Durability Evaluation of Complete Dentures Realized with "Eclipse Prosthetic Resin System"

CRISTINA BORTUN [1], ANGHEL CERNESCU [2], NICOLAE GHIBAN [3], NICOLAE FAUR [2], BRANDUSA GHIBAN [3], OTILIA GOMBOS [1], ANGELA CODRUTA PODARIU [1]

[1] "Victor Babeş" Medicine and Pharmacy University, 9 Piata Revolutiei 1989, 300070, Timisoara, Romania

[2] Politehnica University of Timisoara, 2 Piata Victoriei, 300006, Timisoara, Romania

[3] Politehnica University of Bucharest, 313 Spaiul Independentei, 060042, Bucharest, Romania

The present study is focused on a multidisciplinary research, regarding the durability of complete dentures realised from light curing UDMA resins. Absence of methyl, ethyl, propyl or butyl monomers from their composition is responsible for their good utilization, because they do not generate contact allergies. For testing there was used Eclipse Prosthetic Resin System (DENTSPLY International Inc. - DeguDent GmbH, Hanau Germany), which consists of: Base Plate, Set-Up and Contour Resins. Using the technology recommended by the producer, there were realized nine samples, which were mechanically tested with Zwick Roel equipment. A pair of finite prostheses, realized with the help of this system, was used by finite elements method (3D scanning, software Pixform Pro Program, program CAD – Ansys Workbench (ANSYS Multiphysics) or ABACUS / CAE version 6.6.1). Static analyses for stress and strain were based on „reverse engineering" method. In the end, experiment certification took place also through fatigue tests (Walter-Bai Dynamic Testing Machine). The following mechanical parameters were determined after testing: Young's modulus of elasticity: 2908.45 MPa, ultimate tensile strength R_m = 59.49 MPa; total elongation A_t = 4.582 %, at a medium force value of 1203N. Stress and strain analysis of the denture subjected to different loadings, was revealed through chromatic spectres on denture virtual models. The warm colours indicate the areas with problems. By finite elements method one can realize noninvasive numerical procedures, which reveal the risk areas that can lead to dentures' fracture; thus, one can correct and improve the complete dentures quality. Following the fatigue tests, we may consider that mechanical properties of Eclipse allow a five years warranty for complete denture.

Key words: complete dentures, light curing resins UDMA, finite elements analysis, fatigue

1937 was a crossroads year in complete dentures' technology. The reason was that, in this year heat curing resins were introduced in dental medicine and also there were realized the first chemical studies (in the laboratories lead by Otto Bayer from IG Farben in Leverkusen, about diacryllic composite resins- type urethan polymers). It took more than 30 years until these resins penetrate into complete dentures technology, together with the improvement of lightcuring systems and microwave pollymerization. Lightcuring, as a strengthening method of some dental materials, appeared as technology around 70s and developed continuously. If initially ultraviolet light was used for polymerization, today the most wide-spread method is that with visible radiations (electromagnetic waves with wavelength belonging to visible spectrum). The light source is represented either by halogen bulb or by stroboscopic lamps with xenon.

The technical and scientifical objective approach of dental materials and prostheses quality and durability is very important for their lifetime increasing. Noninvasive and invasive experiments allowed testing of static, dynamic and fatigue mechanical properties of prosthetic pieces, with aim of evaluating their lifetime, which means in fact usage warranty [2, 3, 7, 9]. Because of its efficiency and flexibility, numerical simulation tends to replace the experiment, allowing applications that are difficult or impossible to investigate through other methods. Diversification of appliances in medicine and especially in dental medicine, made from numerical analysis with finite elements a possibility for testing new materials and for leading to existing technologies optimization.

Using of light curing system Eclipse Prosthetic Resin System allows a rapid achieving of complete dentures, eliminating the intermediate working stages, like investment and classical heat curing. Light curing diacryllic composite resins from Eclipse Resin System contain base monomers UDMA (aliphatic urethane dimetacrilate - urethane oligomers) and acryllic copolimers, an anorganic submicronic silical filling, a light curing initiating system and aditives. The system consists of three resin types, which can be manipulated/handled like wax (Base Plate, Set-Up and Contour Resins). In order not to make mistakes regarding light curing protocol, this is indicated by the producer in many variants, which correspond to the different technical procedures. This system is extremelly efficient, because a complete denture base can be achieved in 30 minutes, if we have the master model. The „wax-up" is practically made on denture polymerized base and, after check-out, the rest of the pattern (saddles' flanks) is lightcured; afterwards the denture is classicaly finished.

Although the necessary time for obtaining the prosthesis is at least 30 min, the great disadvantage of UDMA system is the lower durability of the prosthesis, up to five years. The purpose of the paper is to identify the risk areas, which can cause denture breakdown (by a non-invasive technique, namely finite elements method). The outcome would be the obtaining of information necessary to improve overall prostheses quality.

* *email: cristinabortun@gmail.com*

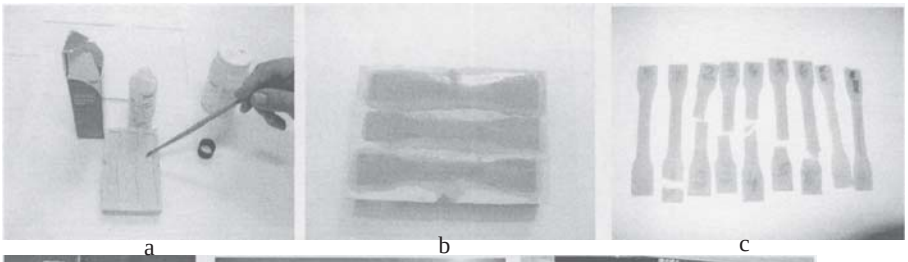


Fig. 1. Samples: a,b,c. making of material samples; d. Zwick Roel equipment for samples testing until breaking; e. complete dentures; f. Eclipse processing unit II

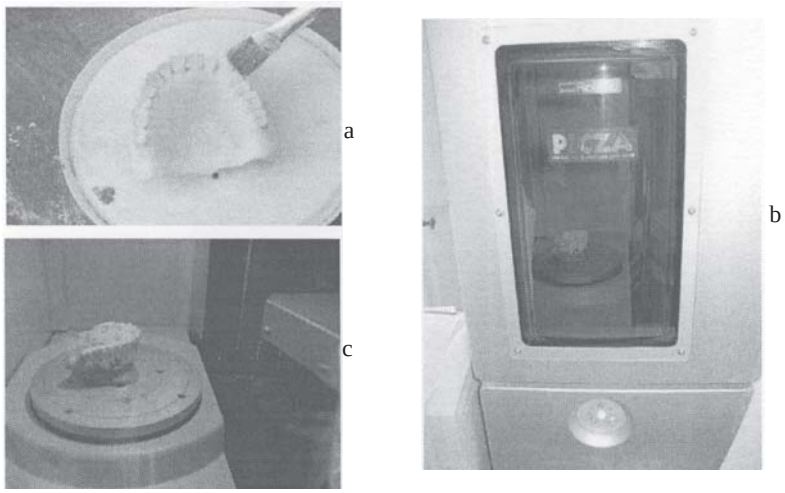


Fig. 2. 3D scanning: a. Upper denture impregnation with CAD spray; b. 3D scanner LPX 1200 of Roland company; c. Scanning detail

Objectives of the study

Studies were centered on finite elements analysis at static and dynamic solicitation (stress, shearing and total deformation) of some complete dentures, realized with Eclipse Resin System light curing technology; finite elements analysis is also helpfull in making some predictions regarding place and time of stress/ strain apparition and indicate the areas with fracture risk.

Materials and methods

As testing and evaluating material we used: Eclipse Prosthetic Resin System, Dentsply International Inc. - DeguDent GmbH, Hanau Germany). Using the technology indicated by the producer, we realized special 9 samples and a pair of complete dentures.

The equipment used for experimental testing, fitted with software analysis systems, was Zwick Roel equipment (Zwick GmbH & Co. KG, Ulm, Germany) (fig.1d); with its help, there was determined the material breaking moment, after samples elongation tests.

The real geometric model of the dentures is 3D scanned, using triangulation principle, with a 3D scanner LPX 1200 belonging to Roland company. Processing of scanned images was realized through reverse engineering method**.** Scanning was performed with Dr. PICZA program, followed by obtaining of „point clouds" (set of tridimensional points) which describe the prosthesis' surface.

The scanned real model is divided in individual elements with determined dimensions, interconnected with nodes. Pixform Pro Program was used for processing point clouds, which were transformed into surfaces networks, which are exported as files with DXF extension and imported in a program CAD – Ansys Workbench (ANSYS Multiphysics) or ABACUS/CAE version 6.6.1, where the denture tridimensional model is created. On virtual model there are made experimental tests for dentures static solicitation and fatigue degradation, which are revealed through chromatic spectres, which are visible on denture's components, where stress is always shown in warm colours while quiet zones are shown in blue. The method became necessary, because it lies at the basis of some more advanced analyses (to variable solicitation), in order to explain more complex phenomena, which are responsible for complete dentures degradation.

Experiments checking on computer was realized through samples fatigue tests, on a dynamic testing mashine (Walter-Bai Multipurpose Dynamic Test System, Series LFV, fig. 3) with pulse loading cycles to which maximum force was considered 300 N.

For each cyclic loading, there was registered the number of cycles until sample breaking, allowing this way an evaluation of fatigue resistance of the tested material.

Results and discussions

At the static tensile tests for experimental light curing resin, there were obtained the following results: the tensile strength – σ_U = 59.49 MPa, Young's modulus – E=2908.45 MPa and fracture toughness K_c=24.93 MPa·mm$^{1/2}$. First, we realized loadings for lower denture, namely the establishing of zones for support and for forces applying (fig. 4); after that, there was activated the program for determining the equivalent stress and maximum shearing for a force of moving the denture toward the prosthetic field of 80-100N (fig. 4, c, d). Total strain of lower denture has the characteristics shown in figure 4, e.

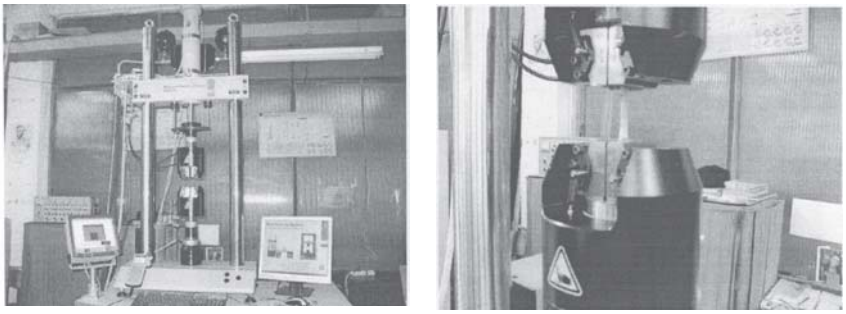


Fig. 3. Dynamic testing mashine Walter-Bai (Multipurpose Dynamic Test System, Series LFV): a. Whole equipement; b. detail

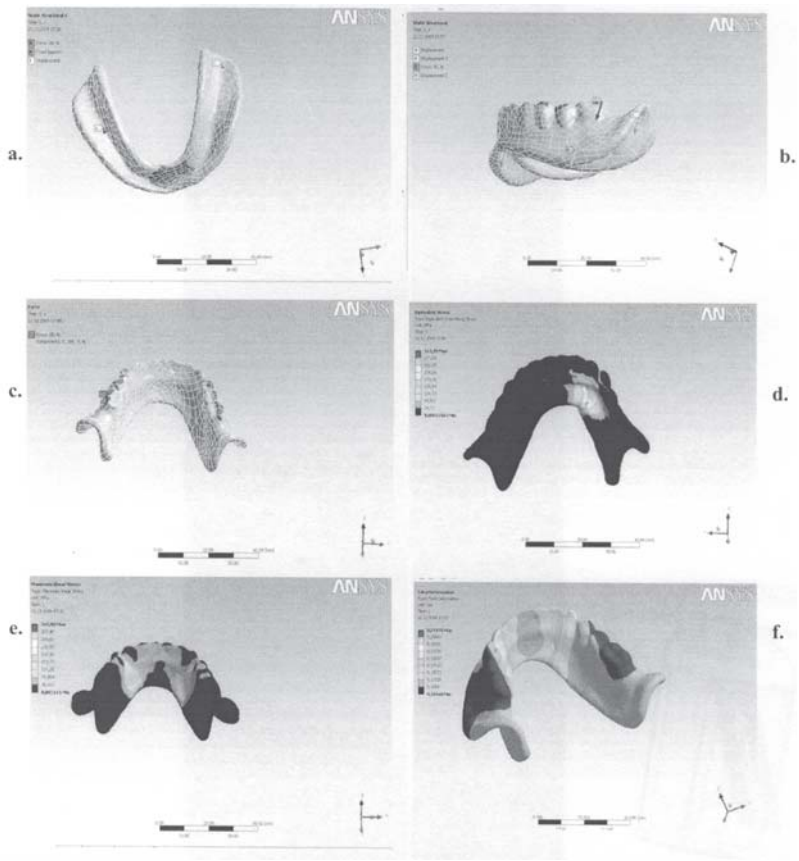


Fig. 4. Aspects of experimental study (Ansys Workbench (ANSYS Multiphysics): a,b- establishing of support zones; c- loading with forces of 80 N on active cusps; d. determining of equivalent stress zone; e- shearing zone; f- Total denture strain

For upper denture the loading system is more complicated, because there were taken into consideration the fibro mucous resilience zones, which are different for alveolar ridge (0.2 mm) and for palatus(torus 0.1 mm; distal third - 0.4 mm, rest of the palatus 0.2 mm). The forces that move the denture towards the prosthetic field are applied on the oral cusps from the maxillary sustaining zone.

There is obvious the frontal stress zone, also visible on palate, which can induce the denture's median fracture (otherwise the most frequent met in practice).

Simulation of some structural defects in palate anterior third has no big impact on denture's stress or breaking (fig.5, a), while apparition of such a defect at the junction of two resilience types of the denture (like junction between distal third and the medium third of palatus) generates an increasing stress with possible implications in denture breaking on palatal midline (fig. 6).

After fatigue testing, one observed that Young modulus had a medium value of 2900 MPa and tensile ultimate strength was around 60 MPa. The results that we obtained showed a relative good fatigue behavior for our experimental light curing UDMA.

Crocker [1] realized a description of three elastic-plastic models: von Mises, linear Drucker-Prager and cavitation model plus calculation of relevant model parameters and realizes prediction of sensitive areas.

Other researchers [8] studied / used Mann-Whitney test (α=0.05) to quantify the differences between the stresses of maxillary and lower complete dentures and found them out statistically significant ($P<0.001$). They concluded that, this might be the main reason why maxillary dentures fracture more often than lower dentures.

Naik [5] wanted to determine the causes for the fracture of complete dentures and divided them into material factors and clinical / technical factors. In his opinion, there is need for denture care instructions after denture's delivery; he also concluded that, it is important to use resins that have increased fracture toughness.

According to fracture analyses, complete dentures behaves like a shell structure, which is subject to tensile stress and shear stress according to the membrane theory [6]. In fracture test the breaking occurred at 1245 N concentrated load. The principal strain/stress and maximum shear strain were observed in the posterior palatal part of the median sagittal line. The fracture testing took place in centric occlusion and the principal strain and stress were observed in premolar and posterior palatal area along the median sagittal line. It was also concluded that the formation and fracture progresses from the posterior palatal region toward the upper anterior palatal part [6].

Fatigue depends on material structure [2, 3, 4, 7, 9]. Fatigue degradation process is characterized by the fact that, plastic deformations are situated around defects or cracks. Fatigue breaking has a progressive- hidden

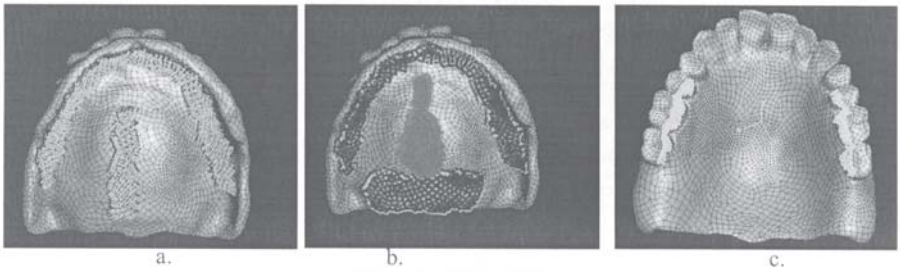
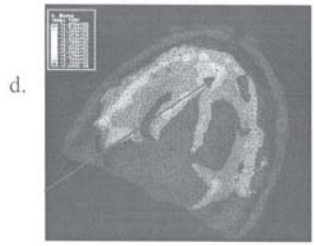


Fig.5. Loading of virtual model (ABACUS/CAE version 6.6.1): a,b- support zones; c- forces applying; d- equivalent stress with possibility of inducing median fracture



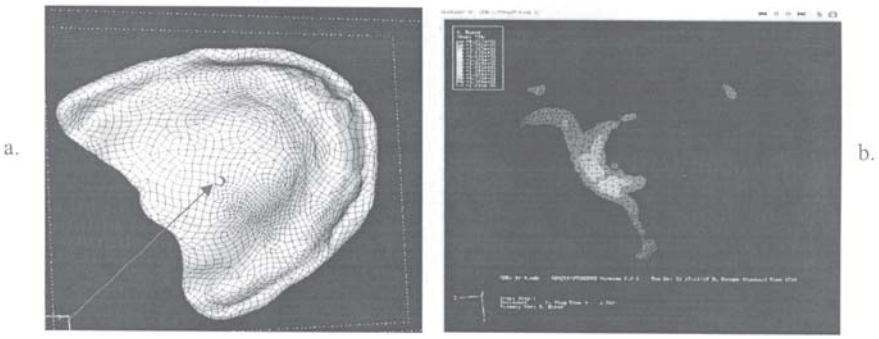


Fig. 6. Simulated structural defect and its effect (ABACUS/CAE version 6.6.1): a. meshed prosthesis; b. stress induced by a defect

character; the prosthetic piece conducts itself normally, untill the crack extended on a certain length and then the final breaking is started, by overstressing the material from the remained section. Evaluation of material fatigue resistance is a characteristic in estimation of complete dentures durability.

In comparison with other previous researchers, our results are in accordance with theirs, permitting to identify the most dangerous fields of the complete dentures. Also, by knowing these zones, we may avoid their appearance by proper techniques, in order to increase the durability of the complete dentures, made of light curing UDMA composite materials.

Conclusions

Studies on finite elements analysis at static and dynamic solicitation (stress, shearing and total strain) of some complete dentures, realized with Eclipse Resin System light curing technology, may reveal the following conclusions:

- knowing the fatigue properties for this material, the safety degree in using the denture by patients can be guaranteed on a period of five years.
- the fatigue tests may conduct to finding out of the breaking moment of complete denture.
- the calculus model used in the finite element analysis for the complete denture was validated by fatigue tests performed on real prosthetic pieces.
- there also can be tested new materials which can be successfully used in the prosthetic dentistry.

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