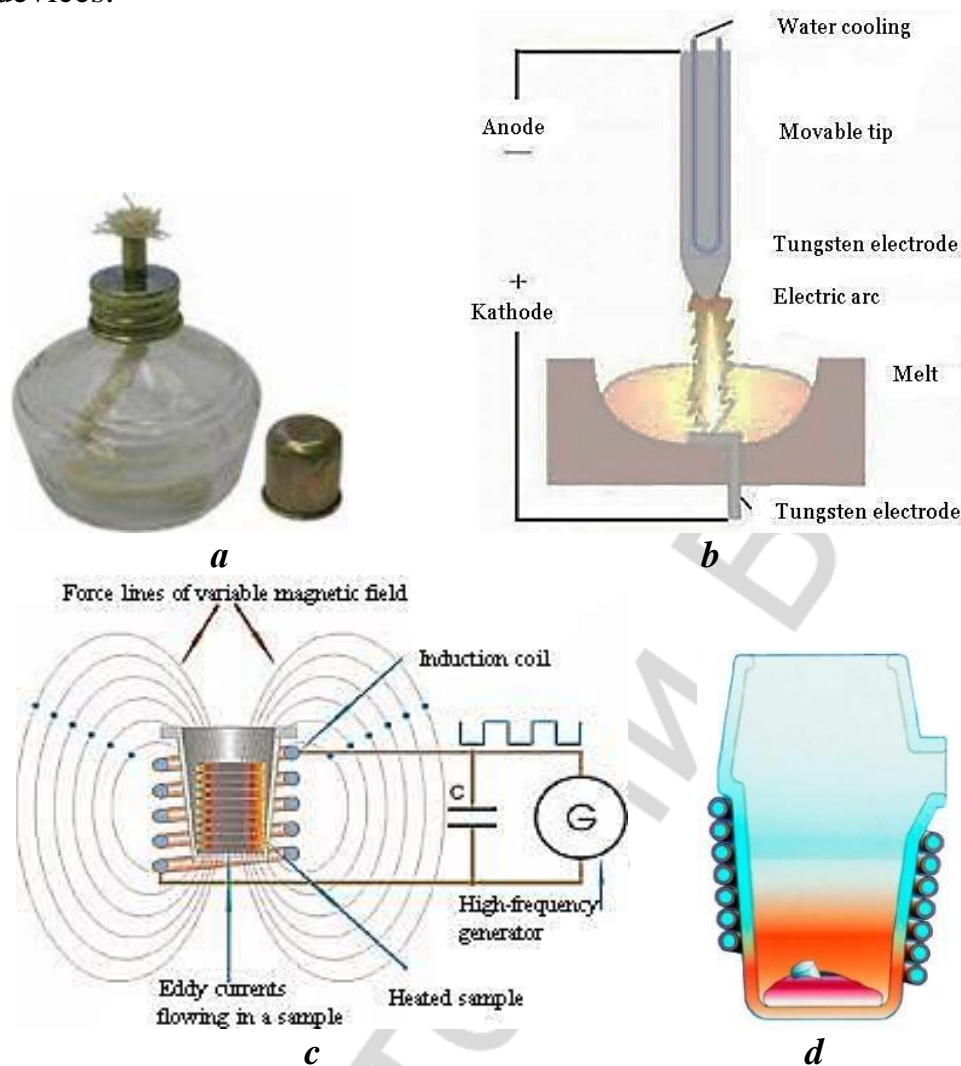


Fig. 11. Apparatuses and devices used in dentistry for melting of metals and their alloys: *a* — spirit torch; *b* — electric arc furnace; *c* — induction furnace; *d* — electrical resistance furnace

Arc settings for melting metals and their alloys are the devices meant for melting with the help of electric discharge (fig. 11, *b*). Anode (negative electrode) has water cooling and is made of tungsten. This is the movable construction during melting. Kathode (positive electrode) is situated in the base of crucible. During melting both electrodes approach each other until electric arc of the direct current appears and connects them. This electric arc has the temperature of 4000 °C and may lead to overheating of the melt. Besides, controllable and repeatable melting of the alloy is impossible. This method is unacceptable for melting of noble alloys, because a big amount of brittle structures appears in the cast.

Melting of metals and their alloys in induction furnaces is a method of melting metals and their alloys with the help of electromagnet induction (electric and magnet induction are values, which characterize electromagnetic field).

Electric furnace works as a transformer in which water-cooled inductor is the primary winding, and metal in crucible is the secondary winding and the load as well. Voltage of high frequency from induction coil affects the molten alloy. Inside of ceramic or graphite crucible the eddy currents appear. Alternating magnetic field heats the alloys and leads to its melting (fig. 11, c).

Electrical furnace of resistance (EFR) is an electrothermal setting, in which heat is produced due to current passage in the conductor. Heating is provided by resistance of the conductor coil during current passage. Heating coil holds below the output tray, into which crucible with the melt is installed. The heat of the coil passes to the crucible and the alloy (fig. 11, d). In dentistry electrical resistance furnace is widely used for melting of alloys of metals.

Casting, technologies of casting, devices and auxiliary materials, used for casting.

Casting is a technological process of manufacturing items by pouring molten metal or alloy of metal, which is in the liquid phase, into a special mold where it gets solid. In dentistry the following methods of pouring metal into molds are used: free casting, casting under pressure, centrifugal casting, vacuum casting.

Free casting — metal fills the mold free, under gravitation forces. Free molding is used only for casting of low-fusible alloys of metals into gypsum molds.

Casting under pressure — metal fills the mold, which appeared after burning out of wax, under the pressure of 3.5 Bar, produced by a piston or air with the use of casting machines. Casting under pressure delivers more tight casts, excludes porosity, underfills, shrinkage voids.

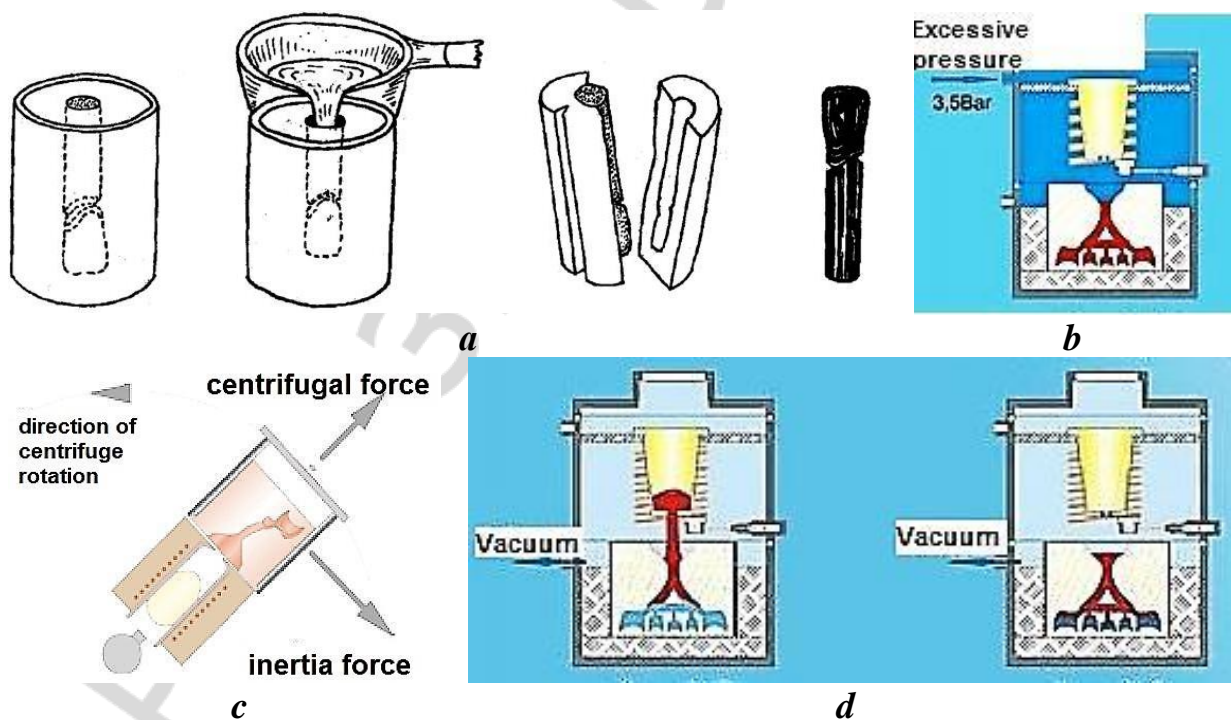


Fig. 12. Methods of pouring metal into molds: a — free casting; b — casting under pressure; c — centrifugal casting; d — vacuum casting

Centrifugal casting is pouring of the alloy into rotating mold by centrifuging. Metal fills refractory mold under gravitation and centrifugal force.

Vacuum casting is pouring of the melt by vacuum suction. Only closed processes of melting with the use of resistance furnaces or induction furnaces can work. Vacuum creates underpressure of air in the casting mold, decreasing resistance for its filling by metal during casting. The melt fills the mold under gravitation and underpressure action. External pressure is used for maximal full filling of the cast with the melt.

Tools used in casting technology of metal alloys: sprue base, casting ring, and auxiliary materials (sprue forming pins, sprue, reservoir etc).

Crucible former (sprue base) is a conoid metallic or polymer hollow tool, used for creating a space for molten metal passage into crucible during casting (fig. 13, a).

Crucible (casting ring, casting box) is a hollow cylinder of various sizes, made of metal alloy or polymer material, installed onto crucible former and used for investing of wax models and sprue systems by refractory materials (fig. 13, b).



Fig. 13. Sprue base (crucible former) (a) and casting ring (b), used for making crucible and sprue system

Sprue formers are wax or ashless plastic patterns of 1.5–4 mm diameter, used to form casting channels in investment material (fig. 14, a).

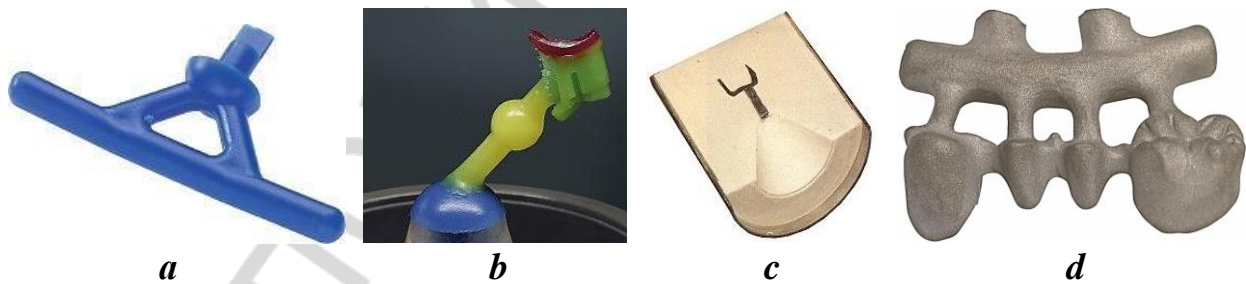


Fig. 14. Sprue formers (a), sprue reservoir (b), casting mold (c) and a cast (d)

Casting channel is a channel in investment material, meant for filling the mold with molten metal by casting.

Sprue reservoir is a depo for constructional material, made out of wax model for decreasing shrinkage of the material and liquation (fig. 14, b).

Casting mold is a system of elements, including refractory investment material with the cavity inside, which is filled with molten metal during casting and therefore forms the cast (fig. 14, c).

Sprue system is a system of channels, through which the molten metal is delivered into molds.

A **cast** is the product, received at pouring of liquid metal into casting mold (fig. 14, d).

Sprue trunk is the excess of constructional material, which got solid inside of casting channel after casting.

Segregation is heterogenous crystallization of alloy in some parts of the cast. In golden, steel and other alloys one of most heavy components segregates from the rest of the mass in liquid phase, due to difference of densities. This process depends on the speed of cooling down and alloy type. Segregation can be decreased by lowering heating temperature, increasing speed of pouring the metal and slowing down of its cooling, as well as introducing into the metal the additives which create cryptocrystalline structure (nickel for stainless steel, molybdenum — for cobalt chrome alloy). Segregation decreases strength properties, corrosion resistance and plasticity.

THE CAD/CAM TECHNOLOGY

The CAD/CAM technology — the automated production of dentures by means of computer modeling and milling on machines with numerical program control. For milling preparations from cobalt-chrome, nickel-chrome, titanium-aluminum-vanadium alloys and titan (99.5 %) with a diameter up to 100 mm and thickness from 10 to 30 mm are used.

Milling (milling processing) — processing of materials by cutting them with the help of a mill. In the process of milling two objects — the rotating mill and preparation (future detail) participate.

Computer-aided design (CAD) is the use of computer systems to assist in the creation, modification, analysis and optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. CAD output is often in the form of electronic files for print, machining, or other manufacturing operations.

CAD may be used to design curves and figures in two-dimensional (2D) space; or curves, surfaces, and solids in three-dimensional (3D) space.

CAD is an important industrial art extensively used in many applications, including automotive, shipbuilding, and aerospace industries, industrial and architectural design, prosthetics, and many more.

Computer-aided manufacturing (CAM) is the use of computer software to control machine tools and related machinery in the manufacturing of workpieces. This is not the only definition for CAM, but it is the most common, CAM may also refer to the use of a computer to assist in all operations of a manufacturing plant, including planning, management, transportation and storage.

CAM is a subsequent computer-aided process after computer-aided design (CAD) and sometimes computer-aided engineering (CAE), as the model generated

in CAD and verified in CAE can be input into CAM software, which then controls the machine tool.

Traditionally, CAM has been considered as a numerical control (NC) programming tool, where in two-dimensional (2-D) or three-dimensional (3-D) models of components generated in CAD with other “Computer-Aided” technologies, CAM does not eliminate the need for skilled professionals such as manufacturing engineers, NC programmers, or machinists. CAM, in fact, leverages both the value of the most skilled manufacturing professionals through advanced productivity tools, while building the skills of new professionals through visualization, simulation and optimization tools.



Fig. 15. Sequence of CAD/CAM technology

The majority of CAD/CAM systems include the information module for obtaining the image, the computer module for information processing and modeling of the denture (CAD-module), the milling module with computer management for production of the denture (CAM-module). Receiving the information of an object is provided by means of the intraoral camera, the stationary scanner or the contact profilometer.

In the conditions of clinic intraoral cameras (optical 3D scanners) allowing obtaining of the optical “impression” — three-dimensional display of prosthetic tissues, are used. Light reflected from prosthetic tissues by means of the photosensor is transformed to a stream of electric impulses which are quantized and transferred to the computer for further processing.

In the conditions of a dental laboratory transformation of the received information to the digital format accepted for computer processing is carried out by scanning of plaster model by the special device with the laser or the optical

scanner. The following fabrication stage of CAD/CAM restorations — computer modeling of a design of the denture. By means of a special computer program (CAD-module) the denture is designed on a virtual model. Computer programs contain standard shapes of teeth or the catalog of the teeth created individually. The virtual model of the denture can always be “removed” from model to consider in any perspective and in any section.

Information of the dentures containing in files can be used for carrying out the following milling in special devices.

Machines with the numerical program control (NPC) are used for milling. The important characteristic of the machines used for CAM milling is the quantity of freedom degrees during processing of the detail. The machines used in dentistry can be 3, 4 and 5 axial. The more freedom degrees, the detail with the bigger complexity can be made.

Artificial crowns and frameworks of ceramic-metal dentures can be made by milling with the use of CAD/CAM technologies (fig. 16).



Fig. 16. Frameworks of metal dentures from Co-Cr alloy (a) and Ti-Al-V alloy (b) made by milling with the use of CAD/CAM technology

TECHNOLOGY OF METAL ALLOYS SELECTIVE LASER SINTERING

SLS (Selective Laser Sintering) — creation of three-dimensional object from powdery materials with their agglomeration by means of the CO₂ laser (fig. 17). A powder of cobalt-chrome alloy, titan and its alloys with a grain size < 85 microns is used for selective laser agglomeration of dentures.

Sequence of the SLS technology:

- Powder with a layer of 0.15 mm is applied on a mobile bottom of the installation.
- A laser burns out a contour of the first layer of the detail. Powder under the laser beam influence is sintered.
- The mobile bottom lowers on 0.15 mm.
- The new layer of the powder is put over the first layer.

- The laser burns out a contour of the second layer detail and “cauterizes” it to the first.
- The cycle is repeated before the full formation (cultivation) of the detail.

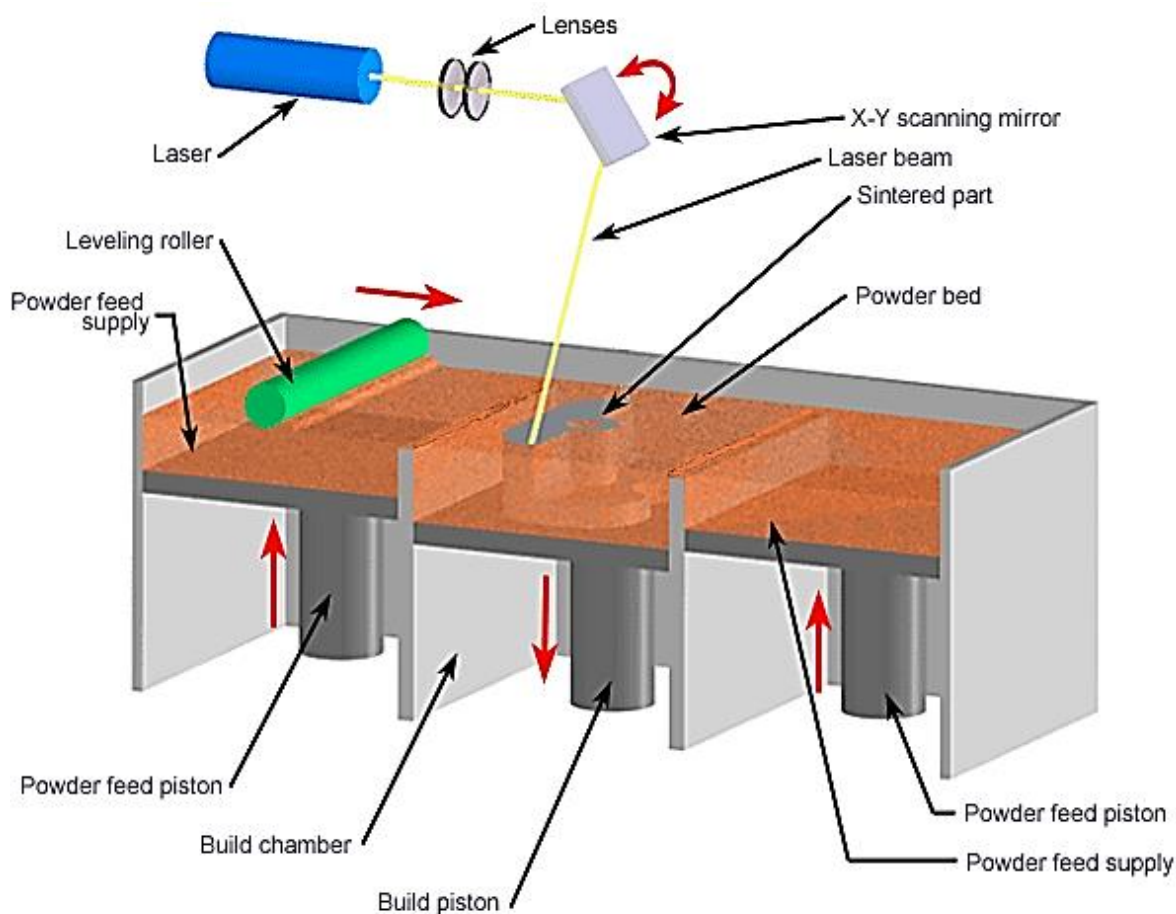


Fig. 17. Structure of the SLS technology

Fixed dentures (crowns, frameworks of ceramic-metal bridges of a small extent), frameworks of the cast removable dentures and implants can be made by the SLS technology (fig. 18).



Fig. 18. Metal crowns (a) and metal framework (b) of the cast removable denture made by SLS technology

TECHNOLOGY OF METALS AND METAL ALLOYS SINTERING IN FORMS

MIM (Metal Powder Injection Molding) — the use of initial raw materials in the form of metal and nonmetal powders which are formed into products of given sizes and are exposed to the heat treatment at a temperature below a melting point of the main component.

Raw materials for production of MIM technology details are fine metal powders and the alloying elements in fraction from 1 to 20 microns, mixed with thermoplastic binder (softener).

The metal powder is mixed with the softener (such composition is called granulate) and is loaded into the bunker of the casting machine. Melting of polymeric binding happens at a temperature from 170 °C to 200 °C, granulate turns into the uniform weight and fills in under pressure the compression mold heated to temperature from 125–145 °C where it is hardened. The semi-finished product consisting of the metal powder and the softener and keeping the detail geometry after molding operation turns out. Then the semi-finished product is put into the furnace for removal of the binder where under the influence of 110–140 °C in the presence of nitric acid and in a stream of inert gas from it the binder is removed. Further the semi-finished product gets into the special high-temperature furnace with the adjustable atmosphere (vacuum, nitrogen, hydrogen depending on a brand of the cemented material) where at temperatures of 1290–1400 °C there goes a sintering of its particles, and formation of a ready detail. Implants, braces, etc. are made by the technology of metals and metal alloys sintering in the forms (fig. 19).

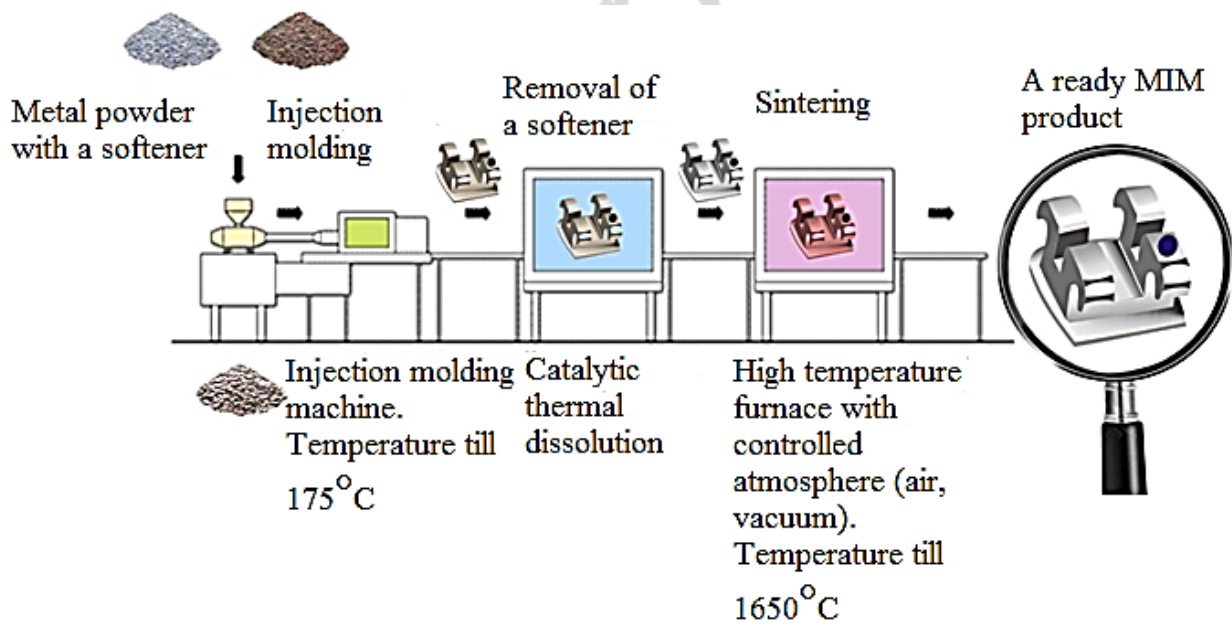


Fig. 19. Sequence of the MIM technology

ELECTROEROSIVE (ELECTRODIGIT) METHODS OF PROCESSING

Electroerosive methods are based on the use of an electric erosion phenomenon — the directed local destruction of electroconductive materials as a result of thermal action of pulse electric discharges between an electrode-

instrument and an electrode-preparation. The electrode-instrument made of copper or graphite and the processed preparation from a cobalt-chrome alloy or a pure titan have to be shipped in the working liquid (oil, the distilled water, etc.) and also connected to the generator of electric impulses. At a supply to electrodes of an electric impulse in the interelectrode interval there is a local maximum of the electric field intensity, therefore in this place there is an electric breakdown, it means that the carrying-out canal with a high concentration of free charge carriers is formed. Current between electrodes increases. Ions move on this channel to the cathode, and electrons — to the anode. Under the influence of these streams of surfaces of electrodes are exposed to the strengthened heating. In this place metal melts and evaporates, the hole of a spherical form is formed.

Electroerosive processing is used for adhesive properties of the metal surface improvement due to the microretentional surface creation, elimination of individual molding defects, production of telescopic crowns with a frictional pin.

TECHNOLOGY OF THE PLASMA APPLYING

The technology of ion-plasma coverings applying belongs to the vacuum methods and is carried out by arc evaporation of metals with the synchronous processing of coverings by the bunch of gas ions that modifies a composition and a structure of the evaporated layer directly during the process of coverings applying. The spraying of special coverings over the products is carried out for giving demanded physical and chemical, mechanical, biological properties to them.

By means of these vacuum methods of protective and decorative coverings applying it is possible to form layers of various metals and their alloys: titan, zirconium, aluminum, silver, chrome, nickel, niobium, tantalum, stainless steel, titan nitride, zirconium nitride, titanium dioxide, zirconium oxide, aluminum oxide, the titan oxycarbide, zirconium oxycarbide, titan carbonitrid, etc. The vacuum ion-plasma dusting is finishing operation. The subsequent mechanical processing of details, their soldering, welding aren't allowed.

Galvanotechnics — the section of applied electrochemistry which includes galvanoplastics and galvanization.

Galvanoplastics — receiving rather thick layer of metal rainfalls on a surface of any subject. At the galvanoplastics rainfall are massive, strong, easily separating from the covered surface. The method of the galvanoplastic is used in dentistry for production of single ceramic-metal crowns from gold (99.9 %) with the thickness from 200 to 300 microns (fig. 20).



Fig. 20. A metal-ceramic crown where metal core is made of gold by galvanoplastics

Galvanization — an electrolytic precipitation of a thin layer of the metal on a surface of any metal subject for its protection from corrosion, for the wear resistance increase, in the decorative purposes, etc. Galvanization is applied in dentistry in the decorative purposes by precipitation of gold on a surface of removable dentures full-cast frameworks from cobalt-chrome alloys and in manufacturing techniques of diamond abrasive tools.

TECHNOLOGIES FOR CONNECTING PARTS OF DENTURES TOGETHER

Soldering is a process in which two or more metal items are joined together by melting and flowing a filler metal (solder) into the joint, the filler metal having a lower melting point than the workpiece. Soldering differs from welding in that soldering does not involve melting the work pieces. In brazing, the filler metal melts at a higher temperature, but the workpiece metal does not melt. Formerly nearly all solders contained lead, but environmental concerns have increasingly dictated use of lead-free alloys for electronics and plumbing purposes.

Solder is a fusible metal alloy used to join together metal workpieces and having a melting point below that of the workpieces.

Soft solder is typically thought of when solder or soldering is mentioned, with a typical melting range of 90 to 450 °C. It is commonly used in electronics, plumbing, and assembly of sheet metal parts. Manual soldering uses a soldering iron or soldering gun. Alloys that melt between 180 and 190 °C are the most commonly used. Soldering performed using alloys with melting point above 450 °C is called “hard soldering”, “silver soldering”, or brazing.

Golden solder — Au (75 %), Cd (5 %), Cu (13 %), Ag (5 %) with melting temperature 821 °C and is used for connecting parts of golden.

Silver solder (IICP-37) — Ag (37 %), Cu (10 %), Ni (4 %), Cd (0.5 %) other metals (20 %), melting temperature is 800–850 °C. It is used for connecting parts of steel dentures.

Solder for Co-Cr alloys — Co (60.5 %), Cr (28.5 %), Fe (1.5 %), Mo (3 %), Si (4 %), C (0.5 %), Mr (1.5 %) and B (1 %). Melting temperature is 1100–1150 °C, temperature of soldering 1180 °C (Wirobond – Solder, BEGO, Germany).

Solder for Ni-Cr alloys — Ni (66 %), Cr (19 %), Fe (5 %), Mo (5.5 %), Si (3.5 %) and B (1.0 %). Melting temperature is 1020–1150 °C, temperature of soldering 1165 °C (Wiron – Solder, BEGO, Germany).

Soldering flux. In metallurgy, a flux (derived from Latin fluxus meaning “flow”), is a chemical cleaning agent, flowing agent, or purifying agent. Fluxes may have more than one function at a time. They are used in both extractive metallurgy and metal joining.

Some of the earliest known fluxes were carbonate of soda, potash, charcoal, coke, borax, lime, lead sulfide and certain minerals containing phosphorus. Iron ore was also used as a flux in the smelting of copper. These agents served various functions, the simplest being a reducing agent which prevented oxides from forming on the surface of the molten metal, while others absorbed impurities into

the slag which could be scraped off the molten metal. As cleaning agents, fluxes facilitate soldering, brazing, and welding by removing oxidation from the metals to be joined. Common fluxes are: ammonium chloride or rosin for soldering tin; hydrochloric acid and zinc chloride for soldering galvanized iron (and other zinc surfaces); and borax for brazing or braze-welding ferrous metals.

In the process of smelting, inorganic chlorides, fluorides (see fluorite), limestone and other materials are designated as “fluxes” when added to the contents of a smelting furnace or a cupola for the purpose of purging the metal of chemical impurities such as phosphorus, and of rendering slag more liquid at the smelting temperature. The slag is a liquid mixture of ash, flux, and other impurities. This reduction of slag viscosity with temperature, increasing the flow of slag in smelting, is the original origin of the word flux in metallurgy. Fluxes are also used in foundries for removing impurities from molten nonferrous metals such as aluminum, or for adding desirable trace elements such as titanium.

In high-temperature metal joining processes (welding, brazing and soldering), the primary purpose of flux is to prevent oxidation of the base and filler materials. Tin-lead solder (e. g.) attaches very well to copper, but poorly to the various oxides of copper, which form quickly at soldering temperatures. Flux is a substance which is nearly inert at room temperature, but which becomes strongly reducing at elevated temperatures, preventing the formation of metal oxides. Additionally, flux allows solder to flow easily on the working piece rather than forming beads as it would otherwise.

The role of a flux in joining processes is typically dual: dissolving of the oxides on the metal surface, which facilitates wetting by molten metal, and acting as an oxygen barrier by coating the hot surface, preventing its oxidation. In some applications molten flux also serves as a heat transfer medium, facilitating heating of the joint by the soldering tool or molten solder.

Fluxes for soft soldering are typically of organic nature, though inorganic fluxes, usually based on halogenides and/or acids, are also used in non-electronics applications.

Fluxes for brazing operate at significantly higher temperatures and are therefore mostly inorganic; KF, NaF, LiF and CaF are mostly added to composition of boric fluxes for soldering. The first three fluorides are used at the soldering temperature below 850 °C, while CaF is used at the soldering temperature above 850 °C.

Welding is a fabrication or sculptural process that joins materials, usually metals or thermoplastics, by causing coalescence. This is often done by melting the workpieces and adding a filler material to form a pool of molten material (the weld pool) that cools to become a strong joint, with pressure sometimes used in conjunction with heat, or by itself, to produce the weld. This is in contrast with soldering and brazing, which involve melting a lower-melting-point material between the workpieces to form a bond between them, without melting the workpieces.

Many different energy sources can be used for welding, including a gas flame, an electric arc, a laser, an electron beam, friction, and ultrasound. While often an industrial process, welding may be performed in many different environments, including open air, under water and in outer space. Welding is a potentially hazardous undertaking and precautions are required to avoid burns, electric shock, vision damage, inhalation of poisonous gases and fumes, and exposure to intense ultraviolet radiation.

Laser beam welding (LBW) is a welding technique used to join multiple pieces of metal through the use of a laser. The beam provides a concentrated heat source, allowing for narrow, deep welds and high welding rates. The process is frequently used in high volume applications, such as in the automotive industry.

Electron beam welding (EBW) is a fusion welding process in which a beam of high-velocity electrons is applied to two materials to be joined. The workpieces melt and flow together as the kinetic energy of the electrons is transformed into heat upon impact. EBW is often performed in conditions of vacuum in order to prevent dissipation of the electron beam.

Gas metal arc welding (GMAW), sometimes referred to by its subtypes metal inert gas (MIG) welding or metal active gas (MAG) welding, is a welding process in which an electric arc forms between a consumable wire electrode and the workpiece metal(s), which heats the workpiece metal(s), causing them to melt, and join. Along with the wire electrode, a shielding gas feeds through the welding gun, which shields the process from contaminants in the air. The process can be semi-automatic or automatic. A constant voltage, direct current power source is most commonly used with GMAW, but constant current systems, as well as alternating current, can be used. There are four primary methods of metal transfer in GMAW, called globular, short-circuiting, spray, and pulsed-spray, each of which has distinct properties and corresponding advantages and limitations.

Submerged arc welding (SAW) is a common arc welding process. It requires a non-continuously fed consumable solid or tubular (flux cored) electrode. The molten weld and the arc zone are protected from atmospheric contamination by being “submerged” under a blanket of granular fusible flux consisting of lime, silica, manganese oxide, calcium fluoride, and other compounds. When molten, the flux becomes conductive, and provides a current path between the electrode and the work. This thick layer of flux completely covers the molten metal thus preventing spatter and sparks as well as suppressing the intense ultraviolet radiation and fumes that are a part of the shielded metal arc welding (SMAW) process.

REFERENCES

1. *Anusavice, K. J.* Phillips's science of dental materials / K. J. Anusavice. 12th ed. Elsevier, 2013. 572 p.
2. *Van Noort, R.* Introduction to Dental materials / R. Van Noort. 2nd ed. 2002. 298 p.
3. *Manappallil, J. J.* Basic dental materials / J. J. Manappallil. 3rd ed. Jaypee Brothers Medical Publishers (P) Ltd., 2010. 441 p.
4. *McCabe, Jf.* AWG. Applied dental materials / Jf. McCabe. 8th ed., Blackwell, 2008. 303 p.
5. *O'Brien, W. J.* Dental Materials and Their Selection / W. J. O'Brien. 2nd ed. Quintessence Publishing Co., 2002.

РЕПОЗИТОРИЙ БГМУ

CONTENTS

Introduction.....	3
Metals and alloys of metals, used for production of dentures and appliances.....	3
Classification of metals.....	3
Properties of constructional metals and their alloys.....	7
Requirements for metals and alloys of metals, used in dentistry for fabrication of dentures.....	10
Classification, composition of constructional alloys.....	11
Classification of metal alloys.....	11
Constructional metals and alloys of metals (compositions).....	12
Forms of production of metals and their alloys for fabrication of dentures and other aims.....	14
Auxiliary alloys of metals.....	16
Instrumental alloys of metals.....	16
Solders.....	17
Technological processes of manufacturing dentures of metal alloys.....	18
Processing of metals by pressure.....	18
Thermal processing of metal alloys.....	23
Casting of metal alloys.....	24
The CAD/CAM technology.....	29
Technology of metal alloys selective laser sintering.....	31
Technology of metals and metal alloys sintering in forms.....	33
Electroerosive (electrodigit) methods of processing.....	33
Technology of the plasma applying.....	34
Technologies for connecting parts of dentures together.....	35
References.....	38

Учебное издание

Полонейчик Николай Михайлович
Гарабурда Дарья Викторовна
Метелица Кристина Игоревна

**МЕТАЛЛЫ И СПЛАВЫ МЕТАЛЛОВ В СТОМАТОЛОГИИ.
ТЕХНОЛОГИЧЕСКИЕ ПРОЦЕССЫ, ПРИМЕНЯЕМЫЕ
ПРИ ИЗГОТОВЛЕНИИ ЗУБНЫХ ПРОТЕЗОВ
ИЗ СПЛАВОВ МЕТАЛЛОВ**

**METALS AND ALLOYS OF METALS IN DENTISTRY.
TECHNOLOGICAL PROCESSES USED FOR PRODUCTION
OF DENTAL PROSTHESES OF METAL ALLOYS**

Учебно-методическое пособие

На английском языке

2-е издание

Ответственный за выпуск Н. М. Полонейчик
Переводчики Д. В. Гарабурда, К. И. Метелица
Компьютерная верстка Н. М. Федорцовой

Подписано в печать 21.02.18. Формат 60×84/16. Бумага писчая «Хероx office».
Ризография. Гарнитура «Times».
Усл. печ. л. 2,32. Уч.-изд. л. 2,5. Тираж 200 экз. Заказ 526.

Издатель и полиграфическое исполнение: учреждение образования
«Белорусский государственный медицинский университет».
Свидетельство о государственной регистрации издателя, изготовителя,
распространителя печатных изданий № 1/187 от 18.02.2014.
Ул. Ленинградская, 6, 220006, Минск.