Quantitative Analysis by Pixel Intensity and Fractal Dimensions for Imaging Diagnosis of Periapical Lesions
Shahrazad Sami Saeed¹, Usama Morad Ibraheem², Manar Mudhafar Alnema³
¹²³Oral & Maxillofacial Surgery, College of Dentistry, University of Mosul, Iraq

Abstract

Aims of study: To perform quantitative analysis of periapical lesions by pixel intensity, fractal dimensions in diagnosis of periapical lesions.

Subjects, Material and Methods: Twenty-six patients aged between 8-40 years classified as age groups: Group 1 from 8-18 years, Group 2 from 19-29 years, Group 3 from 30-40 years and with periapical lesion in maxillary and mandibular anterior teeth and premolars diagnosed by their clinical sign and symptoms and radiographic findings who attended to the maxillofacial unit in Al Al Jamhori Teaching Hospital and Specialist Center of Dentistry/Right Bank in Mosul city were include in this study. The periapical radiograph for all twenty-six patients had taken by bisecting angle technique. All The periapical radiograph, then digitize to convert them to the digital form for detection pixel intensity, the developed imagej software version 1.34s software was used for image processing then found the pixel intensity for all lesions and also histogram. Periapical lesion shows fractal behavior which is quantitative evaluation of periapical area and fractal dimensions also measured.

Result: Significant correlation found between pixel intensity and fractal dimension and histopathological result.

Conclusion: Fractal dimension and pixel intensity calculation could be recommended as a quantitative and objective method for the differential diagnosis of clinical suspicious periapical lesions.

Key words: periapical lesions, pixel intensity, fractal dimensions.

INTRODUCTION

Periapical inflammatory lesions occur as a local immune response of periradicular tissue to the chronic stimulation caused by microorganisms that invade and destroy the dental pulp.¹²³ The fundamental principle of periapical inflammatory lesion involve the progression of a bacterial infection from the dental pulp to the apical foramen which results in a localized inflammatory response concurrent with bone resorption identified as a radiolucent in radiographs. Histopathological categories of periapical lesion referred to as apical periodontitis.⁴⁻⁵⁻⁶⁻⁷⁻⁸ Apical periodontitis means a group of inflammatory disorders of the periapical tissues caused predominately by a mixed microbial infection in the endodontic system of the affected tooth.⁹⁻¹⁰⁻¹¹ Digital imaging, with pixel intensity, holds the possibility of qualitative and quantitative analyses of bone density and architecture. Pixel intensity (PI) analysis consider as a simple method that provide objective measures of radiographic density of alveolar bone.¹² Its means measurement of blackness or whiteness in a 8-bit digital image on a scale from zero (totally black) to 255 (totally white)¹³ The number and size of the pixels, together with the number of shades of grey available in radiograph, decided the amount of information in an image.¹⁴ The word “fractal” comes from the Latin word fractus that means fracture or broken.¹⁵⁻¹⁶ Its defined as a mathematical methods for describing and analyzing complex shapes and structural patterns, expressed numerically as fractal dimension (FD).¹²

So that, the fractal dimension utilized to estimate complex geometric structures quantitatively. Generally, the higher the dimension, the more complex the shape.¹⁷⁻¹⁸⁻¹⁹ The complexity of the structure is represented by a single number that is calculated with a computer algorithm.²⁰ Several techniques for fractal dimensions calculation were proposed, with box counting method being the most commonly employed in dental radiology.²¹⁻²² Box-counting algorithm is predominately employed to quantify the trabecular pattern by counting the trabecular bone and bone marrow interface. The method also assesses the boundary of trabecular bone and marrow, a higher box counting value indicates a more complex structure.²¹⁻²³ Fractal dimensions is stand for as the absolute value of the slope of the least square regression line.²⁴ Essentially, the fractal dimensions methods are reported to be unaffected by difference in exposure, alignment,
and choice of region of interest. In dental radiology, the fractal dimension calculation was utilized to estimate and quantify the trabecular bone structure for the detection of bone changes associated with periapical periodontitis, periodontal disease, bone surgery and systemic diseases. Fractal dimensions have also been utilized for estimation of dental implant sites and detection of osteoporosis.

MATERIAL AND METHODS

Twenty six patients aged between 8-40 years classified as age groups: Group 1 from 8-18 years, Group 2 from 19-29 years, Group 3 from 30-40 years and with periapical lesion in maxillary and mandibular anterior teeth and premolars diagnosed by their clinical signs and symptoms and radiographic findings who attended to the maxillofacial unit in Al Jamhori Teaching Hospital and Specialist Center of Dentistry/Rightin Mosul city were included in this study. Informed consent was taken from all the patients before their inclusion in the study. A special patients record sheet was formulated to record the history, clinical examination, radiographic findings, ultrasound examination and histopathological examination.

Conventional Periapical Film Radiographic Examination

The periapical radiograph for all twenty patients had taken by bisecting angle technique. Dental x-ray unit (68kVp,8Ma, 2 mm filtration) and Kodak E-speed used to take the periapical radiograph. This technique involves that the appropriate sized film packet(size 2), is positioned and orientated in the mouth with about 2 mm extending beyond the incisal or occlusal edges, to ensure that all of the tooth will appear on the film. The patient is then asked to gently support the film packet using either an index finger or thumb keeping the film as close to the teeth as possible. The central x-ray beam is directed perpendicular to the imaginary bisector that bisects the angle formed by long axis of the tooth and the film. The imaginary bisectors creates two equal angles and provides a common side of the two imaginary equal triangles, the two imaginary triangles are right angles and are congruent. The conventional radiographs were then processed automatically in fresh chemicals, the radiographs were viewed and evaluated on a viewing box under normal operating illumination and the surgeon specialist in maxillofacial unit were asked to make a detailed description of periapical lesion. All The periapical radiograph then digitize to convert them to the digital form for detection pixel intensity, the developed imagej software version 1.34s software (National Institutes of Health, Bethesda, MD: http://rsb.info.nih.gov/ij/image). NIH Image is a public domain program that can be downloaded from the World Wide Web (http://rsb.info.nih.gov/ij/Java 1.3.1_13),was used for image processing then found the pixel intensity for all lesions and also histogram. The pixel intensity was analyzed after analogue radiographs were scanned into a computer. The histogram (Histogram plot the pixel intensities in x-axis and the corresponding number of pixels in the y-axis) of the image is computed and stored in a variable, and then the index value of the histogram that has the maximum number of pixels is noted.

![Histogram](image1)

Figure (1): Index value of the histogram that has the maximum number of pixel

Periapical lesion shows fractal behavior which is quantitative evaluation of periapical area. All procedures for calculation of the fractal dimension were performed by using Image J version 1.34s software. Region of interested(ROI)were selected as 22 _ 16 pixel-sized squares that located at the apex of tooth. Lamina dura, periodontal ligament and related regions, and root apices were not included within ROI. The saved images were processed using the method developed by Demirbas et al. (2008) methodology. The region of interest(ROI) were cropped and were transferred to Image J version 1.34s by using the program menu. To remove the fine-scale and medium-scale variations in image brightness caused by the difference in the thickness of the object and the radiation exposure, the cropped ROI was duplicated and the duplicated image was blurred with a Gaussian filter (kernel size _ 35). The blurred image was then subtracted from the original image and then the resultant image was converted to binary by threshold at the gray value of 128 so that the segmented objects approximated the bony trabecular pattern. With this process, the regions that represent trabecular bone were set to black and marrow spaces were set to white. Finally, the image was skeletonized and was used for fractal analysis. On skeletal binary image, the skeletal structure indicated the bone pattern, whereas non skeletal structure represented the bone marrow. All digital manipulations and measurements were made within the...
ROIs rather than of the entire original intraoral radiograph. The fractal dimension of the skeletonized image was calculated with Image J version 1.34s by using the box-counting function from “analyze” menu, as follows: the image was covered by a square grid of the equally sized tiles and the number of tiles containing at least black pixel (which refers to the trabecular bone) was counted. The width of the square boxes were 2, 3, 4, 6, 8, 12, 16, 32, and 64 pixels. The resulting number of the counted tiles were plotted against the total number of the tiles in double logarithmic scale and FD was calculated from the slope of the line fitted on the data points.

![Image](image_url)

**Figure (2):** Slope of the line fitted to the data points along with the FD Value

![Images](image_url)

**Figure (3):** Steps of fractal dimensions measurement; A: a region of interest from a digitized radiograph of the periapical area of maxillary central incisor; B: the result of blurring this region; C: the result of subtracting B from A; D: adding 128; E: binary version of image C; F: skeletonized image.

**RESULT**

**Table (1):** Descriptive Statistics of pixel intensity

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>Minimu m</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyst</td>
<td>6</td>
<td>1.265800</td>
<td>0.1122517</td>
<td>0.0458266</td>
<td>1.1854</td>
<td>1.4887</td>
</tr>
<tr>
<td>Abscess</td>
<td>5</td>
<td>1.227880</td>
<td>0.0492093</td>
<td>0.022071</td>
<td>1.1440</td>
<td>1.2672</td>
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<tr>
<td>Granuloma</td>
<td>11</td>
<td>1.080864</td>
<td>0.0756884</td>
<td>0.0228209</td>
<td>0.9428</td>
<td>1.1735</td>
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<tr>
<td>Phoenix abscess</td>
<td>4</td>
<td>1.126457</td>
<td>0.1469727</td>
<td>0.0734864</td>
<td>1.0137</td>
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<tr>
<td>Total</td>
<td>26</td>
<td>1.158831</td>
<td>0.1197209</td>
<td>0.0234792</td>
<td>0.9428</td>
<td>1.4887</td>
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Table (2): ANOVA statistics for pixel intensity

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>Minimum</th>
<th>Maximum</th>
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<tbody>
<tr>
<td>Cyst</td>
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<td>3.371</td>
<td>1.376</td>
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<td>85</td>
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<tr>
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<td>44.40</td>
<td>5.595</td>
<td>2.502</td>
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<td>51</td>
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<tr>
<td>Granuloma</td>
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<td>103.18</td>
<td>21.165</td>
<td>6.382</td>
<td>84</td>
<td>148</td>
</tr>
<tr>
<td>Phoenix abscess</td>
<td>4</td>
<td>79.00</td>
<td>12.356</td>
<td>6.178</td>
<td>61</td>
<td>89</td>
</tr>
<tr>
<td>Total</td>
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<td>77.00</td>
<td>28.940</td>
<td>5.676</td>
<td>38</td>
<td>148</td>
</tr>
</tbody>
</table>

Table (3): Duncan's Multiple Range Test of pixel intensity

<table>
<thead>
<tr>
<th>Sum of Squares</th>
<th>Df</th>
<th>Mean Square</th>
<th>F</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>3</td>
<td>5272.777</td>
<td>22.658</td>
<td>0.000</td>
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<tr>
<td>Within groups</td>
<td>22</td>
<td>232.712</td>
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<tr>
<td>Total</td>
<td>25</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Table (4): Descriptive Statistics of fractal dimensions

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Duncan's grouping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abscess</td>
<td>5</td>
<td>44.40</td>
<td></td>
</tr>
<tr>
<td>Cyst</td>
<td>6</td>
<td>54.83</td>
<td></td>
</tr>
<tr>
<td>Phoenix abscess</td>
<td>4</td>
<td>79.00</td>
<td></td>
</tr>
<tr>
<td>Granuloma</td>
<td>11</td>
<td>103.18</td>
<td></td>
</tr>
</tbody>
</table>

Table (5): ANOVA statistics of fractal dimensions

<table>
<thead>
<tr>
<th>Sum of squares</th>
<th>df</th>
<th>Mean</th>
<th>F</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
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<td>3</td>
<td>0.055</td>
<td>6.158</td>
</tr>
<tr>
<td>Within groups</td>
<td>0.195</td>
<td>22</td>
<td>0.009</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>0.358</td>
<td>25</td>
<td>0.009</td>
<td></td>
</tr>
</tbody>
</table>
Table (6) Duncan's Multiple Range Test of fractal dimensions

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Duncan's Grouping</th>
</tr>
</thead>
<tbody>
<tr>
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<td>A</td>
</tr>
<tr>
<td>Granuloma</td>
<td>11</td>
<td>1.080864</td>
</tr>
<tr>
<td>Phoenix abscess</td>
<td>4</td>
<td>1.126475</td>
</tr>
<tr>
<td>Abscess</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Cyst</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

p-value is 0.001

DISCUSSION

When the user adjusts the whole image to make it more suitable for diagnostic purposes, the term “image processing” usually is applied. Image processing techniques are an acceptable technique that can be used to assist dentists in improving the diagnosis. Image processing enables extraction of signals of diagnostic interest from a radiograph. However, it cannot produce information that is missing. The interest in digital image processing methods has arisen from the recent possibility of improving the quality of visual information for human interpretation. Particularly in oral pathology, this improvement in image quality is essential for a better diagnosis, especially if the original source of the digital image is a conventional radiograph. Our study proved that the granuloma had higher pixel intensity than abscess and cyst which may be due to the content of cyst which is fluid and abscess which is pus and exudates and this give lower gray scale level than granulation tissue of granuloma, while phoenix abscess has pixel intensity between granuloma and abscess and this may be due to phoenix abscess is granuloma with abscess formation and this give lower gray value and this finding disagree with the result of Shrout et al., 1993, who found that granulomas had a narrower range and lower grayscale value than did cysts.

In the present study we further asserted that variation in the gray scale value of a periapical lesion is associated with histological changes, with a direct correlation between the value and the type of material that fills the lesion, and this result consistent with Camps et al. 2004. Teixeira et al., 2010 revealed that the pixel intensity values in the areas of periapical disease induced in rats indicated greater bone resorption than the means of these values on the control side for the three experimental periods (p<0.05). Even small periapical bone resorption was already sufficient for determining changes in the pixel values of that area in the direct digital method, when compared to their respective controls. The pattern of bone trabecule characterized by a number of measures including area of the bony plates, circumference of the trabecule, number of bony and marrow regions, thickness of the trabecule, trabecular spacing, and osseous fractal dimension. It has been demonstrated that cancellous bone is made of interconnected trabecular structures with an underlying geometric pattern, thus making it a tool for defining a mathematical fractal pattern.

Periapical lesion shows fractal behavior which is quantitative evaluation of periapical area. This method is difficult to use for quantifying an entire radiolucent lesion because it may only be employed on a small fragment of that radiolucent area. Nearby anatomy such as sinus and proximity to adjacent structures such as root apices can participate to noise and degrade benefit information. With these limitations in mind, fractal analysis has been capable to detect early changes in periapical trabecular pattern in a defined small region of interest on periapical radiographs and this agree with the results of Chen et al., 2005; Yasar and Akgunlu, 2005. Our study explained that fractal dimensions increase in chronic periapical abscess and cyst as the bone density have been decreased and demineralization increase, this result is in harmonies with the result of Ruttimann et al., 1992, who investigated the structural changes on ten dry mandible fragments before and after decalcification with acid and found that fractal dimension increased as demineralization increase.

The explanation of this result in that the loss of fine trabecular structure as a result of demineralization may produced abrupt density changes in radiographic images and thus cause changes in the fractal dimension. In other words elevation in fractal dimension may occur as a reflection of increase in the roughness of the image corresponding to the architectural disorganization of trabecular network via demineralization and this agree with the result with Yasar and Akgunlu, 2005; Sogur et al., 2013; Chen and Chen, 1998. But this result is disagree with the results of Southard et al., 1996, whom established that decreasing value of fractal dimension occur with increased decalcifications. The
diversity of the results has been explained by anatomical variations, discrepancies in the techniques employed to acquired two-dimensional bone images, procedures for measuring fractal dimension and/or differences in region of interested to be measured and this agree with Pornprasertskul et al., 2001. Our result established that fractal dimension reduced in granuloma and phoenix abscess as the demineralization of bony trabecule is less than that in cyst or abscess and may due to granulation tissue formation this result is in harmonies of the result of Sogur et al., 2013. Our study demonstrated significant correlation between pixel intensity and histopathological result and this results agree with result of Raghav et al. 2010 also our result shows significant correlation between fractal dimension and the result of histopathological examination and this result again is similar to the results of Raghav et al., 2010.

CONCLUSIONS

- Pixel intensity and histogram can be used for differential diagnosis of periapical lesion
- Fractal dimension calculation could be recommended as a quantitative and objective method for the detection of clinically suspicious periapical lesions

REFERENCES

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