THE USE OF CERAMIC MATERIALS IN ORTHOPEDIC DENTISTRY.
(Literature review)

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Today, the dental market offers a variety of ceramic materials for all types of indirect restorations: from veneers that do not require preparation to multi-link partial non-removable dentures for the chewing group of teeth. For successful treatment results, it is very important to know the properties of ceramic materials and systems. The problem of manufacturing orthopedic structures is difficult due to the fact that recently an increasing number of patients have put the aesthetics of orthopedic structures in the foreground and for this it is necessary to discover new materials or compounds that can satisfy the desires of patients in an aesthetic aspect. To substantiate the positive qualities of ceramic masses in orthopedic dentistry.

Keywords: *ceramics, aluminum oxide, glass ceramics, lithium disilicate.*

For successful treatment results, it is very important to know the properties of ceramic materials and systems. This article describes the main groups of modern ceramic masses. A detailed description and characterization of ceramics based on aluminum oxide have been carried out. The word "ceramics" comes from the Greek keramos, which means "baked earth". A more modern definition is materials that contain metallic and non-metallic elements (usually oxygen) [2]. They have a number of common properties due to the nature of their atomic bonds (ionic and covalent): hardness, inelasticity and brittleness. These characteristics are opposite to metals, which are non-brittle (exhibit an elastic nature) and plastic, due to the metallic bond of atoms. In addition, ceramics have a wide range of light transmission (from transparent to opaque) depending on the microstructure, different particle size and hardness, refractive index, porosity, etc. According to the microstructure, dental ceramics can be in glass form (amorphous composition) without a crystalline phase, in the form of glass with a small amount of substances in the crystalline phase, in the form of a material with a crystalline structure and a small addition of glass, as well as in the form of a polycrystalline structure (with a complete absence of glass). Depending on the manufacturing technique, the following types of ceramics are distinguished: powder-liquid for application, pressed and mechanically processed or machine ceramics [1].

Classification of ceramics by microstructure This classification divides ceramics according to the level of content of crystalline components and glass (non-crystalline structure) in it, which can be combined into 4 main categories with several subgroups.

1. Glass ceramics
2. Filled glass ceramics
3. Filled oxide ceramics
4. Oxide ceramics Glass ceramics consists of silicon oxide, also known as quartz (SiO_2) with a small aluminum content.

In nature, aluminosilicates, which also contain impurities of potassium and sodium, are known as feldspar. In dentistry, artificially synthesized feldspar represented the first ceramic masses for the manufacture of porcelain orthopedic structures

Due to the invention of vacuum furnaces for firing porcelain, the strength characteristics have been improved. The bending strength varied from 50 to 60 MPa and was achieved as a result of the resulting lower porosity of the material. Ceramics were used for cladding metal frames, as well as in the form of a solid structure for porcelain veneers made using refractory stamps or platinum foil [1]. However, the compression loads received during chewing still caused numerous chips in such restorations. Filled glass ceramics were developed by Corning Glass Works in the late 1950s. The basic principle of obtaining a solid material is its molding as a result of cooling of molten glass. During the sequential heating of the glass, a controlled crystallization process takes place, as a result of which crystals originate and grow. These transformations from pure glass to partially crystalline glass are also called ceramization. Thus, glass ceramics is a multiphase composition containing a residual glass phase with a finely dispersed crystalline phase. The number, growth pattern and size of the crystals are regulated by the time and temperature of the ceramic firing.

There are two important aspects in the formation of the crystalline phase – the nucleation of crystals and their growth. The level of these two processes is maximum at different temperatures. That is why the first firing takes place under conditions optimal for maximum crystal nucleation, after which the temperature rises and crystal growth occurs. The key to the strength of any glass ceramics is the ordered arrangement of crystals in large quantities in the glass phase. During ceramization, the crystalline phase grows and can occupy from 50 to almost 100 percent of the material.

There are 3 subgroups classified by crystalline fillers. The composition of the glass is almost the same as that of pure glass (category 1). Among the fillers, leucite, lithium disilicate or fluorapatite are isolated. Leucite in dental porcelain is obtained by increasing the potassium oxide content in aluminosilicate glass. Lithium disilicate crystals are embedded in an aluminosilicate matrix in the same way [2]. Feldspar glass ceramics with a low content of leucite In the 1980s, Horn actively used ceramics with a low content of leucite ($K\,Al\,Si_2\,O_6$) in his experiments for the structures of metal-ceramic restorations. In modern dentistry, such ceramics are called feldspar. Leucite was added to increase the coefficient of thermal expansion, as a result of which the material could be applied as a cladding layer. Initially, the bending strength of feldspar ceramics was 30-40 MPa. Recent developments in dentistry have made it possible to synthesize feldspar ceramics, which have smaller particle sizes and a more uniform distribution in a glass matrix, resulting in increased strength characteristics (bending strength up to 150 MPa).

The methods of its manufacture have also changed. Thus, powder-liquid formulations for cladding aluminum-based ceramic frames In-Ceram (Vita Zahnfabric) and Nobel Procera (Nobel Biocare) have been released. These materials have a low coefficient of thermal expansion (8x10-6/K). The most famous representative of VitaVM13 (Vita Zahnfabrik) [5]. Also, feldspar with a low content of leucite is used for fine-grained machine blocks [26]. Vita Mark 2 (Vita) blocks for the Seges Cad system (Sirona Dental), released in 1991, are the most famous product that is still used in dentistry under the same name. Studies performed by Vita prove the survival rate of inlays and onlays made of Vita Mark 2 material by more than 99% during the year [9-12].

In the structure of such feldspar ceramics, the particles are arranged randomly and have different sizes of leucite crystals (with an average particle size of 20 microns), as a result of which it has relatively low chip resistance and abrasive properties similar to enamel [29]. Nevertheless, feldspar ceramics have high transparency and, consequently, the highest aesthetic indicators [8]. Glass ceramics with a high content of leucite (up to 50%) An increase in the content of leucite led to the appearance of a new type of ceramics. Leucite ceramics with respect to feldspar have improved strength characteristics (greater resistance to thermal shock and chemical erosion, bending strength of more than 200 MPa), leucite crystals are able to resist the development of chips in finished ceramic structures, partially absorbing the energy of cracks [34]. However, due to the loss of transparency, the aesthetics of this ceramic is slightly lower than that of feldspar [32, 37]. The materials are available in the form of powder-liquid, blocks for machine processing, as well as in the form of pressed ceramics. The most widely used pressed ceramic IPS Empress (Ivoclar Vivadent) (bending strength 220 MPa), which is also available as machine blocks for the Cerec 3 Cad-Cam system [4, 25]. IPS Empress Blocks (Ivoclar Vivadent) The following pressed leucite ceramics have similar properties: Finesse (Dentsply), Authentic (Jensen), OPC (Pentron), PM9 (Vita), machine ceramics Paradigm C (3M ESPE) [2, 20].

It should be noted that the strength of machine and pressed systems, both leucite and feldspar ceramics, is higher than that of liquid-powder systems [30]. This is due to minimizing the formation of micropores formed by trapped air bubbles during the manufacturing process (which often occurs during the application of powder-liquid) [13-15]. Glass ceramics reinforced with lithium disilicate Feldspar and leucite ceramics are well adapted as single orthopedic structures, but their strength characteristics do not allow them to be used for bridge structures. In this connection, Ivoclar Vivadent has released glass ceramics filled with SiO2 -Li2 O-SiO2 – lithium disilicate under the trade name Empress 2. Lithium disilicate crystals (Li2 Si2 O5) occupy 70% of the volume in glass ceramics. Lithium disilicate crystals have an elongated "vermicelli-like" shape (Fig. 4), which leads to reflection and branching of the cracks formed [21]. E.max Press microstructure based on IvoclarVivadent materials Thus, the crack energy is quenched by the microstructure, allowing to increase the bending strength of the material to 450 MPa and compressive hardness approximately 3 times higher than that of leucite ceramics [33]. The current name of Ivoclar Vivadent's Empress 2 has changed to E.max. The material is produced in pressed and machine form. Due to the low index of refraction of light by lithium disilicate crystals, ceramics are quite transparent and can be used for whole restorations or covered with a facing layer for greater aesthetics [25]. In addition to single crowns, veneers and inlays, ceramics can be used as a material for the manufacture of bridges up to the second premolar [4]. Oxide ceramics with glass fillers For a long time, metal-ceramic crowns were considered the only option when choosing a durable non-removable orthopedic structure, especially when it came to bridges. However, the complete absence of light transmittance of the metal significantly reduced aesthetic performance. The invention of lithium disilicate ceramics partially solved the issue of aesthetics, however, even modern bridges with a frame based on lithium disilicate are shown only to replace dental defects up to and including the second premolar, due to their insufficient strength characteristics that could withstand the chewing load on the distant teeth [28]. In 1988, Alumina Alumina ceramics with an aluminum content of about 85% were introduced to the dental market under the brand In Ceram (Vita Zahnfabric) with a bending strength of 400-500 MPa [5]. This type of ceramics differs from filled and unfilled glass ceramics, with a significantly stronger bond of particles (crystals). The system was developed as an alternative to single metal-ceramic structures to replace the metal frame with a more aesthetic ceramic one [16, 17]. Later, the In Ceram Spinell and In Ceram Zirconia systems were released, complementing the In Alumina segments. Chemically, oxide ceramics are a matrix based on aluminum oxide or another metal (metal combinations) filled with lanthanum aluminosilicate glass [4, 31]. Aluminum and magnesium oxides (MgAl2 O4), or the so-called spinel, give ceramics the highest transparency and moderate bending strength (350 MPa), as a result of which such a material can be used as frames for highly aesthetic frontal single structures. Alumina-based ceramics have high bending strength (450 MPa) and moderate transparency and can be used as frames for single structures of both the frontal and lateral groups of teeth. Ceramics using zirconium, based on In Ceram Alumina, but with the addition of ZrO2, has a maximum bending strength (up to 650 MPa) and is mainly used for bridge structures up to 3 units [2]. It is obtained by the interpenetration of two phases of composites. This is a very time-consuming process, called "sliding casting". To form the frame of a crown or bridge prosthesis, metal oxide-based clay is applied to a refractory model (a duplicate of the working model in the laboratory), after which it is sintered without shrinkage for 10 hours at a temperature of 1120 ° C. The resulting porous matrix is infiltrated by molten lanthanum glass at a temperature of 1100 °C for 4-6 hours. The pores of the ceramic matrix are filled, and the material becomes extremely hard [1].

The milling process of the block takes 30-40 minutes. Pre-sintered ceramic blocks have shown excellent properties, higher capillarity radically reduces the firing time and glass infiltration after sawing out the structure, reducing the manufacturing time of the final product, while the quality of ceramics remains the same high [27]. Oxide ceramics Research continued, and soon oxide ceramics were released with the complete absence of glass as a filler. Thus, the oxide content in such ceramics reaches 98-99%. Sintered monophase ceramics are obtained by direct sintering of crystals without filling the crystal matrix, resulting in a solid, air- and glass-containing structure. To give high mechanical strength, resistance to temperature and corrosion, oxide ceramics include borides, carbides, nitrides, titanites and yttrium. The medical use of high-strength aluminum and zirconium ceramics for the first time found a place in implantology as a material for hip replacement [1]. This technology has found application in orthopedic dentistry for the manufacture of crowns and non-removable partial dentures based on zirconium and aluminum. The first solid polycrystalline material was produced under the name Procera Allceram Allumina (Nobel Biocare) of Swedish manufacture with bending strength up to 700 MPa and aluminum content up to 99.5% [36, 39]. In the UK, a Techceram (Techceram) system based on aluminum oxide has been developed, similar to Procera All Ceram Allumina. Aluminum powder is pressed and fired at a temperature of 1600 ° C. At the same time, the shrinkage of the material is 20% [1]. The frame, made of alumina ceramics, is then lined with glass ceramics [23]. The advantage of the increased aluminum content in these systems is the very high transparency of the frames, similar to glass ceramics, as well as increased strength. The bending strength of $Al_2 O_3$-based materials is equivalent to the strength of zirconium ceramics obtained using the In-Ceram system. However, even greater strength of the frames was needed, as a result of which materials with a high content of zirconium were obtained. Zirconium (also called zirconium dioxide, chemical formula ZrO_2) is a compound that is chemically insoluble in bases and acids. Obtained from zirconium sand ($Zr_2 SiO_4$, alvite) or zirconium clay (ZrO_2, baddeleyite, brazilite), the oxide undergoes several crystallographic phases during cooling from the molten state to room temperature. The melting point of zirconium is 2715°C. Cooling at 9 ° C, the cubic phase crystallizes, then at 2370 ° C it transforms into a tetragonal phase and, cooling to 1163 ° C, passes into a monoclinal phase. During cooling, during the transition from the tetragonal to the monoclinal phase, there is a significant increase in the volume of the structure. To stabilize the process, yttrium oxide (Y2 O3) is added up to 5% by weight [39]. Aluminum (0.2 – 1% by weight) increases the resistance of the material to corrosion and aging. Zirconium has a set of physical characteristics that is twice superior to aluminum oxide ceramics in strength and hardness. The bending strength varies from 900 to 1000 MPa [18, 19, 38]. The tensile strength is stated from 8 MPa·m1 / 2 to 10 MPa·m1 / 2. These figures are significantly higher than those of previous types of ceramics. Zirconium has ideal physical properties for the manufacture of bridge prosthesis frames for the anterior and chewing groups of teeth. More often there are problems with chipping and peeling of facing ceramics. Using the method of slow cooling in a glaze furnace in order to equalize the heat transfer of zirconium and facing porcelain, it is possible to increase the resistance of porcelain to chips by 20% [4].

Dental high-strength zirconium ceramics mainly differ in manufacturing methods and further processing [7]. Sintering is especially important because it directly affects the formation of the crystal structure, and thus more or less homogeneous and structurally flawless materials are obtained. The manufacture of HIP zirconium in a dental laboratory is a very time–consuming procedure: for several days the zirconium is sintered, the sintering process is completed by final firing at high temperature and pressure above 1000 bar (hot isostatic pressing). The result is a highly homogeneous solid material [22]. An alternative option is pre-sintered zirconium blocks with a strength of 55-70% of the final result for milling using a Cad-Cam module [14]. The lower initial strength makes it much easier to cut out structures from them, while reducing the wear of the cutters. After obtaining the required structure, the linear shrinkage during sintering is 20%. That is why the frames are cut out a little larger and receive the necessary volume after final sintering in the laboratory. The advantage of the Cad-Cam method is that any cracks and surface defects during sawing from the block are completely eliminated after the final sintering of the structure in the laboratory. The bending strength of structures made of zirconium oxide is identical in both cases [4]. Microcracks exist in all ceramic materials and originate during the production of ceramics, its processing in the laboratory or during cyclic chewing loads. In a humid oral environment, crack propagation is accelerated by stress corrosion. In yttrium-stabilized zirconium, tangential loads at the crack end cause a local transformation of a tetragonal, less voluminous crystal structure into a monoclinal crystal structure with an increase in volume by 5%. During these transformations, the crack energy is effectively extinguished (Pospiech called this the "air cushion" effect). Thus, zirconium has the ability to prevent the growth of a new crack and "repair" existing ones. [6, 13, 15, 24]. Zirconium blocks are cut using computerized milling machines. Thanks to zirconium-based ceramics, it is possible to make small-area connectors of bridge prosthesis links, as well as thin walls of structures [30]. Due to the fact that zirconium has a strength similar to metals, theoretically this material can completely replace metal frames of prostheses in the future, as well as all-metal structures. It is known that when applying porcelain cladding to ceramic frames, the dental technician does not encounter structural deformation, as when working with metals [35]. Moreover, the tendency of metal structures to change shape for a long time is a problem for fixing partial non-removable dentures on implants, since in this case the most precise packing of the structure is important, due to the complete lack of mobility of abutments, unlike real teeth [3]. Zirconium has become so popular in dentistry that most ceramic frames of orthopedic structures are made from it. However, do not forget about the aesthetic aspects of aluminum oxide and the relatively low cost of obtaining the material in comparison, This geographical aspect opens up huge prospects for the purification and processing of domestic raw materials with further introduction into the dental market of its own production, which will significantly reduce the cost of aluminum oxide frames in Asia and will allow them to be widely used for the manufacture of single highly aesthetic crowns, as well as frames bridges for the frontal group of teeth.

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