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STRENGTH PROPERTIES OF ELASTIC DENTAL MATERIALS ON THE BASE OF MODIFIED POLYACRYLATES

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A comparative analysis of the strength properties of hydrogel composition and implants made of polymethylmethacrylate was conducted. Based on polyvinylpyrrolidone and 2-hydroxyethyl-methacrylate including additives of hydrophobic monomers a composition for making soft lining have been proposed. The adhesion strength (tension) of elastic materials bond by the method of "shear" and "breakaway" was studied. It was determined that adhesive strength values of hydrogel composition are quite high. It makes possible applying the composition as cover layer for the removable dentures basis.

Key words: hydrogel; composition; adhesive strength; elastic material; rupture strength; acrylate samples.

Introduction

The history of development of basis dental materials reaches the XVI century [1]. The first sample of denture was made by a French pharmacist of porcelain. The middle of the XIX century gave humankind a new material – rubber which was used by Delobor as a basic material for dental prosthetics. The mentioned material was acknowledged as the best within 100 years. At the time, they were quite functional materials improving esthetic qualities of the prosthesis. Evolution of dental prosthetics was occurring quite rapid for pretty short time. A sensational breakthrough happened in 1935. In that time the method of processing acrylates in the form of polymer-monomer composition have been proposed [2]. Acrylic compositions rapidly displaced rubber due to its manufacturability, hygiene as well as good esthetic qualities. Prostheses are becoming more functional however they have insufficient mechanical strength.

In orthopedic dentistry elastic materials are increasingly applied in the manufacture of basis removable denture [3, 4]. Unlike solid basis polymers, elastic materials protect the mucous membrane from trauma, improve retention as well as reduce the time of adaptation. Elastic basis materials weaken and amortize the peaks of masticator pressure ensuring its redistribution through the base of the prosthesis on the mucous membrane of the prosthetic bed. Above mentioned promotes the slowing down the resorption processes and atrophy of the alveolar process as well as the alveolar part of the jaw creating favorable conditions for further prosthetics [2, 4–6]. Elastic materials are used for reduced salivation, impaired fixation of the prosthesis, abnormal occlusion as well as to give a new shape to the old prosthesis [7]. Despite a number of convincing and obvious advantages, when using an elastic soft pad, there is an unresolved problem of connecting the soft elastic pad with the basis of the prosthesis solid base [8].

A number of researchers have been solved this problem [9, 10] who focused on improvement of the bond strength under the conditions of materials laser irradiation. The same researchers consider that usage of sandblasting machines in the treatment of work surfaces impairs the bond between materials. H. Zhang [11] has investigated the increase in the bond strength between a soft elastic lining and a hard basis under active oxygen.

Some authors [12, 13] confirm that the polymerization of materials under high temperature takes more time than in the polymerization of self-polymerizing elastic substrates however the quality of final product is much higher and the bonding of soft substrate with solid basis is considerably better. Therefore, further research to increase the strength of the connection between the solid part of the basis and different types of soft linings is relevant.

Currently, the industry offers various options of elastic plastics for effective removable prosthetics among which are well-known elastic plastics made of polymethylmethacrylate, in particular: Villacryl Soft (Poland) and Latacryl-L (Ukraine).

The goal of the study was to research the possibility of application a hydrogel lining as a cover layer for removable denture basis. Determine the strength properties of the bond of elastic materials with the prosthesis basis. Carry out a comparative analysis of the strength properties of implants made of polymethyl methacrylate, in particular Villacryl Soft and Latacryl-L.

Object and methods of research

For the production of soft lining we have proposed a composition based on polyvinylpyrrolidone and 2-hydroxyethylmethacrylate including the additives of hydrophobic monomers developed at the Department of Chemical Technology of Plastics Processing of Lviv Polytechnic National University. The composition was prepared of polyvinylpyrrolidone of 12 000 molecular weight. The benzoyl peroxide was applied as initiator of polymerization [14, 15].

Application of a linning made of such hydrogel material is attractive in the question of good biotolerance, sorption ability and respective highly elastic state.

To compare the strength characteristics, the acrylic plates were joined with Villacryl Soft and Latacryl-L elastic materials.

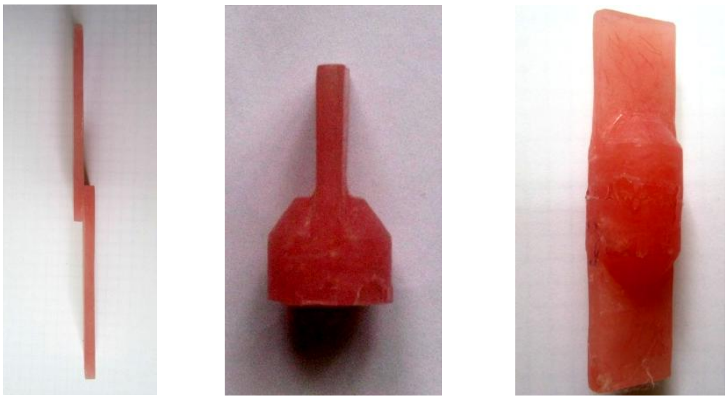
Villacryl Soft is a polymethacrylate material used to make soft linings in partial and complete dentures as well as to make epiprostheses which supplement the lack of soft tissue. Make in the form of a composite which includes: powder (acrylic polymer), liquid (acrylic monomer – diisoctyl phthalate, ethyl acetate), varnish (polyvinyl acetate, methyl ethyl ketone).

Latacryl-L is a composition made of suspension polyethyl methacrylate which does not contain methyl methacrylate and is applied in dental practice for the manufacture of soft linings in both partial and complete dentures.

The adhesion strength of the samples was tested via shear method according to ISO 6922:1987 [16]. The prepared elastic linings were applied to acrylate samples (plates) (Fig. 1, *a*) of the bonding area size of 20×8 mm and holded in a thermostat at a temperature of (333±5) K for 2.5 h after approval. The obtained samples (Fig. 1, *a*) were filled with distilled water for 48 h at the room temperature. The research of adhesive strength of hydrogel lining with an acrylic plate was carried out using rupture machine of 050/RT-601U brand "Kimura Machinery" company at velocity of moving traverse of 25 mm/min. The value of adhesive strength (W) was calculated by formula (1):

$$W = P/S, \quad (1)$$

where P – the load which destroys the sample, kg·f; S – bonding area, cm^2.



a *b* *c*

Fig. 1. Acrylic model samples:
a – the elastic lining connected to acrylic plates for shear testing;
b – basic view of the sample, acrylic "fungus";
c – an acrylic sample ("fungus") in combination with an elastic lining for research on breakaway

The studies concerning the determination of bond adhesive strength were conducted by "breakaway" method according to ISO 6922:1987. The method essence is to determine the index of destructive force when stretching the standard specimen with a force directed perpendicular to the plane of the joint.

Fig. 1 shows acrylic samples in combination with an elastic lining for "shear" and "breakaway" research.

Acrylate samples ("fungus") of 20 mm diameter and 10 mm of height (Fig. 1, b) were used for research and holded in thermostat at the temperature of (333±5) K for 2.5 h after approval. The obtained samples (Fig. 1, c) were filled with distilled water for 48 h at the room temperature. The values of adhesive strength (Wb) were calculated by formula (2):

$$W_b = F/S_1 , \tag{2}$$

where F – destructive load, kg·f; S_1 – joint area, cm^2.

Research results and discussion

The adhesion of the polymer material (substrate) to the base is frequently characterized by adhesive strength.

Adhesion strength is the stress which must be applied to joint to cause the components abruption. It is determined in two ways: 1) simultaneous abruption of one part of adhesive joint from the other relative to the entire contact area; 2) gradual delamination of the adhesive joint. The first method is applied in the work – breakaway of the elastic lining.

Adhesion strength (Wn) includes both the work of breaking molecular bonds (work of adhesion Wa) and the work aimed on the deformation of adhesive joint components (work of deformation Wd), formula (3) [18]

$$W_n = W_a + W_d . \tag{3}$$

The stronger the adhesive bond, the more components of the system will be deformed until it is destroyed. The deformation work can sometimes exceed the adhesion work, even in several times which can lead to the destruction of the basis (substrate). In general, the thermodynamic work of adhesion is the only indicator that is characterized by the adhesion of two bodies and has a physical meaning regardless of the test conditions.

The following types of abruption are possible during the destruction of the adhesive joint:

– adhesive one which causes the complete detachment of the adhesive from the substrate of the contact surface;

– cohesive one which causes the destruction occurs in the volume of the adhesive or substrate;

– mixed one which is accompanied by simultaneous destruction: adhesive and cohesive.

Usually the adhesive strength is estimated by the value of work which was defined in the process of mixed destroying, although the first and second case of fracture is possible, as evidenced by the results obtained during the research.

Grounded on the conducted researches the average values of adhesive strength of joints by the method of "shear" and "breakaway" were determined (Table 1).

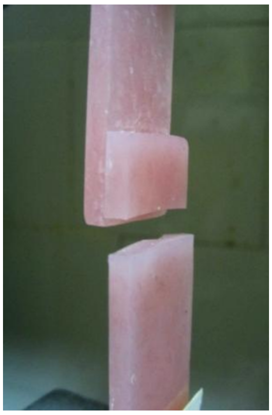
Table 1

Physical-mechanical properties of the bond

No	Type of lining	"Shear" method		"Breakaway" method	
		the average value of stress at destroying, MPa	destruction type	the average value of stress at destroying, MPa	destruction type
1	Villacryl Soft	2.02	mixed	3.2	mixed
2	Latacryl-L	1.25	mixed	3.15	mixed
3	Hydrogel composition	2.32	acrylic plate	5.97	acrylic "fungus"

The destructive stress value of acrylic plate by the method of "shear" makes 3.2 MPa, with a cross-sectional area of 2.4 cm^2. For comparison, the destructive stress at the breaking of the acrylate material. Sample was made in the form scapula according to ISO527-2:2012 [17]. The cross-sectional area of the working part of the sample is 5.6 cm^2 and the destructive stress is 2.24 MPa.

The bond strength of our proposed hydrogel composition based on polyvinylpyrrolidone is so strong that after staying the samples for 48 h in water, the acrylic bases were destroyed down themselves. The layer of hydrogel composition remained intact (Fig. 2, *a*, *b*).



a

b

Fig. 2. Appearance of samples after tests: a – "shear"; b – "breakaway"

According to the derived results, it can be stated that the adhesive strength of hydrogel composition is greater than the strength of acrylic plates used as a basis in hydrogel composition studies and many times higher than the strength of the joints used for comparison linings made of Villacryl Soft and Latacryl-L.

Table 2

Physical-mechanical properties of the bond of acrylic plate and hydrogel composition

No.	Type of lining	The average value of stress at destroying, MPa	Destruction type
1	Acrylic plate	7.62	in the volume of acrylic plate
2	Hydrogel composition	1.95	cohesive

To obtain more reliable result concerning the strength of the joined samples with hydrogel substrate holded them for ten days in water at room temperature (Table 2), 2 h in 3 % hydrogen peroxide solution and 2 h in water at (323±5) K. Then the properties of mentioned samples were stabilized by staying them for 24 h in distilled water.

Consequently a real result of the strength of the investigated hydrogel lining via the shear study was received [19]:

$$S = 1.8 \times 1.5 = 2.7 \text{ cm}^2;$$
$$F = 52.70 \text{ kg·f},$$
$$W = 52.7/2.7 = 19.5 \text{ kg·f/cm}^2 = 1.95 \text{ MPa}.$$

Thus, the bond strength to the hydrogel lining is 1.95 MPa (Table 2).

The study found that the destruction occurred exactly in the volume of the hydrogel layer. Therefore, the adhesion to the acrylic basis is higher than the strength of the hydrated hydrogel composition.

Conclusions

Grounded on the obtained results, it can be stated that the proposed polyvinylpyrrolidone – methacrylate hydrogel composition is characterized by high adhesion to acrylic materials.

Compared to the elastic Villacryl Soft and Latacryl-L plastics the adhesive strength of hydrogel composition containing acrylic-based prosthesis is higher. Mentioned above allows it to be used as a cover layer for removable denture basis in practical dentistry for prevention and treatment.

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МІЦНІСНІ ВЛАСТИВОСТІ ЕЛАСТИЧНИХ СТОМАТОЛОГІЧНИХ МАТЕРІАЛІВ НА ОСНОВІ МОДИФІКОВАНИХ ПОЛІАКРИЛАТІВ

Здійснено порівняльний аналіз міцнісних властивостей гідрогелевої композиції та імплантів із поліметилметакрилату. На основі полівінілпіролідону та 2-гідроксіетил-метакрилату, із додатками гідрофобних мономерів, запропоновано композицію для виготовлення м'яких підкладок. Досліджено адгезійну міцність з'єднання еластичних матеріалів методом "на зсув" та "на відрив". Встановлено, що показники адгезійної міцності з'єднання гідрогелевої композиції вищі, що дає можливість використовувати її як покривний шар для базису знімних протезів.

Ключові слова: гідрогелева композиція; адгезійна міцність; еластичний матеріал; напруження при руйнуванні; акрилатні зразки.