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THE INFLUENCE OF HUMIDITY ON THE HARDNESS OF ACRYLIC OCULAR PROSTHESES

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ABSTRACT

The paper presents a study on the influence of humidity on the hardness of ocular prostheses made of acrylic material. To carry out this study, a determination of the hardness of the ocular prosthesis was made after immersion in artificial tears for seven weeks, performing several determinations of the hardness values of the acrylic material. Since the ocular prosthesis is subject to the humidity of the ocular cavity and external atmospheric factors, the study also focused on determining the humidity of the acrylic material from which the prosthesis is made.

KEYWORDS: ocular prosthesis, hardness, humidity, acrylic material

1. Introduction

An ocular prosthesis is a device that occupies the anterior part of an orbit, and is designed to aesthetically repair an eye lost due to trauma, congenital anomalies, irreparable injuries, or tumours.

The ocular prosthesis is used in cases where an eye has lost its functionality and natural appearance or even in the congenital absence of the eye. The ocular prosthesis is custom-made for each patient, depending on the colour of the person's other eye [1].

Humidity plays a key role in the wear and maintenance of ocular prostheses. The ocular cavity must be kept properly lubricated to prevent irritation and discomfort, while the prosthesis itself should not be allowed to dry out excessively when not worn, as the material may deteriorate.

Because the ocular prosthesis is subject to the moisture of the ocular cavity and external atmospheric factors, there are changes in the properties of the prosthesis [7].

Hardness is a physical property of a material that indicates its resistance to permanent deformation or scratching under the action of an external force.

This can be measured by various methods, such as penetration or indentation measurement, and is important in assessing the quality and performance of materials in a wide range of industrial and engineering applications.

Hardness determination is the process of evaluating a material's resistance to permanent deformation, especially breaking or scratching, under the action of an external force.

The hardness of ocular prostheses refers to their resistance to scratches and other forms of damage.

A scratched or damaged surface can affect the patient's health and quality of life. Factors that influence the quality of the ocular prosthesis are: the material from which the prosthesis is made, the covering with the protective material, humidity and last but not least, care and handling [8, 9].

2. Materials and methods

The production of ocular prostheses underwent a great development with the introduction of polymethylmethacrylate (PMMA) implants 75 years ago.

PMMA stands for polymethyl methacrylate. It is a synthetic polymer that is widely used because it is transparent, lightweight, and has good mechanical properties.

Prostheses made of polymethylmethacrylate (PMMA), are a polymerized product of a mixture of acrylic powder (mainly PMMA) and liquid monomer (mainly methyl acrylate (MMA)) [7].

For the use of the material in ocular prostheses, polymerization must be carried out for a long enough time to prevent residual monomer, which is toxic and can cause adverse reactions, but polymerization for too long can change its colour.

There are two types of orbital implants, porous and non-porous. In the past, non-porous implants were made of glass, rubber, and metals such as steel, gold, or silver, but nowadays the most commonly used materials are silicone, acrylic, and polymethyl methacrylate (PMMA).

Due to its biocompatibility, processability, and durability, PMMA is the standard material for plastic ophthalmic prostheses [8].

3. Determination of ocular prosthesis hardness after immersion in artificial tears

To simulate a real natural environment, namely the placement of a prosthesis in the ocular cavity, and to study the behavior of the acrylic material and how humidity can influence the hardness of the prosthesis, a prosthesis was immersed in artificial tears (purified water, sodium borate, sodium chloride) for a period of 7 weeks.

The determination of the prosthesis hardness was performed at 2, 5 and 7 weeks, with the automatic digital Micro-Vickers HDT-VS1D INSIZE device, from the laboratory of the Faculty of Engineering (Figure 1).

The technical specifications of the device are: load 0.5 (kg), replacement time 10 (s), objective at 40x, brightness of 4 [2].

The stages of carrying out the determinations consist of:

- placing the prosthesis on the device support;
- fixing the specifications used for all determinations;
- focusing the area and marking the length and width;
- data generation, for the control sample (before immersion) and the determinations after 2, 5 and 7 weeks (Figure 2).

***Fig. 1.** Micro-Vickers HDT-VS1D INSIZE hardness tester*

The data obtained from determining the hardness of the prosthesis were summarized in Table 1 and graphically represented in Figure 3.

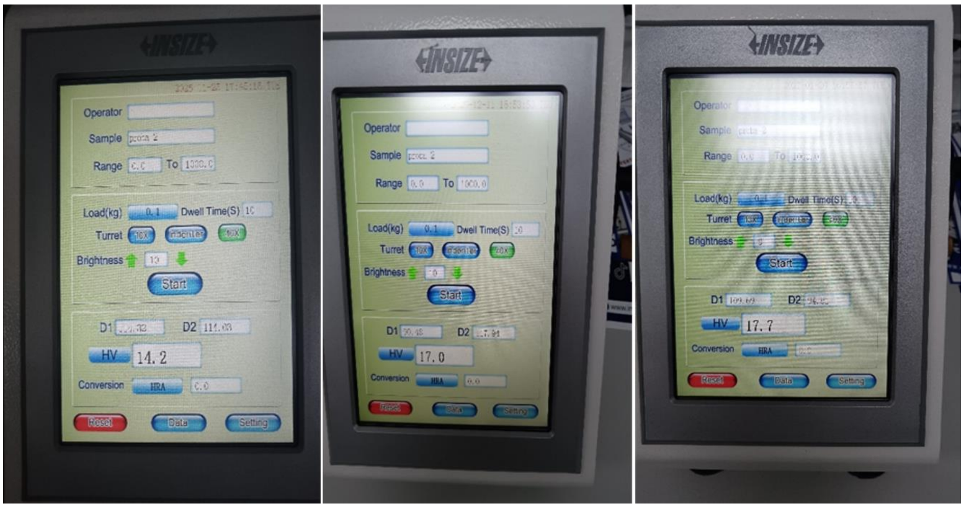

***Fig. 2.** Data generated by the device during the research*

***Table 1.** Ocular prosthesis hardness*

Weekly	D1 (distance 1)	D2 (distance 2)	HV (hardness)
Initial	114.32	114.03	14.2
2 weeks	90.48	117.94	17
5 weeks	105.3	118.4	17.7
7 weeks	109.69	94.81	17.7

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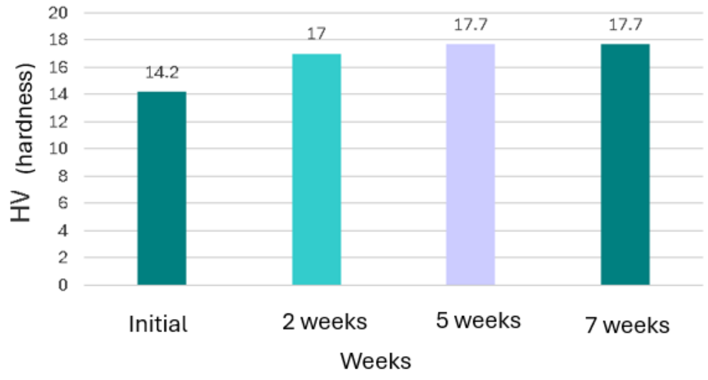

Fig. 3. *Evolution of hardness as a function of immersion time*

Following these determinations, we found that the hardness values increased with the immersion time of the ocular prosthesis in the artificial tear solution. The hardness value remained constant after five weeks of immersion, obtaining the same hardness values in the seventh week of immersion.

The increase in hardness compared to the initial un-immersed sample is due to the capillary channels existing in the ceramic powder used to make the prosthesis being filled with the liquid absorbed by the material [3].

After the capillaries were filled, the material became saturated and the hardness increased, remaining constant after week 5. Therefore, in the final determinations, in week 7, the hardness values remained identical to those measured in week 5.

4. Determining the humidity content of acrylic material

Humidity can have a significant impact on PMMA, causing physical and chemical changes, which can affect the performance and appearance of the ocular prosthesis.

Humidity can have different effects on PMMA. One of the most noticeable things is absorption. PMMA is a hydrophilic polymer, which means it can absorb water from the environment.

Since during the research, it was found that the ocular prosthesis immersed in artificial tears absorbed some of the liquid, the moisture content of the sample was calculated.

Swelling capacity is the property of a material to absorb water or a solvent and consequently, to increase its volume, an essential property for evaluating the hydration behavior of polymers, hydrogels and paint films.

The initial dry sample was weighed, and then after the sample was immersed in artificial tears, several weightings were made over the course of 7 weeks, until it was found that the mass of the sample remained constant.

Fig. 4. *Weighing the sample*

The humidity content of the sample was calculated with the formula:

$$U = \frac{M_f - M_i}{M_i} * 100 \ [\%]$$

where: M_f -final mass; M_i - initial mass; U – humidity.

$$U = \frac{2{,}814 - 2{,}554}{2{,}554} * 100 = 10.18 \ \%$$

After weighing the sample, it was found that at the beginning of the prosthesis immersion in artificial tears, the mass of the sample increased, and after five weeks of immersion it remained constant.

Due to water absorption, the release of residual monomer may increase, this leads to continued polymerization of the resin and higher microhardness values [1].

For the sample immersed in artificial tears, a microscopic analysis of the surface was also performed, on which the solution drops and the trace left by the hardness determination device can be observed (Figure 5).

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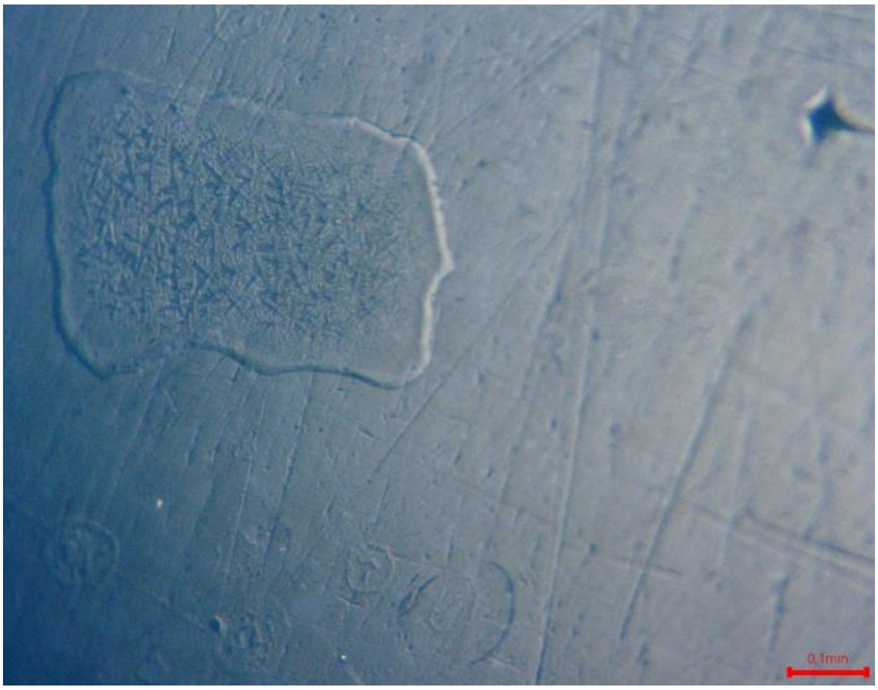

Fig. 5. *Sample surface immersed in artificial tears*

5. Results and discussion

The lifespan of an ocular prosthesis is between 2 and 6 years in an adult, depending on the patient's age, occupation, care of the prosthesis, and the materials it is made of.

Any rough or scratched surfaces can be easily removed by polishing. These aspects make the PMMA ocular prosthesis a very durable prosthesis.

A PMMA prosthesis has the advantage that it can be adjusted at any stage of the manufacturing process, both in terms of colour and shape. If an incorrect estimate has been made, the shape can be adjusted later [7].

This property makes the production of acrylic ocular prostheses easily accessible for fine-tuning. If minor adjustments to the shape are necessary over time, additional material can be pressed or the model can be locally planned to adapt to the new situation of the socket.

Despite these advantages, a disadvantage of PMMA is that it is hydrophobic. Water tends to adhere in droplets rather than form a smooth tear film that would evenly wet the surface of the prosthesis, as would the natural eye.

Once the PMMA implant has absorbed moisture, this can lead to physical changes, such as dimensional change. The prosthesis may swell as water molecules take up space in the polymer structure [9].

Water absorption can affect the mechanical properties, dimensional stability, and overall durability of the material.

Studies are being conducted to increase the wettability (hydrophilicity) of the artificial eye. Among the promising options is adjusting the proportion of ethylene glycol dimethacrylate (EGDMA) already available in the liquid monomer of the PMMA mixture. The addition of polyethylene glycol makes the surface more hydrophilic and reduces bacterial adhesion [8].

6. Conclusions

The influence of humidity on the hardness of acrylic ocular prostheses was determined out after immersing the sample in artificial tears.

The study revealed that the hardness values of the ocular prosthesis immersed in artificial tears increased with immersion time, from 14.2 HV initially, to 17.7 HV in the fifth week, after which the hardness value remained constant until the end of the experiment, namely seven weeks.

The capillary channels existing in the ceramic powder used to make the prosthesis were filled with the liquid absorbed by the material, which led to an increase in hardness compared to the initial un-immersed sample.

After filling the capillaries, the material became saturated and the hardness increased, remaining constant after the fifth week. Therefore, in the final determinations, in the seventh week, the hardness

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values remained identical to those measured in the fifth week.

For the sample immersed in artificial tears, the moisture content was calculated, obtaining a moisture content of 10.18%, which led to higher microhardness values, due to water absorption. The release of residual monomer leads to the continuous polymerization of the resin, resulting in increased hardness.

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