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Chapter 2

Acrylates in Dental Applications

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Abstract

In the presented chapter, the role that is played by acrylates in dentistry has been characterized. In the introduction, subject of oral diseases has been raised as well as an issue of development of dentistry over the centuries. Furthermore, characteristics of the materials that have been used over the years to receive elements used in the form of prosthetic devices or dental implants that in the most favourable way from the user's point of view enable the restoration of the missing piece of the dentition have been performed. Next, composition, functions and types of teeth have been described. In the following sections, materials (including dentures, adhesives, impression trays and dental crowns) widely used in dentistry and dental prosthetics in the preparation of which the key role is played by acrylates have been characterized. The preparation of prostheses was described. Particular attention has been drawn on the possibility of modification of the synthesis of acrylic materials that can lead to the improvement of their properties and result in making them more favourable from the point of view of the patient. The chapter is crowned with a brief description of the studies of properties, which are subjected to dental materials before application in the dental office.

Keywords: acrylates, dentistry, dentures, dental fillings, strength tests of teeth

1. Introduction

Tooth decay, which is undoubtedly associated with dental sciences, was the cause of a great progress and development in that field. It is a disease that causes permanent destruction of the tissues of the tooth. Therefore, a lot of research was conducted in order to create materials appropriate for restoration of those losses. Particularly in the last quarter, there was a very great progress in the field of dental materials science [1–3].

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Complications related to the tooth decay can lead to many diseases of pulp and periodontal. Therefore, scientists are still carrying out research on new materials, therapeutic techniques and medicines. Currently, on the market of medical supplies, it is possible to distinguish materials that:

- Eliminate and prevent pathological conditions.
- Prevent chemotoxic iatrogenic states.
- Treat disease states.
- Stimulate regeneration processes [1–3].

The problem of reconstruction of lost parts of the body as a result of an accident or an illness accompanies human life since time immemorial. The same problem applies to the dentistry. Replacement of tooth structure constitutes an extensive section of dentistry and is necessary from an aesthetic and functional point of view. Some important factors have an impact on the process of reconstruction as well as on achieving a satisfactory effect. Such factors should be mentioned as the availability of suitable materials, growth of technology and procedures used during application and development of fields of science such as chemistry, biology and physics, without which the progress of dentistry would be impossible. In order to enable a better understanding of the above-mentioned considerations in **Figure 1**, dependencies of various sciences applied in dentistry are presented.

The principles of physics, chemistry and biology are certainly used when comparing the physical and structural characteristics of restorative materials as well as during their application. The knowledge of these principles is very important for every dentist because with their help, it is possible to understand the basic phenomena such as melting or cooling of alloys or formation of crystalline structures in tested materials. It is also important to be able to predict

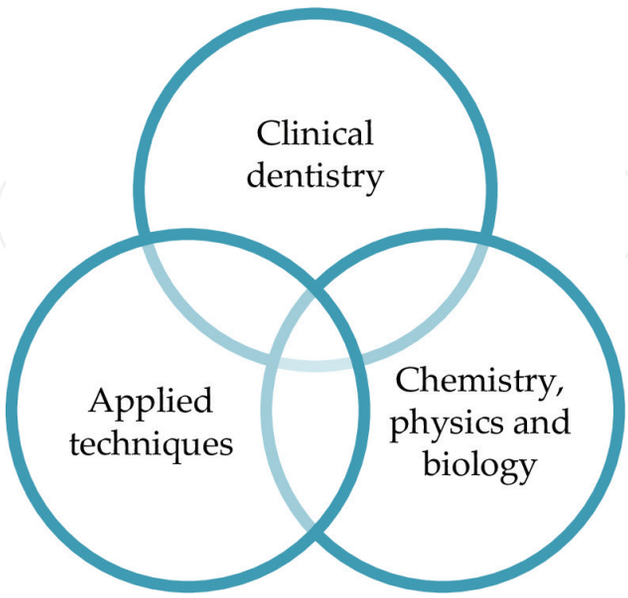


Figure 1. Schematic relationship between the sciences and the development of dentistry.

the chemical reactions which can occur during reconstruction of defects by using different materials or alloys. Of course from the clinical point of view, it is essential that conducted research was as practical as possible. However, practical clinical dentistry and scientific theory will not demonstrate desirable progress and will not become mutually friendly if these areas will not be developing in parallel drawing on mutual reports [4–6].

Continuing the discussion on the development of dentistry, an important issue is undoubtedly a history of this field of medicine, which began several hundred years before the period of Christianity. The first actions in the field of dentistry include the receipt of dentures on the basis of gold by Phoenicians. Subsequently, metals such as tin, copper, silver and lead began to play an important role in the synthesis of dental materials. In 990 B.C., methods of iron processing have been identified. Currently, scientists do not have any information about who and in what way constructed prehistoric dental restorations prevailed at that period. Certainly we can say that the role played during that period by goldsmiths and artisans was as important as that one plays nowadays by dental technicians [4–6].

As for the practice of using dental bridges and crowns, it is likely to be developed in ancient Rome around 500 B.C. The ability of carrying out such treatments is associated with the fact that people possessed appropriate skills of soldering and riveting at such a level that conducted operation did not cause bodily injury. It is obvious that craftsmen and other persons performing such treatments must be characterized by thorough understanding of melting process and execution of fluxes [4–6].

Further development of civilization apart from dental restorations and application of the aforementioned dental bridges and crowns attempts in which improperly functioning tooth was replaced by tooth of another patient or by tooth derived from the animal have been taken. It was based on immobilization of the tooth in the mouth by means of a wire. It should also be noted that ancients personally produced the mentioned wire [7].

Period from 1600 to 1840 was considered as the beginning of dental science. Previously, this field of medicine was perceived as a craft made mostly by craftsmen. In 1746 on a market, a book of Claude Munton entitled *Essay on the dental techniques or dissertation on artificial teeth* appeared and treated with a mechanical aspect of dentistry. In that publication, gold-based buckles and dental crowns that maintained the artificial teeth in the mouth have been described. During the following years, a number of texts about dentistry have been written in which it was mentioned about teeth of ivory, gold pins used for maintaining teeth as well as about porcelain as a material for the preparation of teeth and platinum that was used for the synthesis of dental hooks [7, 8].

Work of R.C. Skinner that was written in 1801 is considered as a first textbook about dentistry. In that time, dentistry began to be perceived as a professional field of science created by dentists and surgeons. In subsequent years, the progress and development of other sciences were accompanied by an invention of the amalgam, which was considered as one of the greatest and most important discoveries in the field of restorative materials (**Figure 2**). Furthermore, a lot of dissertations on the dental subjects have been created, as well as new technologies have been developed at a satisfactory pace [9].



Figure 2. Amalgam as a dental filling.

In the second half of the nineteenth century, a large development of the field of plastic was observed. In 1869, a new material that was called 'celluloid' was presented. In 1871 that material was used as a restoration which was a turning point for the introduction of plastics for the dental industry. Despite its advantages such as ease of handling or resistance to fracture, new material was also characterized by many disadvantages including an undesirable colour change and emission of mercury causing drooling and inflammations in the mouth. Thus, in conjunction with further explorations of new material, next materials that have been proposed by researchers were phenol-formaldehyde resins [10]. As in the case of celluloid despite initial delight of dentists in these resins, it became quickly apparent that they do not meet the basic requirements. Thus in 1935, ICI company unveiled a new material which was poly(methyl methacrylate) (PMMA) also known as 'organic glass' which is associated with its transparent properties. At first, PMMA was not applied in dentistry due to many technological problems. However, in 1937, a new method of synthesis of the mentioned polymer was developed in which PMMA was obtained in the form of beads and not in the form of plates as it was previously the case. Then, a special methodology was developed aimed at combining beads of polymer with monomer in order to obtain an elastic mass. In **Figure 3**, PMMA in a form of plates (A) and beads (B) is presented.

Detailed application of this polymer and the other belonging to the group of acrylates will be presented in subsequent parts of this chapter.

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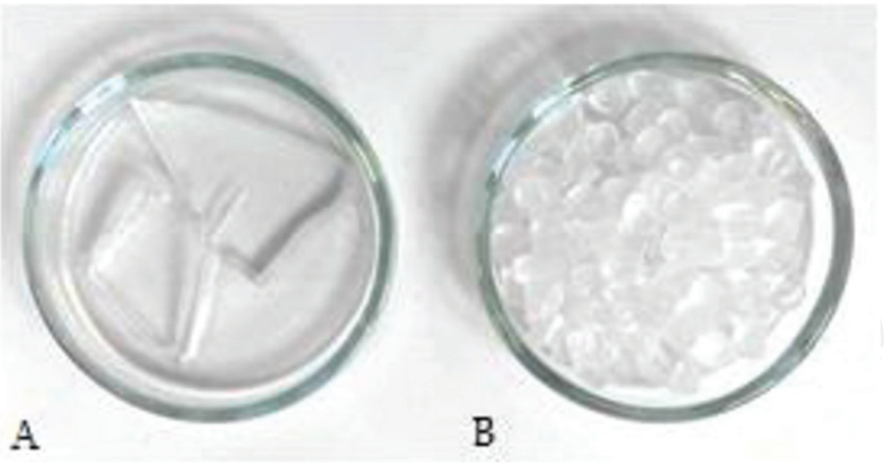


Figure 3. PMMA in a form of plates (A) and beads (B).

2. Anatomy of the tooth

The name 'teeth' refers to the anatomical formations of complex structure occurring in the oral cavity that play an essential role in the digestive system. Teeth fulfil many functions including grinding and crushing of food which significantly facilitates its subsequent digestion and intake in the following sections of the digestive tract [11] (**Figure 4**).



Figure 4. Acrylic teeth.

In human oral cavities, it is possible to distinguish two types of dentitions: primary and permanent one. First of the mentioned occurs in children aged 2–6 and involves incisors, canines and molars. Primary dentition is with the time replaced by permanent one. This type includes 32 teeth, and in comparison to the previous one, it comprises additionally premolars [11]. The different types of teeth in dentition were shown in **Figure 5**.

In the construction of every tooth, three basic elements can be mentioned, i.e. crown, neck and root. Among tissues that form teeth, enamel, dentin, cementum, and pulp have to be mentioned. Enamel—the toughest tissue in the human body—in the vast majority (95%) is made of inorganic compounds. The most innervated and vascularized tissue from the above-mentioned is a tooth pulp [11, 12].

Inadequate oral hygiene which consequently results in the accumulation of food debris and in the development of bacterial flora leads to the development of various types of teeth and periodontal diseases. In some cases, the process of healing of this type of illnesses is complex and lengthy. Therefore, it is necessary to develop this field of medicine whose role is to deal with functioning but also with treatment of teeth, periodontal, all tissues and any other elements contained in the oral cavity. The origins of this science should be sought several thousand years ago. Literature reports indicate that the traces of actions aimed at preventing tooth decay were discovered in the skull of young man whose remains were found more than 14,000 years ago. Areas of dentistry such as orthodontics and prosthetics also are characterized by a long tradition. The hygiene and the aesthetics of oral care were taken in ancient times. Therefore, high attention has been paid to the development of this field of medicine. With the passing of years, new elements that had to meet the growing demand on the market of dental materials have been introduced [11, 12].

Nowadays, it is necessary to use dental materials associated with artificial restorations or with technologies that in perfect way will enable a reconstruction of the missing piece of the dentition. Such materials are undoubtedly dental bridges, crowns, dentures and dental braces [11, 12].

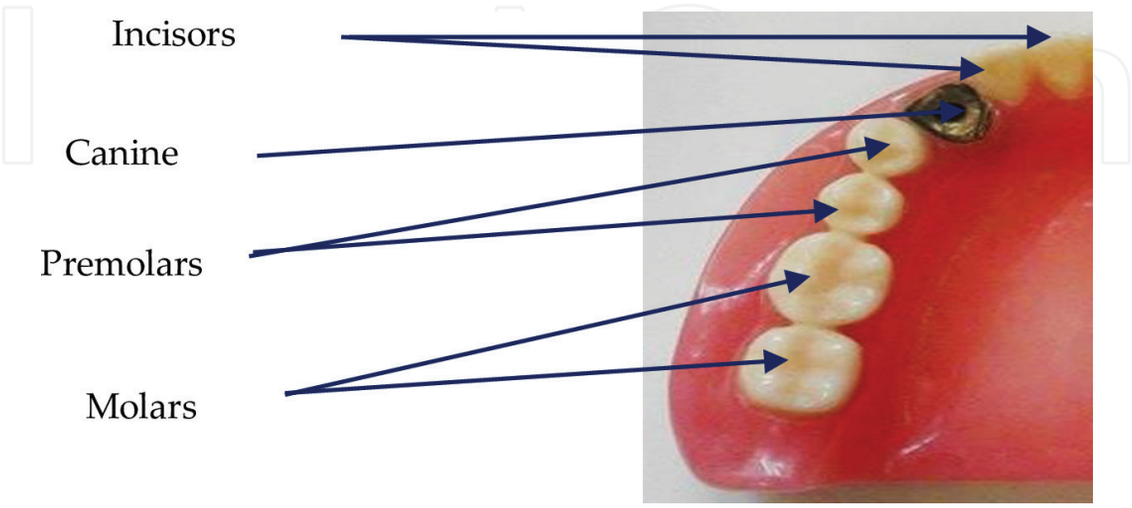


Figure 5. Kinds of teeth in permanent dentition.

3. Bonding materials in dentistry (cements and fillings)

The concept of 'cement' is associated unambiguously with the construction industry. However, it should be noted that this term also refers to the materials constituting the binder in dentistry. There is a wide diversity of dental cements including zinc-phosphate, glass-ionomer, compomer or composites (on the basis of resin). Last of the mentioned due to their characteristics are becoming more and more popular on the market of medical products [13].

Composites based on acrylic resins are materials widely used for dental restorations. These are becoming increasingly popular displacing from the market of medical products amalgam fillings. The use of those fillings caused the problem in terms of safety due to the fact that their main component is toxic mercury. However, it should be noticed that in some ways, they outweigh the fillings on the basis of acrylate resins. In fact, they were characterized by greater durability and better resistance to fracture. Therefore, nowadays, researchers are working on the improvement of the physico-chemical properties of resin based on acrylates [13].

Acrylic materials are included in glass-ionomer cements. This filling is composed of two elements, i.e. powder and liquid. The liquid is an aqueous solution of copolymers of itaconic and polyacrylic acids, while powder contains fluoro-calcium-aluminium-silicon glass. Interesting feature that distinguishes this type of cement from the others on the market of dental products is a very good adhesion to enamel and dentin. Furthermore, glass-ionomer cements are characterized by an ability of forming a chemical bond with the tissue of the tooth which contributes to the cariostatic action of such filling (protection against tooth decay). Polyacrylates contained in the liquid react with the compounds forming the powder and consequently release of various types of ions with a predominance of fluoride anions occurs. As a result of their reaction with polyacids, formation of a gel matrix occurs which combines chemically with the dentin. This is a middle layer of a tooth which is composed of fluid-filled tubules, connective tissues and nerves. The elements included in the dentin are mainly calcium (27%) and phosphorus (13%) [14].

Combining of glass-ionomer cement (**Figure 6**) with the tooth is a result of forming a chemical bond between ions contained in cement and ions of phosphorus and calcium included in the structure of enamel or dentin. Tooth surface must be previously cleaned that has an impact on the effectiveness of the formed combination [14].

Glass-ionomer cement is characterized by good resistance to bending. However, these materials have also some disadvantages including low tensile strength. Undoubtedly, one of the most favourable features of these fillings is their antibacterial activity which derives from the presence of fluorine in their structure [15].

Hybrid cements such as glass-ionomer fillings or those one modified with resin are characterized by slightly better strength properties. It is worth noting that these materials are chemo or light cured. Besides liquid and powder, such cements contain in their composition catalysing system of a micrometric size disposed in the form of capsules. The mentioned system consists of ascorbic acid and potassium persulfate, whereas liquid comprises an aqueous solution of polyacrylic acid containing additionally 2-hydroxyethyl methacrylate (HEMA). The connection



Figure 6. Glass-ionomer cement.

between this kind of filling and a tooth is stronger that a bond that is formed by glass-ionomer cement [16, 17].

Acrylates play an important role also in the compositions of zinc oxide-polyacrylic cements (known also as zinc oxide-polycarboxylate cements). The aqueous solution of poly(acrylic acid) acts as a liquid, while powder is composed of properly processed oxides of magnesium and zinc. While application of the mentioned filling, poly(zinc acrylate) is synthesized. That polymer is characterized by gel consistency. Combining this type of cement with the tooth is accompanied by process of chelating of calcium occurring in dentin by carboxyl groups present in the polymer. However, it is worth mentioning that these cements are characterized by a slightly weak strength properties (such as small bending strength in comparison to other commercially available cements as well as the relatively large thickness that hinders adjusting and deposition of filling in the place of application) [16, 17].

Acrylates represent an important group of components of selected cements based on resin. Particularly key role is played by methyl methacrylate. This compound is almost from the half of the twentieth century used for the deposition of various types of prostheses. Widely used are also composite cements that consist of a mixture of methacrylates (or acrylates) with a glass or with a suitably modified silica. Mentioned restorations belong to the group of materials chemo or light cured. On the market of dental products, a significant role is also played by composites modified with polyacids, i.e. compomers that also can contain acrylates [16, 17].

4. Dentures

4.1. Desirable characteristics of poly(methyl methacrylate)

Dental prostheses are defined as an artificial supplement used to complement or to restore missing teeth. These can be made from a variety of materials including metals, ceramics or plastics. Initially, market of dental products was predominated by ceramic restorations. However, with the development of materials science and polymer technology, ceramics has been supplanted by plastics in this field of medicine [16].

The first dentures based on poly(methyl methacrylate) appeared in the 1930s of the twentieth century. Nowadays, the vast majority of dentures is based on poly(methyl methacrylate) or on the mixture of this polymer with copolymers of methyl methacrylate, butyl methacrylate, or propyl acrylate [17–19].

In dental prosthetics, resins based on acrylates are widely used. What is important, these can be used in the form of a powder or liquid. Such compositions also consist of dibutyl phthalate, acetone as well as a variety of stabilizers [19].

Poly(methyl methacrylate) is the most commonly used polymer. It is a result of many desirable characteristics of this compound with a particular emphasis on high mechanical strength, crack and abrasion resistance, acid resistance as well as the ability of easy coverage of this polymer with selected pigment. Furthermore, economic considerations, ease of application, aesthetics as well as optical properties or biocompatibility are undoubtedly important features speaking in favour of the application of this polymer [13, 17].

Resins based on the above-mentioned polymer show a number of advantages whereby they constitute the desired raw material for the preparation of dentures. Therefore, such materials are used to obtain full and removable partial dentures, prostheses for maintaining and microdentures [20].

4.2. Modifications of poly(methyl methacrylate)

Poly(methyl methacrylate) is characterized by some imperfections that should be modified or improved. One of the mentioned imperfections of these polymers are undoubtedly mechanical properties. Over 60% of dental prostheses is broken or cracked within the first 3 years of use. The repair process of damaged dental materials is time consuming and costly. It should be noted, however, that the vast majority of users of such materials are elderly people for whom subsequent visits in the dentist office constitute a troublesome duty. Hence, the improvement of the mechanical properties of prostheses running with simultaneous maintaining of other desirable from the point of view of the patient characteristics becomes a real challenge for such realms as materials science and dentistry [13, 21].

An important disadvantage of poly(methyl methacrylate) is a tendency of microorganisms to adhere to its surface which contributes to the microbial growth on the prosthesis made of this material. One of the results of such phenomena is the occurrence of inflammation in the oral

cavity. It is also worth noting that dentures based on poly(methyl methacrylate) are characterized by a significantly larger resistance to wear in comparison to ceramic restorations. Hence, many attempts are undertaken in order to improve the resistance which can be achieved, for example, by increasing the cross-linking degree of the polymer or by change of conditions of the polymerization process.

It is possible to distinguish three methods that can solve the problem of PMMA imperfections. These are the

- Replacement of PMMA by other polymers
- Chemical modification of PMMA by grafting with other polymers
- Introduction to the matrix based on PMMA additives of differ origin [22, 23]

Improvement of the physico-chemical properties of acrylates can also be obtained by copolymerization as well as by development of blends or interpenetrating polymer networks based on poly(methyl methacrylate). An impact on the characteristics of the mentioned acrylic resins has undoubtedly addition of various types of organic or inorganic compounds that takes place during process of the polymerization [22].

On the basis of the research, it was found that the introduction to the resin based on bisphenol A glycidyl methacrylate (BIS-GMA) inorganic fillers of micrometric size causes a significant improvement in the strength properties of the material. Moreover, the same effect is reached by addition of inorganic fillers having a nanosize to the matrix based on poly(methyl methacrylate) [24, 25].

An interesting modification of resins based on PMMA is the addition of titanium dioxide. The nanoparticles of this inorganic oxide contribute to the antibacterial properties of the resin. These properties are the result of cytotoxic effects of oxide radicals generated by treating the titanium compound with UV radiation. Furthermore, it was found that the antibacterial activity of TiO_2 is additionally intensified by the presence of metal or metal oxide (e.g. Fe), and therefore, Acosta-Torres et al. carried out a synthesis of the resin based on poly(methyl methacrylate) containing nanoparticles of TiO_2 and Fe_2O_3. Anehosur et al. came to the same conclusion. In the research, they have identified the biocidal properties of the acryl polymer resin modified with titanium dioxide in relation to the selected bacterium, i.e. *Staphylococcus aureus*. Numerous studies and observations conducted by these scientists lead to the conclusion that titanium dioxide subjected to an appropriate radiation effects on the inhibition of the growth and the development of the mentioned strain of bacteria [17, 26, 27].

Next interesting additive that has an impact on mechanical properties of acryl polymer resins is zirconium oxide. Gad et al. on the basis of their research concluded that introduction of the mentioned oxide improves significantly flexural strength of described dentures. Better effect is observed by the introduction into acrylic resin zirconium oxide in the form of nanotubes as evidenced by the conclusions drawn on the basis of the research of Yu et al. [19, 28].

It has also been proved that the addition of substances such as nitrile rubber or materials of ceramic origin such as aluminium oxide affects the improvement of properties such as impact strength, fracture strength or hardness. Such conclusions have been reached by Alhareb et al. [29].

An interesting addition to the acrylic resins forming of the base of dental prostheses represents nanoparticles of gold, silver and platinum. These substances give the mentioned material antifungal properties. This addition is intended to prevent the occurrence of fungal diseases as well as to improve oral hygiene. Promising effect was observed in the case of the introduction of nanoparticles in an amount of 2.0 wt.%. Then, the most visible antiadherent effect was observed in relation to the fungi of the genus *Candida albicans* [30].

Pan et al. on the basis of their research have been stated that the introduction of hydroxyapatite into PMMA-based resins also results in an improvement of mechanical properties of acrylic dentures made of such composite. Hydroxyapatite is an inorganic compound characterized by the properties that are desired in medical applications, i.e. non-toxicity or biocompatibility. Recently, this interesting material constitutes an addition to the polymer matrix that contributes to the improvement of its mechanical properties [31].

Acrylic materials used in dentistry are commonly reinforced by means of different types of fibres wherein special attention should be paid on ceramic, carbon and glass fibres. Their introduction into the material is aimed towards the improvement of the material resistance to severe stress. Kostoulas et al. [32] in the framework of the research described the effect of the addition of glass fibres on the properties of acrylic denture. Similar conclusions have been drawn by Narva [33] based on research undertaken in the framework of the doctoral dissertation concerning strengthening of dental prostheses.

Analysis of the results allows the conclusion that the presence of glass fibres greatly affects the mechanical properties of the tested prostheses. Significantly greater impact resistance of reinforced dental restorations was observed. Furthermore, dentures modified with glass fibers demonstrated more resistance to cracking. What is essential, it was found that the modification using the described fibers has a better impact on the prosthesis than the addition of metal elements [12, 31–33].

Besides glass fibers, the preferred addition to the dental restorations also provides aramid fibres. Raszewski [12] proved that the modification of the denture with this kind of fibres contributes to a clear improvement in mechanical strength of the tested material. Braden et al. [34] in their publication also drew attention to the effect of the addition of the polyethylene fibres to the prosthesis on its properties. These fibers are characterized by the superior properties in comparison to the previously described glass fiber. However, due to the difficulty of combining them with the acrylic resin, it is necessary to use a low-temperature plasma in order to enable synthesis of this composite [12, 34].

Balos et al. [35] in their research undertook the characteristics of acrylic resins modified with nanosilica. An analysis of the obtained materials included defining of mechanical properties such as elasticity or bending strength. The researchers also determined the cytotoxicity of modified materials. Based on the analysis, it was found that for most of the tested prostheses, addition of SiO_2 nanoparticles resulted in an increase of bending strength and in improvement of the modulus of elasticity. It is noteworthy that the amount of added nanosilica is very important because introduction of too much amount causes that material becomes toxic [35].

4.3. Preparation of dentures on the basis of poly(methyl methacrylate)

Poly (methyl methacrylate) constitutes a raw material for the preparation of artificial teeth. However, this polymer to be able to be used for this purpose should be characterized by a high molecular weight and a high cross-linking degree. The starting material consists of PMMA or a copolymer of the mentioned polymer with 1,4-butanediol dimethacrylate or with ethylene glycol dimethacrylate [12].

Crucial meaning for the quality of the denture has a method of polymerization. It is generally carried out at elevated temperature. However, for some substrates that have a tendency towards spontaneous polymerization, process must be carried out at room temperature [12, 36].

Preparation of artificial teeth from the raw material which is PMMA is a multistep process. Initially, 90% of the mixture is represented by monomers, and the remaining 10% constitutes a pigment selected depending on the desired colour of the final product. Depending on the requirements of the final material, it is possible to obtain colourless acrylic mass or mass with the white or pink colours. White acrylic mass is then used to produce dental crowns, inlays or artificial teeth, while the pink one is useful in obtaining products such as impression trays [12, 36].

The next step is subjecting the mixture of trituration process by means of ball mills. Such process depending on the properties of applied reagents takes 24–48 h. Homogeneous mass after trituration process is left in a closed container until reaching the material of gum consistency. Such a mass is then divided into smaller parts which are distributed to the appropriate forms. The moulds are then assembled and subjected to pressing at elevated temperature. At high temperature and under elevated pressure, polymerization process takes place, and final product is obtained. Next, obtained polymer is gradually cooled and formed into its final form by cutting off unpolymerized portions. Subsequently, obtained teeth based on PMMA are affixed to the polymeric plate. An alternative method for the preparation of artificial teeth is a method using the process of injection into the mould at elevated pressure. Molten polymer mixed previously with pigment is subjected to this process [12, 36].

Prepared dental prostheses are characterized by a lack of smell, and furthermore, their sizes can be easily adjusted according to the user [36].

5. Dental adhesives

The primary function of dental adhesives is affixing to the tooth surface or to the elements included in the oral materials such as dentures or dental bridges used in order to restore or to reconstruct a tooth [37].

As in the case of dental prostheses based on poly(methyl methacrylate), dental adhesives made of this polymer are also characterized by slightly poor mechanical properties. From the user's perspective, the most important is proper adhesion of glue to the enamel or dentin (bone tissue from which the core of the tooth is built).

With inadequate adhesion of the adhesive, which results in insufficient adhesion of the prosthesis, or a dental bridge phenomenon of secondary caries can occur, then treatment is

considerably less effective. Hence, various attempts aimed at improvement of the properties of dental adhesives based on PMMA as well as at strengthening the existing bonds between the adhesive and the prosthesis are taken.

Solhi carried out a number of syntheses, during which the surface of the nanoclays (pristine sodium montmorillonite) was grafted by poly(methyl methacrylate). Such an obtained system was characterized by a clearly better mechanical properties and exhibited higher adhesion to the dentin [37, 38].

6. Dental impression trays

Acrylic materials represent an important component used in the preparation of individual impression trays. As in the case of above-described cement materials, also materials used for the preparation of impression trays consist of liquid and powder. The fluid is a mixture of methyl methacrylate (90% of a liquid), a suitable catalyst and an oil of mineral origin, while powder consists of inorganic fillers such as talc, chalk or aluminium oxide [11].

The first step in order to obtain an impression element is preparation of plates of a certain size from a previously prepared mixture of liquid and powder. It is essential to choose a suitable proportion of the components. Then, the mixture is prepared in a silicone container. The plate is then introduced into a gypsum mould; elements protruding from the model are cut off. Next, plate is wiped to a smooth surface, and then prepared material is subjected to polymerization process [11].

7. Dental crowns

The term 'prosthetic crown' refers to the permanent restoration that is used to restore the proper tooth crown. Furthermore, such materials are also used to improve conditions of occlusion, to restore teeth using implants as well as for aesthetic purposes.

Among prosthetic crowns, uniform and complex crowns can be distinguished wherein acrylic materials play a significant role in both of these types. The first of the mentioned is made up of one type of material, i.e. acrylates, metal or porcelain. Those made of acrylates in dental prosthetics serve as temporary crowns; however, taking into account the properties of polymer material, which is used predominantly porcelain. The characteristic that causes less and less interest in acrylic materials is undoubtedly low abrasion resistance [11].

8. Studies on physico-chemical properties of prepared dental materials

An important step in the preparation of dental materials is the development of their composition and synthetic parameters. However, an equally important step is performing a series of tests of the obtained materials for characterization of their physico-chemical properties or in order to evaluate whether reagents selected for the synthesis lead to the formation of elements

having the desired characteristics. Therefore, it is necessary to carry out durability tests or spectroscopy. Analysis of the results of these studies is important from the point of view of both the user and the dentist.

Figure 7 shows examples of probes applied in the strength studies of prepared dental components; accurate description of the probes is presented in **Table 1**.

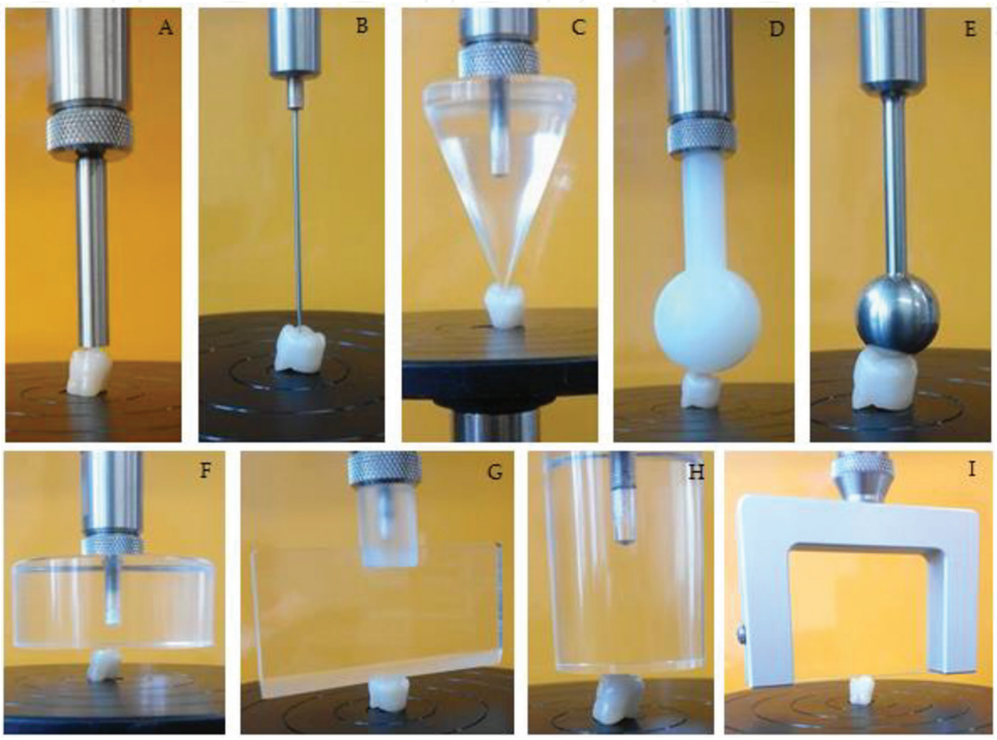


Figure 7. Examples of probes applied in the strength studies.

Designation	Type of probe
A	Cylinder, stainless steel 6 mm
B	Needle, stainless steel 1.0 mm
C	Cone, acrylic glass 40 mm
D	Sphere, nylon 25.4 mm
E	Sphere, stainless steel 12.7 mm
F	Cylinder, acrylic glass 50.8 mm
G	Blade, acrylic glass 60 mm
H	Cylinder, acrylic glass 25 mm
I	Wire, stainless steel 0.03 mm

Table 1. Set of probes applied for strength tests.

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In **Figure 8** examination of synthesized artificial tooth using a spectrophotometer is shown.

Above-presented studies are extremely important from a practical point of view and in terms of the subsequent application. Physical and chemical properties of dental materials described in this section have an impact on the comfort of future use and on maintaining of the oral health of the patient. Therefore, carrying out various types of mechanical studies and analysis of the attained results in order to determine the final properties of the prepared product is necessary before implementation.

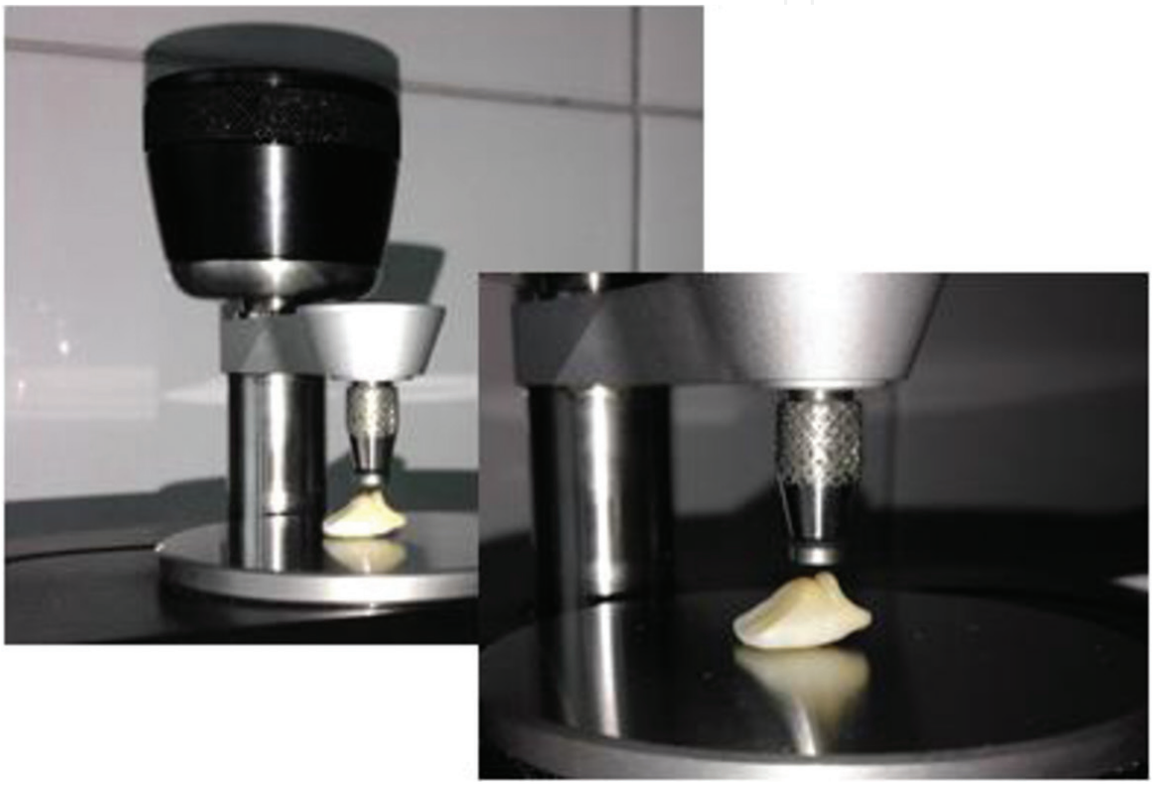


Figure 8. Spectroscopic analysis of prepared dental materials.

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