

Mechanical Properties of Some Dental Resins in Wet and Dry Conditions

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The objective of this paper was to review the acrylic based resins biodegradation phenomena. The general objectives are based on multidisciplinary research of biomaterials used in dental medicine. For this analysis, different types of polymers were evaluated for water absorption and mechanical strength degradation caused by exposure to saliva. Two sets of 10 specimens were prepared from the analyzed materials according to manufacturer recommendations. The mechanical properties determined on wet samples were lower than those of samples from the same materials, tested dry. Difference between the mechanical properties determined in wet and dry was higher for those materials in which the degree of water absorption was higher. This indicates a clear influence of saliva on the biodegradation of these materials.

Key words: dental polymer, mechanical properties, saliva

Continuous development and progress of the polymer's industry with application in general and dental medicine has its ground in the importance of these biomaterials in the health domain. Using of these resins in different technological variants for the restoration of the oral cavity is benefic from childhood till geriatric period [1-5].

Among the achieving technologies of the complete dentures one can distinguish: heat-curing, self-curing, injection, light-curing, casting and microwave use. The heat-curing technology follows the ISO 1567:1999/AmD 1: 2003 standard.

The modern light-curing technology of the complete dentures bases appeals to a rapid system of achieving the prosthetic bases from aliphatic urethanedimetaacrilates - urethane oligomers and acrylic polymers, an anorganic submicronic silica filling, a light-curing initiation system and aditives), skipping the intermediate working phases, like investment and classical heat-curing. Eclipse Resin System consists of three types of resins- Base plate, Set Up and Contour Resin, from which only the first two are in contact with the oral tissues. (Set Up- is used only for assembling of the artificial teeth).

Long term deterioration of the polymeric complete dentures in oral environment is still an unsolved problem. It can be induced by the manufacturing technology, by

polymer's defects and distorsion in warm and humid environment [6], material's fatigue and aging. One needs to take into consideration also the various aggressions of the external and internal environment, like: acids, alkalis, alcohol, tobacco, thermal fluctuations etc., and also the contact with water and salivary enzymes, refined or not food remains, biologic products of excretion, fluctuation of the oral balancing system, the contact with living tissues, viruses and yeasts. It seems that, the enzymes from human saliva play an important role, namely hydrolyses, which are able to produce a softening of the polymers' surface, presumably by inducing a hydrolyzing process of monomer [7].

The practitioners consider the polymeric chains as being insoluble structures and this is the reason why, most of the doctors recommend the dentures storing during the night in water recipients. Because these dentures absorb water anyway during function and storing, one may suggest that this is the cause for polymers biodegradation in time, with consequences upon their biomechanical properties [8]. It seems that, the solvent effect is given by the hydrolytic degradation, which effect shortens the lifetime of the dentures or other polymeric restoration. In the figure below, one can notice the hygroscopic and hydrolytic causes and effects of the polymeric chains [8, 9].

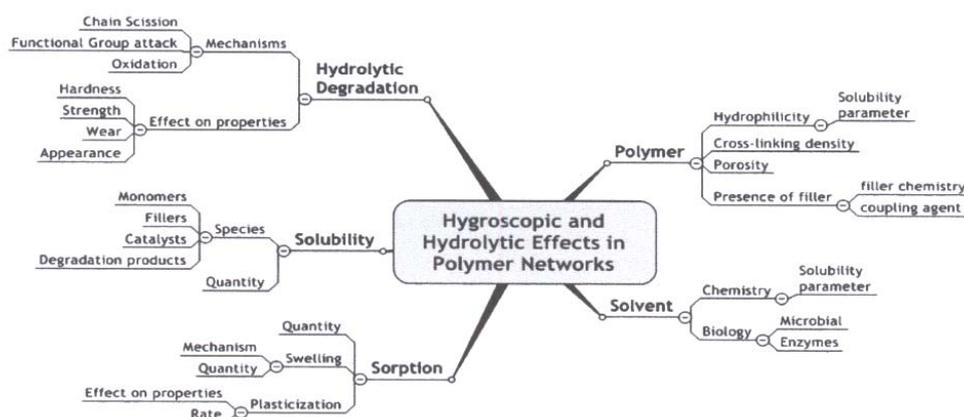


Fig. 1 Factors affecting the hygroscopic and hydrolytic properties of polymer networks [8]

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The biomechanical study of the dental resins, implying different technologies, is necessary to understand the causes of the prosthetic failures. These failures are given not only by the material defects, which appear in all dentures- dependent on the material structure (with or without the presence of reinforcing filler); they can also appear follow-up the technological procedures for achievement of the prosthetic pieces, their processing and solubility [8]. Most of the resins distort and fracture at low level of tension, dependent on the environmental or loading conditions [4,5].

This is the reason why, the study of the biomaterials can lead to dentures durability increasing and to long time warranty for their efficiency in the oral cavity. Thus, one may reduce the dentures repairing and reoptimization costs.

The aim of the study was to compare the mechanical properties of some dry heat-curing and light-curing resins with those of the humid resins, within a multidisciplinary collaboration in the field of biomaterials.

Experimental part

Dentistry-denture base polymers samples of different composition and realized by two different technologies, according to manufacturer's indication and to ISO 1567:1999/Amd 1: 2003 standard were taken into study. A comparative evaluation was made between samples sets (2 mm in thickness, 30 mm in length and 5 mm in width) immersed in saliva and samples kept in dry environment. There were analyzed 20 samples of heat-curing resin - Meliodent and 20 samples of two light-curing resins from the same system - Eclipse Resin System, which have contact with the oral environment: Eclipse Base Plate and Eclipse Contour Resin. Ten samples from each polymer brand were kept in saliva with low level of microbial content and neutral index of pH, at 37°C, for thirty days. The other ten samples/ resin were kept dry for thirty days. The samples were weighed after 48, 144, 312 and 720 h, determining the water percentage content (ASTM D 570). Through experimental tests and software analysis, using Zwick Roell equipment, there was determined the moment of sample breaking or fracture after stretching with a software named testXpert, which can standardize the applications. Further the mechanical properties of the studied materials were evaluated, with the help of tensile tests, according to SR EN ISO 527.

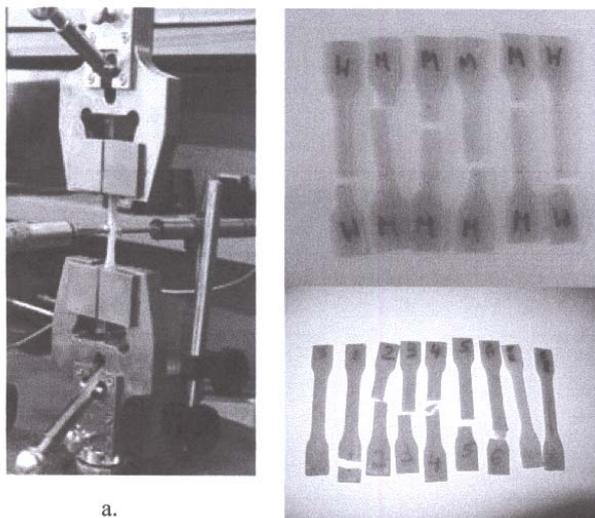


Fig. 2.. Determination of tensile mechanical resistance: a. Zwick Roell equipment in action; b. Meliodent samples broken after stretching; c. broken Eclipse samples

Results and discussions

In order to perform the present study in similar conditions with those from the oral cavity, the first stage of the study consisted in testing the non-activated saliva of the patients, namely the index of pH and germs content, through Vivacare line CRT tests. The saliva was collected through outflow over the inferior lip for 5 min, on an empty stomach, at subjects with tucked hawse and oral breathing. Then the pH indicator strip was immersed in the saliva and thus, one could rapidly find out the value of pH index.

The salivary pH had normal values (5.75 – 7.05), with a mean value of 6.

The Vivacare line CRT (Caries Risk Test) bacteria 2 in 1 kit test, (Vivadent, Liechtenstein/Europe) was easy to use, because the quantitative value of the germs was revealed in 48 h, not only for Streptococcus but also for Lactobacillus. The test package provided a quantification of microorganisms' number- cocci or bacilli, which lead to the possibility of giving a prognostic regarding the caries attack. The values lower than 10^7 were considered normally, without major consequences, while the values higher than 10^8 revealed a high caries-receptivity. The tests results showed a level 2 setting from 4 possible, so the saliva was not severe contaminated. Regarding the analyzed materials, all of them enclosed a certain amount of water, during immersion in saliva. The highest water absorption had the heat-curing resin Meliodent, and the lower- Eclipse Base Plate.

Initially one determined the specific weight in grams. This represents the difference between the measured weight and the initial weight. Thus, one could demonstrate that the tested polymers absorbed water from saliva. The evaluation was performed at 48, 144, 312 and 720 h, namely after one month. The chart contains the maximal and minimal samples from each material. The results showed that, Meliodent has the highest water absorption capacity, followed by Eclipse Contour Resin and then by Eclipse Base Plate.

There was realized the chart correlation between the analyzed polymer and the percentage humidity content, which indubitable reveals that the heat-curing resin absorb more water than the other light-curing resins.

After the evaluation of the mechanical properties using Zwick Roell equipment, one determined that the humid samples (kept in saliva) had significant lower values than the samples kept dry, realized from the same material.

One took into consideration the Young elasticity modulus - E and ultimate tensile strength - Rm. The table below shows the mean values after the samples analysis (table 1).

The results show an evident difference among the tested materials. The heat-curing resins have a lower value of the elasticity modulus than the UDMA resins from the second category. Its values decrease distinctly in humid environment, especially in case of Eclipse Base Plate.

The mechanical strength has also decreased values along with the immersion in saliva, in case of all the evaluated polymers.

The results generally indicate a higher decrease of mechanical strength values at light-curing materials (Eclipse), compared with heat-curing materials (Meliodent). Regarding the elasticity, the heat-curing materials tend to show higher decrease than the light-curing materials (fig. 4,5). The difference between the mechanical properties established in humid and dry environment indicates the evident role of the saliva upon the biodegradation of the dentistry-denture base polymer.

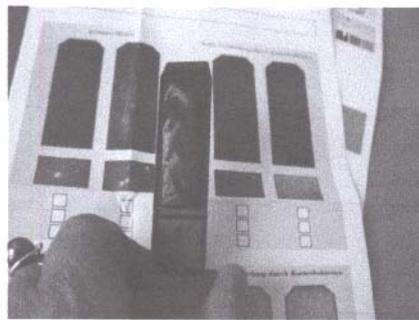
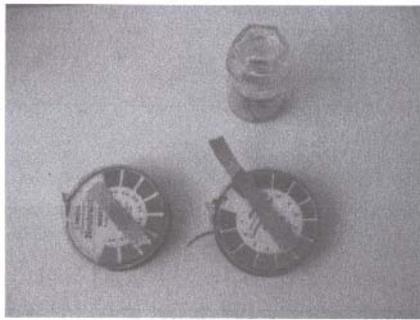


Fig. 3. Saliva evaluation:
a. pH index; b. Quantitative evaluation of Streptococci and Lactobacilli microorganisms

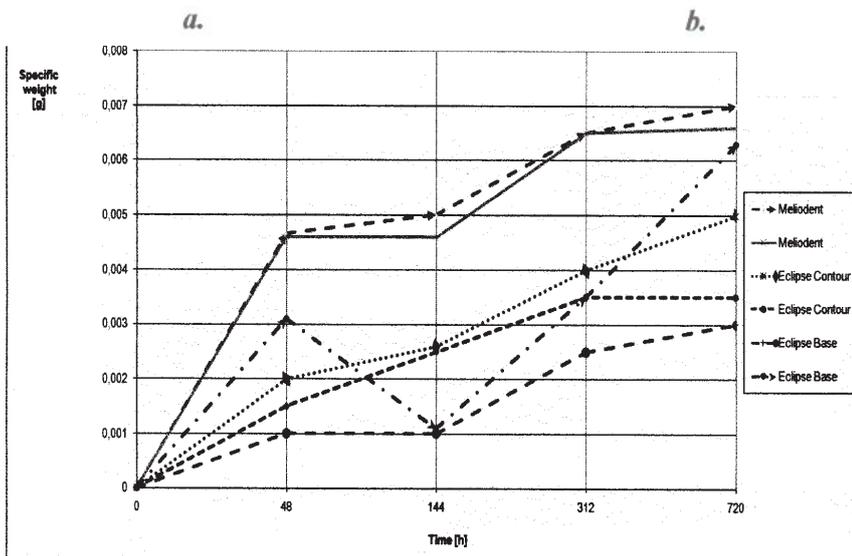


Fig. 4. The correlation between the specific weight and time for the tested polymers (Specific weight = Measured weight - Initial weight)

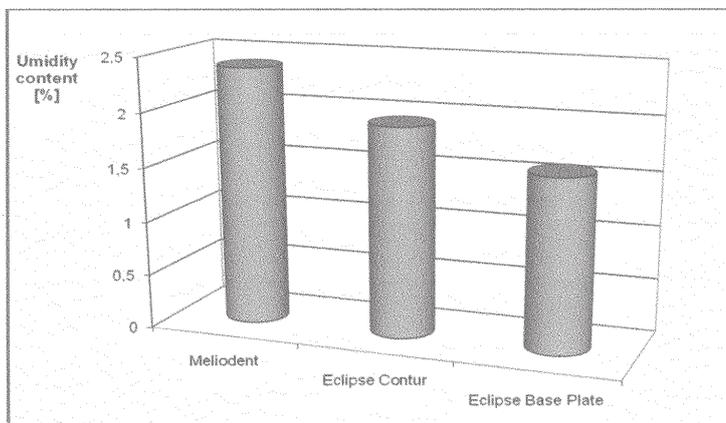


Fig. 5. Chart representation of the correlation polymer- percentage humidity content

Complete dentures, as social prosthetic solutions, address especially to senior patients. These prosthetic pieces frequently deteriorate and have an optimum lifetime relatively reduced compared to other prosthetic restorations. The problem of repairing or re-doing the dentures is delicate in case of seniors, not only from the financial point of view but also from the accommodation to the new prosthetic piece point of view. This is the reason why, it is important to know the causes of dentures deterioration and their optimization possibilities. The studies in this area are of great importance, because the changing of the dentures' mechanical properties is special for the oral health of the senior patients.

The saliva samples were collected from subjects with no oral health problem, because the studies showed the influence of the acid pH in generating prosthetic stomatitis [10]. The authors also determined that, the concentration of methacrylic acid increases together with the pH values, probably as result of metil methacrylate hydrolysis.

The researchers offered a solution to this problem when demonstrated that: when curing took place at higher temperature for a longer time, the monomer content

decreased from 1% in weight to less than 0,1% [11].

The literature especially debates the mechanical properties and the durability of the composite resins used in direct restorations. Data regarding the resins used in complete dentures technology are rarely presented.

On this line it was shown a strong correlation between increasing the concentration of cross-linking agents and the reduced solubility of polyethylmethacrylate polymers [12].

Ferracane [8,13] reveals that, the presence of fillers in a polymer network can greatly affect solvent uptake and dissolution, possibly in direct relation to its proportion as it reduces the overall volume of the absorbing polymer. The polymers used for the tests have different fillers, which were not detected in the present study and may influence the water absorption and imbibition.

Studies have shown that the solubility parameter of the solvent is the most important consideration, the solvent effect being the highest when there is minimal solubility parameter mismatch between the solvent and the polymer itself [14]. The effect of solvent on the polymer network has been described as plasticizing. The physical effect of a

| Materials | Normal conditions | | Humid conditions for 1 month | |
|-----------------|-------------------|----------------------|------------------------------|----------------------|
| | E [MPa] | R _m [MPa] | E [MPa] | R _m [MPa] |
| Meliodent | 3015,6 | 52,77 | 2568,5 | 48,51 |
| Eclipse Base | 4527,6 | 94,46 | 3921,5 | 66,76 |
| Eclipse Contour | 4255 | 40,53 | 2777 | 25,39 |
| Eclipse Setup | 4151 | 70,07 | 4059 | 46,13 |

Table 1
THE MECHANICAL PROPERTIES
OF THE STUDIED MATERIALS
KEPT DRY AND IN HUMID
ENVIRONMENT FOR ONE
MONTH

plasticizer molecule consists in separating polymer chains and producing softening by reducing the effectiveness of entanglements [8].

A highly crosslinked polymer network results from the free radical polymerization of dimethacrylate monomers, which also leaves unreacted monomers, polymerization promoters and oligomers. In filled polymers, ions from the filler particles may also be released. These components may constitute a biological concern, since they can be dissolved from the network.

The uptake of water or solvent by a dental polymer may cause swelling that affects the dimensions of the prosthesis. However, since the polymer network contains porosity and free volume between chains, especially in the region near crosslinks, it is theoretically possible for water to be absorbed without creating a change in volume [14-18].

Conclusions

The multidisciplinary studies are benefic for the knowledge of biomaterials' properties, for reducing the failures of their using and for their optimization.

The polymeric networks can absorb water, dependent on their chemical structure and the dentures achievement technology.

This has consequences upon the biomechanical performances of the complete dentures and their lifetime, with an evident influence on senior's oral health.

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