Pesquisa Brasileira em Odontopediatria e Clinica Integrada 2018, 18(1):e3978
DOI: http://dx.doi.org/10.4034/PBOCI.2018.181.33
ISSN 1519-0501

ORIGINAL ARTICLE

Use of Artificial Neuron Network to Predict Dental Arch Form

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Academic Editors: Alessandro Leite Cavalcanti and Wilton Wilney Nascimento Padilha

Received: 15 January 2018 / Accepted: 16 March 2018 / Published: 20 March 2018

Abstract

Objective: To develop diagnostic reference for arch form using Artificial Neuron Network (ANN) from tooth size and arch dimension variables on scanned-dental cast from patients with class I malocclusion treated orthodontically. **Material and Methods:** One hundred and ninety pairs of dental cast pre-post orthodontic treatment gathered from Orthodontic clinics were scanned and then all dimension variables were measured using Image Tool (gender, tooth size and arch dimension). The multivariate data were analyzed statistically using Stata (Lakeway Drive, College Station, Texas USA). The statistic results were compiled to build the neuron network software for analyzing arch form. **Results:** Gender and all variables from pre-treatment do not influence arch form. Intercanine width, canine depth, intermolar width, and molar depth are variables that influence arch form. The result of the statistical analyses can be used to develop software based on artificial neural network. Output program is the arch form, such as oval, square or tapered. The software can describe arch form with the accuracy of 76.31%. **Conclusion:** A software using Artificial Neuron Network to describe arch form can be used for diagnostic reference to Class I malocclusion.

Keywords: Dental Arch; Tooth; Malocclusion; Neural Networks.

Introduction

Despite wide acceptance of the idea that arch forms vary among individuals, there is a long orthodontic tradition of seeking a single ideal arch form. Dental arches are correlated with the dimensions and the shape of the face. This variation was caused by variation in tooth size, so that it is not the goal of orthodontic treatment to produce dental arches of a single ideal size and shape for everyone. Tooth size variations relate to ethnic groups and gender [1-6].

The basic principle of arch form in orthodontic treatment is that within reason, the patient's original arch form should be preserved [7]. Most thoughtful orthodontists have assumed that this would place the teeth in a position of maximum stability. During orthodontic treatment, a lot of changes occurred within dental arches. Crowding and deformed arch form in malocclusion do not show the actual original arch forms and size, so that this condition can be changed during orthodontic treatment. At the end of the treatment, a good stability and normal function is expected [8].

A longitudinal study concerning stability of arch form was reported that when intercanine and intermolar width had been changed during orthodontic treatment, there was a strong tendency for these teeth to return to their pre-treatment position [9]. From the literature, three basic qualitative arch forms have been repeatedly described as tapered, oval, and square.

Successful orthodontic treatment is based on comprehensive diagnosis and treatment plan. Diagnosis and treatment plan are based on clinical examination, cast analysis, radiograph analyzes, face and profile. The cast analyzing is a time consuming procedures. Nevertheless, it is a vital part of diagnosis and subsequent treatment planning process [10].

Software to replace dental cast analysis has not been used widely. OrthoCAD iCast™ [11,12] and three-dimensional cast analysis are difficult to apply and expensive [12]. UTHSCSA Image Tool (The University of Texas Health Science Center, San Antonio, TX, USA) is a free image processing and analysis program for Microsoft Windows 95™ or Windows NT™. Image Tool can acquire, display, edit, analyze, process, compress, save and print 8 and 16 gray scale and up to 24bit color images [13]. This software can be applied to measure scanned-dental cast. Dental cast can be transformed with scanner [14] or digital camera [15]. Transformed data is analyzed applying artificial neuron network. Traditionally, artificial neuron network refers to a network of biological neurons. Now, it refers to a computer model of an interconnected group of artificial neurons that uses a mathematical or computational model for information processing based on a connection approach to computation.

The objective of this research is to develop diagnostic reference for arch form qualitatively using artificial neuron network from tooth size and arch dimension variables on scanned-dental cast from patients with class I malocclusion treated orthodontically.

Material and Methods

This is a diagnostic research using scanned-dental cast, upper and lower, pre-post orthodontic treatment of Class I malocclusion. One hundred and ninety pairs of dental cast were gathered from Orthodontic clinics in Jakarta and scanned, as seen in Figure 1, using 2D ScanMaker 5800 (Microtek International Inc., Hsinchu, Taiwan).

The independent variables were gender, tooth size and arch dimension before and after orthodontic treatment. The depending variables were arch form. Tooth size and arch dimension variables were obtained by measuring on scanned-dental cast using Image Tool.

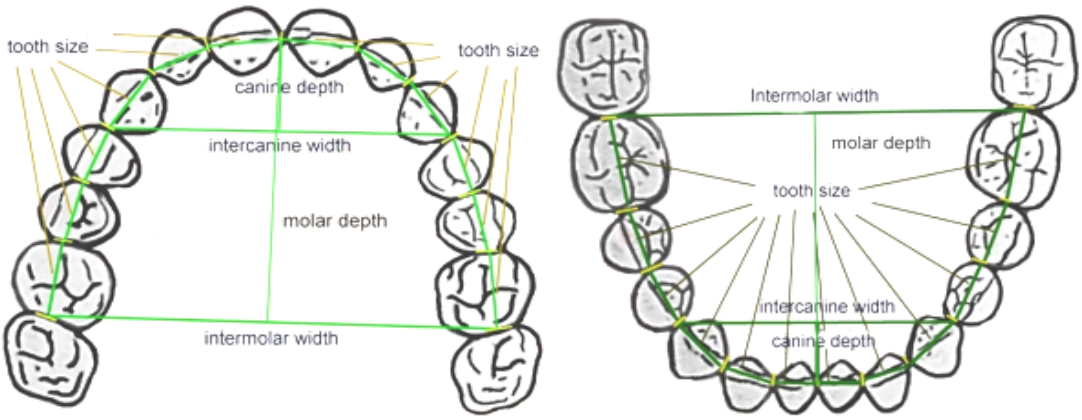

Figure 1. Measurement variables on scanned-dental cast.

The result of the ordered logistic can be used to develop software based on artificial neural network. This program uses Matlab (Matrix Laboratory) a multi-paradigm numerical computing environment (MathWorks Inc., Natick, MA, USA) and has backpropagation learning algorithms framework. Several functions in toolbox neural Matlab were used to build this algorithm framework. This framework can be implemented to recognize arch form after doing orthodontic treatment. The artificial neural network consists of three layers such as input layer, hidden layer and output layer. Each layer has its own activate function.

Statistical Analysis

The multivariate data were analyzed statistically using Stata (Lakeway Drive, College Station, Texas, USA). The statistic results were compiled to build the neuron network software for analyzing arch form.

Ethical Aspects

This project was approved by Faculty of Dentistry University of Indonesia Ethic Committee.

Results

One hundred and ninety pairs of dental cast pre-post orthodontic treatment (22.1% were male and 77.9% were female) gathered from Orthodontic clinics were scanned using. The characteristic of the samples can be seen in Figure 2.

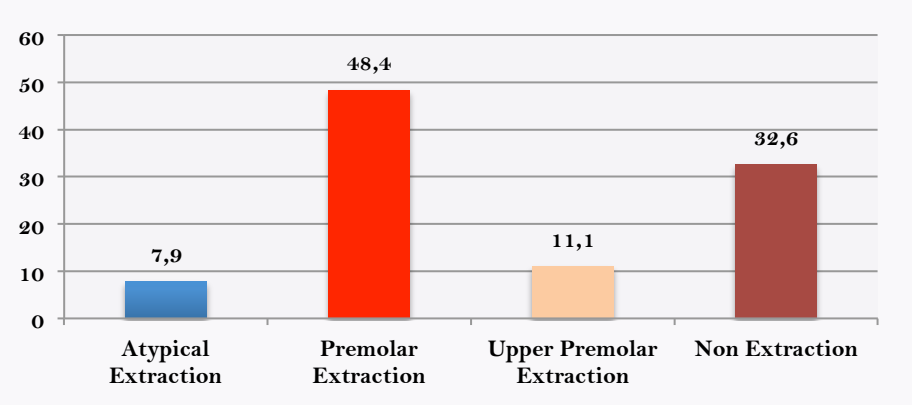

Figure 2. Distribution of dental cast according to Orthodontic Treatment.

Gender and all variables from pre-treatment do not influence arch form (Tables 1 and 2). Therefore, only post treatment data are included for arch form analysis (Table 3).

Table 1. Significances of ANOVA among arch form, arch dimensions and gender upper jaw (Uj) and lower jaw (Lj) before and after orthodontic treatment.

Variables	Before Treatment (n=190)		After Treatment (n=190)	
	p UJ	p LJ	p UJ	p LJ
Gender	0.9304	0.3453	0.5547	0.6993
Intercanine Width	0.8297	0.8219	0.4927	0.5062
Gender	0.0081	0.6081	0.0216	0.6476
Canine Depth	0.1765	0.9863	0.1399	0.9778
Gender	0.7794	0.7353	0.3602	0.7261
Intermolar Width	0.2633	0.8167	0.4871	0.6653
Gender	0.3451	0.7716	1.0000	0.7891
Molar Depth	0.5664	0.9650	0.9340	0.1126
Gender	0.4777	0.6556	0.2001	0.3880
Anterior Perimeter	0.2753	0.3239	0.3179	0.8951
Gender	1.0000	0.4602	0.5471	0.2695
Posterior Perimeter	0.9888	0.9385	0.7471	0.5200

Table 2. Ordered logistic result on arch form with arch dimensions variable.

Variables	Coef.	S.E.	z	p	95% Conf. Interval	
CW Before	0.2192721	0.0603452	3.63	0.000*	0.1009977	0.3375466
CW After	-0.7006912	0.0877038	-7.99	0.000*	-0.8725876	-0.5287949
CD After	0.9195279	0.114068	8.06	0.000*	0.6959588	1.143097
MW After	0.1476045	0.0517452	2.85	0.004*	0.0461857	0.2490232
MD After	-0.1517233	0.0377958	-4.01	0.000*	-0.2258017	-0.0776449

*=p<0.05; LR chi2(5) = 106.25; Prob > chi2 = 0.0000; Log likelihood = -275.83445 ; Pseudo R2 = 0.1615; n = 380.

Table 3. Ordered logistic analyses result.

Variables	Coef.	S.E.	z	p	95% Conf. Interval	
CW After	-0.5825585	0.0788515	-7.39	0.000*	-0.7371047	-0.4280123
CD After	0.9671332	0.112066	8.63	0.000*	0.7474879	1.186779
MW After	0.1938738	0.0496407	3.91	0.000*	0.0965798	0.2911678
MD After	-0.1421536	0.0369641	-3.85	0.000*	-0.2146018	-0.0697053

* =p<0.05 ; LR chi2(4) = 92.46; Prob > chi2 = 0.0000; Log likelihood = -282.72851; Pseudo R2 = 0.1405; n = 380.

From 190 upper jaw data, 60% was used for training, and 40% for testing. Testing was carried out 20 times. Input parameters are intercanine width, canine depth, intermolar width and molar depth. Output program is the arch form, such as oval, square or tapered. Using artificial neural networks to describe arch form, the software program could rightly determine 76.3158% of arch form correctly.

Discussion

Aside from this research, nowadays, the new concept of digital models is as reliable as traditional plaster dental casts, with high accuracy, reliability, and reproducibility. With their advantages in terms of cost, time, and space required, digital models could be considered the new gold standard in current orthodontic practice [12].

The beta function is considered an accurate mathematical model of the dental arch, but using the tip of the canine as a reference point was found difficult to digitised using a software compared to proximal contact point used by the parabolic shape equation, especially for the abrasive canine [14]. The reference parameter used for parabolic equation are the same with the reference point in this research.

Measurements were performed using image tool [13]. This program can be used for measuring using computer. For the calibration system, the dental casts are digitized while sitting on a sheet of millimetre graph paper in transforming by scanner [16,17].

Ologit estimates ordered logistic models of ordinal variable of dependent variable on the independent variables. This is a statistical technique that can sometimes be used with an ordered (from low to high) dependent variables. Ordered logistic analysis provides only one set of coefficients for each independent variable. Therefore, there is an assumption of parallel regression. That is, the coefficients for the variables in the equations would vary significantly if they were estimated separately. The intercepts would be different, but the slopes would be essentially the same. When the data of this study tested by this analysis, the result showed no significant difference on gender and several variables on before and after treatment measurement. This concludes that the parameters influencing arch form are as follows intercanine width, canine depth, intermolar width and molar depth. That is why these 4 parameters used for constitute the ratio (Table 3).

Optimal likelihood is 92.46 with intercanine width, canine depth, intermolar width and molar depth variables giving significant difference from ordered logistic analysis with negative cut offs (-5.2582 and -1.3239). This concludes intercanine width, canine depth, intermolar width and molar depth give influence for judging arch forms.

Traditionally, software programming was based on digital logic and could solve logical problems. The similarity between artificial neuron networks and biologic neuron networks can solve the problem in the same way. Artificial neuron networks work in the same manner as biologic neuron networks do. Artificial neuron networks can describe arch form, the software developed could identify 76.3158% of arch form correctly. This number is optimum after several experiments of

combining learning rate, epoch and maximum error. The rest (23.6842%) of the data can not be recognized by the program due to overlapped distribution of the arch form data. These findings can also occur in humans. The additional dimension is needed to enhance the performance of this software program.

Conclusion

Variables in diagnostic reference influencing arch form for class I malocclusion are as follows intercanine width, intermolar width, canine depth, and molar depth after orthodontic treatment. Using artificial neuron networks to describe arch form, the software could identify arch form correctly.

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