THE VALIDATION OF AN ACRYLIC RESIN FOR THE COMPLETION OF BIOMECHANICAL STUDIES ON A MANDIBULAR MODEL

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ABSTRACT

Aim of the study The aim of this study was to validate the use of a self-curing acrylic resin for the completion of a mandibular model for in vitro studies. **Material and methods** 25 test specimens were made of acrylic resin (Duracryl Plus, Spofa Dental). The samples were divided in 5 groups, based on monomer to polymer ratio. The determination of the elasticity modulus and of the Poisson's ratio for the studied samples was performed using the electrical resistive tensometry method. The samples were submitted to traction testing on a universal testing machine. **Results** The elastic characteristics of the material varied significantly depending on the components proportion. The evaluated ratio is 3 parts of powder to 1.5 parts of liquid. This combination presented elastic characteristics similar to those of the spongy bone from the anterior region of the mandible, as well as an average viscosity that contributes to pouring in complex forms, to a proper work time and to a low curing contraction. **Conclusions** Based on the obtained results, we can consider the use of self-curing acrylic resin, in a ratio of 3:1.5, as being justified for creating a mandibular model to be used in biomechanical tests.

Keywords: acrylic resin, strain gauges, mandibular model, modulus of elasticity, Poisson's ratio

INTRODUCTION

The splinting of teeth with periodontal condition represents a therapeutic mean to achieve functional balance in the complex treatment of periodontal disease. An important aspect in choosing the type of splinting is the mechanical interaction between the employed materials and the dentoperiodontal substrate with the supporting bone [1, 2].

There is very little information in the literature regarding the impact of bone resorption and periodontal splinting on the biomechanical response. Because of this, the use of splinting and the selection of its type remain a difficult decision for practitioners.

In order to quantify these aspects, one can use several methods, each with limitations, advantages and disadvantages: photoelasticity, finite element analysis and resistive electric tensometry [3-5]. When aiming at creating a mandibular model to simulate different hypotheses and clinical scenarios, a decisive aspect is the selection of the right material able to reproduce the bone substrate. This material must provide mechanical and elastic properties similar to the mandibular bone, as well as a viscosity and a working time appropriate to the model's complexity intended to be achieved. Katz et al. mention that the bone is not a homogeneous material and its properties will vary according to the age, sex, the type of bone and location [6]. O'Mahony et al. noticed differences between the modules of elasticity in different regions of the mandible [7]. The in vitro studies require the use of an isotropic material with elastic properties similar to the mandibular bone from the region of interest. In this respect, regardless of the chosen method, it is necessary to determine the elastic constants for the employed material, in advance, in order to create the mandibular model.

The literature reports different materials that were studied, aimed at the evaluation of tensions at the level of bone in various situations: acrylic resin, epoxy resin, polystyrene resin, polyurethane resin [4, 8-10]. The modulus of elasticity is an important elastic characteristic, its values indicating the material rigidity.

The aim of this study was to validate the use of a self-curing acrylic resin for the completion of a mandibular model in the in vitro studies. To that purpose, the objectives were to determine the elastic constants of the acrylic resin, by studying different situations with varying proportions between the components. The two characteristics, the modulus of elasticity E and Poisson's ratio □ were determined by means of traction testing. The determination of the two characteristics was performed using resistive electric tensometry. This method enables the high precision measurement of specific longitudinal and transverse strain.

This material will be used to create a mandible replica which will be studied regarding the deformation and tensions by means of resistive electrical tensometry that occurs in the bone mass, in various clinical situations.

MATERIAL AND METHODS

Obtaining the test specimens

25 test specimens were manufactured from acrylic resin (Duracryl Plus, Spofa Dental, Czech Republic, No. lot: 2373741) by pouring in a silicone mould (Fig. 1).

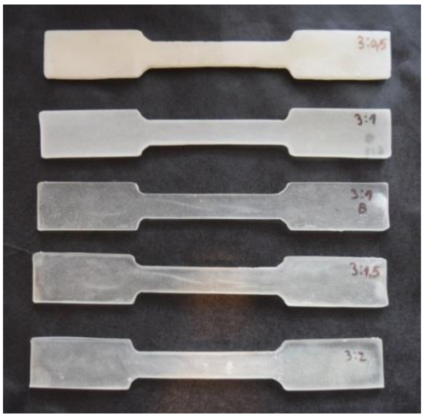

Figure 1. Test specimens from acrylic resin corresponding to the five groups

The samples were divided into 5 groups, corresponding to different proportions between the powder and the liquid components and to the polymerization technique (self-curing and heat curing - 50˚C, 15 minutes, 2.5 bars) (Table 1).

Table 1. Test specimens classified into 5 groups

Group	Volumetric ratio powder : liquid	Polymerization technique
A	3:0.5	Self-curing
B	3:1	Self-curing
C	3:1	Heat-curing
D	3:1.5	Self-curing
E	3:2	Self-curing

After manufacturing, the samples were visually inspected in order to detect the presence of potential material defects, as well as the inclusions of air. The final samples were processed to obtain the required dimensions of the recommended testing samples as specified by the STAS SR EN ISO 527-1: 2012 standard, describing the traction test [11]. This way, flat testing specimens of rectangular section were obtained. The sample dimensions are: length L = 150 mm, width l = 20 mm and thickness = 3 mm. Each testing specimen presented a calibrated central area with the length Lo=60mm, width l0=10 mm and increased section end. The two ends were armed with metallic plates that offer the required resistance to the grip area in the stand of the trial machine.

Applying the strain gauges

In order to determine the specific deformations, two strain gauges were applied on the testing specimens. The tensometric sensors were selected on the dimensional criteria in order to allow the positioning on longitudinal and on transversal direction.

There employed strain gauges had the following dimensions and resistive properties: 6 mm length, 2 mm width and an electric resistance of 120±0.03 Ω at 24˚C (EA-06-240LZ-120/E, Micro-Measurements Group, Vishay, Nr. lot: R-A59AF524).

For the installation of strain gauges, the following steps were taken:

1. the surface was properly prepared: the degreasing was done with isopropyl alcohol, the abrasion with a paper of granulation 220, the removal of the remaining dust after abrasion and again degreasing;
2. the landmarks for the gauge orientation were drawn;
3. the tensometric sensors were fixed with the cyanoacrylate adhesive Z 70, one on the longitudinal direction, and the second one on the transversal direction (Fig. 2);

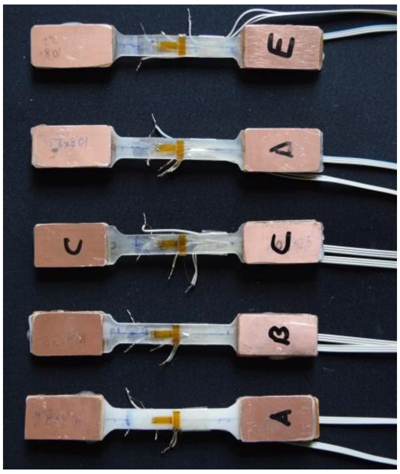

Figure 2. The test specimens, with metallic plates and strain gauges

4. the tinning of the conductors was performed using a thermostat soldering bit with a proper gluing alloy;
5. the verification of gauges was performed before the measurements were initiated [12].

The measurement of specific deformations, provided by the strain gauges was performed using the Wheatstone - Vishay P3 bridge type (Fig. 3).

Figure 3. The Wheatstone bridge – model P3, Vishay [13]

Mechanical testing

The traction testing was performed on a WDW-5CE computer assisted machine, which can be found at the Laboratory of Mechanical Testing at the Department of Mechanical Engineering, Mechatronics and Robotics of the Technical University “Gh.

Asachi” in Iasi (Fig. 4).

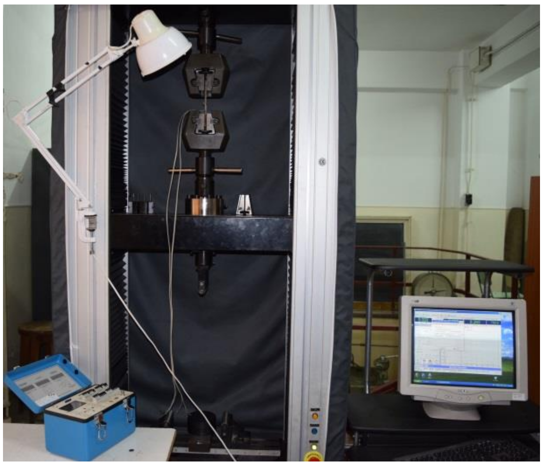

Figure 4. The testing machine type WDW-5CE and the Wheatstone tensometry bridge

The test specimens were fixed between the wedge grips of the machine (Fig. 5). The traction testing of the test specimens was then performed on the machine, with a load speed of 0.5 mm/min, till failure. The static tests were performed at room’s temperature (23°C).

The indication of specific deformations given by the strain gauges was done on the Vishay P3 bridge. Signals from the gauges glued to the specimens were obtained and the values of specific deformation in the area and on the direction of the gauge were determined.

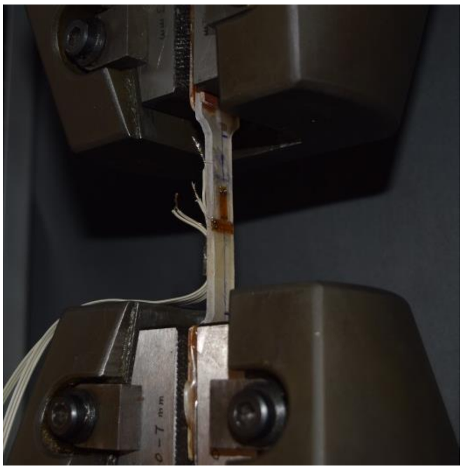

Figure 5. The positioning of the test specimen between the machine’s wedge grips

Calculating the modulus of elasticity and the Poisson’s ratio

The data thus obtained was processed in order to determine the values of the elastic constants of the material. Based on this data, we determined the constants of elasticity as slopes of the curve approximation lines. Consequently:

1. The longitudinal modulus of elasticity– E (Young modulus) is determined as the line of approximation of the graphic represented in the coordinates of normal tension (σ)/ specific longitudinal deformation (εL), by means of the points determined based on the signals output by the longitudinal strain gauge (Fig. 6).

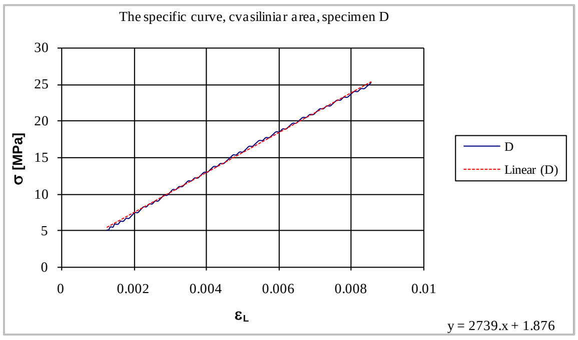

Figure 6. The variation of normal stress depending on the longitudinal specific deformation

The normal stress was calculated with the relation:

$$\sigma = F/S0 \qquad (1)$$

where:

σ - normal stress;

F- force of traction;

S0 - area of the tested specimens transversal section [14].

2. The coefficient of transversal contraction – ν (Poisson’s ratio) is determined based on the drawn curve in the coordinates of the transversal specific deformation (εT) / longitudinal specific deformation (εL), using the signals obtained both from the longitudinal gauge, as well as from the transversal one (Fig. 7).

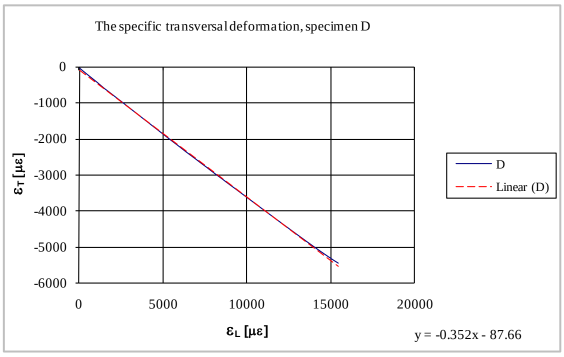

Figure 7. The variation of transversal specific deformation depending on the longitudinal specific deformation

RESULTS AND DISCUSSIONS

This study, started with the assumption that the variation of the two components in the manufacture of the acrylic resin would determine different values of elastic constants, different viscosities and different setting times. The initial step considered the proportion indicated by the manufacturer (3:1) with a self-curing technique and next four more mixing variants were evaluated. Another direction focused on the self-curing and on the heat-curing. Table 2 presents comparatively the values of the elasticity modulus and of the Poisson's ratio for the 5 groups.

Table 2. Elastic characteristics of the acrylic specimens ($p<0.05$)

Group	Elastic modulus E (MPa)		Poisson's ratio ν	
	Mean	SD	Mean	SD
A	2461	53.18	0.336	0.06
B	3060	77.06	0.342	0.09
C	3965	157.08	0.349	0.06
D	2739	111.83	0.352	0.05
E	2477	96.80	0.359	0.05

The elasticity modulus represents an essential characteristic for the validation of an experimental model. This characteristic differs both between the cortical bone and the spongy bone, as well as among different areas of the mandible.

An important area of interest in the study was the anterior region of the mandible, for which different values of the elasticity modulus and of the Poisson's ratio of the spongy bone are reported in literature: 1.37 GPa/0.29- 2.5 GPa/0.3 [15].

Considering the literature reported elastic parameters of mandibular anterior spongy bone, the results of this study revealed that the specimens of A, D, E groups might be considered as reliable bone substitute in experimental studies.

Taking the aspects relating to preparation, manipulation and setting time of the material into account, we can make the following considerations:

- in group A, the mixing of the two components was done with difficulty, because of the increased mixture viscosity. This did not allow the pouring of the material into the conformer, but its placement by means of jagging.
- in group D, the mixture of the two components determined a homogenous mixture, having a medium viscosity. This allowed the pouring into the conformer, with an average setting time.
- in group E, by mixing the two components, a homogenous mixture was also obtained, having a low viscosity, which allowed an easy pouring into the conformer, with an increased setting time, but with the disadvantage of an increased contraction.

Thus, the use of acrylic resin ratio from group D in further experimental studies regarding mandibular model biomechanics was considered adequate.

CONCLUSIONS

1. The elastic characteristics of the material varied significantly in relation to the proportion of the components.
2. The volumetric ratio 3 parts powder: 1.5

parts of liquid, presented elastic characteristics similar to those of the spongy bone from the anterior region of the mandible, as well as an average viscosity. This allows the pouring into complex forms, a proper work time and a low contraction.

3. Taking the obtained results into consideration, the use of this self-curing acrylic resin (3:1.5) can be justified for the manufacturing of a mandibular model. This conclusion was reached through biomechanical tests, by means of different methods of work: resistive electric tensometry, photoelasticity.
4. The values obtained for the elastic constants will be used in future studies to calculate the tensions that appear in the mandible model and to perform an analysis using the finite element method.

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