

## DETERMINATION OF FRACTAL DIMENSION OF THE FUNCTIONAL MASTICATORY TEST PATTERNS

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### ABSTRACT

*Valid diagnostic assessment of the state of dentoalveolar system and its masticatory function, in particular, is considered to be an important scientific task of modern prosthodontics. Plenty of the developed ways are based on the use of up-to-date information technology, especially on computer analysis of graphic data. The development of the enhanced methods for the evaluation of masticatory efficiency in patients with both full and partial adentia urged the search of its clear and informative indicators. According to the authors, digital image fractal dimension index can meet these needs. Since most of the available masticatory function assessment methods involve the obtaining large amount of fragments different in their quantity, size and shape. The photography of the multiplicity of these ‘spasmodically’ located objects allows the processing of the received image with the help of graphic editor and converting it into numeric data.*

*Thus, the aim of the research was to study the fractal dimension of the masticatory test images, taking into account the peculiarities of the patients’ denture defects. Computer software for digital image processing ImageJ 1.50b was used in the research, since it provides the option of computer calculation of the fractal dimension index. The comparison of the masticatory tests of 30 persons with intact teeth (control group) and 33 persons with denture defects has revealed statistically significant deviation in their fractal dimension index. The reduction of the range of conventional statistical norm (1.49-1.66) to the values fluctuating from 1.47 to 1.51. was observed. Therefore, the decrease of the mean value of the fractal dimension from 1.56 (St.Err.= 0.02) to 1.50 indicates the reduction of chopping function in the given masticatory test patterns. As a result, the suggested method will allow the use of fractal dimension index as an integral indicator of masticatory efficiency level.*

**KEYWORDS:** masticatory efficiency, masticatory test, image fractal dimension.

### INTRODUCTION

The implementation of computer technologies is seen to be a common trend of modern dental diagnostics as they provide the ways to facilitate the routine procedures of collecting, analyzing and archiving a large amount of information [Kosyh Je et al., 2011; Bondarenko A, Kacuk A,

2005; Strugajlo V, 2012; Tomakova R, Filist S, 2012; Shelomensteva I, 2017]. The use of image graphical indicators can also bring up to date masticatory tests, involving the mastication of the test patterns, collection of the chopped fragments, obtaining the digital photos and mathematical adjectives of every particular fragment with their further colligation [Korol D et al., 2017]. Fractal dimension is considered to be one of such indicators widely used in digital image processing software. Fractal theory has been widely acknowledged by the researchers in dental sphere mainly

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due to its ability to characterize geometrically complicated objects [Zaporozhchenko I, 2015; Leszczyński P, Sokalski J, 2017].

The conducted literature review proves that valid and precise criteria of masticatory efficiency evaluation are still under research [Soboļeva U et al., 2005; Van Der Bilt A et al., 2006; Van der Bilt A, 2011; Eberhard L et al., 2014; Korol D et al., 2015; 2016; Flores-Orozco E et al., 2016]. A masticatory test results in obtaining an array of fragments different in shape, size and mutual positioning. Thus, such a 'state of chaos' can be treated and studied from the point of view of fractal theory.

Taking into consideration this fact, we have developed the following hypothesis: digital images of the masticatory test fragments can be characterized with a particular level of fractal dimension, and its value for the patients with denture defects will deviate from the masticatory test results of the patients with intact teeth. Therefore, the aim of this research is to study the fractal dimension of digital images of masticatory tests taking into account the patients' denture defects.

#### MATERIAL AND METHODS

The participants of the given research were divided into two groups. The first group included 30 persons aged from 18 to 25. Normal occlusion and the absence of any denture defects were the main selection criteria for this group, which was taken as the control one. The second group consisted of 33 persons at the age of 25-55 with denture defects of either maxilla or mandible in different combinations. Masticatory efficiency loss by Agapov fluctuated from 6 to 94% in the representatives of this group. It should be also noted, that the ratio of men to women in the first group was 15 men to every 15 women, while in the second group it was 17 to 16 respectively. All the research participants provided their prior, free and conscious written consent to conduct the given studies, which was approved by the Institutional Committee on Bioethics and corresponds to the principles listed in Helsinki Declaration (Br. Med. J. 1964; p. 177), with further addendum.

Agar cylinders were used as standardized masticatory patterns. After the mastication these agar fragments were thoroughly collected, dried and spread in a specialized photo box against the dark background. After that digital images with the res-

olution of  $1270 \times 720$  pixels were taken and archived (Fig. 1). Their further processing was performed with the help of computer software ImageJ 1.50b. It implies phased photo conversion into 8-bit format, thresholding and determination of fractal dimension index (D).

#### RESULTS AND DISCUSSION

The prior statistical analysis performed with the help of computer software Statistica 10.0 showed that the mean value of fractal dimension index for the first group made up 1.56 (St.Err.= 0.02). Proximal median value (1.55) and statistical distribution symmetry within this sample indicate parametric values and their correspondence to the normal Gaussian distribution within population. The minimum value of this parameter in the first group equaled to 1.40, while the maximum one was 1.71. Special attention should be paid to the mean fractal dimension in the bottom and top quartiles (1.49 and 1.66 respectively), since they can be treated as the limits of conventional statistical norms (Fig. 2A).

The mean value of fractal dimension index for the second research group made up 1.50 (St.Err. = 0.001) and being combined with median value of 1.49 and statistical distribution symmetry corresponded to the common parametric distribution laws within population. In this case the mean fractal dimension values in the bottom and top quartiles of the given sample were fixed at the level of 1.47 and 1.51 respectively (Fig. 2B).



FIGURE 1. Digital image of masticatory pattern fragments

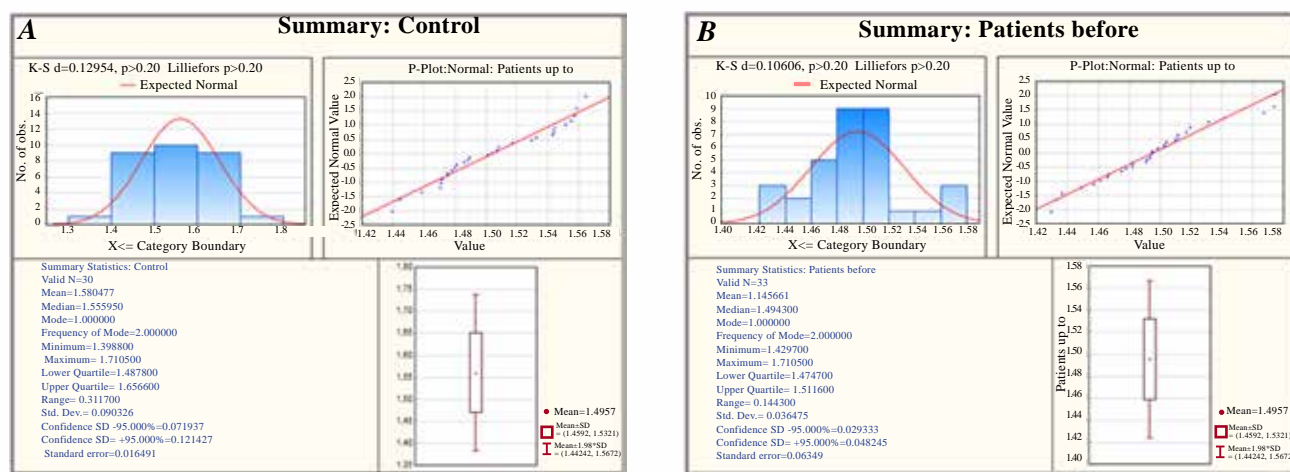


FIGURE 2. Prior statistical results of the fractal dimension index values in the first (control) (A) and in the second (B) research groups

Mann-Whitney U Test (Spreadsheet 2)  
By variable independent  
Marked tests are significant at  $p < 0.0500$

Variable	Rank Sum Group 1	Rank Sum Group 2	U	Z	p-value	Z adjusted	p-value	Valid N Group 1	Valid N Group 2	2*1 sided exact p
Dependent	1170,000	846,0000	285,0000	2,883149	0,003937	2,883218	0,003937	30	33	0,003466

Mann-Whitney U Test (Spreadsheet 2)

FIGURE 3. Comparison results of the mean values of fractal dimension indices in both research groups

In order to compare the results received in both research groups we used Mann-Whitney nonparametric statistical technique to compare the mean ranks of two samples (Fig. 3).

Taking into account the statistical significance ( $p=0.003$ ), the null hypothesis of the mean rank was equality rejected while the alternative hypothesis of the significant difference existence between the fractal dimension of the digital images of masticatory test results in patients with intact teeth and with denture defects was accepted with  $U=285$ .

### CONCLUSION

The presence of denture defects causes the decrease of masticatory efficiency. From graphical point of view this features fragment size growth and their quantity decrease. Therefore, the changes of general image structure caused the decline of fractal dimension index by 0.06. All the mentioned above provides the evidence to insist on the opportunity of the use of digital image fractal dimension index as a valid and reliable indicator of masticatory efficiency changes.

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