Estimation of chemical resistance of PFM dental ceramics by neural network

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Abstract: artificial neural networks are one of the intelligent systems that apply experimental data in order to obtain the hidden rule among data and model the system. Despite the high ability of neural networks, this method has limited application in biomaterial engineering so that it has not been used for estimating the chemical resistance of dental ceramics. The purpose of this research is to determine the mass concentration of ions eluted from dental ceramics emerged in an acid and draw on the results to develop a feed forward back propagation neural network to simulated the mechanism of elution of this type of ceramics. By designing such an intelligent system, it is possible to investigate and determine the eluted ions from each type of dental porcelains in a long period of time and anytime without the necessity of doing long experiments and high cost. Furthermore, this system is able to change the composition of each porcelain as software in a simulated media and compute the changes of ion's elution and consequently draw on the best possible combination for a particular powder. Because of high correction coefficient and low normalized root mean square error (NRMSE) between the measured data and the estimate data, it is concluded that the artificial neural network has a great potential in investigating the model of the system and it is high ability in modeling the mechanism of the elution in dental ceramics

[Siamak haghipour, Sayana rostami. **Estimation of chemical resistance of PFM dental ceramics by neural network.** *Life Sci J* 2012;9(4):2986-2996]. (ISSN: 1097-8135). http://www.lifesciencesite.com. 439

Keywords: Neural networks, chemical resistance, porcelain, ICP, PFM.

1. Introduction

Dental materials have to satisfy strict criteria because of their long therapeutic durability in the oral cavity. One of the most important properties of all restorative dental materials is their chemical resistance. Chemical resistance or chemical durability depends on the structure and the composition of the powder materials, laboratory conditions and type of restoration [1]. Also non-durability of porcelain can result in more important release of ions from the surface and then it causes porosity. The resulting porosities not only decrease the crack growing resistance, but also allow bacteria and oral liquids penetrate and this can result in plaque. The increase of elution from the surface of porcelain causes undesired consequences in body. ISO and ADA standards are usually used for testing the chemical resistance of restorative materials [2, 3] using acid solutions. The goal of these methods is to find out the amount of eluted ions after an exposure in different periods from several hours to several days. In order to study the chemical durability of dental materials, it is necessary to expose them to an acid solvent for a long period and register the amount of eluted ions in different time intervals.

Any reports have found in the literature about long period-ion release from dental ceramic restorations. But this method requires a lot of time and cost. There has not been any report introducing techniques for determination of chemical release amount during a long period testing. The aim of this study was to design an intelligent system to compute the amount of released ions from feldespathic porcelain materials.

2. Artificial Neural Network

Artificial neural networks (ANN) are inspired by the biological neural system and its ability to learn through example. Instead of following a group of well-defined rules specified by the user, neural networks learn through intrinsic rules obtained from presented samples. The most commonly used ANN architecture is the multilayer back propagation neural network. Back propagation was created by generalizing the Widrow- Hoff learning rule to multiple-layer networks and nonlinear differentiable transfer functions [15]. Input vectors and the corresponding target vectors are used to train the network until it can approximate a function, associate input vectors with specific output vectors. Standard back propagation is a gradient descent algorithm, as is the Widrow-Hoff learning rule, in which the network weights are moved along the negative of the gradient of the performance function. The term back propagation refers to the manner in which the gradient is computed for nonlinear multilayer networks. Back propagation neural 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. There are numerous variations of the basic algorithm that are based on other standard optimization techniques, such as conjugate gradient and Newton methods [15]. The one used in this paper is the feed forward Back propagation training algorithm designed to minimize the Normalized root mean square error (NRMSE) between the actual (estimation) output and the desired (target) output. Fig. 1 shows the principle of the feed forward back propagation training algorithm. The basic learning algorithm can be summarized as follows:

- Step 1: Set the initial values of weights
- Step 2: Compute the outputs of all neurons layer-by-layer
- Step 3: Compute system error
- Step 4: If error is small enough or learning iteration is too big, stop learning

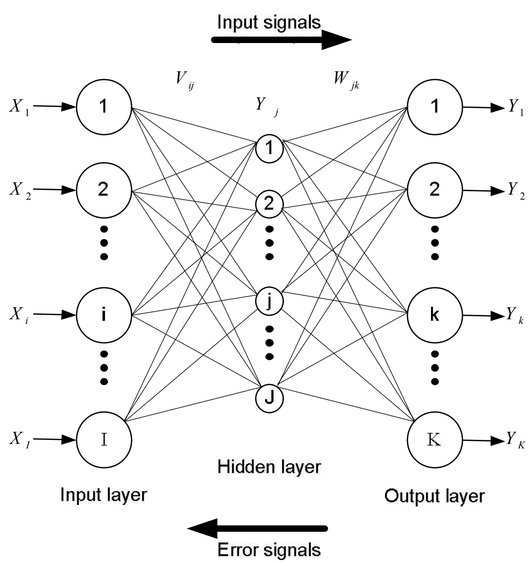

Figure 1 principle of the feed forward backpropagation training algoritm

- Step 5: Compute learning errors for every neuron layer-by-layer
- Step 6: Update weights along negative gradient of error
- Step 7: Repeat from Step 2

3. EXPERIMENTAL PROCEDURES

According to the aforementioned, preparing some experimental samples from PFM prosthesis is needed in which the obtained data for training the network will be used. The obtained data from each sample include two parts. The first part was the weight percentage of porcelain composition used as the network inputs. The second part of data was related to the amount of eluted ions from the surface of porcelain used as outputs of the network. So, experimental procedure in this study was included in three major steps:

- Sample preparation
- Determining the composition of each porcelain
- Determining the percentage of eluted ions in the specific time intervals

a. Sample preparation

Six types of vastly used commercial porcelain powders were employed to make the samples as the following:

Noritake, Alldent, CeramcoIII, Ivoclar, Vita, CeramcoII.

It should be noted that these powders contained different compositions that was needed in this research. The first step in making the samples is preparing the frame work. For making the frame work, referred to ASTM book to find out standards. After investigation, no standards were found. At first, different samples were designed as frame works but finally the Fig. 2 was selected as a suitable design. The reason for this selection was making similar conditions for all samples i.e. the width, dimension of the samples and firing condition in the furnace should be the same. In this method of designing, samples with 1*1 cm dimension were made then a small plate was considered in order to put label over the samples. At the bottom of the metal plate, a metal bar was devised to be placed in the hollow of the crucible and they underwent the same heat in all directions. Besides another characteristic of this scheme is the possibility changing and correcting the width and its dimension in order to optimize the favorite size. After designing the frame work the mold was prepared. For this purpose a mold of plaster of high stone gypsum was prepared from the expected design. A plaster mold is smeared with a microfilm insulator and filled with inlay wax.

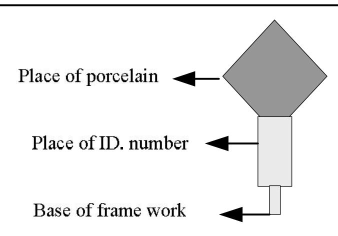

Figure 2 selected design for framework

Then the wax is taken out from the mold. Waxen samples are placed at the bottom of the cylinder and the surface of the samples is smeared with vaco film. After the vaco film was dried, the cylinder moved to the bottom. For removing moisture a filter paper was placed on the inner side of cylinder. Next, casting plaster was blended with the liquid inside the vacuum mixer to send the air bubbles out completely. The plaster inside the cylinder was poured over the vibrator and after the plaster dilated, the cylinder was exposed to 40 degree centigrade warm water to start hygroscopic expansion. After the casting plaster was set (approximately after 24 hours), the cylinder was placed inside the burn out furnace. (Temperature of this furnace is 900 to 950 degree centigrade), after 15 to 20 minutes the liquid wax was evaporated and become ready for casting. For casting at first the alloy (super cast alloy manufactured in thermo bond alloy MFG) was melted inside the crucible and after melting, the cylinder was placed at the bottom of crucible. The centrifuge which had been tuned in advance was released to force the molten alloy to go to the cylinder vents. The cylinder is let get colder in the ambient temperature. 24 hours later the cylinder is depleted of the cast. The metal samples are segregated by sand blast machine with aluminum oxide and air pressure from the plaster completely. Then the samples are placed in ultrasonic set with choleric acid and extra plaster is separated from the surface of the alloy because of slight vibration sound waves. After that the thickness of samples are equalized by the stone molt and becomes 0.3 mm. Then the samples are boiled by distilled water for 5 minutes to remove all impurities from their surface. Then the samples are put in the furnace to be degassed. Then a diluted layer of opaque is put over the metal samples. After firing the pre layer of opaque, the main layer of opaque is placed over it. In each sample, the porcelain powder is diluted with its liquid and is placed on the opaque. In order to compact the powders, the samples are vibrated and their moisture is removed. To obtain and correct the favorite shape, dimension and width, the porcelain powders were placed for the second time and were exposed to thermal procedure. Glaze liquid without glaze powder was used for glazing the samples and then was put over the dentin surface by paint brush. Since using the enamel powder makes the samples homogeneity and also the operated experiment unreliable, enamel was not used in making samples. To maintain and retain the samples, half-liter flasks were applied. Applying distillated water, 0.3 molar hydrochloric acid was prepared and poured into flasks. The flasks in the oven were exposed to the temperature of 50 degree centigrade and every day, 50cc of the solution inside the flasks was taken and the mass concentration of eluted ions was measured. In order to examine the accuracy of the results, after taking each sample its pH was measured.

b. determining the combination of each porcelain

In order to determine the percentage of the amount of composition in each porcelain, ICP and Atomic Absorption Spectrophotometer were applied. This method was operated by solving each powder into different acids (hydrofluoric acid, per chloric acid, nitric acid and hydrochloric acid) and giving that to the apparatus. Table 1

The main parts of porcelain are made of this composition. The rest consist of pigment, B_2O_3, and some other elements. Because of their less effect in the amount of elution, they were ignored

c. Determination of the amount of eluted ions from the surface of porcelain in particular intervals time

After resting the samples into the 0.3 molar hydrochloric acid, the amount of 50cc was taken every 10 days and the percentage of ions Si^{+4}, Na^{+}, K^{+}, Ca^{+2} and Al^{+3} were determined. Since the amount of eluted ions from the surface of porcelain was about ppb, for determining and estimating their amount, ICP (varian-735OES) with ultrasonic nebulizer was used. The reason for using this nebulizer was its high ability and power in atomizing the present elements in the solution. The obtained data from lab records, after process was computed based on the amount of eluted ions from each gram of porcelain sample. This data are shown in Table 2. Also in order to get more accurate comparison and investigation, the amount of eluted ions from the surface of each porcelain sample has been illustrated in Fig. 3. In addition to recorded results and for more accurate estimation, the values of pH for each sample were measured and recorded in a period of three mounts. These values have been illustrated in Fig. 4

TABLE I. WEIGHT PERCENTAGE OF EACH PORCELAIN COMBINATIONS

Mean of composition %	Porcelains type					
	nor take	*All dent*	*Ceramic III*	*Viola*	*vita*	*Ceramic II*
Al_2O_3	*14.16*	*14.96*	*14.31*	*13.43*	*14.76*	*13.48*
Boa	*0.02*	*0.74*	*0.22*	*0.76*	*1.27*	*0.02*
CIO	*0.40*	*0.89*	*0.44*	*0.94*	*0.67*	*0.60*
CeO_2	*0.00*	*0.38*	*0.19*	*0.36*	*0.00*	*0.02*
k_2O	*12.26*	*13.08*	*12.98*	*12.94*	*12.40*	*12.85*
LiO_2	*0.19*	*0.09*	*0.33*	*0.00*	*0.85*	*0.48*
Mao	*0.30*	*0.0 2*	*0.09*	*0.01*	*0.23*	*0.41*
Na_2O	*4.02*	*3.08*	*2.55*	*3.11*	*2.92*	*3.04*
SiO_2	*65.62*	*58.25*	*62.59*	*58.73*	*59.48*	*63.21*
TiO_2	*0.01*	*0.13*	*0.03*	*0.11*	*0.20*	*0.00*

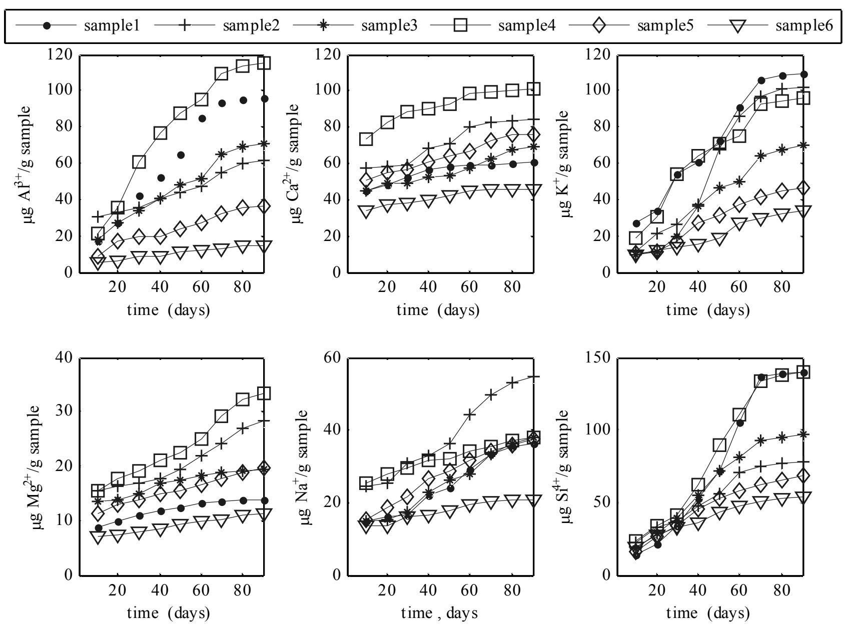

Figure 3 comparision of the amount of eluted ions from the surface of all samples

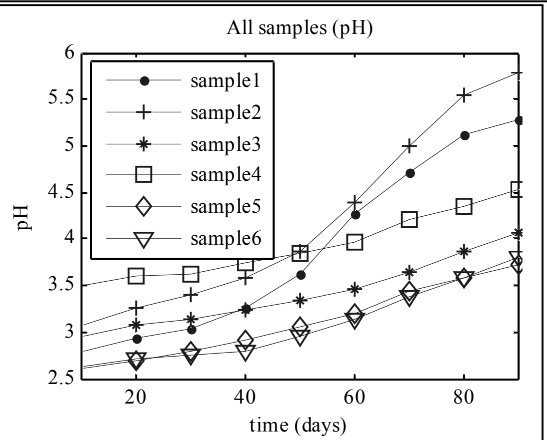

Figure 4 recorded values of pH for each sample

TABLE II. THE AMOUNT OF ELUTED IONS FROM EACH GRAM OF SAMPLES

INPUT DATA				OUTPUT DATA					
Sump.	Mean of composition %		Time (day)	Mass of eluted ion per gram of samples					
	Al_2O_3, BaO, CaO, CeO_2, K_2O	LiO_2, MgO, Na_2O, SiO_2, TiO_2		$\mu g\ Mg^{2+}/g$ sample	$\mu g\ Ca^{2+}/g$ sample	$\mu g\ K^{+}/g$ sample	$\mu g\ Na^{+}/g$ sample	$\mu g\ Si^{4+}/g$ sample	$\mu g\ Al^{3+}/g$ sample
1	14.16	0.19	10	8.76	44.57	27.33	14.94	13.8	17.06
			20	9.84	48.14	34.24	16.02	21.8	26.95
	0.02	0.30	30	10.92	52.4	54.06	16.76	33.87	41.98
			40	11.87	56.9	60.79	22.08	53.03	52.47
	0.40	4.02	50	12.55	58.66	72.5	24.01	71.6	64.93
			60	13.18	59.01	91.35	28.98	105.09	85.03
	0.00	65.62	70	13.67	59.56	106.27	33.4	136.79	93.82
			80	13.86	60.24	108.31	35.46	139.48	95.58
	12.26	0.01	90	13.89	60.66	109.39	36.45	140.32	96.5
2	14.96	0.09	10	15.55	57.18	11.23	24.63	22.97	30.82
			20	16.33	58.34	21.07	25.44	32.73	33.5
	0.74	0.0 2	30	16.79	59.36	26.81	30.7	37.76	35.81
			40	17.77	68.46	37.25	33.13	47.38	40.75
	0.89	3.08	50	19.46	71.1	68.43	36.17	55.62	43.98
			60	21.84	80.31	85.74	44.44	70.74	47.2
	0.38	58.25	70	24.32	82.42	96.84	49.64	74.76	55.35
			80	26.92	83.91	101.05	52.91	76.8	59.92
	13.08	0.13	90	28.32	84.48	102.01	54.77	77.73	61.61
3	14.31	0.33	10	13.52	44.96	10	15.07	18.15	17.85
			20	13.93	49.14	11.53	15.25	28.35	27.27
	0.22	0.09	30	14.92	49.45	19.63	17.49	39.63	33.65
			40	16.83	52.05	36.32	22.76	55.47	40.52
	0.44	2.55	50	17.58	53.06	46.32	26.32	71.55	48.17
			60	18.31	57.58	49.52	28.05	81.28	51.5
	0.19	62.59	70	18.83	62.44	63.89	33.51	92.68	64.97
			80	19.29	67.75	67.81	36.29	95.19	69.45
	12.98	0.03	90	19.41	69.06	70.23	37.78	97.28	71.16
4	13.43	0.00	10	15.53	73.62	18.68	25.44	23.42	21.58
			20	17.74	82.56	30.83	27.95	33.72	35.38
	0.76	0.01	30	19.03	88.46	54.27	29.38	41.76	60.72
			40	21.09	90.08	64.42	31.63	62.07	76.72
	0.94	3.11	50	22.47	92.7	71.02	32.24	89.38	87.34
			60	25.04	98.53	75.1	34.21	110.66	95.02
	0.36	58.73	70	29.13	99.26	92.99	35.58	133.59	109.27
			80	32.42	100.56	94.58	37.26	138.44	113.82
	12.94	0.11	90	33.46	101.43	96.11	37.8	140.13	115.22
5	14.76	0.85	10	11.27	50.71	10.1	15.31	15.88	9.11
			20	13.05	54.95	11.54	18.54	27.22	17.54
	1.27	0.23	30	13.9	56.6	17.08	21.6	34.1	19.65
			40	14.88	60.82	27.01	26.64	45.77	20.1
	0.67	2.92	50	15.44	63.88	31.76	28.83	53.19	23.55
			60	16.54	66.4	37.45	31.7	57.87	27.11
	0.00	59.48	70	17.88	72.92	41.31	34.28	62.78	32.4
			80	18.91	75.67	45.18	36.05	66.08	35.61
	12.40	0.20	90	19.75	76.29	46.44	37.59	68.48	36.14
6	13.48	0.48	10	7.16	33.77	10	13.49	19.91	5.16
			20	7.35	37.31	12.43	13.61	27.47	6.68
	0.02	0.41	30	7.88	38.3	13.95	16.28	33.03	8.77
			40	8.5	39.75	15.74	16.63	36.61	9.18
	0.60	3.04	50	9.27	42.49	18.53	18.04	43.32	11.49
			60	9.82	45	27.56	19.47	48.08	12.51
	0.02	63.21	70	10.17	45.46	30.11	20.19	50.65	13.34
			80	10.99	45.89	32.4	20.57	52.7	14.3
	12.85	0.00	90	11.27	46.11	33.58	20.8	53.8	14.64

4. SIMULATION BY NEURAL NETWORKS

The process consists of testing with a 4-layer network (11-12-12-6) of feed forward back propagation. The input layer was structured based on data related to the chemical combination of dental ceramics (Al_2O_3, SiO_2, K_2O, LiO_2, CeO_2, BaO, MgO, CaO, Na_2O, TiO_2) and the exposure time of samples to acid and output layer based on data related to the mass concentration of eluted ions from the surface of ceramic (Si^{+4}, Na^{+}, K^{+}, Ca^{+2}, Mg^{+2}, Al^{+3}). The selected model with 11 neurons in input layer, 12 neurons in the first hidden layer, 12 neurons in the second hidden layer and 6 neurons in the output layer was obtained according to try and error. For modeling, matlab software and neural network tool box were used and according to its commands, the hidden layers of the network were determined. As a transfer function, sigmoid transfer function for both hidden layers and linear transfer function for output layer were selected. For network training, back propagation algorithm was applied [7]. The resulted data in 10, 20, 30, 40, 60, 70, 80 and 90 days of experiment in the process of network training and resulted data in the fifth period of the experiment were taken out of the process of training and used for network testing. With the help of obtained experimental data, the neural network for estimating the chemical resistance of dental ceramics was modeled as Fig. 5

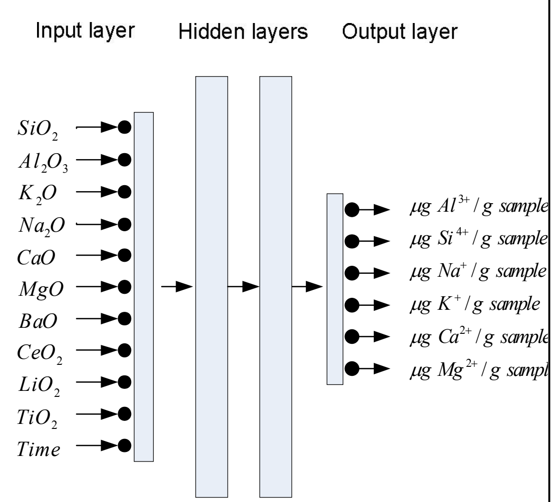

Figure 5 the neural network model applied in this study

In order to examine the efficiency of learning algorithm a criteria named performance index is used. This can do comparison between the application of neural network algorithm and other learning algorithms. The performance index used in this process is normalized root mean square error.

5. RESULTS

Fig. 6 and Fig. 7 show the comparison between measured data (ME) and estimated data by the neural network (NN). In all six ceramic samples, the value of out put for each mentioned ions, both from the obtained results for experiments and neural networks are depicted. The designed system is an intelligent system and has the ability of accurate prediction from the release process of ions from the surface of dental ceramics. In order to present the capabilities of his system, study two examples of its applications.

A. The ability of predicting the amount of the elution of each ion in periods more than 3 month

The experimental records done in this study are related to a period of three months but the designed system has the ability of receiving the information related to components of each porcelain and then estimating the amount of eluted ions from its surface in a long period of time. For this purpose, the sample 2 was used for this test. In this sample, the data related to release in the fourth month was recorded so it was possible to compare the network out put with experimental records and determine the accuracy of the network. Then the information data to this sample was presented as the percentage of the components in chemical composition of powder and the out put was examined as diagram of release up to fourth month. The results about experimental data and the network out puts have been showed up to 120 days in Fig. 8. In the diagrams related to the release of aluminum, magnesium and sodium as it was obtained from experimental recordings, it was expected that after third month the slope of diagrams fell down and the rate of release become approximately constant. Considering Fig. 8 the out puts of the network were according to this situation. In the diagram of calcium elution, after third month the gradient was upward and the rate of release wasn't stable. Regarding that this situation is according to experimental recordings in the fourth month, then the prediction was correct and in this sample, calcium elution rose up to fourth month.In the diagram resulting from silica elution, against the measured data in the fourth month, the out put of network had a slight increase but the slope of diagram in this range was some who could be accepted the estimated data by the neural network with the reasonable error.In the diagram of potassium elution, the diagram in fourth month undergoes a sudden hefty fall which is contrary to fact and experiences the network error.

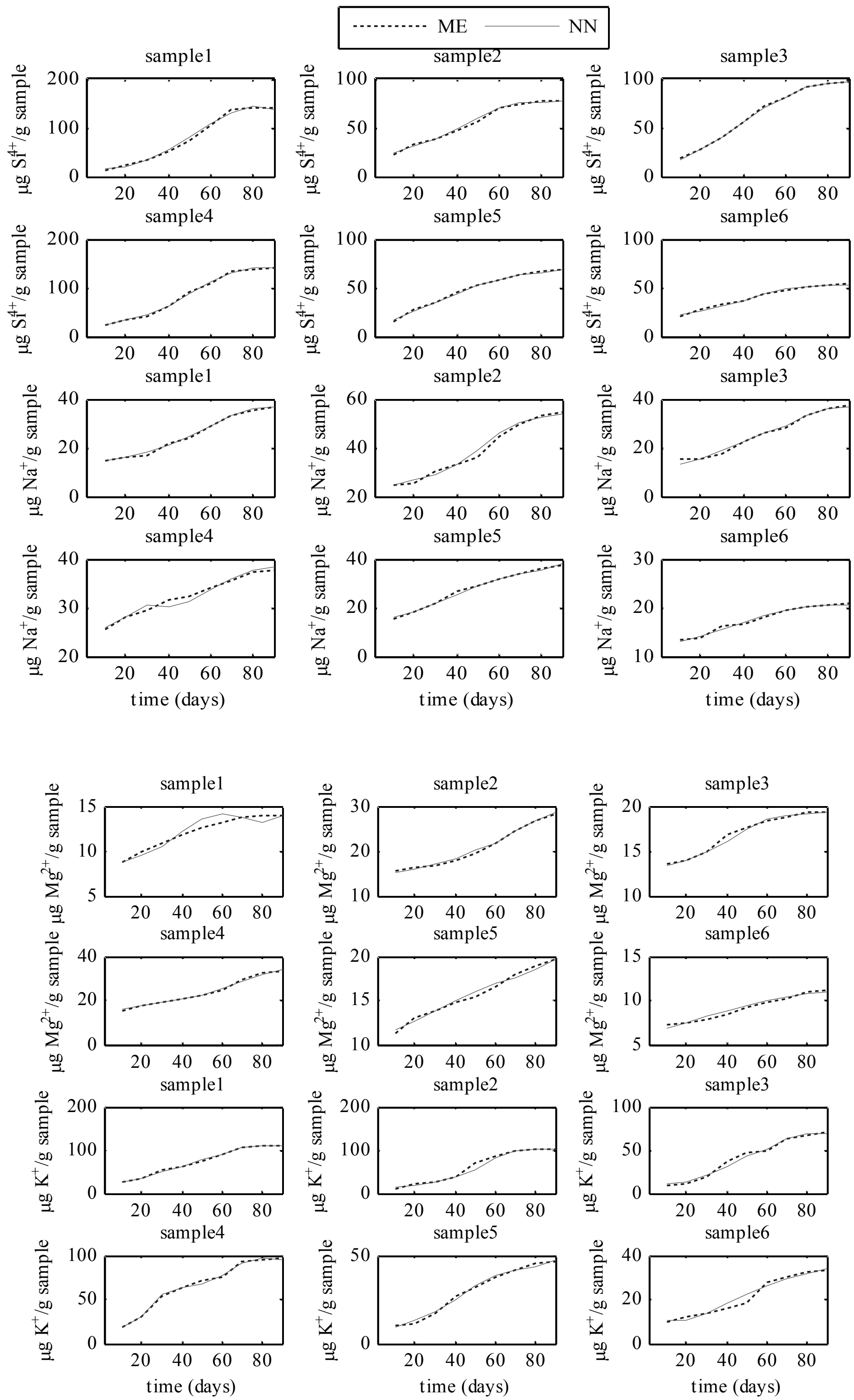

Figure 6 the comparison between the measured and computed values for Si^{4+}, Na^{+}, Mg^{2+}, K^{+}

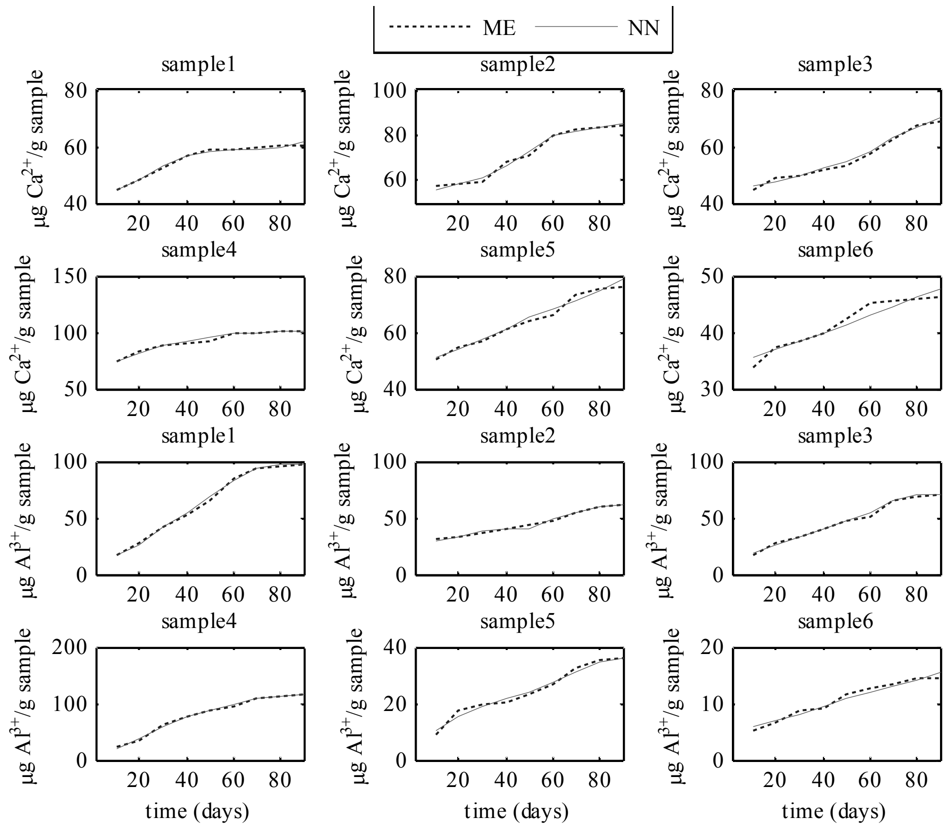

Figure 7 the comparison between the measured and computed values for Ca^{2+}, Al^{3+}

B. the possibility of prediction of release in each type of dental porcelain with changing its components

In this situation, the system has the ability to estimate the diagram of release as the output of network after getting the data related to a new sample or changing the composition of each sample. For this purpose, sample 3 was used for testing. Considering the fact that the composition of each porcelain are chosen based on some particular criteria and definite percentages, the range of variation of these components are small and it is possible only to increase or decrease the amount of the composition in this range. For this reason, in the selected sample as the testing sample, the composition was changed in the selected range and give to the network as new inputs. Then the new out puts were depicted as the diagram of release Fig. 9. As it can be seen from Fig. 9, the observed changing in new diagrams are approximately in the range of main sample and follow its patterns. The difference, however, is that the changes in the components of powder have caused increase and sometimes decrease in release. This characteristic gives the possibility of examining and studying the impact of changes any components of powder on the release mechanism in a simulated media and so improving the quality of powder production. To assess the accuracy of the network in detecting the system, the value and the percentage of error in each sample and for the recorded times were computed and showed in Table 3. Considering the obtained results, the mean error of network in predicting the elution rate of magnesium, calcium, potassium, sodium, silica and aluminum are 2.06, 1.51, 4.77, 2.43, 2.81 and 3.35 successively. We can say that the mentioned network has a good accuracy in estimating the behavior of dental ceramics

6. DISCUSSION

According to ADA and ISO standards for testing the chemical resistance and durability of dental ceramics, an acid solution must be used. In this study hydrochloric acid has been used for testing chemical resistance of dental ceramics.

TABLE III. THE RATE AND PERCENTAGE OF OBTAINED ERRORS OF EACH SAMPLES IN RECORDED TIMES

Sample	Time (day)	Comparison of the measured data (ME) and data estimated by neural network (NN)											
		$\mu g\ Mg^{2+}/g$ sample		$\mu g\ Ca^{2+}/g$ sample		$\mu g\ K^{+}/g$ sample		$\mu g\ Na^{+}/g$ sample		$\mu g\ Si^{4+}/g$ sample		$\mu g\ Al^{3+}/g$ sample	
		Δ	Δ%	Δ	Δ%	Δ	Δ%	Δ	Δ%	Δ	Δ%	Δ	Δ%
1	10	0.07	0.78	0	0.01	0.46	1.7	0.4	2.73	0.97	6.56	0.09	0.52
	20	0.35	3.69	0	0.01	1.62	4.52	0.25	1.57	1.71	8.51	0.61	2.32
	30	0.44	4.16	0.69	1.3	2.87	5.6	1.78	9.59	0.26	0.78	0.78	1.89
	40	0.32	2.65	0.46	0.81	2.07	3.29	1	4.75	1.11	2.05	2.17	3.97
	50	1.08	7.95	0.16	0.27	4.16	5.42	0.47	1.9	8.53	10.65	4.51	6.49
	60	1	7.05	0.02	0.03	0.46	0.5	0.29	1.01	2.68	2.49	1.51	1.81
	70	0.09	0.63	0.89	1.51	1.98	1.9	0.4	1.2	5.59	4.26	0.54	0.58
	80	0.68	5.15	0.84	1.41	1.17	1.07	0.61	1.68	3.99	2.78	0.92	0.95
	90	0.05	0.34	1.22	1.97	0.17	0.15	0.01	0.03	1.05	0.76	0.03	0.03
2	10	0.22	1.41	1.03	1.83	1.55	12.14	0.1	0.4	1.36	5.59	0.97	3.25
	20	0.21	1.32	0.15	0.26	2.2	11.64	1.45	5.41	2.03	6.62	0.36	1.06
	30	0.21	1.23	2.2	3.57	0.49	1.86	1.54	5.27	0.62	1.62	1.86	4.94
	40	0.6	3.28	1.98	2.97	1.6	4.12	0.05	0.14	0.97	2.01	1.19	3.01
	50	0.72	3.55	1.55	2.13	12.78	22.97	2.58	6.66	4.38	7.3	4	10.01
	60	0.19	0.88	0.48	0.6	1.95	2.32	1.85	4.01	0.21	0.3	2.21	4.47
	70	0.03	0.14	0.4	0.48	0.11	0.11	0.49	0.97	0.58	0.77	1.18	2.18
	80	0.15	0.56	0.62	0.75	1.48	1.44	0.61	1.17	0.22	0.29	0.67	1.13
	90	0.24	0.84	1.11	1.3	0.43	0.43	1.01	1.87	0.23	0.29	-0.46	-0.74
3	10	0.19	1.4	0.76	1.66	0.03	0.26	1.66	12.35	0.72	4.16	1.29	6.74
	20	0.04	0.3	1.63	3.43	1.19	9.37	0.36	2.31	0.94	3.43	1.36	5.25
	30	0.09	0.59	0.31	0.62	1.66	7.79	1.5	7.91	1.41	3.43	0.98	3
	40	0.77	4.81	0.23	0.45	4.35	13.6	0.06	0.27	-0.34	-0.61	0.7	1.76
	50	0.17	1	1.94	3.52	4.17	9.9	0.13	0.48	1.65	2.36	1.01	2.14
	60	0.34	1.83	0.35	0.6	0.75	1.49	1.18	4.05	0.61	0.75	2.53	4.68
	70	0.17	0.9	0.44	0.71	0.22	0.34	0.31	0.92	1.43	1.57	0.11	0.17
	80	0.09	0.49	0.67	1.01	1.6	2.31	0.47	1.31	1	1.04	0.48	0.69
	90	0.11	0.59	0.98	1.4	0.36	0.51	0.64	1.73	0.77	0.8	1.41	2.02
4	10	0.62	3.86	0.13	0.17	0.44	2.43	0.4	1.53	1.08	4.41	0.36	1.7
	20	0.34	1.93	1.76	2.18	0.59	1.96	0.13	0.46	1.36	4.21	0.83	2.29
	30	0.12	0.64	0.75	0.86	0.96	1.74	1	3.3	1.42	3.28	0.18	0.3
	40	0.08	0.37	1.61	1.76	0.92	1.45	1.29	4.24	1.03	1.68	0.53	0.7
	50	0.09	0.41	2.78	2.92	4.08	6.09	0.86	2.73	2.33	2.67	0.78	0.9
	60	0.29	1.16	0.23	0.24	1.95	2.53	0.64	1.9	1.74	1.54	1.88	1.94
	70	0.2	0.68	0.61	0.61	2.77	3.07	0.27	0.75	2.84	2.17	2	1.86
	80	0.44	1.37	0.13	0.13	2.47	2.54	0.25	0.67	1.54	1.1	0.1	0.09
	90	0.35	1.05	0.89	0.88	1.3	1.37	0.53	1.37	0.04	0.03	0.59	0.51
5	10	0.32	2.75	0.17	0.33	0.84	9.02	0.64	3.99	0.81	4.87	1.21	11.72
	20	0.33	2.59	1.14	2.11	1.23	9.65	0.14	0.76	1.6	6.25	1.95	12.51
	30	0.06	0.45	0.82	1.43	0.74	4.14	0.05	0.24	1.09	3.08	0.37	1.92
	40	0.05	0.36	0.6	0.98	2.31	9.35	1.16	4.54	1.13	2.53	1.7	7.8
	50	0.56	3.51	1.4	2.15	0.92	2.8	0.41	1.41	0.39	0.74	0.68	2.81
	60	0.39	2.3	2.03	2.97	1.71	4.37	0.33	1.04	0.85	1.45	0.47	1.7
	70	0.25	1.41	1.87	2.63	0.68	1.61	0.6	1.8	0.1	0.17	0.99	3.15
	80	0.46	2.48	1.38	1.85	1.58	3.62	0.71	2	0.48	0.73	1.31	3.82
	90	0	0.01	2.32	2.95	1.1	2.31	0.49	1.28	0.6	0.88	0.15	0.41
6	10	0.24	3.48	1.6	4.52	0.49	4.66	0.34	2.58	2.09	9.5	0.79	13.28
	20	0.18	2.34	0.35	0.94	1.51	13.83	0.56	3.92	1.62	6.26	0.19	2.77
	30	0.31	3.79	0.09	0.23	0.12	0.88	0.71	4.55	1.76	5.63	0.77	9.63
	40	0.37	4.13	0.03	0.07	2.48	13.63	0.39	2.31	0.7	1.89	0.17	1.82
	50	0.23	2.43	1.23	2.99	3.92	17.45	0.31	1.67	0.05	0.11	0.76	7.08
	60	0.22	2.17	2.14	4.99	1.3	4.94	0.04	0.2	0.27	0.56	0.54	4.51
	70	0.26	2.54	0.95	2.13	0.65	2.19	0	0	1.08	2.09	0.31	2.38
	80	0.29	2.71	0.25	0.54	0.33	1.02	0.02	0.08	0.32	0.61	0.19	1.35
	90	0.35	3.17	1.66	3.47	0.8	2.32	0.11	0.54	1.04	1.97	1.02	6.51

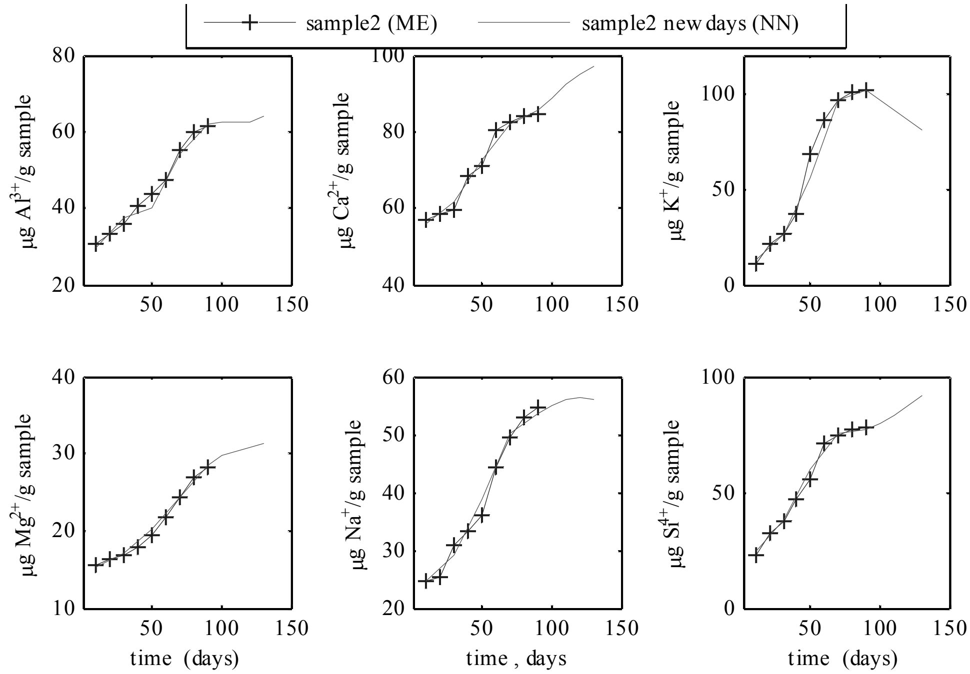

Figure 8 the results of network prediction for a long period

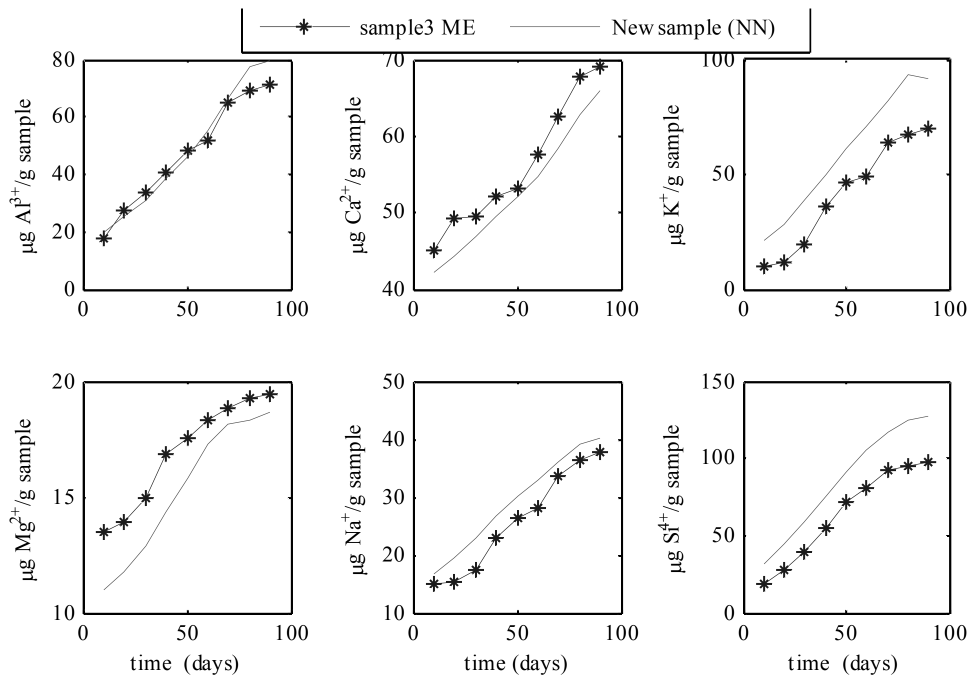

Figure 9 the results of network prediction with changing the compositions

Hydrochloric acid was suitable because there a lot of patients with gastric disorders that have lower pH values in oral cavity due to the presence of hydrochloric acid. Also the length of this experiment differed from ISO standard. It was also desirable to include in this research the longest possible elution of ions from dental ceramics in order to test the long term predicting possibilities of this method. The artificial neural network method presented in this study is currently been used in different fields of engineering, medicine and etc. The application of experimental data in this study was using them in training and testing the network and finally extracting a model according to practical results. The results of past studies confirmed this hypothesis that the elution of ions from the surface of dental ceramics in an acid solution is slightly carried out. Despite the fact the number of data and measuring time intervals were relatively low, even in the method of artificial neural networks showed a very accurate prediction of the wear behavior of dental ceramics. The observation of high correlation coefficient and low normalized root mean square error between measured and estimated output values approve the network's capability in learning and extracting the model of the system. The only problem was small number of input data sets and type of information given to network i.e. input data sets used to train the network, were only about the component of materials used for making each porcelain. Even though some other parameters such as productivity of each powder, effecting factors in sintering process, the created phase and… are effective in the mechanism of release which haven't been considered in this research. Because of this reason, extraction of a very accurate model for the system was impossible while in the small number of information the minimum and least difference obtained between the measured and estimated mass of eluted ions per gram of dental ceramic sample were observed. Artificial neural network has a great potential for investigating not only the chemical stability of materials, but also other properties such as wear resistance, flexural strength and etc. Artificial neural networks have great potentials, for example it is possible to calculate, compute and evaluate the amount of eluted ions, without needing to experiments and spending time and high cost. Moreover, the system making a virtual experimental medium that gives possibility to dental porcelain manufacturers to change the percent of chemical composition used for making each powder as a software and studying the changes in the amount of ion elution from its surface in an interval and in this way obtaining the most optimum combination for a powder with lost elution. Comparing pH and release diagrams in each sample, it is observed that as an average, the maximum pH increase takes place in samples with maximum elution. In other words, the amount of elution is proportionate to the pH variation. It can be concluded that the pH increase is related to the increasing amount of ion elution from the surface of porcelain and making junctions with OH groups existing in the solution. Then, the acidity of solution and increment of amount of eluted ions decreases and pH increases. Since studying the papers about pH variation based on time, the maximum increase of pH is in the first three months and after that its amount changes with a constant rate. So in this study, the amounts of pH recordings were also examined up to the third mount. In addition, as it was evaluated before, the amount of ion elution from the surface of porcelain is proportionate to the rate of pH variations. Therefore, it is estimated that the rate of elution after three months remains stable. The authenticity of results by neural network according to predictions after stimulating and drawing the graphs of elution in period more than 90 days Fig. 8 was confirmed i.e. as it was anticipated after the third month as an average the amount of elution approximately remained stable. In related graphs to pH Fig. 4, sample1 (.) and sample2 (+) have erratic movements. In sample 2 the amount of pH has a slight rise up to fifteenth day but then the amount of pH dramatically changes. Comparing this diagram with other diagrams related to elution in Fig 3, it was observed that in the diagram of sodium release, this sample has had a sharp rise after 50^{th} day. Also in sample 1 the amount of pH was increasing regularly up to 40^{th} day but after that it suddenly soared up. Also the in the diagram related to the potassium elution is observed in this sample. It can be concluded that the most critical factor in pH variations is related to the elution of sodium and potassium because sudden increase of these two ions in comparison with other ions has had more impact on pH variations

Acknowledgement

The authors would like to thank Tabriz Branch, Islamic Azad University for the financial support of this research, which is based on a research project contract.

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9/6/2012