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 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.
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.

### 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.

### 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.
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.

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.

C. Apply Wireless Intra-Oral pH Telemeter

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

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 I

<table>
<thead>
<tr>
<th>pH of solution</th>
<th>Elect. 1</th>
<th>Elect. 2</th>
<th>Elect. 3</th>
<th>Elect. 4</th>
<th>Elect. 5</th>
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<tr>
<td>8.925</td>
<td>435</td>
<td>435</td>
<td>448</td>
<td>432</td>
<td>420</td>
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<tr>
<td>8.090</td>
<td>394</td>
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<td>409</td>
<td>392.5</td>
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<tr>
<td>7.625</td>
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<td>371</td>
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<tr>
<td>7.065</td>
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<tr>
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<tr>
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<tr>
<td>2.070</td>
<td>75.5</td>
<td>74.5</td>
<td>97</td>
<td>75</td>
<td>62</td>
</tr>
</tbody>
</table>
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 moring                          
| 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 : micro 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                               

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

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