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RESEARCH BRIEF

Feasibility of fractal analysis for detecting primary bone changes in chronic periodontitis

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Abstract

Background: Periodontitis is an inflammatory disease of the supporting tissues of teeth. Although several clinical and radiographic symptoms have been employed to detect periodontitis; however, no scheme has yet been introduced for the detection of gingivitis-to-periodontitis transition phase. Fractal analysis, as a mathematical tool to explore morphological features, has efficiently been used to investigate the complex structural pattern of alveolar bone texture. **Aim:** In this study, fractal analysis is examined for its feasibility to efficiently detect trabecular structure of interdental bone for individuals with healthy gums from patients with moderate periodontitis using digital images. **Materials and Methods:** Patients are divided into two groups of healthy individuals (H-group) and patients with moderate periodontitis (MP-group) (20 individuals in each sample group). Clinical indices involving pocket depth, attachment loss, and bleeding on probing, digital radiographic periapical images of posterior mandibles region are provided using phosphor plate system, and two rectangular regions out of interdental zone of mandibles molars are selected as regions of interest for each individual. The use of box-counting algorithm of image J software, fractal dimensions (FD) for both regions are then calculated, out of which the mean FD index is obtained for each patient. Clinical and FD indices are finally compared for both groups through a *t*-test examination. **Results:** Clinical indices for H-group are noticeably higher than those of MP-group ($P \leq 0.05$). The mean FD for H- and MP- groups is 0.84 and 1.02, respectively. Statistical analysis proves a significant difference between the two groups for this index. **Conclusion:** Fractal analysis can efficiently quantify changes in trabecular pattern of bones, implying that temporal variation of such index may effectively demonstrate disease progression. The proposed scheme can be effective to detect and monitor variations due to periodontitis. **Clinical Significance:** Fractal analysis is a non-invasive method for early detection of moderate periodontitis.

Keywords: Fractal analysis, fractal dimension, moderate periodontitis

Introduction

Periodontitis is an inflammatory disease of the supporting tissues of teeth, which is usually produced by special microorganisms or group of microorganisms, and is typically characterized by vast destruction of periodontal ligament (PDL) and alveolar bone. Clinical view can identify periodontitis from gingivitis.[1] Exact examination of alveolar bone is a prerequisite for detection, treatment plan, and prognosis determination of periodontal diseases.[2] Alveolar bone changes provide suitable information to determine periodontal status.[3] Alveolar bone loss is an evident sign of periodontal destruction. Four stages of initial lesion, early lesion, established lesion, and advances lesion are defined to describe transition from healthy status to periodontitis. Initial, early, and established lesions are defined as gingivitis, while advanced lesion is classified as periodontitis.[4] Although several clinical and radiographic characteristics are used for the periodontitis diagnosis;[5] however, no diagnostic method is proposed to detect gingivitis-to- periodontitis transition phase.[5] After the introduction of fractal analysis, the method is extensively used in different fields of medical sciences. Today, fractal analysis is efficiently employed to study the complex pattern of trabecular structures from which fractal dimension (FD) index is introduced as a quantitative result of this image processing scheme. Despite subtractive technique, this method examines trabecular structural patterns, as well as bone density, and is independent of radiation geometry;[6,7]

thus, it is not necessary to iterate exact radiation geometries for serial radiographs. This study is aimed at the feasibility evaluation of fractal analysis of non-standard digital images to differentiate healthy alveolar bone from those with moderate peritonitis.

Materials and Methods

Forty patients were selected as the sample in our study. For every single individual in the study, periodontal indices including packet depth (PD), attachment loss (AL), and bleeding on probing (BOP) were measured and recorded. All measurements were counted in six sites of each tooth using Williams Probe. If BOP was observed in the site 30 s after probing, the site would be considered BOP positive. The sampling system used in the study was based on the categorization proposed by the International Workshop of Classification of Periodontal Diseases and Conditions (1999).[8] Those individuals without BOP, who lacked clinical symptoms were considered normal and patients with pocket depths between 4 and 6 mm in at least two posterior quadrant of mandible, AL of between 3 and 4 mm, and a lack of furcation involvement and tooth mobility were considered to have moderate periodontitis. All the participants in this study had at least 20 teeth. Those patients with systemic problems, in addition to the patients who received surgical or non-surgical periodontal in the past 6 months, those with history of root canal therapy and pre-apical lesion in the region of interest (ROI), and those with severe periodontitis were excluded from the study.

Imaging

After acquiring the consent from all the participating patients, we took periapical images of their mandibular molars. The images were photographed suing size 2 phosphor plate. All the radiographic images were taken through parallel technique. The imaging device was adjusted to 60 kVp and 7 mA emission configuration and an emission duration of 0.12 s. After scanning the imaging plates, the captured images were saved in 8-bit TIFF extension files.

Image analysis

On the images, two 50 × 100 pixels rectangular areas of the interproximal bone were chosen as the ROI. These regions were between the roots of the teeth in mandibular molars and did not include PDL and the roots. Despite the fact that the initial size for the rectangular ROI was considered to be 50 × 100 pixels, the ROI was not necessarily been chosen according to the initial speculated size. The ROI areas under study were cropped, and drawing upon White and Rudolph's method the images were processed, using certain computer software, namely, image J. FD was calculated using box counting algorithm in the software. The mean FD of the two regions was scrutinized and recorded as the FD final index for each patient.

Statistical analysis

To compare the BOP between the two groups, we used Chi-square test. Moreover, independent *t*-test or its non-parametric equal (Mann Whitney) test was used to compare DP, AL, and FD indices. The whole statistical operations in this study were conducted in SPSS.

Results

The average age of the healthy participants was 37 ± 7.3, and 42 ± 42 for moderate periodontitis. There were 12 men (60%) with average age of 35.6 ± 8.4 and 8 women (40%) with average age of 39.8 ± 4.3 in the healthy group. In the MP-group, there were 14 women (70%) with the average age of 42.4±−8.2 and 6 men (30%) with average age of 45.2 ± 7.6. Based on the outcomes of the *t*-test, there was no significant difference between the average age of the two groups ($P > 0.05$).

Clinical findings

The outcomes of the clinical measurements of the two groups are presented in Table 1. In the healthy group, 8.3 ± 7.3% of the sites and in the periodontitis group 9.2% ± 5.2 of the sites were BOP positive. Based on the results of the statistical Chi-square test, the BOP index of the periodontitis group was noticeably higher than healthy group ($P \leq 0.05$).

Knowing that the quantitative indices in this study did not have normal distribution due to Kolmogorov Smirnov test, we used Mann Whitney test to compare such indices. The mean of the PD index in the healthy group was 1.84 ± 0.24 and in the periodontitis group was 5.32 ± 10.82.

The AL index for the two groups was 1.24 ± 0.12 and 3.4 ± 2.1 accordingly. The results of the statistical tests showed that these clinical indices were significantly higher for the periodontist group ($P \leq 0.05$).

Calculating FD

The mean and the standard deviation of FD in the healthy group was 1.01 ± 0.08, and in the periodontitis group was 0.84 ± 0.07. According to the Mann Whitney test, the mean of FD in the medium periodontist group was meaningfully lower than one in the healthy group ($P \leq 0.05$).

In the H-group, 7.3 ± 8.3% of sites and in the MP-group 9.2 ± 5.2% of the sites were BOP positive. The mean of PD index

Table 1: The results of the clinical data and FD between the two groups

Index	H-group	MP-group
BOP (%)	7.3±8.3	9.2±5.2
Pocket depth	0.24±1.84	10.82±5.34
AL	0.12±1.24	2.1±3.4
FD	0.08±0.01	0.07±0.84

FD: Fractal dimensions, AL: Attachment loss, BOP: Bleeding on probing

in the H-group was 1.84 ± 0.24 and in the MP-group was 5.34 ± 10.82. The AL index for the two groups was 1.24 ± 0.12 and 3.4 ± 2.1 accordingly. The results of the statistical test showed that these clinical indices were significantly higher in the MP-group in comparison with the H-group ($P \leq 0.05$). The mean FD in the patients with moderate periodontitis was 0.84, while it was 1.01 in the H-group. The outcomes of the statistical analysis showed a significant difference in this index between two groups.

Discussion

Transition from gingivitis to periodontitis may last from several weeks to years. In gingivitis, the inflammation is limited to soft tissues. Progression of inflammation to bone is the primary sign of periodontitis. Early detection of bone loss is necessary to prevent the progression of the disease, which is impossible by radiography.[9] Subtraction technique was proposed for detection of these primary bone changes.[10,11] In this technique, serial radiographs are evaluated for detection of density changes.[12] However, there exist several considerations such as standard radiation geometry or requirement to special equipments.[12,13] The technique also requires at least a 30% change of bone mineral mass to detect bone resorption in serial radiographs.[14] However, fractal analysis can effectively characterize the complexity of trabecular structure of alveolar bone independent of radiation geometry.[6,7] The results of bone FD are not affected by small variations of radiation angles and radiation factors limited to clinical standards.[15]

Several researches are found in literature which have dealt with changes of alveolar bone due to periodontitis using fractal analysis.[16-18] According to these results, FD can differentiate between healthy bone and that of affected by severe periodontitis.[18] Conventional radiographs were used in these studies. After scanning these radiographs, they were converted to digital formats,[19,20] which changes the resolution of images. Thus, digital imaging is used in this study.

The results of our study are similar to previous studies that demonstrated the direct relation between FD and periodontal status. Fractal analysis is also suitable for detection of primary stages of periodontitis. According to our results, this method may characterize initial changes of trabecular structure in moderate periodontitis before bone resorption. The method, however, requires a viable classification system to effectively classify patients according to periodontal disease risk, before any applicable implementation. Longitudinal studies with large sample volume may help define a normal FD spectrum for specific sites. It is strongly recommended to devise longitudinal prospective studies to inspect temporal FD and clinical status of disease progression. ROI location and site effects on FD values are not well recognized yet, though some studies deny any ROI location effect on the FD. Such claim, however, seems to need more evidence.

Conclusion

Clinical indices for H-group are noticeably higher than those of MP-group. The mean FD for H- and MP- groups is 0.84 and 1.02, respectively. Statistical analysis proves a significant difference between the two groups for this index. Due to results of our study, fractal analysis can efficiently quantify changes in trabecular pattern of bones, implying that temporal variation of such index may effectively demonstrate disease progression. The proposed scheme can be effective to detect and monitor variations due to periodontitis.

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