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Ageing process influence on mechanical properties of polyamide - glass composites applied in dentistry

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Properties

ABSTRACT

Purpose: The application of polymeric materials for medical purposes is growing very fast. Polymers have found applications in such diverse biomedical fields as tissue engineering, implantation of medical devices and artificial organs, prostheses, ophthalmology, dentistry, bone repair and many other medical fields. The requirements for materials used in the construction of removable dentures are becoming more and more demanding. The introduction of improved flexible materials has been a considerable advance. The aim of this work was to determine how the properties of thermoplastic materials change over time in terms of weight changes and artificial saliva sorption. Purpose of this paper was to evaluate the influence of the ageing process on mechanical properties of polyamide - glass composites applied in dentistry.

Design/methodology/approach: Polyamide samples about the diversified content of the glass fibre were produced with method of the injection moulding. Denotation of the absorbency of artificial saliva was performed on standardized samples according to the norm. Samples were dried up to fixed mass, and then they were soaked in artificial saliva. Two temperatures of examination were applied 23°C and 30°C.

Findings: An influence of the absorbability on mechanical properties of composites was determined. Examinations allowed to show that the absorbency of artificial saliva through composite is dependent on the temperature.

Research limitations/implications: To fully evaluate the influence of the ageing process on mechanical properties of polyamide - glass composites applied in human body environment it is planned to continue described research. Simultaneous influence of the ageing process on mechanical properties of polyamide - glass composites shall be tested.

Originality/value: Applying strengthened thermoplastics with glass fibre on dentures is a new look at materials applied in dentistry.

Keywords: Biomaterials, Biocomposites, Mechanical properties, Dental prosthesis

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1. Introduction

Man did replacements for broken or sick units of the human body were in imagination of a man from the past. This has given birth to a new branch of science, called *'biomaterial science'*. This branch of science is interdisciplinary in nature and encompasses a variety of disciplines such as Engineering, Physics, Chemistry, Biology, Toxicology, Biochemistry, Surgery, Dentistry. Metals, Ceramics, Polymers and Composite materials are used in the fabrication of medical devices. Biomaterials are materials of natural or man-made origin that are used to direct, supplement, or replace the functions of living tissues of the human body. Use of biomaterials dates far back into ancient civilizations. Artificial eyes, ears, teeth, and noses were found on Egyptian mummies. Chinese and Indians used waxes, glues, and tissues in reconstructing missing or defective parts of the body. Over the centuries, advancements in synthetic materials, surgical techniques, and sterilization methods have permitted the use of biomaterials in many ways. Medical practice today utilizes a large number of devices and implants. Biomaterials in the form of implants (vascular grafts, sutures, bone plates, heart valves, intraocular lenses, ligaments, dental implants, etc.) and medical devices (pacemakers, biosensor, artificial hearts, blood tubes, etc.) are widely used to replace or restore the function of traumatized or degenerated tissues or organs, to assist in healing, to improve function, to correct abnormalities, and thus improve the quality of life or the patients. Biomaterials are expected to perform in our body`s internal environment, which is very aggressive. For example the pH of body fluids in various tissues varies in the range from 1to 9 [1-9].

To determine effect of the implant on the body, the characteristics of the material that must be considered as: toxic or irritational qualities of the material or its break down products (molecular level), or of additives incorporated into the material: mechanical characteristics of the material: fabricability of the material into the desired implant form and the effect of fabrication altering the material, i.e., oxidation of the surface, residual solvent, mould contamination, etc.: quantity of the material (systemic level), size and shape of the material (tissue level); surface structure of the material (cellular level), sterilizability of the material, possible antigenicity of the material (immunological response), thrombogenicity antileukotaxis (infection predisposition); carcinogenesis [1-4].

To determine the effect of the body on the implant, the material must be examined for changes, such as: degradation or other changes in molecular structure (i.e. cross linking or phases); changes in mechanical properties; wear particles; state of hydration; elution of low molecular weight species; protein saturation or oxidation of the surfaces; cellular ingrowth calcification [1-4].

Polymers remain the most universal class of biomaterials, being extensively applied in medicine and biotechnology, as well as in the food and cosmetic industries. The application of polymeric materials for medical purposes is growing very fast. Polymers have found applications in such diverse biomedical fields as tissue engineering, implantation of medical devices and artificial organs, prostheses, ophthalmology, dentistry, bone re-vectors and many other medical fields.

Correct understanding of physical, electrical and mechanical properties of polymers has high influence on their use in dentistry. It is essential mainly because materials used in that trade are exposed to the influence of the oral cavity environment and occlusion bite forces. Moreover, dentures undergo periodic cleaning and polishing procedures during various prophylactic activities. In order to apply a polymer material in dentistry successfully, it is essential to choose its properties optimally. Polymers used in dentistry have to meet specific biologic, strength and technological standards.

Most importantly, they [2-3]:

- should be non-toxic,
- should not cause oral cavity and other tissue irritation,
- should not cause allergic reactions,
- should be resistant to various physical and chemical factors that occur in the oral cavity environment,
- should have adequate strength, hardness, rigidity and abrasion resistance.

Dental treatment is one of the most frequent medical treatments performed upon human beings. Dental treatment ranges from filling cavities to replacing fractured or decayed teeth. A large variety of material are used in the dental treatment such as cavity lining, cavity filling, luting, endodontic, crown and bridge, prosthetic, preventive, orthodontic, and periodontal treatment of teeth. These materials are also generally described as biomaterials. The choice of material is dependent on its ability to resemble the physical, mechanical and aesthetic properties of natural [8-10].

Dental prostheses are prosthetic restorations commonly used in implant dentistry. One of the most familiar types of prosthesis is dentures. Different dental prosthesis options fall into two general groups: removable and non-removable. Removable prostheses are generally easy to clean and maintain. Although they are typically less expensive than non-removable restorations, they are not as stable and require a longer adjustment time than complete non-removable prostheses. Non-removable prostheses offer patients a sense of having a permanent tooth replacement. However, they are also difficult to clean and are more prone to recurrent dental disease. Therefore, patients with non-removable prostheses must maintain a high level of hygienic vigilance when caring for their restorations [8–11].

Flexible dentures, the latest prosthodontic solutions also known as nylon dentures, are perfect alternatives to conventional and partial acrylic dentures. Made of a special thermoplastic material, flexible dentures are highly comfortable as well as resistant to breaking (Fig.1.and Fig.2.) [12].

In comparison to conventional acrylic dentures, they have numerous advantages that make denture wearing incredibly easy and pleasant for patients:

- they are much thinner than conventional dentures
- they stay firmly in place (have better stability and retention) and do not slip or fall off
- they do not produce allergic reactions
- they have no metal clasps but aesthetic gum tissue-colour clasps made of thermoplastic nylon
- they are lightweight and flexible; they do not break and crack
- they take up less space in oral cavity.

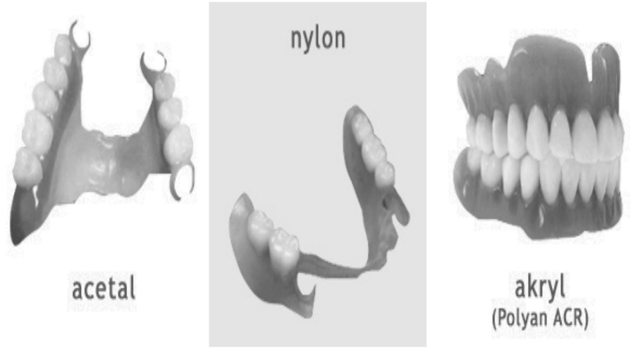

Fig. 1. Examples of partial prostheses [12]

The application of nylon-like materials to the fabrication of dental appliances has been seen as an advance in dental materials. This material generally replaces the metal, and the pink acrylic denture material used to build the framework for standard removable partial dentures (Fig.3).

Fig. 2. Example of flexible dentures [14]

Fig. 3. Example of nylon partial prostheses [15]

Thermoplastic resins and co-polymers have many advantages over conventional powder or liquid resin systems. Thermoplastic resins tend to have predictable long-term performance. They are stable and resist thermal polymer unzipping. They also exhibit high creep resistance and high fatigue endurance as well as excellent wear characteristics and solvent resistance. Thermoplastic resins typically have very little or almost no free monomer in the material. A significant percentage of the population is allergic to free monomer and these materials offer a new safe treatment alternative for these individuals. In addition, thermoplastic materials have almost no porosity, which reduces biologic material build up, odours, and stains and exhibit higher dimension and colour stability. All of these factors become important when producing long-term provisional prostheses during implant or complex restorative cases, or when used for permanent removable appliances. Typically, the thermoplastic resins are more flexible and stronger than their traditional counterparts are. Elastomeric resins can be added to the resin polymer formulas to create greater flexibility, which reduces fracturing. Thermoplastic resins can also be reinforced with glass filler or fibres to further enhance their physical properties. At the same time, these restorations can be relined and repaired, by repressing the restoration. The thermoplastic resins can produce single cast or pressed restorations that are strong, lightweight, flexible appliances in tissue or tooth colour matched materials that never need adjusting. These restorations display excellent aesthetics and provide long-term comfortable use for the patient. This provides excellent alternative cosmetic restorations for aesthetic-conscious patients [16].

Thermoplastic resins are used for a broad variety of applications from removable flexible partial dentures, preformed partial denture clasps, fibre reinforced fixed partial dentures temporary crowns and bridges, provisional crowns and bridges, obturators and speech therapy appliances, orthodontic retainers and brackets, impression tray and border moulding materials, occlusal splints, sleep apnea appliances, and implant abutments [16].

Composites are becoming more commonly used in dental and medical applications to replace metal and polymer materials. Composites are materials that consist of two or more types of different components (e.g. metal, ceramic or polymer) and they offer a variety of advantages compared to one-component materials [20]. For example, in dental applications, composites are better aesthetically (based on colour) than metals and they possess the good component qualities of the composite, such as the high strength of fibres in fibre-reinforced composites, which have been successfully used for example in fixed partial dentures [1]. In FRC, the polymer matrix itself is not durable enough for load-bearing applications but, with the aid of reinforcing fibres, the strength of the composite increases [17-19, 21-23].

2. Experimental setup

Examinations described in the article are preliminary examinations. Determining changes of the absorbency of polyamide glass composites was a purpose of research. Preparing three kinds of polyamide pellets was the first stage of to do samples bye 6.6 Durethan of the Lanxess company, with the diversified content of the glass fibre of Eras 5001 / 4.5 mm/ of 15

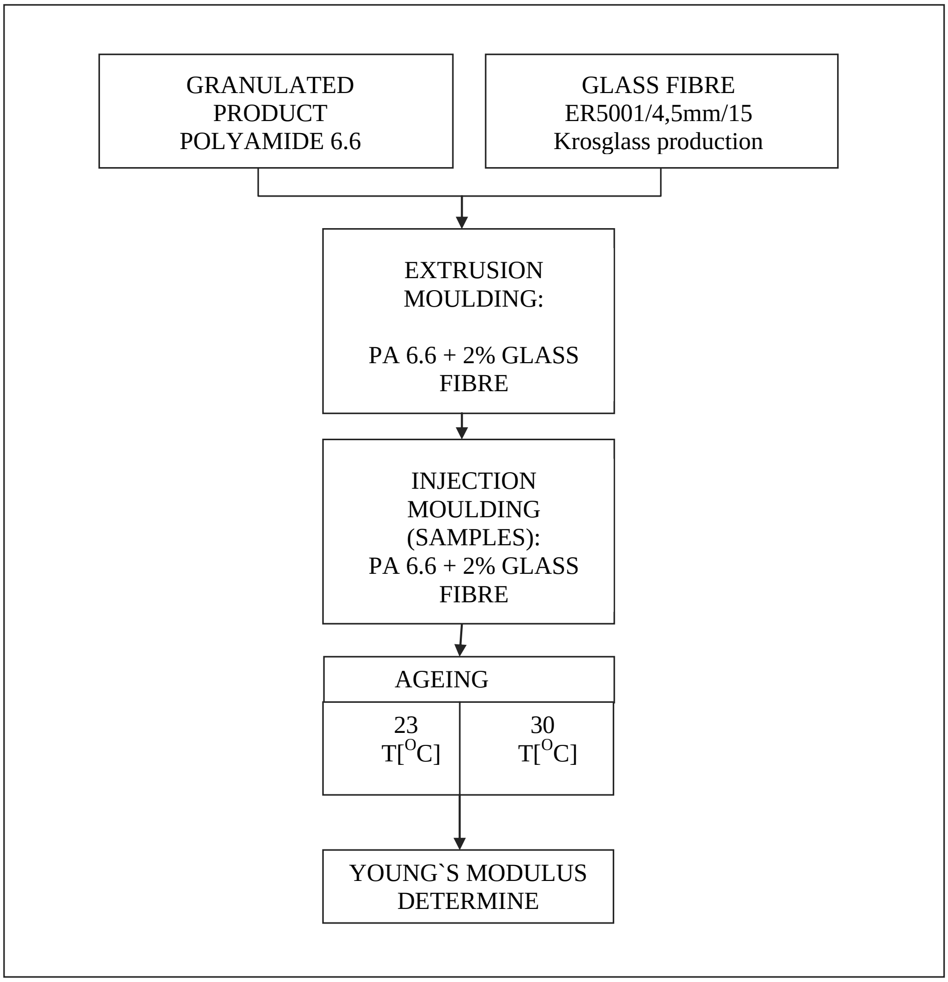

Fig. 4. Flow diagram of examinations

KROSGLASS productions. Figure 4 is showing the outline of examinations.

Pellets were carried out at the Central Mining Institute on extrusion machine of ZSE 27 HP type of the Leistritz Company. Prepared pellets were dried off on the SHINI Dospel Plastics drier CD- 9. Performing the injection was held at the cooperation with the Czestochowa Technical University in an Institute of the Materials Engineering where on the Krauss Maffei injection moulding machine KM 65 - 160C1 samples were received. In the process of the injection three types of samples differing in the content of the glass fibre according to the established research program were received. Forty five samples were prepared for examinations. Samples before the accession to examinations were left weighed and described (Fig.5.).

With a view to conducting research preparing artificial saliva was essential. Chemical reagents for the preparation should be about the analytical cleanness and dissolved in the water about the II degree of purity according to ISO 3696 [24]. The chemical composition of artificial saliva was described in Table 1.

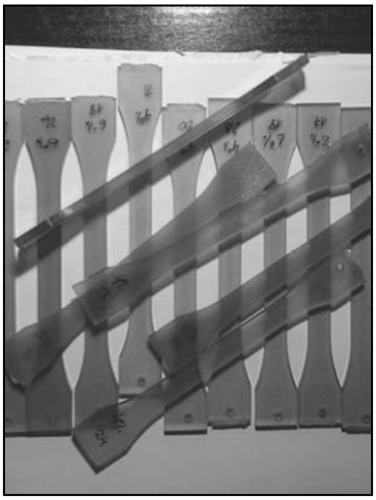

Fig. 5. Samples for examinations

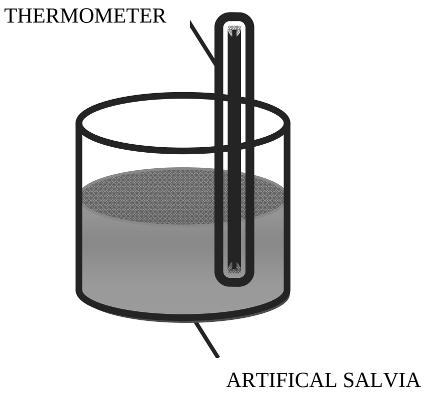

Fig. 6. Scheme of research stand I

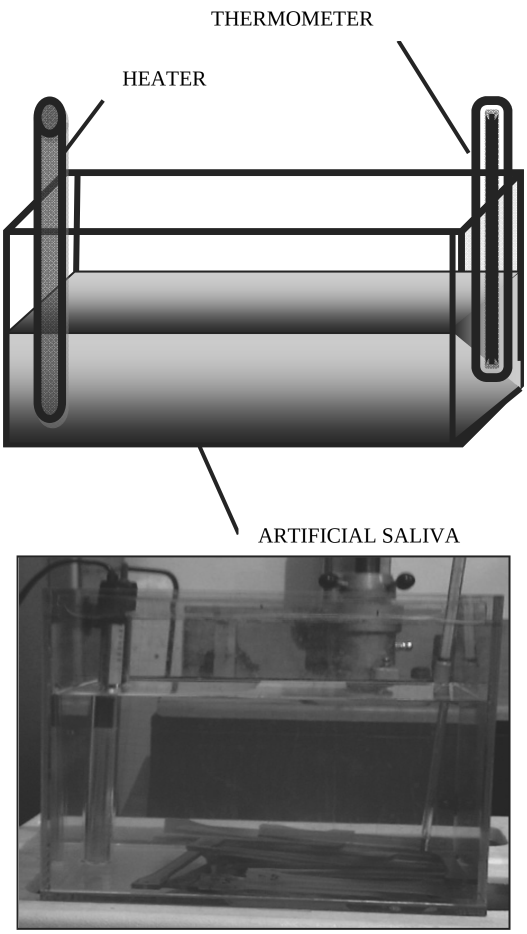

Fig. 7. Scheme of research stand II

Two stands were built for ageing examinations (See Fig.6. and Fig.7.). Examinations were conducted by 10 days. The temperature of artificial saliva was appropriately 23°C and 30°C.

Table 1.
Chemical reagents to artificial saliva [24]

ARTIFICIAL SALIVA	
Na_2HPO_4	0.260 g/l
NaCl	0.700 g/l
KSCN	0.330 g/l
KH_2PO_4	0.200 g/l
$NaHCO_3$	1.500 g/l
KCI	1.200 g/l

3. Results

Received results of measurements were averaged and they presented in the Figure 8. Examinations allowed to show that the absorbency of artificial saliva through composite is dependent on the temperature. The high temperature of artificial saliva caused faster absorbing by composite.

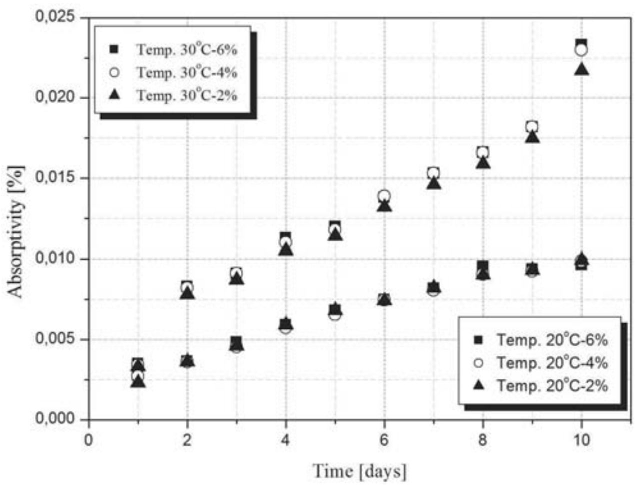

Fig. 8. Graph of the absorbency from the time

The influence of the content of the glass fibre on the absorbency is slight. Received findings of the Young`s modulus are presented in the Figure 9. The Young module is higher for samples which were ageing in the increased temperature.

During examinations on samples white sediment was observed. After chemical analysis it turned out to be the carbonate (See Fig.10.).

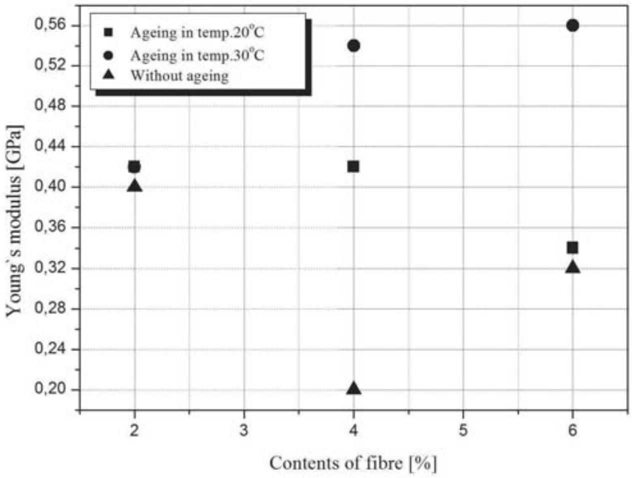

Fig. 9. Graph of the Young`s modulus

Fig. 10. Sediment on samples

4. Conclusions

Examinations allowed to show that absorbency of artificial saliva through composite is dependent on the temperature. The high temperature of artificial saliva caused faster absorbing by composite.

On the basis of achieved results it is possible to make the following conclusions:

- the absorbency of the polyamide is independent of the percentage content of the glass fibre,
- after first 24 h is appearing the biggest jump in assumed mass, later is spending the process running monotonously,
- the change of dimensions is comparable for all samples,
- the Young module is higher for samples which were ageing in the increased temperature.

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