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Original Research Article

Apparent Diagnosis of Periapical Lesions by Particle Swarm Optimization Algorithm

Sirous Risbaf Fakour[1], Mohammad Naebi[2], Eshaghali Saberi[3], Ahmad Naebi[4], Somayeh Hosseini Tabatabaei[5], Nasim Davtalab Behnam[6], Hamideh Kadeh[7], Vida Maserat[8], Ali Mohsenpour[9], Nazanin Kamyab[10], Sara Pourabbas Kheiralddin[6]

[1]Oral & Dental Disease Research Center, Department of Oral and Maxilofacial surgry, Zahedan University of Medical Science, Zahedan, Iran
[2]Oral & Dental Disease Research Center, School of Dentistry, Zahedan University of Medical Science, Zahedan, Iran
[3]Department of Endodontics, Oral & Dental Disease Research Center, Zahedan University of Medical Science, Zahedan, Iran
[4]State Key Laboratory for Manufacturing Systems Engineering, Systems Institute, Xi’an Jiaotong University, Xi’an, China
[5]Assistant professor of operative dentistry, oral and dental disease research center, Zahedan university of medical science, Zahedan, Iran
[6]School of Dentistry, Tabriz University of Medical Science, Tabriz, Iran
[7]Oral & Dental Disease Research Center, Department of Oral & Maxillofacial Pathology, School of Dentistry, Zahedan University of Medical Science, Zahedan, Iran
[8]Oral & Dental Disease Research Center, Department of Oral & Maxillofacial Radiology, School of Dentistry, Zahedan University of Medical Science, Zahedan, Iran
[9]Physics Department, Faculty of Sciences, Urmia University,p.o.box165,Urmia,Iran
[10]Department of Oral and Maxilofacial Medicine, School of Dentistry, Rafsanjan University of Medical Science, Rafsanjan, Iran

***Corresponding author**
Eshaghali Saberi
Email: saberiendo@yahoo.com

Abstract: Diagnosis of periapical lesions with no human intervention is discussed in this study. Particle swarm optimization, in principle, is a computing volutionary technique and an optimization population-based method. The purpose of this paper is to diagnose periapical lesions with processing image using particle swarm optimization(PSO)algorithm in the X-Ray Digital (XRD) images that facilitate conducting a more accurate diagnosis. This algorithm is based on examination of the color changes around the tooth roots in the XRD images. The color of the periapical lesions around unhealthy tooth root is darker(Lucent)compared with that of the healthy tooth root (Lucent).The difference between this study and previous ones is computation of the color changes by image processing algorithm for diagnosis of the periapical lesions. Methodology of this algorithm on XRD image is to investigate the color changes around tooth root and to show the lesion existence. After running the algorithm, if the lesion is apical root around, PSO algorithm can recognize periapical lesios and identify its location. This algorithm provides useful and successful results for the presented tests and experiments. Using this algorithm, it is possible to save time, reduce errors, and have a more accurate diagnosis. Among the potential applications of this algorithm is to intelligently help dentist robots, which will be used in the future.
Keywords: Particle Swarm Optimization Algorithm, Periapical Lesions, Image Processing

INTRODUCTION

Apical granulomas and radicular cysts are the most significant chronic periapical lesions, which are not separable radiographically [1]. Periapical lesions triggered by bacterial infection of pulpal and endodontic environment are characterized by the destruction of mineralized tissues surrounding the root apex as a consequence of the local host response[2].In this context, cytokines play a major role in the modulation of inflammatory immune responses within the periapical microenvironment[2&3].Currently, investigation of periapical lesions is carried out by x-ray radiography and analysis of the restoration treatment trend as well [4]. Furthermore, the absolute and final identification of the lesion state is accomplished by biopsy histopathologic investigations [4,5]. Incidentally, the X-ray radiography is unable to identify such a nature [6]. To define the nature of the lesion, doing biopsy is of necessity [4,5], which carries much trauma to the patient and is inapplicable in every disease[6,7].

Nevertheless, X-ray radiography includes its own disadvantages and restrictions, such as two-dimensional constraints, super imposition of the anatomical structures, incorrect identification of the lesion, the incapability of detecting the small changes in bone, etc [8-12].

Image processing has been considerably developed since 1964, and resulted in creating digital ground surface images which are applicable in agriculture and forestry. Developing the Computed Axial. Tomography(CAT)Scanners, revolutionized medical sciences, and it is considered image processing that was entered to the world of entertainment and robots later. By imaging a glass with image processing Optical Character Recognition(OCR) it is possible to control the imaging it in a portion of a second, where the monitoring is transferred from computer to machine, and in case of problems, the system stops and alarms in order to required checkups automatically[13].

First in 2016, image processing coupled with particle swarm optimization(PSO)Algorithm was used for diagnosis and treatment of dental decays and fillings, by which the location of decay and restoration can be detected[14].

To identify dental periapical by XRD images the dentists check around the roots on XRD images. If there is a lucent (darkness) with the relatively small size or a large size it is detected as granuloma and periapical lesion, respectively. However, the definitive diagnosis and the nature of lesion is carried out by biopsy, which is not a smart process.

Image processing and PSO algorithm are used in intelligent identification and treatment of dental problems recently. Thus, the population of PSO algorithm is known as points in XRD image in where particular image color are stored, their locations are altered by PSO algorithm formula, and finally are moved to new points in the image. When a spot in the image is transferred to the fitness function with its own color content, each part of the population is transferred to the fitness function as the area of image, in every phase. Formerly, the fitness function, finds the point having color closer to the desired (decay and tooth restoration), based on specific formulas, and considers it as the most suitable point. The key function returns to the original state again and finds the most proper originating place in previous stage in order to compare. In case the value of this process is less than the most applicable amount, it will be replaced by it; i.e., in this stage the obtained point is more provable than the previous one. The aim of this study is to suggest a method for Diagnosis of periapical lesions using image-processing algorithms coupled with PSO algorithm, with no human intervention.

METHODS AND MATERIALS

In this study, we employed the methods and algorithmic formulas used by Naebiet al [14].

Standard algorithm PSO indicated a population with member. Any member is one potential solution in D-dimensional space of the problem [15] which is displayed as following:

$$\vec{X} = \left(X_{i1}, X_{i2}, ..., X_{iD}\right) \quad (1$$

Any member saves one memory of own previous best situation (pbest):

$$\vec{P} = \left(P_{i1}, P_{i2}, ..., P_{iD}\right) \quad (2)$$

And also one rate along any dimension:

$$\vec{V} = \left(V_{i1}, V_{i2}, ..., V_{iD}\right) \quad (3)$$

The vector $\vec{P}_g \left(g\ best\right)$ also is obtained for best neighborhood fitness. In any iteration, $\vec{P}_g$ and vector of $\vec{P}$ current member integrate together until adapt rate of member along any dimension. Then, given rate is used to calculate new situation of member. That section of rate adaption which is affected by previous best situation is called cognition section and that section affected by best neighborhood is considered as social section. Now, consider minimalization on which, f is fitness function, that should be minimized. The equation (5) showd th dimension change of best situation of member.

$$P_i^d(t+1)=\begin{cases} P_i^d(t) & \text{if } f\left(\vec{X}_i^d(t+1)\right)\geq f\left(\vec{P}_i^d(t)\right) \\ X_i^d(t+1) & \text{if } f\left(\vec{X}_1^d(t+1)\right)< f\left(\vec{P}_i^d(t)\right) \end{cases} \tag{4}$$

In standard algorithm PSO, in iteration t, the D- dimension of rate and situation of ith member change with equations (5) and (6) respectively, w, C1 and C2 are f non-negative real constant parameters. r1, id(t) and r2. id(t) are independent random numbers with uniform distribution in the range of [16,17].

$$V_i^d(t+1)=\omega V_i^d(t)+c_1r_{1i}^d(t)(P_i^d(t)-X_i^d(t))+c_2r_{2i}^d(t)(P_g^d(t)-X_i^d(t)) \tag{5}$$

$$X_i^d(t+1)=X_i^d(t)+V_i^d(t+1) \tag{6}$$

In FITNESS function, we calculate average of 20% of picture points. This value multiple Algha is ThresholdX (7). Also this value multiple Beta is Threshold Around (8). P, row, column, a and count are point of picture, maximum row of picture, maximum column of picture, point of sheep's jaw or human jaw in picture and number of selecting points for calculating. Pij is color value of image(i,j,1) or image(i,j,2) or image(i,j,3). $X_{ij}$is one point in place of image(X_i,X_j ,1…3) and X_i is value of 1…row and $X_j$is value of 1…column.

$$ThresholdX=\alpha\times\frac{20}{100}\times\frac{\sum_{i=row}^{i=1}\sum_{j=column}^{j=1}p_{ij};\ p_{i=1..row,j=1..column}\geq a}{\sum_{i=row}^{i=1}\sum_{j=column}^{j=1}count=count+1;\ p_{i=1..row,j=1..column}\geq a} \tag{7}$$

$$ThresholdAround=\beta\times\frac{20}{100}\times\frac{\sum_{i=row}^{i=1}\sum_{j=column}^{j=1}p_{ij};\ p_{i=1..row,j=1..column}\geq a}{\sum_{i=row}^{i=1}\sum_{j=column}^{j=1}count=count+1;\ p_{i=1..row,j=1..column}\geq a} \tag{8}$$

We can detect edges ofsheep's jaw and human jaw with formula 9.

$$\begin{aligned} point_A &= image(X_i, X_j-const,:);\ point_B = image(X_i, X_j+const,:); \\ point_C &= image(X_i-const, X_j,:);\ point_D = image(X_i+const, X_j,:) \end{aligned} \tag{9}$$

We use formula 10 for calculating of average points in around ofX.

$$Avgpoint=\frac{\sum_{i=X_i+d}^{i=X_i-d}\sum_{j=X_j+d}^{j=X_j-d}p_{ij}}{\sum_{i=X_i+d}^{i=X_i-d}\sum_{j=X_j+d}^{j=X_j-d}countavgpoint=countavgpoint+1} \tag{10}$$

In the last part of FITNESS function is related to existence or nonexistence of preapical lesion in X point and around of X point (11).

$$Exist\_preapical\_lesion = \begin{cases} 1 \;\; ; & x_{ij} \leq ThresholdX \;\; and \\ & Avgpoint \leq ThresholdAround \;\; and \\ & (|A-B| \;||\; |C-D| \leq ThresholdAround) \\ 0 \;\; ; & Other \end{cases} \qquad (11)$$

RESULTS

First, four photos from a sheep's jaw (sheep's jaw is belong to died sheep) are presented.Figure1 shows the state of pre-lesions (normal bone). In Figure 2,3 and 4, lesions can be observed in sheep's jaw. So, the difference between Figure2, 3 and 4 is related to lesion size (large and small lesion).Next, another four photos are shown from human jaw, where periapical lesion has been detected in Figure5, while figure 6, 7, and 8were taken one, three, and eight months after treatment, respectively. Photos from sheep jaw (Figures 1 to 4) were taken with a digital X-ray radiography machine; whereas the photos of human jaw (Figure5 to 8) were taken with another digital radiography machine. The difference between the digital X-ray radiography machines is the quality of their photos. The qualities of pictures are important for diagnosis in field of image processing.

First, the particles are distributed throughout the images for diagnosis. Distribution of particles can be observed in the left side of the images. Then, the particles start to move upward side of the image. During the process, PSO algorithm calculates the amount of transition for each particle. After running the algorithm, if the lesion is apical root around, PSO algorithm can recognize it and identify its location. In Figure 1, there is no lesion, while Figure8 (nine months after treatment) shows that the lesion is improving. Therefore, periapical lesion is fading and algorithm can't diagnose periapical lesion. In comparison, in Figures 2, 3, 4, 5, 6 and 7, which show lesion, the algorithm detects and shows their location by cross of green and red lines (right pictures) after particle distribution (picture in the left) and particle motion and transfer on the images.

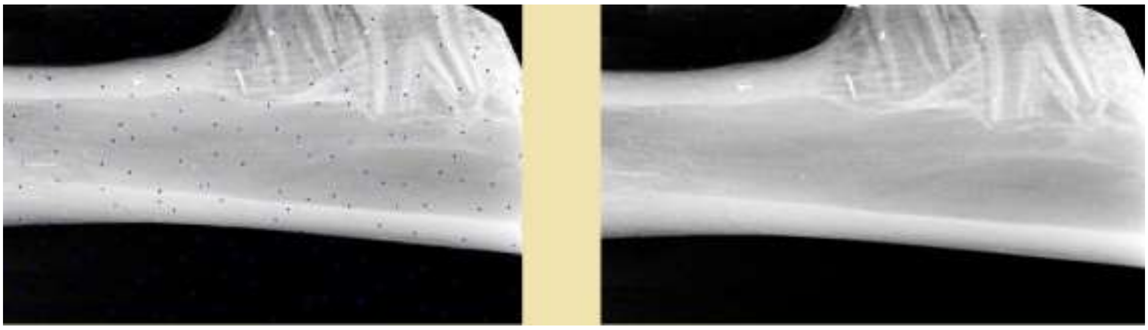

Figure 1: In the left picture, the particles are distributed throughout the images for diagnosis of periapical lesion and in the right picture, our method can diagnosis that in the picture doesn't have periapical lesion.

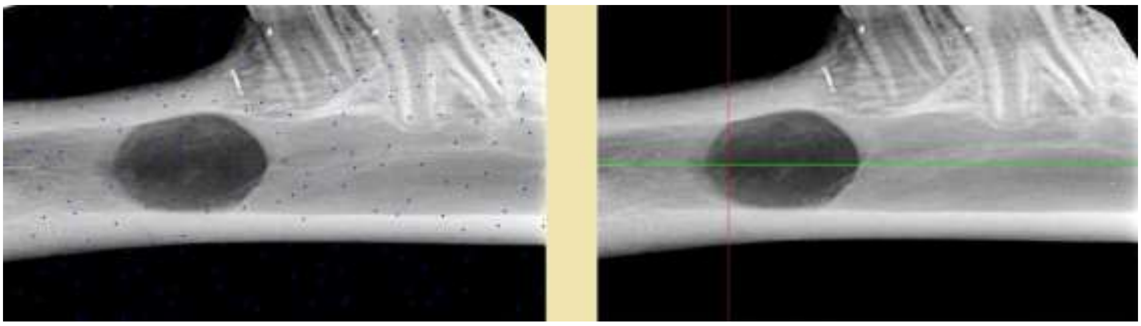

Figure 2:In the left picture, the particles are distributed throughout the images for diagnosis of periapical lesion and in the right picture, our method can diagnosis periapical lesion(crossing the green line with the red line)

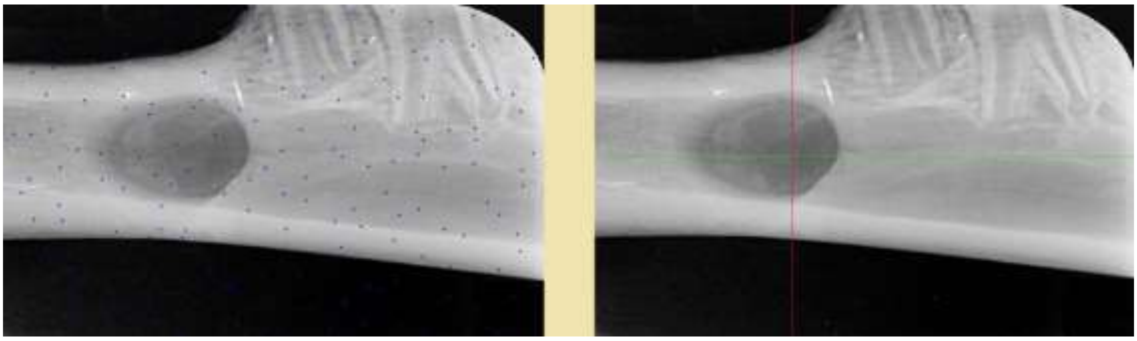

Figure 3: In the left picture, the particles are distributed throughout the images for diagnosis of periapical lesion and in the right picture, our method can diagnosis periapical lesion(crossing the green line with the red line)

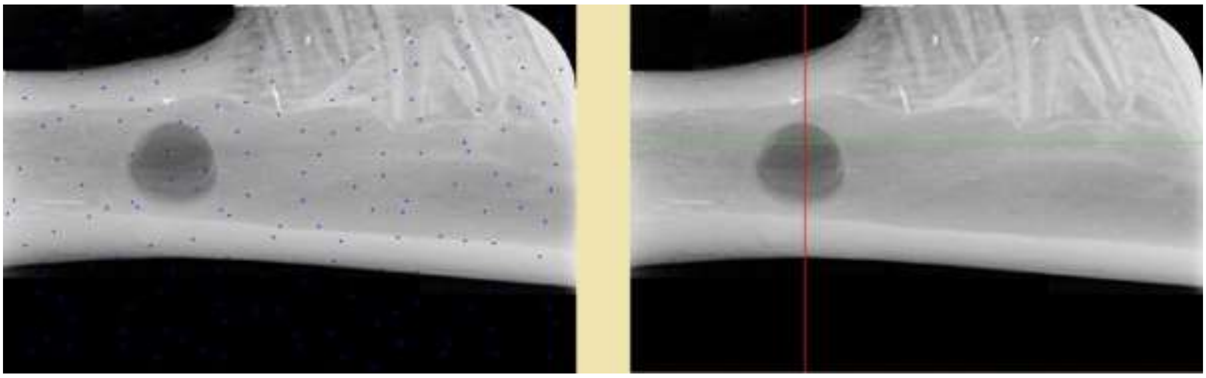

Figure 4:In the left picture, the particles are distributed throughout the images for diagnosis of periapical lesion and in the right picture, our method can diagnosis periapical lesion(crossing the green line with the red line)

Figure 5:In the left picture, the particles are distributed throughout the images for diagnosis of periapical lesion and in the right picture, our method can diagnosis periapical lesion(crossing the green line with the red line)

Figure 6:In the left picture, the particles are distributed throughout the images for diagnosis of periapical lesion and in the right picture, our method can diagnosis periapical lesion(crossing the green line with the red line)

Figure 7:In the left picture, the particles are distributed throughout the images for diagnosis of periapical lesion and in the right picture, our method can diagnosis periapical lesion(crossing the green line with the red line)

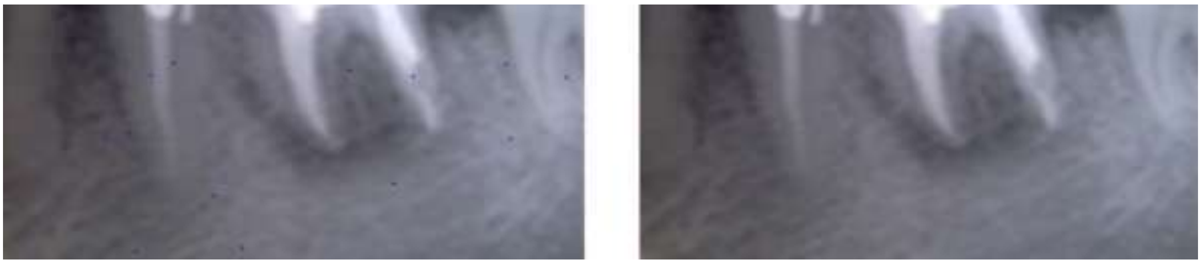

Figure 8: In the left picture, the particles are distributed throughout the images for diagnosis of periapical lesion and in the right picture, our method can diagnosis that in the picture doesn't have periapical lesion.

As seen in figures for one models (human jaw and sheep jaw), we have considered a few members for one of them and a lot of members for another. In table(1)we have tried to consider a few members that study different parameters including the coefficients, values of threshold for excitation and the convergences for three pictures that the periapical lesion exist for human respectively. For large and average lesions 25 particles and for small ones 16 particles is considered. The less members of population, the faster convergence happens and this shows power of our method. In table 1, alpha indicates the diagnosis coefficient for a point like X that if not chosen properly, we can't diagnose desired point. In this case, other points may be diagnosed as periapical lesion. Beta indicates amount of diagnosis around the point. If the average of points around X becomes less or equal to the average of diagnosis, there is a lesion around that point. If amount of beta is not chosen precisely, we can't diagnose any lesion around the point. For diagnosing the lesion point we need to diagnose Surrounding points. To diagnose properly, point X must be smaller than Threshold X and the average of points around X must be smaller than Threshold Around. Purpose of convergence is this meaning that our method can find best answer in less steps running. In table 1,two columns is related to convergence. In the one of columns is showed step of diagnose periapical Lesion by first member. Next column shows that 70% of population could converge the place of first member.

Table 1: Effect parameters for diagnose periapical Lesion in Human jaw.

Number particles	Avgpoints (color value)	Alpha	Beta	ThresholdX	ThresholdAround	Convergeof First member (1-100 step)	Converge of 70% members (1-100 step)
16	144	40%	60%	58	86	3	10
	138	45%	50%	62	69	4	22
	169	50%	50%	85	85	2	6
	185	55%	60	102	111	3	11
	150	60%	40%	90	60	3	35
25	120	40%	60%	48	72	3	6
	119	45%	50%	54	60	4	10
	110	50%	50%	55	55	3	7
	136	55%	60	75	82	4	10
	134	60%	40%	80	54	2	4
25	104	40%	60%	42	62	3	8
	117	45%	50%	53	59	2	4
	117	50%	50%	59	59	8	15
	175	55%	60	96	105	3	10
	112	60%	40%	67	45	6	7

DISCUSSION

This work was aimed to evaluate the periapical lesions in radiographic images and its difference with the study of Naebi et al. was that in the previous work, this method was used for diagnosis of decay and restorations, while in this work, this technique has been used for detecting the periapical lesions[14].

A clinician will have to take X-rays radiographies and to interpret stereotypes, in order to follow- up his/ her own patients and to assess their healing process of periapical lesions. The follow-up time is a crucial factor in evaluating the apical lesions that influences the progressing of the treatment. Healing apical periodontitis is a certain active process and any changes in bone interpreted as Healing or Disease, require enough time and doing such treatments is impossible within a few months and through the X-ray. Alternatively, the observations in a short period over several months after the treatment may only be capable of showing signs of Healing and, they cannot be considered as accurate and precise prognosis of the treatment. Hence, the minimum time required for evaluating the significant changes of this process is within a year, nevertheless, for assessing the confirmation of the treatment outcomes, its continuing up to more than 3 or 4 years may be crucial [18].Since the tooth root is influenced by periodontal and restorative changes over the time, the longer perpetuation follow-up time will cause these factors effects on treatment outcomes, and it can be recognized in a better way. However, the radiographic observation is the most important factor and the basis and foundation of the assessment of endodontic treatment. It should be emphasized that, wrong interpretation of x-ray stereotypes is one of the risks in assessment of treatment outcome. Since, in order to interpret these points lots of matters should be considered, (the surrounding tissue of the root, especially in posterior teeth and etc.), furthermore by changing the angle of incidence and changes in film placement and overlying the adjacent anatomical structures (maxillary sinus and mental foramen), the radiographic images of periapical region can be changed, hence, they can be considered as other reasons for wrong interpretation of these stereo types [19]. It has been revealed that when six people without any consultation with each other observe and interpret an x-ray radiographic stereotype, only 50% of them will get the same estimations, furthermore, different interpretations are presented when radiographs are shown to a person at two different times. Therefore, it is suggested that, two independent people be used for interpreting the radiographs, and if the disagreement happens between them, consultation with each other is necessary to get an agreement, and if not so, a third person can be asked for offering his/ her opinion, differences will be reduced from 50 % to 25% in this case [20]. According to the pre-mentioned facts, if the storage of data is possible by memories in the system, data of patients will be stored, and one can compare follow up radiographs with stereotypes before and after treatment changes in terms of apical lesion size changing of patients simultaneously, and the errors and differences of clinicians in the interpretation of X-ray radiographic image scan can be largely reduced. In this paper, two systems were used, the first one was PSO algorithm, which comes with image processing, and it is used for detecting the size of the changes intelligently, and the second one was radiographic patient information storage system that provides PSO algorithms when required. One can refer to the mass Particle Swarm Optimization (PSO) features as the memory in this system, in which the information of proper solutions can be preserved by all the particles, in other words, in the algorithm of mass particle, every particle can benefit by their previous information. However, no such behaviors and features exist in other evolutionary algorithms. For example, there is no such a memory system in the genetic algorithms, and by population growth previous information of the system disappears suddenly.

As well as, in this algorithm, the populations are connected to each other and their problem are solved through the exchange of the information in a high speed convergence way. According to the author of this article, by recording the density changes of the pre apex bone and processing images, this algorithm probably will be capable of processing and evaluating the trend of healing the lesions.

CONCLUSIONS

So far, the identification of the pre-apical lesions on radiographic images has been fulfilled by the dentists. In order to gradually reduce the human intervention in diagnosis and tore place intelligent systems with humans, the systems need to be smart. In this study, we implement and introduce the PSO algorithm with the help of image processing for detecting periapical lesions. Through this method, particles with PSO algorithm formula changes their location and move to new areas of the image, during the same stages. Simultaneously, the fitness function finds the location of point with color closer to that of periapical lesion using a specific formula. In this way, it can be stated that the algorithm has correctly diagnosed the lesion though action steps. Our results show that this method can be used for diagnosis of periapical lesion in radiographic images with a 97% detection rate.

In future work, optimized image processing with other algorithms can be used for the development of research on apical dental lesions. New system applicable for the treatment of periapical lesions can be used, as well. Also we will study on CBCT image using this method

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