Evaluation of Mandibular Trabecular Bone by Fractal Analysis in Pediatric Patients with Hypodontia

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Abstract

Objective: In the literature, it is still unclear whether the trabecular structure of the jaw in subjects with hypodontia is different from those without hypodontia. Hence, the aim was to determine whether the mandibular trabecular bone structure of children and adolescents with hypodontia differs from the control group by using the fractal analysis method in this study.

Materials and Methods: A total of 138 radiographs of 69 cases and 69 control subjects (mean age 13.2±10.1) were evaluated. The age and gender of subjects in the case and control groups were matched. Three regions of interest (ROI) were selected from the panoramic radiographs. Mann-Whitney U and Wilcoxon tests were used. $p<0.05$ was accepted for the significance value.

Results: The mean fractal dimension (FD) values of ROI1, ROI2, and ROI3 were 1,25, 1,20, and 1,13, respectively. The means FD values obtained from the ramus region were higher than the other regions ($p<0.05$). The FD values did not differ significantly according to gender and age ($p>0.05$). The FD values of the case group were lower than the control group for ROI3 ($p<0.05$).

Conclusions: The results of this study showed that the mandibular trabecular bone quality of pediatric patients with one missing tooth was different from the healthy group. The difference in the mean FD values from the ROIs indicates that the ramus has a denser structure than the mandibular corpus. Therefore, it shows that individuals with hypodontia may need additional procedures in cases that require orthodontic and implant treatment.

Clinical Relevance: Clinicians should consider that individuals with hypodontia may need additional procedures in cases requiring orthodontic and implant treatment.

Introduction

Hypodontia is defined as the agenesis of one or more teeth in primary or permanent dentition [1]. Tooth agenesis is more common in women, and the most frequently missing tooth is the mandibular second premolar, followed by the maxillary lateral incisor and maxillary second premolar [2].

The etiology of tooth agenesis is complex, and both environmental and hereditary factors are reported to be effective [3]. Environmental factors leading to tooth agenesis include infectious diseases (e.g., rubella), various traumas in the tooth region, surgical procedures, chemotherapy or radiotherapy, or impairments in the innervation to the jaw, and factors linked to fetal development in the uterus [4-6]. In addition, it is known that tooth agenesis is accompanied by various syndromes, such as Down syndrome, cleft lip and palate, ectodermal dysplasia, van der Woude syndrome, oral-facial-digital syndrome type I, Rieger syndrome, and holoprosencephaly [7]. Although epigenetic and environmental factors contribute to tooth agenesis's etiology, there is convincing evidence that genetic factors prevail in the pathogenesis of the disease [8].

Today, fractal analysis is a popular method that quantitatively expresses the quality of bone tissue [9-11]. The FD values calculated by the box-counting method in trabecular bone are expected to be between 1 and 2. Values close to 2 represent a more complex bone microstructure, while values close to 1 refer to simpler bone microstructures highlighting the porosities of bone [12].

In hypodontia patients, it is valuable for the clinician to know the bone quality in treatments such as dental implant applications and orthodontic treatment [13, 14]. It has been reported that permanent tooth agenesis may cause insufficient alveolar bone development [15-17]. On the other hand, the relevant literature reports that the effect of hypodontia on trabecular bone structure is not clear [18]. For these reasons, it was aimed to determine whether the mandibular trabecular bone structure of children and adolescents with hypodontia is different from the control group by the fractal analysis method.

Material And Methods

The Sütçü İmam University Clinical Research Ethics Committee granted the ethical approval to the present study (approved no. 2021-04). The presented study was retrospectively carried out in the Sütçü İmam University, School of Dentistry, Department of Pedodontics in full compliance with the current ethical principles and the 1964 Declaration of Helsinki and its subsequent versions. The radiological records of the child and adolescent individuals who applied to the Sütçü İmam University, Pedodontics Outpatient Clinic for various dental treatment reasons were analyzed. To ensure standardization in the study, we included only the pediatric patient with agenesis of the mandibular second premolar in the study group.

According to the analysis of 95% confidence (1-α), 80% test power (1-β) and d=0.77 effect size, the number of samples to be taken in each group was determined as 6 according to the one-tailed independent samples t test analysis [19]. However, in order to increase the power of the sample, 67 people were included in each group in our study.

Sixty-nine child and adolescent individuals with agenesis of the mandibular second premolar consisted of the study group, while 69 child and adolescent individuals without hypodontia, matched with the study group for age and gender, consisted of the control group. Both groups were selected from child and adolescent individuals with mixed dentition periods. Each individual in the case and control group were matched for age and gender.

In both groups, radiographs with insufficient image quality, diagnosis of disease and drug use affecting bone metabolism, presence of syndrome, genetic disease, deep dental caries in the missing tooth region, apical and periodontal pathology were excluded from the study.

All panoramic radiographs were obtained by the same technician on the GENDEX GDP-700 device (Kavo Kerr, Biberach, Germany) at 66 kVp, 6.3 mA and 14 sec acquisition procedures according to the manufacturer's reference values.

A total of 138 panoramic radiographs, 69 of the study group and 69 of the control group, were saved to the lab computer is 2441x1149 pixel, 300 dpi resolution, 8-bit color depth, and Joint Photographic Experts Group (JPEG) format. In this study, the box-counting algorithm, which is primarily preferred in the fractal analysis method, was used [11].

All the image processing and fractal analysis procedures were conducted via the ImageJ v1.52 (NIH, Bethesda, MD, USA) program. The first step for fractal analysis was to select the region of interest manually. In all panoramic radiographs, trabecular bone structures in three ROIs located on the left side of the mandible (the quadrant with agenesis teeth) were measured.

ROIs in the mandibular left posterior region were selected from:

(1) The center of the region between the mandibular foramen and the anterior border of the ramus (**Figure 1a**),

(2) The area between the apical level of the mandibular molar and the upper border of the mandibular canal (**Figure 1b**),

(3) The missing tooth region, between the mesial root of the first mandibular molar and the root (or anticipated root) of the second mandibular premolar (**Figure 1c**).

ROI1 was selected as a 20x20 pixel square, while ROI2 was a 30x10 pixel rectangle and ROI3 was a 40x20 pixel rectangle (**Figure 1**). The selected ROIs were duplicated (**Figure 2a**). The duplicated images were blurred with Gaussian filter (Sigma 35). The purpose of this step is to eliminate the large-scale brightness changes that may occur due to different object thicknesses and the presence of overlapping soft tissues and to preserve only density differences (**Figure 2b**). The images obtained with the Gaussian filter were subtracted from the original images (**Figure 2c**). One hundred twenty-eight gray pixel values to each pixel location in the images were added (**Figure 2d**). The images were binarized as the next step to secure two parts representing bone marrow and trabeculae. (**Figure 2e**). The resulting images were eroded; thus, the noise was reduced (**Figure 2f**). In the next step, dilatation was applied to the image to make the structures more apparent (**Figure 2g**). The colors of the regions denoting the bone marrow and trabecular bone were changed to the opposite colors (**Figure 2h**). The final images were skeletonized using the 'Skeletonize' option (**Figure 2i and Figure 2j**). Using the software's box-counting algorithm, the images were divided into 2, 3, 4, 6, 8, 12, 16, 32, and 64 pixel-sized squares, and the number of frames containing trabeculae and the total number of frames was calculated. The values obtained in the logarithmic scale chart were included. The slope of the line aligned to points on the chart yields the fractal dimension value.

In the present study, two oral and maxillofacial radiologists performed the measurements blindly and independently. The mean FD value of each region of interest was calculated and used for statistical analysis. For evaluating the intra and inter-observer reliability, the measurements of were repeated two weeks after the first measurements.

Statistical Analysis

Data analyses were performed using IBM SPSS Statistics 26.0 (Statistical Package for Social Science) package program. Kolmogorov Smirnov test was used to evaluate whether the data were normally distributed. Since the data did not show normal distribution ($p<0,05$), Mann-Whitney U and Wilcoxon tests were used. Also, reliability analysis was performed for intra-observer and inter-observer agreement. $p<0.05$ was accepted for the significance value.

Results

A total of 138 radiographs of 69 individuals with hypodontia (36 females, 33 males) and 69 control subjects (36 females, 33 males) were evaluated. Since age and gender were matched in the patient and control groups, the mean age of the individuals in both groups was 13.2±10.1. There was no statistically significant difference in the distribution of age and groups according to gender, $p>0.05$).

The intra-rater reliability coefficients for ROI1, ROI2, and ROI3 were 0.898, 0.875, and 0.902 for rater 1, and 0.912, 0.921, and 0.885 for rater 2, respectively. Interobserver Cronbach's alpha values for ROI1, ROI2, and ROI3 were also 0.928, 0.896, and 0.901, respectively. Intra-observer and inter-observer consistency was nearly perfect.

The mean fractal dimension values of ROI1, ROI2, and ROI3 were 1,25, 1,20, and 1,13, respectively. Table 1 shows the mean fractal values of ROIs by total sample, gender, age, and case-control groups. According to Wilcoxon test, there was a statistically significant difference between fractal dimension values obtained from ROIs. While the mean fractal dimension value obtained from the ramus region was the highest, the fractal dimension value obtained from the edentulous area was the lowest ($p<0.05$) (**Table 1**). The fractal dimension values obtained from all ROIs did not differ significantly according to gender and age ($p>0.05$) (**Table 1**). When the fractal dimension values of the case-control groups were compared, the values obtained from ROI1 and ROI2 did not differ according to the groups, while ROI3 showed a significant difference ($p<0.05$) (**Table 1**) (**Figure 3**). The fractal dimension values of the case group were lower than the control group.

Discussion

Hypodontia treatment requires a multidisciplinary as a combination of orthodontics, fixed and removable prosthesis, and oral surgery approach and treatment includes different approaches according to the age of the child and the dentition period [20, 21]. If orthodontic treatment and dental implants are to be applied in the early period in order to preserve the bone structure in hypodontia patients, it is recommended to wait for the completion of growth and development, that is, approximately 16-20 years of age [22, 23]. In the literature, early placement of dental implants in children with hypodontia has only been applied in severe tooth deficiency, and these are case reports [24-26]. One the other hand, in orthodontic treatment, it is reported that the speed of tooth movement increases as the bone density decreases, and that the anchorage should be increased according to the need in the regions where the bone density is low [27].

It will be beneficial for the clinician to know the status of the bone tissue in the patient group with hypodontia. In the literature, the effects of many systemic diseases on the jaw were investigated using the fractal method [28, 29]. However, there is only one study in individuals with hypodontia [18].

Individuals in the permanent dentition and mixed dentition period were evaluated in the study. Although the time of dental implant applications is reported as the completion of growth and development, our results may give an idea in terms of mandibular jawbone trabeculation for both orthodontic treatment and dental implant patients.

There are many recent studies related to bone quality through fractal analysis and dental radiology in the literature [9, 11, 12, 30]. In the calculation of fractal dimension values, methods such as power, caliper and box counting methods are used [31]. It has been stated that the methods to be used in the analysis of mandibular and maxillary bones should differ. Although there are many methods to calculate, the most preferred is the box counting method [32]. Therefore, this method was used in this study.

Most studies evaluated the fractal dimension on periapical, bitewing, and panoramic radiographs. Recently, the number of studies working fractal dimension on CBCT images has been increasing. However, the number of studies is still limited [33]. Magat et al. [34] compared DPR and CBCTs in the evaluation of trabecular bone by fractal analysis and stated that it would be more feasible and appropriate to choose panoramic radiographs because of the disadvantages of CBCTs such as higher radiation and lower image resolution. DPR was the method of choice due to its advantages in the presented study, considering the pediatric patient group.

It has been reported that the FB is affected by the parameters of ROI selection, size, shape, and the region where it is placed. It has been stated that the use of linear ROIs is insufficient to evaluate the trabecular structure, therefore, a planar ROI selection should be made [35]. Planar ROIs were selected in this study. The size of the selected ROIs differed by region, as individuals were in the mixed dentition period and were studied in a limited area.

According to the literature, it is seen that the mean fractal values vary between 1.10 and 1.83 in healthy individuals. In this study, mean fractal values ranged from 1.04 to 1.26. The results we obtained were within the limits of the literature. In studies, FD values were generally evaluated in individuals over the age of 18 [29, 36-40]. There were a limited number of studies evaluating the trabecular bone structure of children and adolescents with fractal dimension [28, 41, 42]. The mean age (11.67 ± 2.53 years.) and fractal dimension values (1.29 ± 0.06) of the individuals in Yagmur et al.'s study [41] were quite close to those in this study. The reason for the differences in fractal dimension values stated in the studies may be due to the difference in the number of samples, fractal dimension calculation method, gender and age distributions.

It is known in the literature that fractal dimension values are lower in females and in the older age group [38]. However, fractal dimensions did not differ according to age and gender in this study. There is not a limited number of studies in the literature in which these findings can be directly compared.Similar to this study, in a study evaluating the fractal dimensions of children's condyles [42], it was emphasized that trabecular structure did not change according to age, except for those aged 6 years. In another study [43], it is stated that trabecular bone scarcity is more pronounced in individuals under the age of 20. Kavitha et al. [44] reported that fractal values of trabecular bone were lower in females than males all ages. Hormonal problems, the number of systemic diseases and the increase in drug use with age in females may cause this situation [45]. As far as we know, there was no study in the literature evaluating the effect of gender in this age group.

In this study, the FD values of different ROIs of individuals on the same side were significantly different from each other. When the FD values of all individuals were examined, it was seen that the FD values calculated from the ramus region were the highest and the FD values calculated from the regions with missing teeth were the lowest. A larger FD indicates a denser and less porous trabeculae [32]. According to this information, it can be said that among the regions examined in this study, the trabecular complexity in the ramus region is higher than in other areas. In addition, Yaşar and Akgünlü [37] observed that the differences in occlusal forces occurring in the dental and edentulous areas during chewing caused some changes in the trabecular bone structure, resulting in lower FD in the dental areas. In this study, fractal values obtained from structures adjacent to the dentulous regions were lower. Consistent with our result, there are studies in the literature that indicate that there are differences in fractal dimensions of ROIs evaluated on the same side, as well as in studies conducted in the same regions [37, 39, 40, 44].

The number of studies evaluating FD is high in the literature. While it was stated that FD was higher in patients using bisphosphonates [46], the FD values of patients with sickle cell anemia [43] and chronic renal failure were found to be lower than healthy subjects. In this study, the FD value of the hypodontia group was found to be significantly lower than that of the healthy group ($p<0.05$). There was only one study in the literature evaluating the effect of hypodontia on trabecular bone [18]. In this study, Creton et al. [18]. investigated possible bone structure changes due to hypodontia with fractal analysis and other radiographic measurements and reported that there was no significant difference between the groups. However, they observed a greater FD when the number of missing teeth increased. The difference between Creton et al. [18] and us may be due to the fact that they used the caliper method when calculating fractal dimension values in their study and classified tooth deficiency as hypodontia, oligodontia or dental agenesis. In addition, similar to this study, Creton et al. [18] also included only individuals with left mandibular second premolar agenesis.

The limitation of the current study is that only one missing tooth was evaluated in the study groups and the sample size was small. In future studies, the number of patients should be increased and edentulous status should be evaluated. In addition, studies that include both cortical bone and trabecular bone in a wider age range can be done by categorizing missing tooth cases.

Conclusion

The results of this study showed that the mandibular trabecular bone quality of pediatric patients with one missing tooth was different from the healthy group. The difference in the mean fractal values from the ROIs indicates that the ramus has a denser structure than the mandibular corpus. Therefore, it shows that individuals with hypodontia may need additional procedures in cases that require orthodontic and implant treatment. In addition, high ramus density is important in procedures such as graft, tooth movement, and orthognathic surgery.

Declarations

Compliance with ethical standards

Conflict of interest: The authors declare no competing interests.

Funding: None.

Ethical approval: The Sütçü İmam University Clinical Research Ethics Committee granted the ethical approval to the present study (number: 2021-04). All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent: For this type of study, formal consent is not required.

Study design: K.T.T., A.S.O. and A.C., Data acquisition: A.S.Ö and K.T.T., Methodology: K.T.T., A.S.O. and A.C., Statistical analyzes: G.M., Writing, review and editing: K.T.T., G.M., A.S.O. and A.C., Supervision: S.O. and G.M.

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Tables

Table 1 The mean fractal dimension values according to total sample, gender, age and case-control groups

	ROI1	p value	ROI2	p value	ROI3	p value
Total	1.25 (1.00 - 1.49)		1.20 (1.00 - 1.37)		1.13 (0.81 - 1.35)	**0.000*†▯**
Gender						
Female	1.26 (1.01 - 1.49)	0.629	1.20 (1.00 - 1.35)	0.448	1.14 (0.88 - 1.35)	0.203
Male	1.24 (1.00 - 1.43)		1.19 (1.00 - 1.37)		1.11 (0.81 - 1.29)	
Age Groups						
4-10 years	1.26 (1.00 - 1.49)	0.578	1.19 (1.00 - 1.35)	0.604	1.14 (0.90 - 1.35)	0.619
11-17 years	1.24 (1.00 - 1.44)		1.20 (1.00 - 1.37)		1.12 (0.81 - 1.35)	
Case-Control Groups						
Case	1.24 (1.00 - 1.49)	0.589	1.20 (1.00 - 1.34)	0.854	1.04 (0.80 - 1.23)	**0.000*▯**
Control	1.25 (1.00 - 1.44)		1.20 (1.00 - 1.37)		1.14 (0.71 - 1.35)	

*p<0.01, ▯ Wilcoxon test,   Mann-Whitney U test

Figures

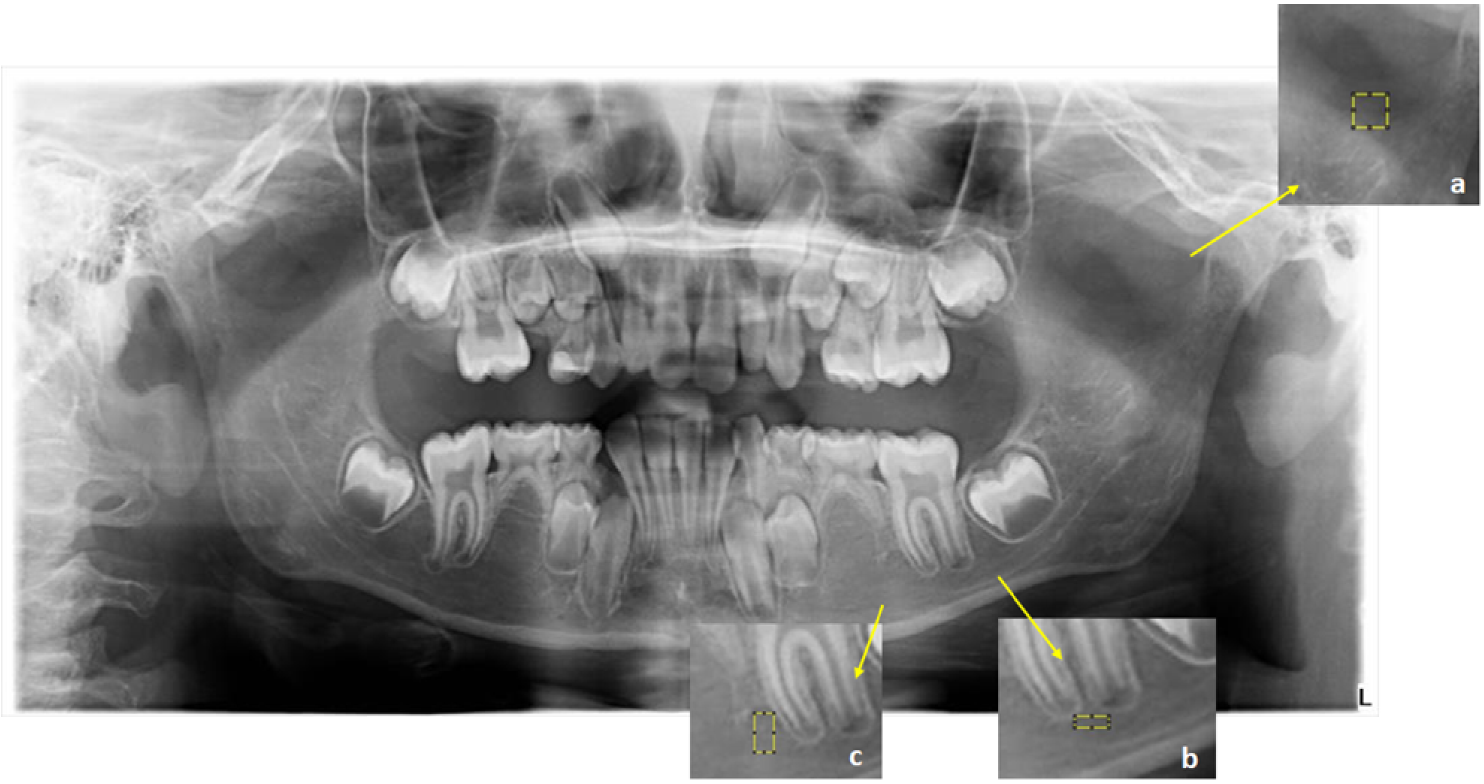

Figure 1

a: The center of the region between the mandibular foramen and the anterior border of the ramus b: The area between the apical level of the mandibular molar and the upper border of the mandibular canal c: The missing tooth region

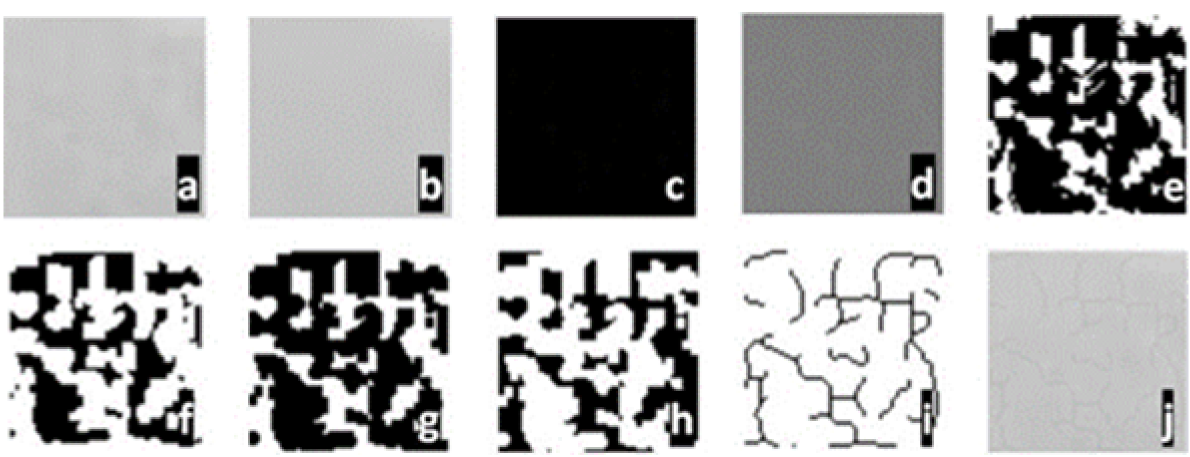

Figure 2

a: Duplicated, 2b: Blurred image, 2c: Gaussian filter 2d: Addition of a gray value of 128, 2e: Binarized, 2f: Erode, 2g: Dilate, 2h: Invert 2i-j:Skeletonize

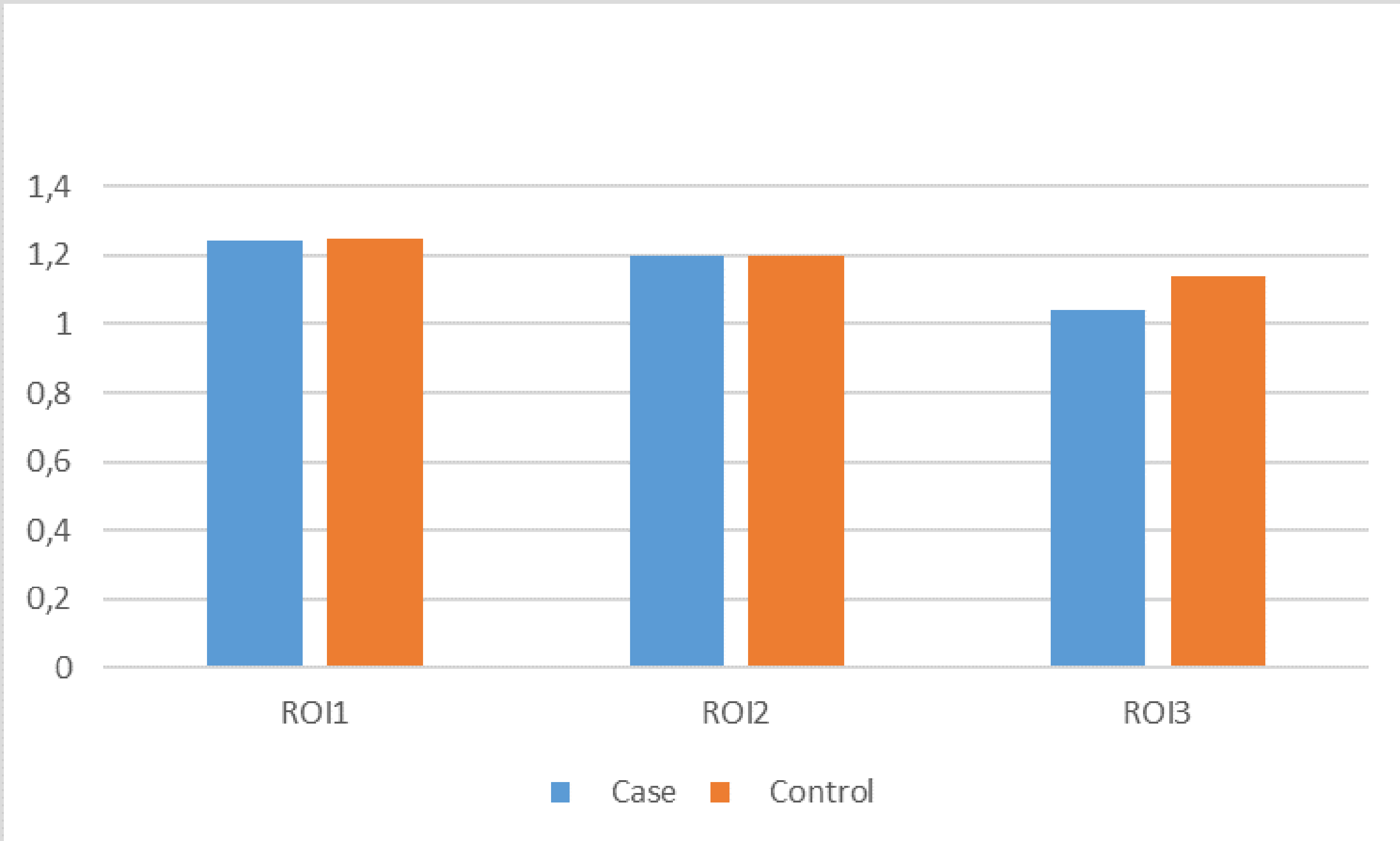

Figure 3

The diaphragm of mean fractal dimension values according to case-control groups