Development of Indwelling Wireless pH Telemetry of Intraoral Acidity

Jung-hoon Ro, Soo-young Ye, Jae-hee Jung, Ah-young Jeon, Yun-jin Kim
In-cheol Kim, Chul-han Kim, and Gye-rok Jeon

***Abstract*—**As the increase of intraoral acidity due to ingestion of sweet foods and acidic beverages usually bring forth a dental caries and a erosion, the measurement of intraoral pH is essential in the study of oral environment. The indwelling intraoral pH telemetry for lasting longer than 24 hours in the mouth was developed to overcome the limits of conventional wire electrode method previously used for salivary and plaque pH measurement, and to assess its effectiveness.

***Keywords*—**pH telemetry, intraoral acidity, wireless.

I. Introduction

THE loss of tooth materials is classified into dental caries, dental erosion, attrition and abrasion. Dental caries is defined as tooth loss by a chemical dissolution of teeth due to acids resulting from the metabolic products of foods by cariogenic bacteria. Dental erosion is also defined as tooth wear produced by chemical dissolution of teeth by acids rather than products by bacteria. The attrition is the mechanical tooth wear produced by the direct contact of occluding or proximal surface. The abrasion is the tooth wear produced by direct contact of exogenous material over tooth surface [1], [2].

Among these, dental caries and erosion are due to foods and drinks. Caries, capable of surface demineralization, is a bacterial disease. The real beginning occurs along with the combination of a specific bacterial population and caries. Nowadays, intra-oral environment has been modified to the extent that those particular species can flourish. Modifications due to the intra-oral environment include the alterations of texture, the acid level and the flow of saliva. And the inter-oral environment can be also changed by refined carbohydrate, food and drink of low pH. Acidic beverages and foods are the etiological factors of erosion [3], [4].

The fermentation within plaque and the subsequent acid attacking the tooth enamel can be assessed by determining the pH profiles of plaque after removing foods and specific carbohydrates. Subsequent investigations have utilized the pH profile technique to determine the cariogenic potential of various foods and sweeteners as well as analysis of potential inhibitors of acid production [5]-[7].

The telemetric indwelling electrode method has been introduced recently but this method has the limit of practical application due to the use of wire. The wire connecting oral sensing device and extra-oral recording instruments is used in a wire telemetry system. In reality, the experimental condition is quite different from that in real life since pH inside the oral cavity is measured while ingesting a specific food and drink. In case of using the wireless communication, data might to be transmitted from the indwelling electrode attach transmitter to the body, which is sometimes very uncomfortable.

The purpose of this study was to develop the wireless telemetry method to supplement the shortcomings of existing methods which measure the intra-oral pH and to evaluate the efficiency in actual measurement. The wireless telemeter measuring the intra-oral pH continuously for a long time was developed in this work.

II. Method and Materials

The wireless intra-oral telemeter system was developed to measure and save intra-oral pH value inside oral cavity. Fig. 1 illustrates the development process of the wireless intra-oral telemeter system composed of 5 parts.

Manuscript received July 31, 2007. This work was supported by a grant of the Korea Health 21 R&D Project, Ministry of Health & Welfare, Republic of Korea (Grant No: A040032).

J. H. Ro is with with the Pusan National University School of Medicine, Pusan, Korea (e-mail: jhro@ pnu.edu).

S. Y. Ye is with the Pusan National University School of Medicine, Pusan, Korea (phone: 82-51-257-2866; fax: 82-51-257-2867; e-mail: syye@ pusan.ac.kr).

J. H. Jung is with Dept. of Biomedical Engineering, School of Medicine, Pusan National University (e-mail: espouir82@hanmail.net).

A Y. Jeon is with Dept. of Biomedical Engineering, School of Medicine, Pusan National University (e-mail: valonica@hanmail.net).

I. C. Kim Jeon is with Dept. of Biomedical Engineering, School of Medicine, Pusan National University (e-mail: cheolydang@nate.com).

C. H. Kim is with Dept. of Biomedical Engineering, School of Medicine, Pusan National University (e-mail: sensor2207@empal.com)

Y. J. Kim is with Dept. of family Medicine, Pusan National University (e-mail : yujkim@pusan.ac.kr)

G. R. Jeon. is with the Dept. of Biomedical Engineering, School of Medicine, Pusan National University, Pusan, Korea (e-mail: grjeon@pusan.ac.kr).

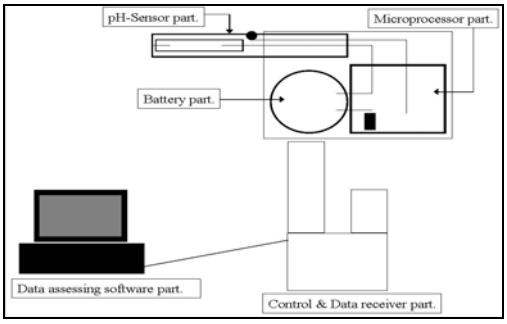

Fig. 1 A component of the wireless intra-oral pH telemeter

A. pH-sensor Part

Among electrodes for measuring the pH, an antimony electrode was suitable because the distance between reference electrode and an antimony electrode is short, and the size of the electrode is small. The principle of pH measurement using antimony electrode is as follows. The voltage difference between a reference electrode and an antimony electrode was measured and displayed into pH value by buffer solution calibrated beforehand. The electrode used in pH measurement was Slimline® Multi-Use pH Catheters (Medtronic, Inc. USA) [8]

B. Microprocessor Part

The microprocessor part is composed of program and microprocessor. The program to operate pH telemeter and the microprocessor, ATmega8L that is 8-bit with 8K Bytes In-System Programmable Flash (Atmel Co. USA), to save pH meter value was used.

C. Battery Part

The electric power was supplied with manganese-lithium coin battery (model: ML612S, Panasonic, Japan). It also provide the long duration of power which was suitable to constantly maintain the operation and was capable of reusing. The wireless intra-oral telemeter device composed of pH sensor and microprocessor, and battery. This device was produced by connection of 3 components, it was waterproofed by Scotch-Weld™ Polyurethane(3M, USA) using Hotmelt in Fig. 2.

Fig. 2 The wireless intraoral pH telemeter

D. Control and Data Receiver Part

The measured value was transmitted by connecting the positive and negative poles through the Polyurethane coating into a produced the intra-oral device. An interfacing device was developed to control of measuring start and stop, transmission the measured value from pH meter in oral cavity , control the intra-oral device, and charge the battery. The transmission method, optic communication through LED, was used for transmit the measured pH value to program as Fig. 3.

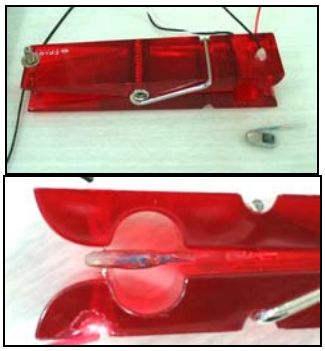

Fig. 3 Data receiver

E. Data Assessing Software Part

The PC software program is developed to control the intra-oral pH telemeter and display the change of pH value according to time. This program could afford to enlarge the specific area and calculate the area below the baseline. The software program assessing data is illustrated in Fig. 4.

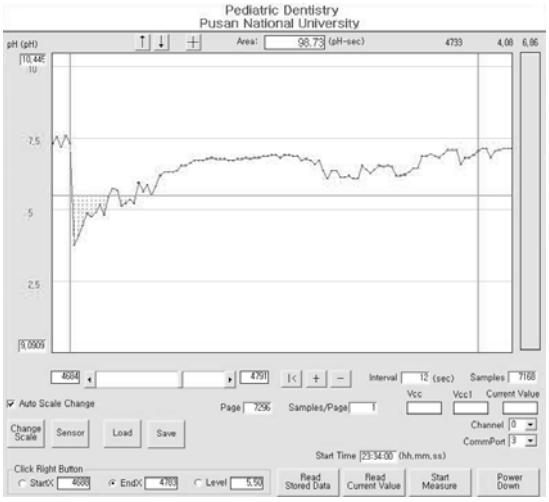

Fig. 4 Data assessing software

III. Results

A. Development of Wireless Intra-Oral pH Telemeter

The wireless intra-oral pH telemeter is consisted of three components, that is, the measurement part of pH sensor composing of antimony electrode, microprocessor part of saving measured data, and battery part of supplying an electric power. These parts are waterproofed and applied at intra-oral. The interfacing device consists of receiver part obtaining saved data and operating equipment, and software part controlling the device inside oral cavity and analyzing received data as shown in Fig. 5.

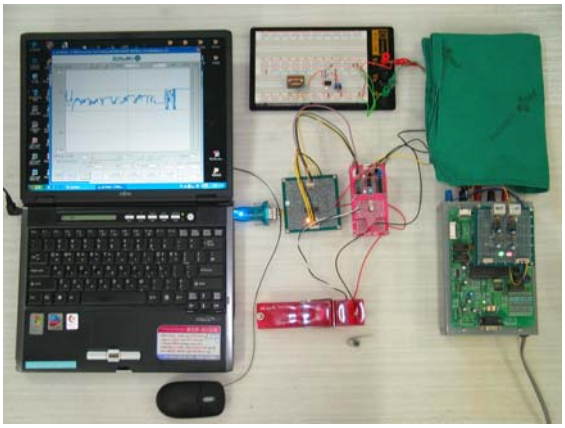

Fig. 5 The wireless intra-oral pH telemeter system

B. Calibration of the Antimony Electrode

The voltages of sixteen levels of pH solutions from pH 2.07 to pH 8.925 were measured with five randomly selected antimony electrode samples. The experimental results are shown in Table I and Fig. 6. The result indicates that each electrode has different absolute voltage at the same pH solution, however, the similar voltage differences were observed for the same pH differences. Therefore, it is necessary to calibrate antimony electrodes with two buffer solutions of pH 7.00 and pH 4.01 before measuring pH.

TABLE I
MEASURED ELECTIC POTENTIAL FOR 5 ANTIMONY ELECTRODES IN EACH SOLUTION UNIT: VOLTS

pH of solution	Elect. 1	Elect. 2	Elect. 3	Elect. 4	Elect. 5
8.925	435	435	448	432	420
8.090	394	394.5	409	392.5	383
7.625	371	371	382	370.5	359
7.065	324	329.5	341	324	319.5
6.996	326.5	332	343	322	318
6.255	287	290	301.5	282	274.5
5.705	246	248.5	268.5	245.5	236.5
5.465	245	246	265	239.5	235
5.195	236	236	249.5	235	224.5
4.495	195	196	215	195	188
4.225	180	182	200	181	173
4.030	170	171	188	170	161
3.515	142	146	161	146.5	128.5
3.050	114.5	120	131	117	101
2.500	92.5	94.5	107	93.5	75
2.070	75.5	74.5	97	75	62

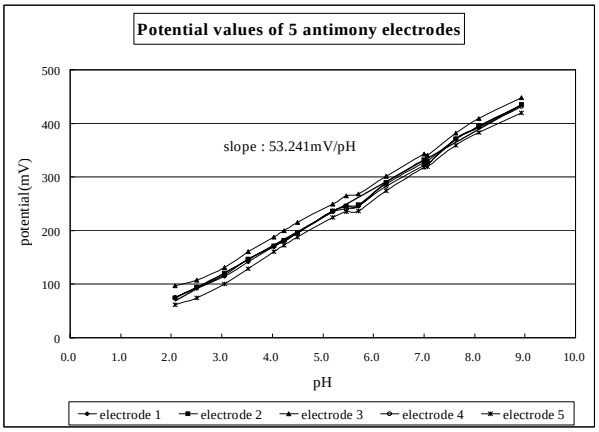

Fig. 6 Potential values of 5 antimony electrodes

Before applying the wireless intra-oral pH telemeter, a pH electrode was dipped into pH 7 and pH 4 buffer solutions for 10 minutes. After the pH value was measured, the voltage values at pH 7 and pH 4 were input into software program to calibrate the electrode as shown in Fig. 7.

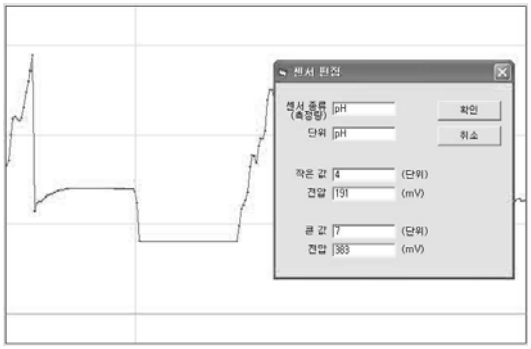

Fig. 7 Calibration of antimony electrodes

C. Apply Wireless Intra-Oral pH Telemeter

The wireless intra-oral pH telemeter is applied by a volunteer at Fig. 8.

Fig. 8 Intra-oral photograph of device

The daily lives such as a mealtime, a kind of snack, activity and sleep state for 24 hour are recorded in Table II. Fig. 9 shows the change of pH value acquired from the wireless intra-oral pH telemeter for 24 hours.

TABLE II
RECORDING ABOUT MEAL TIME AND SNACK KIND, ACTIVITY CONTENTS, SLEEP STATE FOR 24 HOURS

Time	contents
PM 11:34	start measurement
11:40	pH 7 buffer solution (10 min)
11:50	pH 4 buffer solution (10 min)
12:00	pH 7 buffer solution (10 min)
12:20	intra-oral application
AM 2:20	going to sleep
7:30	get up in the mornig
7:35~48	toothbrushing (remove applinace)
7:52	beverage : carrot juice
PM 12:20~12:45	meal time
12:49	beverage : ginger tea
1:22~24	toothbrushing (remove applinace)
3:14	beverage : miero fiber
6:51~7:10	meal time
7:27~30	toothbrushing (remove applinace)
8:38~48	snacks : candy
9:39	beverage : coffee
11:34	end measurement

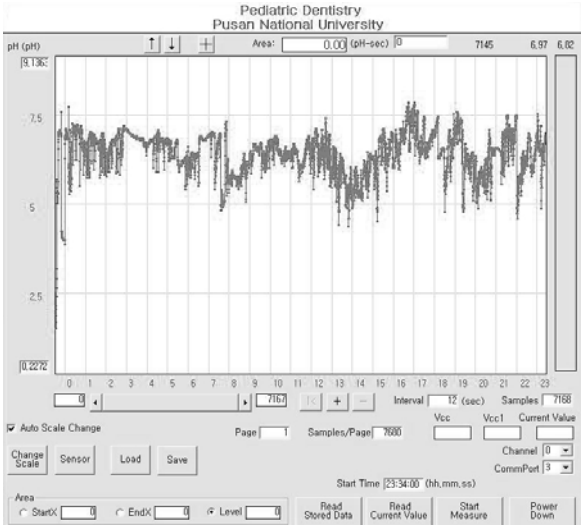

Fig. 9 Intra-oral pH value charges for 24 hours

IV. CONCLUSION

The researches of intra-oral pH-metry were accomplished using wire electrodes. A pH sensor, microprocessor and battery were used to solve the current problem.

The device is an intra-oral equipment capable of 24 hour application. The experimental result is as followed.

Firstly, a wireless intra-oral pH telemeter was developed, which is consisting of internal and external device. The internal device was the measuring part composing pH sensor of antimony electrode and the microprocessor saving the data, and manganese-lithium coin battery. These three parts are waterproofed and the change of the pH value was by measuring part. External device consists of a data receiver and software to accessing the data.

Secondly, the change of the pH was measured from subject for 24 hours. After subject's eating the food and drink, pH value according to time and are recorded for the designated time and kinds of provided food.

Thirdly, the wireless telemetric method could afford to compensate the limit of prior researches. The limitation of the measure time was also overcome in proposed system, in which measurement of pH intra-oral could be free from the routine activity.

REFERENCES

[1] Rytömaa I, Meurman JH, Koskinen J, et al. "In vitro erosion of bovine enamel caused by acidic drinks and other foodstuffs," Scand J Dent Re, 96 , pp. 324-333, 1988.
[2] Johansson AK, Lingström P, Imfeld T, et al. " Influence of drinking method on tooth-surface pH in relation to dental erosion," *Eur J Oral Sci*, 112, pp. 484‐489, 2004.
[3] Fosdick LS, Campaigne EE, Fancher O ," Rate of acid formation in carious areas: the etiology of dental caries," *Ill Dent J*, vol. 10, pp. 85-95, 1941.
[4] 20.Frostell G ," A method for evaluation of acid potentialities of foods," *Acta Odontol Scand*, vol. 28, pp.599-608, 1970.
[5] Kleinberg I, Jenkins GN, Chatterjee R, et al. ,"The antimony pH electrode and its role in the assessment and interpretation of dental plaque pH," *J Dent Res*, vol. 61, pp. 1139-1147, 1982.
[6] Graf H, Mühlemann HR ,"Telemetry of plaque pH from interdental areas," *Helv Odontol Acta*, vol. 10. pp. 94-101, 1966.
[7] Anderson P, Hector MP, Rampersad MA,"Critical pH in resting and stimulated whole saliva in groups of children and adults," *Int J Paediatr Dent* vol. 11, pp. 266-73, 2001.
[8] Pandolfino JE, Ghosh S, Zhang Q, et al. ,"Slimline vs. glass pH electrodes: what degree of accuracy should we expect?," *Aliment Pharmacol Ther*, vol. 23, pp. 331-340, 2006.

Jung-hoon Ro was born in Pusan, Korea, on August 2, 1961. He received the Ph.D. degree in physics from Pusan National University, in 2001. He received the M.S. degree in physics from Pusan National University, in 1984. His research interests include biophysics, mathematical biology and medical engineering. He is currently a professor of school of medicine, Pusan National University and director of Dept.of biomedical engineering in Pusan National University Hospital.

Soo-young Ye was born in Pusan, Korea, on August 28, 1972. She received the M.S. degree in electronic engineering from Pusan National University, in 1998. She received the Ph.D. degree in biomedical engineering in 2004 from the same institution. Her research interests include biomedical signal processing and measurement.

Jae-hee Jung was born in Pusan, Korea, on September 27, 1982.She received the B.S. in biomedical Engineering from Inje University, in 2006. She is currently in the master's coarse in biomedical Engineering from Pusan National University. Her research interests include biomedical signal processing and measurement.

Ah-young Jeon was born in Pusan, Korea, on May 10, 1983. She received the B.D. in biomedical Engineering from Inje University, in 2007. She is currently in the master's coarse in biomedical Engineering from Pusan National University.

In-cheol Kim was born in Busan, Korea, on November 26, 1981. He received the B.D. in biomedical Engineering from Inje University, in 2007. He is currently in the master's coarse in biomedical Engineering from Pusan National University.

Chul-han Kim was born in Pusan, Korea, on September 19, 1955. He received the M.S. degree in electronic engineering from Pusan National University, in 1998. She received the Ph.D. degree in biomedical engineering in 2007 from

the same institution. Her research interests are bio simulation and bio measurement.

Yun-jin Kim was born in Pusan, Korea, on April 23, 1958. He received the M.S. degree in department of preventive medicine from the Yeonsei University, in 1987. He received the Ph.D. degree in department of parasitology in 1992 from the Yeonsei University in 1992. He is currently a professor in department of family medicine, Pusan National University.

Gye Rok Jeon was born in Pusan, Korea, on January 1, 1953. He received the M.S. degree in electronic engineering from Pusan National University, in 1981. He received the Ph.D. degree in electronic engineering in 1992 from the Dong-a University. He was responsible for the Korea Health 21 R&D Project both experimental and theoretical aspects of the project. He is currently a Professor in biomedical engineering.