Digital Microscopy Used in Synthetic Structures Analysis of Dental Prosthesis

M. Baritz[1] and D. Cotoros[2]

[1] University Transilvania Brasov, Precision Mechanics and Mechatronics Department, Brasov, Romania
[2] University Transilvania Brasov, Mechanics Department, Brasov, Romania

Abstract— **In this paper we present some aspects related to the analysis of surface quality for dental materials obtained by synthesis (photo-polymerization) process. In the first part, the biocompatibility properties of dental materials are analyzed, using Fuzzy logic. In the second part, the images obtained from the digital microscope with 500x of magnification, of some samples made of photo-polymerizable materials are analyzed using software dedicated to image processing. The results of these procedures are presented in a modular way in order to highlight both the 3D surface profile and the shape of roughness variation along the selected direction on the studied surface. In the final part of the paper we presented some conclusions both concerning the mechanical tests and images analysis.**

Keywords— **dental prosthesis, photo-polymerization process, digital microscopy.**

I. INTRODUCTION

There was a substantial revolution in dental prosthetics along with the occurrence of oral implant procedures. Oral implant allowed dental prosthetics to use additional pillars that might be inserted where necessary in the prosthetic area. Thus, some edentations that not so long ago could be approached only by mobilizable or entire mobile systems can be obtained today by fixed prosthetic restorations. [1]

The prosthetic parts can be exclusively attached on implants (pure implanter) or mixed (dental-implanter). Prosthetic works on implant may replace from a single tooth to an entire arcade.

They can be made of various materials: metal-acrylate or metal-ceramics. Many times though, the metal-ceramics works (with porcelain antagonists) are preferred especially for the integral rigidity of the structure. On the other hand the acrylic works present the benefit of shocks damping but are not resistant enough both to the forces developed during the food fragmenting and to the effect of fluid substances upon surfaces. [2]

Also on the implantation support they can perform the so called *implant prosthesis*, which is a mobilizable prosthetic device. Based on a small number of implants they may manufacture a prosthesis including special aggregation systems that provide the prosthesis an increased stability and support in comparison to the normal one. Thus, by help of implants dentists may create abutments to apply different super-structures, connected to the fixed telescopic prosthesis. At this time the fixed implantology prosthetics is dominated by bolting but prosthetic works can also be cemented. The prosthetic abutment applied on the implant represents the trans-mucous component while the implant body is covered in order to display a natural tooth aspect. But one of the most difficult issues related to the mobilizable or mobile prosthesis construction and technology is represented by the manufacturing of artificial dental arcades, with the most possible individualized occlusal shape and within its frame, selecting and assembling artificial teeth.

Artificial teeth are usually included in one of the following situations: *single maxillary mobile prosthesis*, with noble alloys as antagonists, acrylic or diacrylic resins, in order to prevent their accelerated wear; *alveolar ridge*; *rubbed off or periodontal antagonists*; or the case when there is a *single dental prosthesis or a metal bridge on the antagonist arcade*. Wherever would be the position of teeth in prosthetic area, artificial teeth are defined by characteristics related to color, shape, dimension and occlusal shape.

Besides for the frontal teeth the order of importance is color, shape, height and width. From the material point of view, the used artificial teeth are consisting of PMMA co-polymerized by reticular agents and usually these are provided with an increased resistance to cracking by using a greater amount of reticular agents. In the contact zone with the prosthetic basis, a lower concentration of reticular agent is recorded, than in the incisal, respectively occlusal areas, in order to facilitate the chemical connection to the polymers in the prosthetic basis. To provide the most physiognomic aspect, artificial teeth use a large range of pigments and to increase resistance of teeth, they are treated with inorganic micro-particles. For long-term successful performance of all dental implant types the following general factors should be considered: biomaterials, biomechanics, dental evaluation, medical evaluation, surgical requirement, healing processes, prosthodontics, laboratory fabrication, post insertion maintenance. All practitioners involved in patient care should be knowledgeable regarding these factors and their interrelationships. Standards of dental practice would suggest the following general contra-indications for the above three categories of dental implants: debilitating or uncontrolled disease, pregnancy, lack of

S. Vlad and R.V. Ciupa (Eds.): MEDITECH 2011, IFMBE Proceedings 36, pp. 230–233, 2011.
www.springerlink.com

adequate training of practitioner, conditions, diseases or treatment that severely compromise healing, e.g., including radiation therapy, poor patient motivation, psychiatric disorders that interfere with patient understanding and compliance with necessary procedures, unrealistic patient expectations, unattainable prosthodontic reconstruction, inability of patient to manage oral hygiene, patient hypersensitivity to specific components of the implant.[12]

II. Determination of biocompatibility based upon fuzzy logic

In order to determine the biocompatibility of the materials used in dental prosthetics and implantology a questionnaire was conceived, which was filled in by a human subjects' sample with prosthetic works made of the same type of acrylic material. [6]

Based on the questionnaire's answers and suing a module of the software developed on Fuzzy logic, we accomplished the analysis of the materials used in manufacturing dental prosthetics works. The result of the analysis is materialized in a graphic presenting the analyzed dental material biocompatibility by means of percents, for the selected subjects' sample.

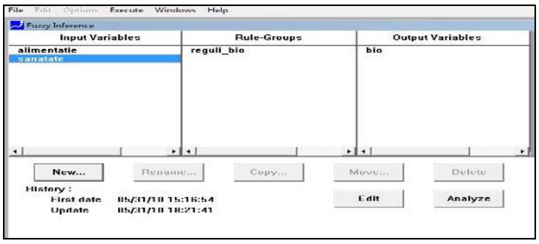

Fig. 1 Main window of biocompatibility analyze software

The first stage in biocompatibility analysis by Fuzzy logic consisted in introducing initial data in a main window (fig.1) considering the most two important causes leading to materials incompatibility: *nourishment and health* of the studied human subjects. Graphics were made at a percent scale of 1 to 100. To each of the two variables may correspond from 2 to *n* concepts. Thus, for the "nourishment" variable we considered as valid the following concepts: "soft food", "hard food", "acid food" and "sweets".

For the second variable "health" we established the concepts: "bad", "average" and "good". Fuzzy analysis continued with the second stage, introducing final data, where we established a single variable as being biocompatibility ("bio") with the following concepts: "null", "partial" and "total".

Fuzzy type analysis assumes the compilation of initial data and of the final ones based upon the definition of certain rules that are presented in a separate window.

Prior to starting the fuzzy analysis process we checked on software basis all the introduced data and rules to avoid the errors during analysis.

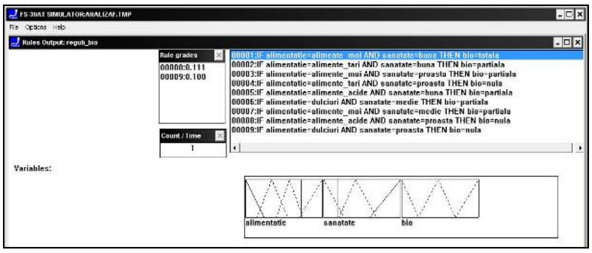

Fig. 2 Biocompatibility results

The last stage, concerning the analysis results was performed using a soft simulator that calculated based upon the numerical values and established rules, the percentage of studied material biocompatibility.

The obtained results reveal the fact that the biocompatibility level stage is remaining at low values due to the health state and nourishment style of the investigated sample of subjects.

III. Polymerization process of restoration materials samples – microscopic analyzes

Most of the restoration materials should withstand forces during manufacturing or mastication, so the mechanical properties are important in understanding and predicting the material behavior under load.

Because a single mechanical property cannot represent a quality measure, the application of the involved principles in a range of mechanical properties is essential, especially considering the human factor implication.

One of the most important applications in dentistry is the study of the forces applied to teeth and dental restorations. The maximum forces recorded by strain gauges and telemetry devices reach 250 to 3500N. [3]

The forces developed in the dental occlusion for an adult subject decrease from the molar area towards the incisors, reaching forces values from 400 to 800N, upon the first and second molar. Of the same importance for the study of forces developed in the natural teeth occlusion, is the determination of stress and strains in the restoration type works, such as insertions, fixed connections, partial and total prostheses.

One of the first investigations of the occlusion forces shows that average biting force in patients with replacement of first molar is determined at 250N for the restored part and 300N for the opposite side, in comparison to the average biting forces for permanent teeth, reaching 665N for molars and 220N for incisors.

In a different study, forces measured for patients with partial prostheses are form 67 to 235N. Generally, the force in women bite is 90N smaller than the one applied by a man. These studies indicate that the mastication force on the first molar with a fixed connection is approx. 40% of the force exerted by the patients with natural teeth. [10, 11]

Recent measurements performed by help of strain gauges devices are much more accurate than those performed with other previous equipments, but generally the conclusions are the same.

These measurements concluded that the forces distribution between the first premolar, second premolar and first molar in a complete dentition can be established as approx. 15%, 30%, and 55% of the normal force.

IV. EXPERIMENTAL SETUP

The experimental setup used for the microscopic analysis of the polymerizable dental materials samples consists of a digital microscope Keyence VHX-600 type, with objective magnification between 500x and 5000x, an object field of 0, 25 mm^2 and software suitable for the assessment studies and surface quality measurements, roughness, 3D representations. [4,5] The used samples were manufactured in the same conditions and assessed according to the same procedures.

Fig. 3 Keyence VHX-600 digital microscope

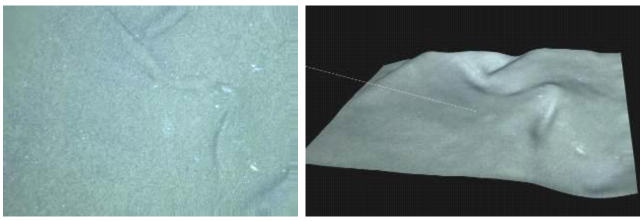

Fig. 4 Samples images from Keyence VHX-600 digital microscope

From the point of view of the polymerization process, an important aspect is represented by the polymerization time, which is a parameter affecting the mechanical characteristics of the prosthesis teeth, dental restorations or implants.

Polymerization time for the composite diacrylic polymerizable resins cannot be measured based on viscosity changes. Approximately 75% of the process takes place in the first 10 minutes, the reaction continues slowly for 24h. The sub-polymerized layer at the surface has an internal conversion ratio of approx. 25%. By comparing some materials used for artificial teeth construction we may notice that in the case of *dental acrylate* (having the following characteristics – compressive strength of 84 MPa, elastic modulus of 1700 MPa and elasticity limit of 55 MPa) this is used in dental technique offices in 80% situations unlike the ceramics materials which are present only in 20% of situations.

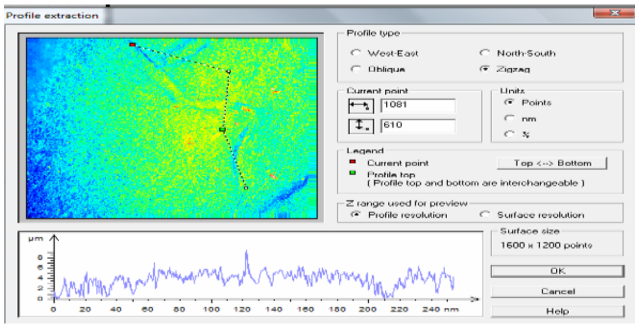

Fig. 5 TE-ECONOM structure, photo-polymerization time of 5 min (images from measurement software)

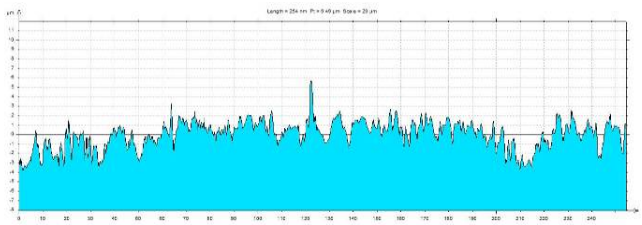

Fig. 6 Roughness profile variation

Duropont composite material (having the characteristics – compressive strength of 90 MPa, elastic modulus of 1600 MPa and elasticity limit of 45 MPa) presents a highly superior hardness to the presently used acrylates. Unlike these, the *duropont* composite polymerizes in 6 atm external pressure conditions and even if it does not show the *cromasit* hardness, the favorable price makes it the most used material for dental prosthetic works. During the performed tests we manufactured some working samples with the same size and volume. First working samples were made of **TE-ECONOM** material and were polymerized for various time intervals (5 min, 6 min, 7 min and respectively 9 min) and monitoring the photo-polymerization process in order to avoid other environmental influences.

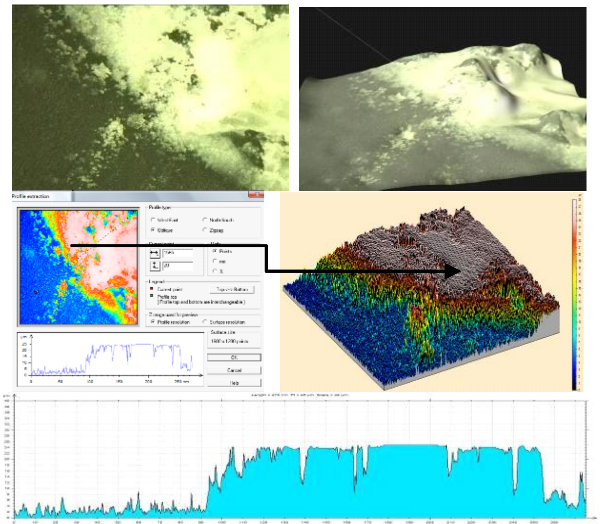

Fig. 7 **VALUX-PLUS** structure– photo-polymerization time of 5 min (500x digital microscope) and roughness profile variation in the area marked for sample **VALUX-PLUS** [9]

The second material was **VALUX-PLUS**, in photo-polymerization process, time 5 minutes and (fig.7.) From the performed measurements presented above we may observe the following: according to the materials polymerization degree we notice changes in their aspect depending on the photo-polymerization time interval; for VALUX PLUS material we observed an incomplete polymerization due to the white spots upon the material surface, while for all the TE-ECONOM samples, the photo-polymerization was uniform, there were no white spots on the material surface; the tested materials withstand very well the applied forces considering that: these analyzed materials resisted up to a 2300 N force, the equivalent of a 117 MPa strain for VALUX PLUS, respectively 2500 N, the equivalent of a 127 MPa strain for TE-ECONOM.

V. Conclusions

All these results are determined considering that the bite force of a human being may reach the maximum value of 270 N. We also noticed based on the surfaces profile analysis that the photo-polymerization process determining the best surface quality must take place along a 6 min time interval for TE-ECONOM material and respectively along 9 minutes for VALUX Plusmaterial. Analyzing the benefits of composite materials based upon resins, used as dental materials, we may find the following: they do not include Hg; due to a suitable edge adjusting and a volume constant in time they do not allow deposits in the contact area between the two materials (root and tooth); there is a biocompatibility with the human organism; they obtain very hard materials with high mechanical resistance and consequently at least 20 years life cycle; the hardness of these materials being below the one of the dental enamel it does not scratch the antagonist teeth during mastication; the hardening reaction of these materials used in the dental office for root canals takes place in a few minutes, which proves to be very comfortable to the patient.

In the future, these researches will be continued with evaluations from clinical practice and taking into account different substances which these materials get in contact.

Acknowledgment

These researches are part of the Grant PNII-IDEI 744 with CNCSIS Romania and we've developed the investigations with equipments in Mechatronic Researches Department from University Transilvania of Brasov, Romania.

References

1. Grosu L., s.a. (1983) Biosistemul orofacial,Cluj- Napoca, Ed.Dacia,.
2. Bratu D., s.a. (1994) Materiale dentare-Materiale utilizate în cabinetul de stomatologie; Editura Helicon;
3. Regenio M, et al. (2009), Stress distribution of an internal connection implant prostheses set, Stomatologija, Baltic Dental and Maxillofacial Journal, 11;
4. Cotoros, DL. et al. (2009) Aspects concerning impact tests on composites for rigid implants, WORLD CONGRESS ON ENGINEERING, London England, Pages: 1658-1661;
5. Cotoros D. (2010) Analyses by image processing of surface quality of mobile skeletal dental prosthesis, International Conference on CNC Technologies, Bucharest, Romania, May 05-07;
6. Stanciu A., Cotoros D., Baritz M., Florescu M. (2008), Simulation of Mechanical Properties for Fibre Reinforced Composite Materials, Theoretical and experimental aspects of continuum mechanics, WSEAS Cambridge, UK, ISBN 978-960-6766-38-1;
7. Ieremia L., Dociu I., (1987) Functia si disfunctia ocluzala, Editura Medicala, Bucuresti, Romania;
8. Lussi A., (2006) Dental Erosion From Diagnosis to Therapy, Copyright 2006 by S. Karger AG www.karger.com, ISSN 0077–0892;
9. http://www.digitalsurf.fr/en/index.html accessed oct.2010;
10. Albrektsson, T. Et al., (2004), Oral implant surfaces: part 1—review focusing on topographic and chemical properties of different surfaces and in vivo responses to them. Int. J. Prosthodont. 17, 536–543;
11. Anders Palmquist et al. (2010), Titanium oral implants: surface characteristics, interface biology and clinical outcome, J. R. Soc. Interface 2010, **7**, S515-S527 doi: 10.1098/rsif.2010.0118.focus;
12. Navaro M. Et al. (2008), Biomaterials in orthopaedics, *J. R. Soc. Interface* 2008 **5**, 1137-1158;

Author: Mihaela Baritz
Institute: University Transilvania from Brasov
Street: B-ul Eroilor nr.29
City: Brasov
Country: Romania
Email: mbaritz@unitbv.ro