THE ROLE OF OPTICAL METHODS IN THE EVALUATION OF THE FUNCTIONING OF ROTARY INSTRUMENTS - PATIENT COMFORT BINOME DURING DENTAL TREATMENTS

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Abstract
Dentistry, particularly in recent decades, has also made important advances thanks to the knowledge of mechanical engineering. By combining knowledge from different practical fields but with common purposes, the dental instruments we see today in dental surgeries were developed. In the framework of research for the realization of this work, together with a team including dentists, an experimental stand was designed at the "Dunărea de Jos" University of Galati for the study of stress and deformation states in the masticatory system upon application of loads. In order to carry out the experiments, the printed PLA model had to be adequately prepared by painting with white matte paint. In order to be able to record the deformations during stress loading after painting with white paint, splashes of black paint (also matt) were applied. A surface to be studied is chosen to be followed by the 2 high resolution cameras of the ARAMIS HS system. The results obtained using optical methods are correlated with other applied methods, which are part of a much broader study represented by tensiometric methods, tests on the specimen made of PLA and tests on experimental modeling of mastication on the human bone specimen.

Keywords: ARAMIS HS system, masticatory system, biomecanics, rotary instruments;

Introduction

Mechanical engineering provides the other branches of human sciences with a whole range of procedures and methods of study. Thus, since ancient times, knowledge of forces and moments has been used for medical purposes.

Dentistry, particularly in recent decades, has also made important advances thanks to the knowledge of mechanical engineering. By combining knowledge from different practical fields but with common purposes, the dental instruments we see today in dental surgeries were developed. By studying the movements that the components of the masticatory system execute, it is possible to predict the forces and moments that arise during the mastication process. In this way, experimental procedures for model-based studies of the interactions between the component elements of the masticatory system can be foreshadowed from a mechanical engineering point of view [1,2,3].

The experiments carried out in various research collectives have dealt with the components of the masticatory system with the forces and moments occurring in the mastication process but also (although less) with the component elements of the rotary instrumentation.

Starting from the influence of the functioning of rotary instruments on the patients' comfort during dental treatments, the aim was to experimentally find the best combinations between:

- the torque obtained and the rotational speed of the burs;
- the torque obtained and the air flow rate (in the case of pneumatic drive) or the micromotor power (in the case of electric drive);
- energy consumed to obtain the desired torque;
- vibrations produced by the rotating instrumentation as a function of air flow rate, etc.

Also of great importance and, one could say not of last importance, the stresses occurring during dental treatments in the components of the rotary instrumentation have been studied in order to achieve an optimal dimensioning of its components[4,5,6]. The state of stresses and strains occurring in the structure of each component element of the dental instrumentation must be known in terms of their interactions with each other and with the dental treatment applied[7,8,9].

The performance of rotary instruments is determined in particular by the approach to root canal curvature, centering ratio, surface and volumetric changes of the root canals. This requires, in addition to appropriate rotary instrumentation, a computerized tomographic analysis that can give an indication of the correctness of the treatment applied[10,11,12,13].

Since performing experiments on human specimens is often difficult due to the lack of material to be studied, the difficult procedures to obtain and especially the impossibility to obtain a certain repeatability of the measurements performed, today it is preferred to study the masticatory system and the dental rotary instrumentation on spatial models obtained by 3D plastic modeling, the most commonly used being PLA [14].

Material and method

In the framework of research for the realization of this work, together with a team including dentists, an experimental stand was designed at the "Dunărea de Jos" University of Galati for the study of stress and deformation states in the masticatory system upon application of loads.

Thus, the designed stand, built under the supervision of Prof. PhD. Eng. CI Mocanu, is shown in Figure 1, on which the test specimen was mounted, printed with a 3D printer in PLA.

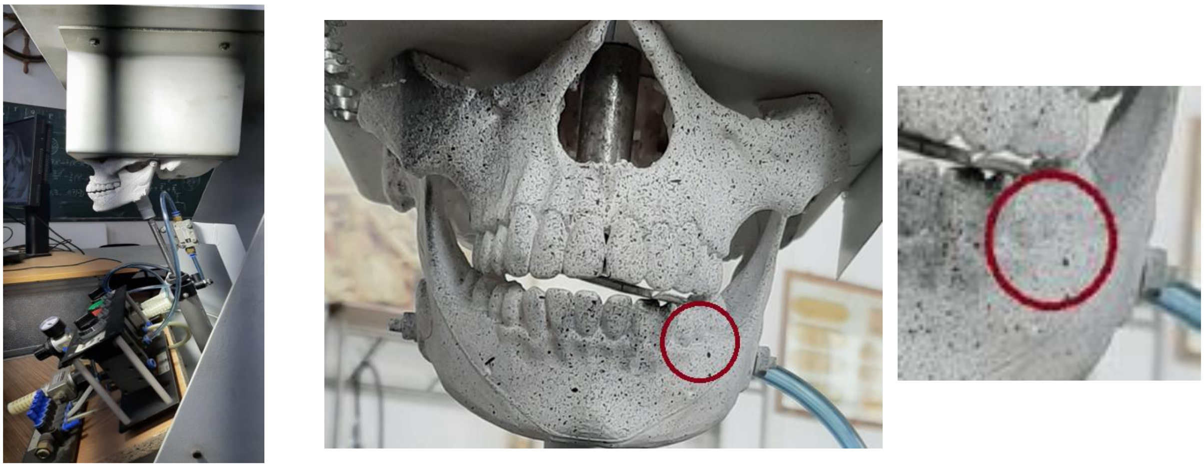
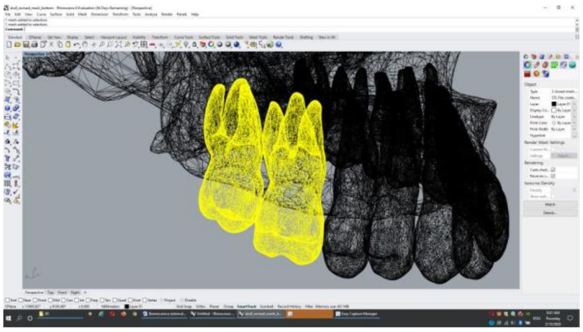


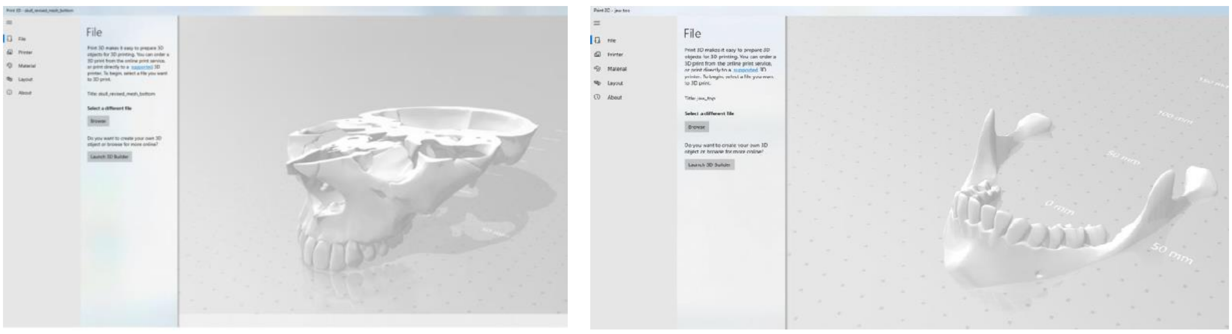
Fig. 1 The designed stand

The PLA specimen was prepared using a scanner after a human model (Figure 2 a). The model obtained and then used for 3D printing is shown in Figure 2b).

An ARAMIS HS optical acquisition system (the abbreviation ARAMIS is from the name of the device and HS stands for High Speed - high speed acquisition rate) from the German company GOM, (Carl Zeiss GOM Metrology GmbH, Braunschweig, Germany), was used for the measurements, Figure 1 . This system allows to record the deformations during the stressing processes and then with a specialized calculation program it is possible to determine the stress distribution arising in the tested specimen. Highlighted in yellow are the molars that will be examined also by numerical modeling [14].



a)



b)

Fig. 2 The PLA specimen

In order to carry out the experiments, the printed PLA model had to be adequately prepared by painting with white matte paint. In order to be able to record the deformations during stress loading after painting with white paint, splashes of black paint (also matt) were applied. A surface to be studied is chosen to be followed by the 2 high resolution cameras of the ARAMIS HS system.

In order to realize the stress load, a compressor was used which produced compressed air at a pressure of 4 bar and which by means of a control system reduces the pressure so that a maximum stress load on a tooth of approximately 100 N is achieved [15, 16]. The maximum value of this maximum stress load is given by the strength capacity of the tooth enamel. Figure 3 shows the mechanical scheme for the realization of the stress load.

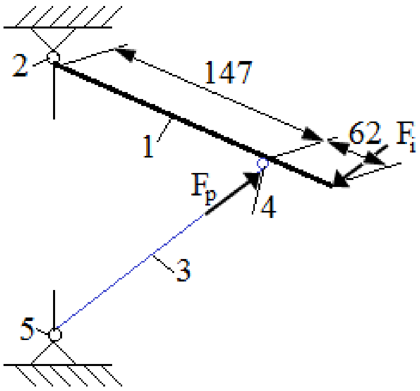


Fig. 3 Tthe mechanical scheme for the realization of the stress load

1. mandible shown schematically;
2. joint of the mandible;
3. the pneumatic piston rod performing the loading load;
4. articulation of the piston rod to the mandible;
5. the articulation of the piston stand piston;

$F_p = 150.72\,N$ - represents the force realized in the pneumatic piston by the compressed air pressure regulated by the air pressure control system;

F_i - represents the force realized at the lateral (occlusal) incisor).

The articulation of the mandible simulates, through the spaces between the mandible and the rest of the skull, the existence of the connection between these components of the masticatory system.

Writing the moment equilibrium equation in relation to the mandibular joint:

$$134F_i - 85F_p = 0$$

We get:

$$F_i = 95.6\,N$$

This value will be used in further numerical modeling to validate the studied procedures.

Results and Discussion

Experimental modeling results

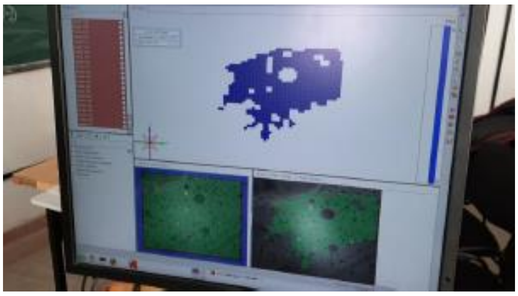
The recorded deformations of the mandibular components are shown in Table 1.

Table 1 *Deformation values recorded in the mandibular components*

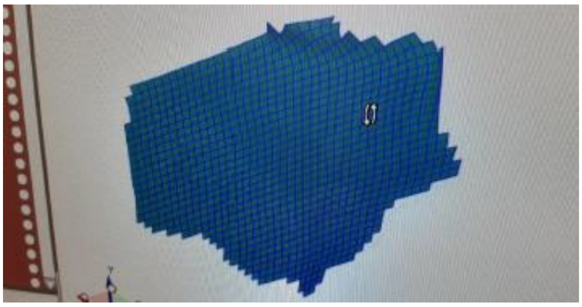
Site	**Deformation** (mm)
Mandible (central incisors occlusion)	0.011
Central incisors (central incisor occlusion)	0.023
Implant (implant occlusion)	0.043
Molar (implant occlusion)	0.022

From the analysis of the deformation state values it can be seen that they are of the order of magnitude of the gap between the tooth and the dental alveolus, i.e. of the order of microns, even if the stress load was at the maximum permissible. This can be explained by the fact that neither in the mandible nor in the teeth are deformations with large values encountered in the human bone at the dental level. Large deformations exceeding microns in the order of microns µm would, in the opinion of dentists, lead to major changes in the mandible-jawbone system. Such displacements, three orders of magnitude larger than normal, can occur in patients with missing teeth. Such a situation may be the subject of future analysis. The physiologic displacements of teeth in the vertical plane 20-28 µm and in the horizontal plane 73-108 µm .

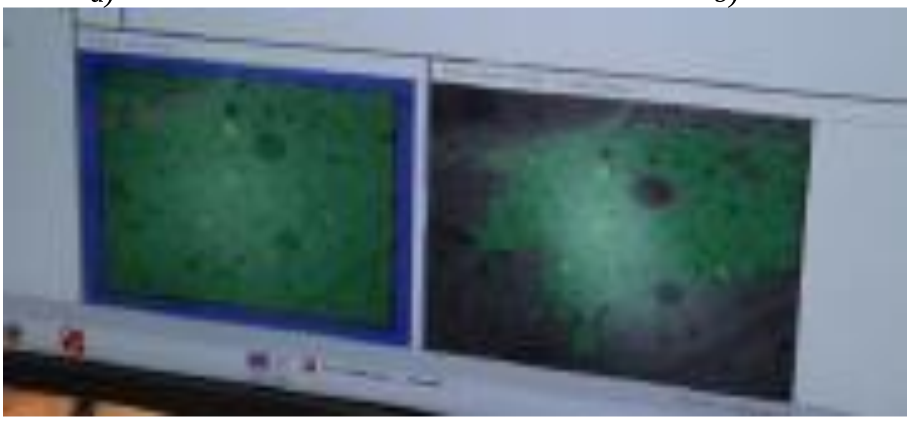
The images acquired with the ARAMIS HS acquisition system, through the software provided by the manufacturer, were processed providing both numerically and graphically the resulting stress state in the mandible after loading, Figure 4. a) shows the area subject to analysis with the optinc system (see the mark in Figure 4 on the mandible). Figure 4b) represents the discretization of the analyzed area performed by the software provided by the manufacturer of the ARAMIS system.Figure 4. c) shows the stress state that arises in the analyzed area after processing the acquired images. As can be seen, the voltages have low values (almost not visible on the graphical image).



a)



b)



c)

Fig. 4 The images acquired with the ARAMIS HS acquisition system

***Table 2** Measured values*

	Numerical	Experiment	Relative Error
	[MPa]		(%)
Equivalent tensions (Von Mises)	3.98	4.26	6.57
Deformations	72	79	8.86

The results obtained using optical methods are correlated with other applied methods, which are part of a much broader study represented by tensiometric methods, tests on the specimen made of PLA and tests on experimental modeling of mastication on the human bone specimen.

Conclusions

The tests carried out on both composite and human material contributed to the co-design of a test stand for the masticatory system. The static and impact tests carried out established a test methodology as well as ways of data acquisition. The establishment of a test methodology contributes, through the conclusions that can be drawn, to an easier design of the dental rotary instrumentation in terms of the stresses, deformations, strains, tensions and vibrations that may occur during dental treatment.

The following conclusions can be drawn from these experimental studies:

1. A unit (stand) test and data acquisition system has been designed.
2. Optical methods have been used for the first time, at least in the literature studied, to analyze the functioning of the masticatory system.

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