Periodontitis Risk Assessment using two artificial Neural Networks-A Pilot Study
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Abstract
Artificial neural networks are currently used for a variety of complex problem solving approaches where a conventional method may not be feasible. Aims & objectives: Levenberg Marquardt and Scaled Conjugate Gradient feed forward back propagation neural network algorithms were compared to assess accuracy for periodontitis risk prediction. Materials and Method: In the present study 230 subjects were assessed for major and minor periodontitis risk factors such as; age, gender, family history of periodontitis, history of periodontal surgery, diet, smoking history, pan chewing habit, history of diabetes, history of hypertension, presence of sub gingival restorations, bleeding on probing, debris index (OHI-S), average pocket probing depth, presence of root calculus, presence of furcation involvement and vertical bone loss. Periodontitis risk assessment was done on a grade of 1 to 5. Results: The Levenberg Marquardt algorithm performed considerably better than Scaled Conjugate Gradient algorithm by converging faster with lesser iterations and produced minimum mean square error in both training and simulation phases. Conclusion: A properly trained neural network with Levenberg Marquardt back propagation algorithm can effectively be used for periodontitis risk prediction.

Key words: Artificial Neural Networks, Periodontitis Risk Assessment, Neural Network Algorithms, Levenberg Marquardt Algorithm

Introduction
It is a known fact that there are many different clinical problems for which it is difficult to find formal algorithms to solve them. Neural networks may be the solution to those problems which cannot be easily solved with traditional methods. The history of neural networks started in mid twentieth century when simple neural network with limited capabilities were conceived. They never got into the main stream applications at that time due to poor generalization capabilities and lack of specificity with high memory loads. After two decades, the whole concept of neural networks changed when the multi-layer neural networks with back propagation learning algorithm was presented. From that time, many different researchers studied the area of artificial neural networks, which led to a vast range of different neural architectures applied to a plethora of different problems.

At present; neural networks are used as principal solutions for various problems like grouping and classification, pattern recognition, approximation, prediction, clusterization and memory simulation. Neural networks may initially seem complex and computer intensive, but actually may integrate well with a clinical environment. Neural network expert systems may be trained with only clinical data and as such can be used where 'rule based' decision making may not always be possible; as is the case in many clinical situations. Neural networks may therefore become important decision making tools within dentistry and have applications both in improving clinical strategies and in maximizing the cost benefit of health care systems (1). The usability, credibility and predictability of automated systems have steadily grown over the past decade and we would like to present the logic for such a system with Artificial Intelligence.

Although it is accepted that the primary cause of periodontitis is bacterial infection of long duration, there are a number of risk factors which may increase the probability of recurrence of periodontal disease during supportive periodontal care (2). The risk may in such cases be caused by other factors than poor oral hygiene measures per se. Cross-sectional and longitudinal studies show conflicting results concerning age as a risk factor for periodontal disease. The effect of smoking on the periodontal tissues has been discussed for decades and only lately has it been possible to demonstrate that smokers definitely have more periodontal problems than non-smokers.

Another important risk factor for periodontitis relates to the insulin dependent and non-insulin dependent forms of diabetes mellitus. Poorly-controlled long-duration diabetics have more periodontitis and tooth loss than well-controlled or non-diabetics and also
the issue of compliance deserves attention. According to Page et al (3); research on the pathobiology of periodontal diseases has increased our knowledge of these diseases and proposes a transition from the repair model to the wellness model of periodontal care. Successful application of the wellness model depends on an accurate and valid assessment of disease risk, as well as institution of risk reduction as an integral part of prevention and treatment. A computer-based risk assessment tool which is now popularly known as Periodontal Risk Calculator (PRC) has been thus developed by them to counter these deficiencies in integration of “Wellness Model” into practical clinical practice. Page et al concluded that the use of the risk assessment tool over time may result in more uniform and accurate periodontal clinical decision-making, improved oral health, reduction in the need for complex therapy, reduction in health care costs and a hastening of the transition from a repair model to a wellness model of care.

Properly trained backpropagation networks tend to give reasonable answers when presented with inputs that they have never seen. Typically, a new input leads to an output similar to the correct output for input vectors used in training that are similar to the new input being presented(4). This generalization property makes it possible to train a network on a representative set of input/target pairs and get good results without training the network on all possible input/output pairs. Feedforward networks often have one or more hidden layers of sigmoid neurons followed by an output layer of linear neurons. Multiple layers of neurons with nonlinear transfer functions allow the network to learn nonlinear and linear relationships between input and output vectors. The linear output layer lets the network produce values outside the range -1 to +1.

The basic backpropagation algorithm adjusts the weights in the steepest descent direction (negative of the gradient), the direction in which the performance function is decreasing most rapidly. Although the function decreases most rapidly along the negative of the gradient, this does not necessarily produce the fastest convergence. The Levenberg-Marquardt algorithm was designed to approach second-order training speed without having to compute the Hessian matrix; while in the conjugate gradient algorithms, a search is performed along conjugate directions, which produces generally faster convergence than steepest descent directions. The scaled conjugate gradient algorithm developed by Moller (5) combines the model-trust region approach used in the Levenberg-Marquardt algorithm with the conjugate gradient approach and is demonstrated to be faster and better converging with reduced memory load. Two popular artificial neural network feed forward back propagation error algorithms namely; Levenberg Marquardt and Scaled Conjugate Gradient algorithms are compared in the present study to assess accuracy for periodontitis risk prediction.

**Materials and Methods**

The study was based on collected sample data of 230 patients from the Post Graduate Dental Wing of PAHER University, Udaipur, India. The variable array sets from 200 of the total subjects was used for training, validating and testing the neural networks during the design phase. The remaining 30 data sets were used in the constructed Simulink network models for each of the employed algorithms; to simulate and assess error difference between observed risk assessment values and calculated output.

The parameters for periodontitis risk assessment consisted of the parameters of age, gender, family history of periodontitis, history of periodontal surgery, diet, smoking history, pan chewing habit, history of diabetes, history of hypertension, presence of sub gingival restorations, bleeding on probing assessed by gingival index described by Loe and Silness(6), debris index (OHI-S)(7), average pocket probing depth, presence of root calculus, presence of furcation involvement and the highest value for vertical bone loss confirmed by radiographs and pocket probing methods for all the four quadrants examined. The Yes/No questions and Vegetarian/Non Vegetarian answer results were considered as character arrays to be converted into 0 or 1 binary values and the digital parameters were converted into double numerical arrays. The arrays were exported into MATLAB and transposed to be plotted as input network parameters. The periodontitis risk assessment for each clinical case was done by two independent specialist examiners on a grade of 1 to 5 and the average value was taken to be final target parameter in the designed neural network.

The Feed Forward Back propagation Artificial Neural Networks (ANN) were designed with two layers having 20 neurons in the hidden layer. Mean Square Error and Regression parameters at convergence were used for comparison, with a maximum of 1000
epochs. A Gradient Descent with Momentum weight and bias learning function with a Mean Square Error performance function (MSE) was used for both Levenberg Marquardt (LM) and Scaled Conjugate Gradient (SCG) algorithms and a hyperbolic tangent sigmoid transfer function was selected for both layers. LM neural network back propagation algorithm was trained for 1000 epochs for a minimum gradient 1e-010 and infinite time.

The neural network designed for Scaled Conjugate Gradient Algorithm was trained for 1000 epochs with minimum gradient of 1e-006, sigma values of 5e-005 and a lambda value of 5e-007. The 230 samples were first trained with LM algorithm to design LM neural network and then the SCG back propagation algorithm was used to train the SCG network with the same set of samples. The output from both the trained networks was saved and the results compared to assess efficiency of these two back propagation algorithms for the specific task of periodontitis risk assessment.

Results

The training phase for Levenberg Marquardt algorithm ran for 24 seconds with six validation checks in 11 iterations. The Best validation performance Mean Square Error of 0.13281 was reached at Epoch 5. The regression R values for the Training Validation and test phases were computed as 0.9997, 0.94344 and 0.96746 respectively. The combined regression for training, validation and test values was R = 0.97809 as shown in.

The input arrays trained with scaled conjugate gradient algorithm was executed for 43 seconds till 20 iterations with 6 validation checks. The best validation performance of 0.33443 was reached at epoch 14 and the gradient recorded a value of 0.23714 at the end of training and the R value for training, validation and test phases were respectively 0.97543, 0.83761 and 0.91896. The combined Regression plot showed an R value of 0.9444 at the end of scaled conjugate algorithm test phase.

The Levenberg Marquardt algorithm training ended with a gradient value of 0.063334 with an optimum adaptive µ value of 1.00e-06 which it acquired at epoch 11; while the scaled conjugate algorithm training session closed with a gradient value 0.23714 and a mean square error value of 0.124 at the end of 20 iterations. The constructed Simulink model for LM algorithm showed an output error ranging from -0.801 to 0.497 and the Simulink SCG model displayed prediction error ranging from -0.603 to 0.993 (Figure 1).

Discussion

Artificial Neural Networks are nonlinear regression computational devices that have been used for over 45 years in classification and survival prediction in several biomedical systems, including colon cancer (8). The feed forward artificial neural networks with backpropagation error are now widely used in medical field. Computational accuracy is one important factor which should not be compromised when designing, using and implementing artificial intelligent systems employing machine-learning devices such as ANNs in order to enhance confidence in the quality and reliability of end results (8).

Best validation performance comparison of LM and SCG algorithms for periodontal risk assessment in the present study showed that the LM algorithm network training converged with an optimal mean square error of 0.13281 at epoch 5; while the SCG algorithm training phase took 14 iterations to reach a much higher best mean square error of 0.33443 leaving LM algorithm better in terms of error management. LM algorithm could perform at least twice better than the scaled conjugate algorithm in terms of target approximation with minimal error which may be due to the fact that the Levenberg marquardt algorithm mostly performs better with moderate amounts of samples with higher accuracy and when the network contains no more than a few hundred weights(9). The LM Algorithm ran total of 11 iterations, for the duration of 24 seconds; while the SCG algorithm was executed for 43 seconds running a total of 20 epochs showing that the SCG algorithm was costly both in terms of time and iterations needed for fitting and validation in
this specific study. This is in contrast with the studies by Møller(5) who was of the opinion that scaled conjugate gradient algorithm was faster and required lesser number of iterations for convergence. The inferior performance of SCG network algorithm in this specific study may be due to the fact that memory constraints were not a major factor in the training of networks and the training time constraints were not imposed (4).

The simulation errors for both the algorithms showed similar trend (Figure 1); with the LM Simulink model displaying much less range of output error with lower and higher error output values being within the range of 0.496 to 0.496 with only 6 data sets outside the minimum limits of -0.2 to +0.2. The SCG Simulink model showed a runtime output error deviation from the target simulation output parameters ranging from -0.603 to +0.993 with 16 out of 30 simulation datasets clearly out of range of a minimum -0.2 to +0.2 error interval; confirming a prediction accuracy of less than 50% compared with LM algorithm.

Neural network algorithms in periodontitis risk assessment can be considered as an alternative to normal clinical methods used for predicting such complex problems; which lack cross examiner validity and standardization. According to the results of present study; multilayer feed forward back propagation error algorithms like Levenberg Marquardt algorithm can successfully shoulder the burden of predicting periodontal risk from a complex array of multifactorial risk factors. These may include major proven parameters(3) like age, smoking history, diabetes diagnosis, history of periodontal surgery, average probing pocket depth, bleeding on probing, sub gingival restorations, root calculus, furcation involvements and vertical bone loss; but also some minor risk factors like family history of periodontitis & hypertension, diet, gender and present oral hygiene status of the subject. Our neural network based computational model included pan chewing habit(10)(11) as an additional risk factor for periodontal destruction and thus supposedly increased the sensitivity and accuracy of risk prediction for till now unseen values of input parameters from subjects for this specific geographic region. Page and his co-workers (12) have conclusively shown the accuracy, usefulness and validity of these machine coded prediction systems. Periodontal Risk Calculator which is the basis of PreViser Oral Health Information Suite (13) uses mathematical algorithms to assess periodontal risk. The viability and validity of such systems have been proved substantially helpful in moulding a health care strategy where age old ‘repair’ model of periodontal care can be effectively replaced by a preventive much less traumatic ‘wellness model’ emphasizing the preventive aspects of periodontal treatment strategies. It can be concluded that a well-trained feed forward back propagation artificial neural network using Levenberg Marquardt algorithm can be used as a viable alternative to predict risk for future periodontal destruction in routine clinical environments where expert specialist clinical opinion may not be readily available and the proven accuracy, reproducibility and global standardization capabilities of machine learning systems using such adaptive artificial intelligence algorithms would in fact be helpful in revolutionizing periodontal treatment strategies into targeting prevention rather than cure.

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