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CONSIDERATIONS ON THE BEHAVIOR OF THE SOFT CONTACT LENS MATERIALS

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Abstract: *Contact lenses are an option for correction of spherical ametropy and ocular astigmatism; may also be used for therapeutic purposes and not least for cosmetic purposes. Compared with air correction, contact lenses allow normal field of view, eliminates peripheral distortion of spectacle lenses, providing a magnification on the retina of about 7%, while allowing the restoration of binocular vision. It also adapts easily to the cornea, with small, relative to the corneal topography respecting the rule of the latter. Most times, contact lenses provide high wearing comfort, a correction lens better than air and can be individualized according to their preferences and comfort carriers. This paper aims to present the main types of materials used in manufacturing contact lenses and insist on time to dehydration very important in their adaptation. Are also presented an experimental test performed on a group of three types of contact lenses.*
Keywords: *Contact Lenses, Materials, Polymers, Adaptation, Dehydration Time, Hydrogel.*

1. INTRODUCTION

Contact lenses are medical devices used primarily to correct various defects of vision as nearsightedness (hypermetropia), farsightedness (myopia), astigmatism, and presbyopia. Contact lenses are small disks of soft material, slightly, concave, which are positioned directly on the eye. This makes choosing the correct lens is essential for comfort and safety vision.
The beginnings of contact lenses is somewhere in the nineteenth century, but the first generation of lenses that could be worn appeared only in the mid twentieth century. With the development of chemical industry and polymer derivatives in particular, also the appearance of biocompatible materials, this optical correction alternative took large scale [1].
The necessity to improve the lifestyle and the people suffering from refractive errors need for not taking good care of glasses, led to the stronger development of the contact lenses industry. Currently, on the market, is a wide choice of types of contact lenses. Starting from the lens from glass, then from the hard plastics that subjects more sensitive are often uncomfortable to wear, it was reached the version of soft lenses, that not only are very comfortable to wear, but they have superior properties as their predecessors [2].
Starting from the idea mentioned above, the evolution of contact lens industry is marked by several significant stages. The first stage is marked by the appearance of hard contact lenses. They are made of hard plastics, such as polymethyl methacrylate, that does not adapt to the shape of the cornea, being quite uncomfortable to wear. In addition, conventional hard contact lenses do not allow a proper oxygenation of the cornea, making them a potential risk factor in corneal lesions and infections. For this reason, a development and improving their quality was inevitable [2].
That appeared hard contact lenses, gas permeable. They are actually quite flexible and allow better oxygenation of the cornea. They are made of hard plastic, porous, allowing passage of a larger amount of oxygen than in the case of soft lenses for daily wear. They offer excellent correction in a wide range of visual problems and are, after an accommodation period, very comfortable for most wearers. Easy to maintain, long lasting, it shows a very low danger of occurrence of infection and are more durable than the soft ones. The main disadvantages are that are easily separated from the eye, can introduce changes in corneal topography during wearing, can be unstable at winking, can have an adaptation protocol more difficult and they have a low hydrophility [3]. However are successfully used for correction of uneven or high values corneal astigmatism and for corneal deformations such as keratoconus. In some cases can improve dry eye problems because they allow exchange of fluid under the lens, because they are permeable to oxygen but not to water [3]. But not everyone can accept this type of lens, some subjects declaring them uncomfortable and in some cases impossible to wear [4].

For this reason, there has appeared soft and flexible contact lens. Soft contact lenses are made from a plastic material containing liquid, fits the shape of the eye, providing high comfort during wear. The main advantages of these lenses: higher oxygen permeability, are wearable, comfortable and with a higher degree of hydration than hard one because of the water content they present. Some can be worn during the night (the port extended) and is especially suitable for athletes and children [4].

2. MATERIALS USED IN THE MANUFACTURE OF CONTACT LENSES

The materials used to manufacture contact lenses today are artificial materials. Their main feature is the molecular structure, determined by the properties of certain atoms to achieve stable covalent bonds. Silicon and carbon are the most representative materials. The molecular structure of artificial materials is represented by the notion of macromolecule. It speaks of a macromolecule when the length of the molecule is usually much larger than the diameter of an atom or molecule. Type, length and shape of macromolecules determine the properties of the specific artificial material. Each component of a macromolecule is called monomer and the polymer is considered a macromolecule.
In optometry are used three types of polymers [5]:
a. Natural polymers - Are obtained from natural raw materials. Most used raw material is cellulose. This is an organic raw material, which appears in the cell walls of plants. In terms of structure it is a fibrous material that is chemically analyzed shows like chains of glucose units, so-called polysaccharide.
b. Modified polymers - They are all natural raw materials, but undergoes some changes. Ethyl cellulose (Cellophane) and nitrocellulose (celluloid) are the principal cellulose derivatives. Nitrocellulose (NC) is a modified polymer as the celluloid developed. Cellulo-aceto-butyrate (CAB) is a modified polymer, which is the main constituent of aceto-nitrile cellulose butyrate.
c. Synthetic polymers - Are polymers made from basic components, which preserves their properties even the slightest resemblance to the products.
The main types of synthetic polymers used in the manufacture of contact lenses are:
- Acrylic glass - Plexiglas is the marketing name of a synthetic glass, very clear and mechanical strength, based on polymethyl methacrylate acid (PMMA);
- Siloxane-methacrylate;
- Fluoro-siloxane-methacrylate - fluorocarbons has the ability to increase the solubility of oxygen and not to let the adhesive deposition. Connections of fluorocarbon make a very soft material. Therefore is trying to combine the properties of siloxane (high permeability of 02), fluorocarbons (small deposits) and other similar ones;
- Hydrogels (poliHEMA) - is a synthetic polymer, a homo-polymer with three-dimensional structure. The inclusion of water is by joining hydroxyl group, linking water with bipolar forces. For water can enter in the material, poliHEMA need it to behave like a rare mesh. Maximum soaked polymer contains about 40% water. By copolymerization of HEMA with vinyl pyrrolidone (VP), embedding property of the polymer to water can be higher. Depending on the proportion of VP, it will make a hydrophilic property up to 70%. The mechanical properties of the material are reduced due to copolymerization. By copolymerizing MMA (methyl methacrylate) can produce materials with special properties. Mechanical of properties of these copolymers are suitable for use as contact lens material, but something better than HEMA / VP copolymerizable.
- Silicone - rubbery silicone (S1R) is a material that does not absorb water (hydrophobic). Hydrophobicity of the silicone ties is the cause of having difficulties in the manufacture of contact lenses. Using silicon as a material for contact lenses, it is determined by its two important properties namely: high oxygen permeability and deposits stability on its surface.
- Silicone rubber - if changes the silicone rubber by introducing a polydispersity component and then a hydrophilisation operation of the surface, it must be yielding a material for the manufacture of contact lenses. A difficulty arising because of the lens surface deposits enzyme that develops during wearing again saturates the surface hydroxyl groups. Thus, areas appear on the surface hydrophilic contact lens.

2.1. Contact lens material properties

Many properties of materials for the manufacture of contact lenses are important in adapting to the human cornea. Their importance is even greater when they have to take into account the particularities of each adaptation from one carrier to another. Checking these properties is done with great severity, both in vitro and in vivo [3].
Physical properties [6]:
- Optical: the index of refraction, dispersion coefficient, transparency (light transmission);
- Mechanical resistance to elongation, specific elongation, shears strength, tensile strength, hardness, specific gravity (density);

- Superficial: the contact angle, the ability softening, swelling, surface condition.
Biocompatibility properties:
- Biophysical: permeability to oxygen and carbon dioxide, water permeability, hydrophilicity and lipophilicity, the extractability;
- Biological: sterilization capacity, degree of favoring the growth of microbes, tears stability, ability to get dirty;
- Clinical adaptability, respect metabolism corneal lens long carrying ability, the ability for the body to be able to adjust to the material.
• Technologic properties- the ability to process using simple procedures.
• Cosmetic features - colors to ensure the proper natural aesthetics.

2.2. Material properties for soft contact lenses (according to [3,5])

a. Swell coefficient and dimensional stability
Insofar as the water absorption in linear direction and in volume is directly related to the amount of water absorbed, there will be a change in the size of the contact lens. PoliHEMA is a polymer stably to changes in temperature, pH and tonicity (osmolarity and concentration) of the environment moisturizer. Temperature dependence of the water content in hydrogel includes other factors. If the temperature of the hydrogel is increased from 4°C to 90°C, created thermal energy causes an increased mobility between the polymer chains, and leaves to the water a much greater freedom to interact with the functional hydroxyl groups. Therefore, there is an increase in the water content at the same time an increase in the coefficient Swell. If the temperature is 40°C, the process is more complex, due to the low thermal energy, but the polymer chains gaining sufficient freedom of movement and provides a perfect interaction with constituents. This process, also called optimization process, resulting in a decrease in the amount of water in the material. It should be noted that this thermally induced change occurs very rapidly, and EWC will return when applying the contact lens on the eye. To maintain dimensional stability of contact lenses and to minimize the dimensional changes between preservation medium of contact lenses and ocular environment, they are kept in a special saline solution that provides pH and their proper tonicity.

b. Mechanical properties
In dehydrated state, poliHEMA, like most polymer hydrogel, is hard and frangible, like PMMA material. When is immersed in water, it becomes soft, with low elastic properties and tensile strength. This weak strength has an effect in terms of the lifetime of the contact lens, which means that soft contact lenses must be replaced more frequently than rigid contact lenses. Together with the water, which plays an important role as regards the mechanical strength of the material, the chemical structure of the polymer is also important. Elastic behavior and stiffness of the polymers in the hydrogel are influenced by the composition and structure of the monomers in the cross-linking structure, which includes both covalent, and ionic bonds, as well as polar forces between the polymer chains. Thus, using such structures could result material with increased elastic stability and hydration. Contact lenses with high water contents available on the market today are far superior to the first generation of hydrogel lenses, based copolymer HEMA+NVP, which were very weak. As a general rule, it is fair to say that a high water content of the material they are made lenses reduce their sustainability, particularly tensile strength, but these considerations may have a minor when contact lenses are indicated for use in a short period of time, on the order of days or weeks.

c. The surface properties
Apparently, hydrogel contact lenses do not change due to the inherent moisture, because they are not fully hydrated. However, there are two factors that influence their behavior when they are applied to the eye. The first factor is that the anterior surface of the contact lens gradually loses water, especially in unfavorable environmental conditions, e.g. air conditioning, dust and wind. The second factor is the chemical, namely the polymer chain can rotate rapidly in response to environmental change: in contact with aqueous substances, hydrophilic groups rotate to the surface antagonistically, when there is contact with hydrophobic groups are numerous, the air or lipids, hydrophilic groups plunges gel, leaving the surface more and more hydrophobic groups. The rotation of polymer chains is a dynamic process, and because of this loss of water by evaporation, is a progressive process.
Molecular processes, for example deposition or protein denaturation, are also able to respond to dynamic processes, which demonstrate the complexity of the ocular surface. Progressive dehydration of the contact lenses has a greater influence on the macroscopic structure of the hydrogel and forms part of the factors that cause discomfort at the end of wear on many respondents. Two properties can describe hydrogel, i.e. surface energy, which is manifested by moisture, and friction coefficient, which underlies the biotribologic behavior of the contact lens. Both properties are closely related to the behavior of the lens in the presence of water.
Studies show that the friction coefficient of both natural hydrogel (cornea) and the synthetic are naturally

lubricated in a hydrodynamic layer of water. This affects the friction coefficient of the extent that, when a lubricating layer separates the hydrogel to the substrate, this property returns the environment, and not the material. A simple analogy is that of a car aquaplaning, i.e. very easy slipping on the water surface is not influenced by the material of which are manufactured tires. Surface energy is a progressive property of hydrogel. It grows quickly to a water content of about 30% and after this value is less rapid growth.

As discussed previously, if an interface surface energy hydrophobic polymer chains decreases rapidly due to the rotation. Almost all of hydrogel materials show excellent surface properties, at the time of full hydration, regardless of the initial content of water. A problem arises when starting the drying process of the material and shows the response to the air and lipid. These processes influence the deposition of substances of the tear film components, which give dry eye symptoms at the end of the day.

d. Material density

The density of the hydrogel depends on the water content of the composition and monomers. A low water content (a more rigid lenses) containing hydrophobic monomers has the highest density of such polymers group. This is the range around 1.22 g/ml to a water content of 10% and a temperature of 20°C. This type of material has widespread use as membranes, and not as contact lenses. Common lens HEMA copolymer, that containing the most hydrophilic monomer group, have a density that gradually decreases from the value of 1.16 g/ml to water content of 38% to a value of 1.05 g/ml at 75% content of water. The values were obtained under normal conditions of temperature and pressure (20°C).

e. Refractive index [7]

The refractive index decreases in direct proportion to increasing water content. The decrease variation is approximately linear to the water content and the values of contact lenses are contained in a relatively small area, falling from 1.46-1.48 for 20% water content to a value of 1.37-1.38 at 75% water content. Due to this analogy, it can quickly determine the approximately content of water in a hydrogel material.

f. Light transmissibility

Transparency is an important property of hydrogel contact lenses, but not all hydrogel polymers are transparent. Translucency and opacity of the hydrogel are associated with chemical instability are water, producing regions of different refractive indices in the surface of the lenses. The hydrogel, which have been demonstrated to such properties, has the advantage of increased strength and permeability. Such materials, having a surface area sufficiently small and have the ability to retain the optical transparency, are mostly used in areas where the permeability and strength of the material are important, for example, contact lenses for extended-wear lenses or the synthetic cornea.

g. Oxygen permeability

A major requirement of contact lenses is that they allow large enough influx oxygen to the cornea, so not to influence proper functioning of corneal metabolism.

A fundamental relation of oxygen permeability of the material would be:

$$P = DS \tag{1}$$

where P is the permeability coefficient of the material gas, D is the diffusion coefficient of the gas through the polymer and S is the solubility of the gas in the polymer.

Irving Fatt chose the use of "k" to define solubility, and in response to this, the literature uses the term Dk to define gas permeability of the material. Although coefficient Dk is a material, Dk/t refers expressly to the permeability of a contact lens to a certain thickness (t). To determine the Dk of a material at a certain temperature is necessary to measure the volume of gas per unit time at which a particular gas passing through an equipment of given size (area and thickness), at a certain gas pressure. When it be consider units Dk units Barrer (Irving Fatt), then the oxygen transmissibility Dk/t will become transformed 10^{-9} Barrer/cm [5].

After oxygen passing through the contact lens is consumed by the cornea. Thus, it is necessary to have a relation in terms of necessary oxygen consumption and the flow of oxygen passing through the contact lens. But there are two problems that arise. The first refers to the true value of material permeability, and the second relates to the use of specific permeability of the material to provide a contact lens transmissibility effectiveness of a certain diameter under a certain prescriptions. It must be consider that Dk mentioned by the contact lens manufacturer is an estimate and not precise, intended to guide prescribers in choosing the most of the contact lens for a particular subject. The problem is particularly important when the projecting portions of the desired contact lens [8]. It is therefore necessary to understand the factors affecting the permeability of conventional hydrogel contact lenses and differences that arise between them and silicone hydrogel lenses.

3. EXPERIMENTAL ANALYSIS OF THE DEHYDRATION TIME OF CONTACT LENSES

The dehydration time of a contact lens is very important because in this way it can be known the duration for which contact lens is comfortable and can provide a good visual acuity for eye wearer [9]. For this it have been chosen contact lenses with different parameters of the constituent materials, trying to simulate their port and see this way what is the optimal time wearing them.

a. Dailies AquaComfortPlus - Daily wear soft contact lens
Contact lens parameters [10]:

- Disposable wear, single usages;
- Material components: 31% nelfilcon (hidrogel) + 69% water;
- Material with high nonionic water content;
- They are spherical lens with daily wear and replacement, with diopters between +6.00 and +0.50 respectively between -0.50 and -10.00;
- Oxygen transmissibility (Dk/t): 26; Tint: Light blue handling tint
- According to the manufacturer, it is the first and only contact lens embedded with a unique triple action moisture: lubricates morning lenses to feel smooth and easy to apply them; humidify the whole day to keep fresh longer lens; refreshes the evening, for comfort throughout the day.

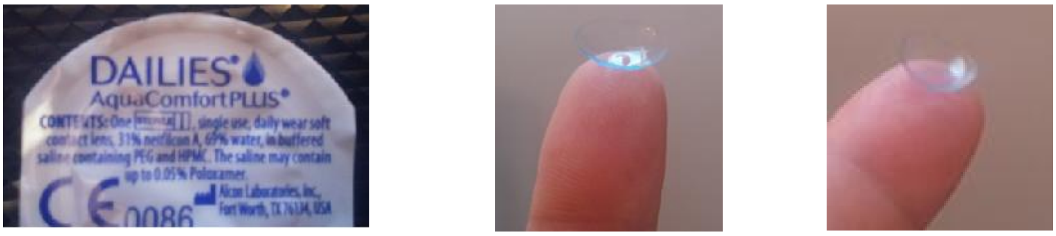

Figure 1. Daily wear soft contact lens dehydration

Time of dehydration for this type of lens was 7h 30 min. The lens can be kept up to maximum 10 hours only with the specification that after this time discomfort will occur in port lens and ocular health may be endangered.

b. Frequency Xcel Toric - Monthly replacement contact lens with daily wear
Contact lens parameters [11]:

- Daily wear, monthly usages;
- Material components: 45% methafilcon A (hidrogel) + 55% water;
- Material with medium nonionic water content;
- They are aspherical lens with monthly replacement, with diopters between -8.00 and +6.00, cylinder from -0.75 to -2.25, with axis from 10° to 180°;
- Dk: 128; Dk/t (@-3.00D): 116; Modulus (MPa): 0.75; Handling tint: Light blue; Centre thickness (@-3.00D): 0.11mm;
- According to the manufacturer, the Frequency Xcel Toric are soft lenses that significantly improve vision with astigmatism. These lenses are not only comfortable and help to stable and accurate account but have an indicator front and back, enabling a more effective handling and application.

Figure 2. Dehydration of the monthly replacement contact lens with daily wear

The dehydration time was 8h and 40 min after which time the lens has become rigid. It is recommended that the lens be put into maintenance solution and kept at least 6 hours or overnight to regain baseline characteristics.

c. Comfilcon A Toric - Monthly contact lens with continuous wear up to 30 days and nights
Contact lens parameters [11]:

- Continuous wear (day and night), monthly usages;
- Material components: 52% comfilcon A (silicon - hidrogel) + 48% water;
- Material with low nonionic water content;

- They are aspherical lens with monthly replacement, with diopters between -20.00 and +20.00, cylinder from -0.25 to -5.00, with axis from 0° to 180°;
- The physical/optical properties of the lens are: Refractive Index: 1.40; Light Transmittance: >97%; Surface Character – Hydrophilic; Specific Gravity: 1.04; Oxygen Permeability: 128 x 10^{-11} (cm^2/sec)(ml 02/ml x mmHg) 35°C (Coulometric method).

Figure 3. Dehydration of the monthly replacement contact lens with continuous wear

In this case, time of dehydrating for the lens was about 16 hours, which shows that the lens may be worn overnight and up to about 24 hours. It is recommended that after this period, at least 2-3 hours to be hydrated in particular maintenance solution.

4. CONCLUSION

The lens functions as the optical element of the eye when are placed on the cornea. Their refractive elements are combined with those of the eye, resulting in a good visual acuity. Despite these advantages, in prescription lenses and their recommendation, is very important the time of dehydrating. Compliance with the manufacturer's recommendations and rules of hygiene are required in maintaining ocular health. Hydrogel contact lenses are soft lenses with a high water content, very comfortable to wear and adapts easily to the eye. But the desire for constant change and innovation in technology, scientists have brought to the fore a revolutionary material with high oxygen transmissibility. Thus silicone - hydrogel lenses appeared. They are soft lenses, very thin, allowing higher oxygenation of the eye (even under conditions of continuous wear) and have a low adhesion on surface, which prevents protein deposits. Silicone-hydrogel lenses have become very popular among contact lens wearers, which led to the creation of this lens material for almost all types of vision correction. Currently certain types of silicone-hydrogel lenses are recommended even as bandages in treating ocular minor injuries in the cornea, dry eye sensation, and are recommended especially for those who spend time in front of computers.

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