Effects of radiotherapy on salivary gland function in patients with head and neck cancers

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Abstract Background/purpose: We explored changes in salivary gland function of head-and-neck cancer patients after radiotherapy, including pH of saliva, stimulated salivary flow rate, and saliva buffering capacity. The pH of saliva included that of parotid gland, submaxillary gland, and total resting saliva. We also investigated whether the acidity of dental plaque lowered pH of saliva.

Materials and methods: From a total of 62 patients, 11 had repeated measurements taken before and every month after radiotherapy. The remaining 51 patients had a single measurement taken after radiotherapy. Seven normal patients served as the control group.

Results: In the repeated measurement group, all examinations decreased dramatically in the 1st month after radiotherapy (P < 0.0001), and recovered from the 3rd month to the 6th month, but the flow rate could not return to pretreatment level. In the single measurement group, uni-labiate linear regression analysis showed that the time-period after radiotherapy was a significant predictor influencing the pH of the submaxillary gland and total resting saliva. Pearson correlation coefficient analysis showed that the pH of dental plaque had a positive linear correlation with that of saliva. Concerning the influence of time-period, within 1 year after radiotherapy, all examinations were dropped. After 1 year the pH of resting saliva and plaque began to increase over time. The stimulated flow rate, pH of stimulated saliva, and buffering capacity, dropped <1 year after radiotherapy group, increased 1–5 years after radiotherapy group, but dropped again >5 years after radiotherapy group.

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Conclusion: Our results indicated that oral hygiene care is important especially during the early period after radiotherapy.

Introduction

Head-and-neck cancer (HNC) is one of the leading causes of cancer mortality in Taiwan. For these patients, radiotherapy plays an important role in the treatment. However, xerostomia caused by salivary gland dysfunction is a common complication in HNC patients after radiotherapy.\(^1\) Considerable acute and long-term side effects severely reduce life quality of HCN patients.\(^2\) At present, there is no effective therapy for xerostomia.\(^3\) Understanding detailed saliva change of HCN patients after radiotherapy is mandatory for prevention of dental caries, periodontitis, mucositis, etc. As salivary glands are in the path of ionizing radiation and very radiosensitive, the striking reduction in saliva output accompanied by significant increases in saliva $\text{Na}^{+}$, $\text{Cl}^{-}$, $\text{Ca}^{2+}$, $\text{Mg}^{2+}$, protein concentrations, and a decrease in $\text{HCO}_3$ content are frequently observed after radiotherapy.\(^4\)

Stimulated salivary production is largely (60–70% of total) derived from the parotid glands, with the balance from other glands; resting (unstimulated) salivary production is primarily due to the submaxillary and sublingual glands and numerous small oral salivary glands.\(^5,6\) On average, unstimulated flow rate of saliva is 0.3–0.5 mL/min, whereas stimulated flow rate is 1.1–3.0 mL/min.\(^7\) Saliva functions in the following areas: (1) modulate pH and the buffering capacity of saliva; (2) cleanse oral microorganisms and dental plaque; (3) modulate demineralization and remineralization; and (4) provide antibacterial action.\(^8\) The buffering capacity of saliva is very important for oral hygiene maintenance of HCN patients after radiotherapy, works more efficiently during stimulated high flow rates but is almost ineffective during periods of low flow with unstimulated saliva.\(^9,10\)

There are different types of acinar cells in different salivary glands. Serous acinar cells, mainly in the parotid glands, are more easily damaged than mucous acinar cells in the sublingual and submaxillary glands after radiotherapy.\(^11\) This study aimed to explore changes in salivary gland function of HCN patients after radiotherapy. Individual functional examinations were performed and all detailed data were collected to plot the change-tendency of every single salivary function. We also figured out whether the acidity of dental plaque decreased the pH level of saliva after radiotherapy.

Materials and methods

Eligibility criteria

Saliva samples from a consecutive clinical cohort of patients were collected during 2010–2011. We obtained samples from 62 head and neck cancer patients (45 male and 17 female participants) at the Department of Oral and Maxillofacial Surgery, National Taiwan University Hospital, Taipei, Taiwan. The study samples were required to be from patients over 18 years old and new to radiotherapy. Those who had already received radiotherapy, taken any medication, or suffered any systemic disease interfering with salivary gland function, and had trouble in communication were excluded. The age distribution of 62 patients was 26–70 years (Table 1). The study was approved by the Institutional Review Board of the National Taiwan University Hospital. All participants provided informed written consent before being included. Among these 62 patients, 11 (7 male and 4 female) had repeated measurements taken before and every month after radiotherapy (Table 2). In this repeated measurement group, functional examinations were performed to track salivary gland changes due to radiotherapy. The remaining 51 patients (38 male and 13 female) had a single measurement taken at an arbitrary time after radiotherapy (Table 3). Additionally, seven normal patients (2 male and 5 female) agreed to participate in this study (Table 4). The following functional examinations and observations were performed and recorded by one person. Salivary samples were collected using GC Saliva-Check Buffer kits (GC America INC. http://www.gcamerica.com/products/preventive/Saliva_Check_BUFFER/index.php.). Samples were collected before meals

<table>
<thead>
<tr>
<th>Study group</th>
<th>Patient no.</th>
<th>Male/female</th>
<th>Median age (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tumor site</td>
<td>Nasopharyngeal</td>
<td>42</td>
<td>52 (26–70)</td>
</tr>
<tr>
<td>Nasal cavity/paranasal sinus</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oral cavity/oralpharyngeal</td>
<td>13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Throat/hypopharyngeal</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parotid gland</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others (neck)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Tumor characteristic</td>
<td>Squamous cell carcinoma</td>
<td>59</td>
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<tr>
<td>Lymphoma</td>
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<tr>
<td>Melanoma</td>
<td>1</td>
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<tr>
<td>Tumor stage</td>
<td>I</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>II</td>
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</tr>
<tr>
<td>III</td>
<td>9</td>
<td></td>
<td></td>
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<tr>
<td>IVA</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>IVB</td>
<td>7</td>
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<td></td>
</tr>
<tr>
<td>Unknown</td>
<td>15</td>
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</table>
or at least 2 hours after meals. For this purpose, samples were collected between 2:00 PM and 4:00 PM during the day for collection to minimize effects of the diurnal variability in salivary composition. During the time of collection, smoking, eating, and talking were prohibited. The following data were also then recorded from the patients at the time point of saliva collection.

Decayed/Missing/Filling Teeth (DMFT)

The DMFT method (D = decayed, M = missing, and F = filling) was used to record patients’ dentition situations. All third molars were excluded.

pH of saliva

The test paper in GC Saliva-Check Buffer kit was put in the opening of Stenson’s duct for 10 seconds for the pH of the parotid gland saliva and recorded as pH(P), and put in the opening of Wharton’s duct for 10 seconds for the pH of submaxillary gland saliva and recorded as pH(S). When patients were in the rest situations, they were asked to spit saliva gently into collecting cups. The test paper was then put in the cup provided by the GC Saliva-Check Buffer kit for 10 seconds for the pH of total resting saliva and recorded as pH(total). The test paper would change color after 10 seconds and the pH could be read according to the color demonstration by the manufacture’s instruction.

Stimulated salivary flow rate

After chewing the bite-wax in the GC saliva-Check Buffer kit for 30 seconds, the patient was instructed to spit saliva gently into saliva collecting cups and this first sample was excluded. Then the patient kept chewing for 5 minutes and spit every 15–20 seconds, which was recorded as flow rate (mL/5 min). The pH of this stimulated saliva was also examined by test paper and recorded as pH(B).

Saliva buffering capacity

The stimulated saliva was also examined by the buffering capacity pad in the kit. The sample was applied on three pads for 10 seconds and the color of the pads were changed individually. The sum of three color scores (green = 4; green/blue = 3; blue = 2; blue/red = 1; and blue = 0) indicated the buffering capacity (high = 10–12; middle = 6–9; and low = 0–5).

pH of dental plaque

The dental plaque from the central incisor and first molar were collected by the probe and its pH was examined by test paper and recorded as pH(p).

Statistical analysis

A mixed model was used in the repeated measurement group because some patients were absent at some
appointments due to discomfort \((n\) was not always equal to 11). The details are demonstrated in Table S1. The change tendency of salivary gland function, including \(\text{pH(P)}, \text{pH(S)}, \text{pH(total)}, \text{buffering}, \text{pH(B)},\) and \(\text{pH(p)},\) before and every month after radiotherapy was analyzed. A universal linear regression model was used in the single measurement group. The influences of age, sex, and time-period after radiotherapy on salivary gland function were analyzed, and Pearson correlation coefficient was used to analyze the relationship among \(\text{pH(p)}, \text{pH(P)}, \text{pH(S)},\) and \(\text{pH(total)}\). Student \(t\) test was also used to distinguish the relationship between time-period and salivary gland function among these groups: pretreatment, \(<1\) year after radiotherapy, \(1–5\) years after radiotherapy, and \(>5\) years after radiotherapy. The software was SAS version 9.2 (SAS Institute Inc., Cary, NC, USA) and the value of \(\alpha\) was 0.05.

Results

DMFT

The average DMFT in the pretreatment group, \(<1\) year after radiotherapy, \(1–5\) years after radiotherapy group, and \(>5\) years after radiotherapy were 14, 10.44, 12.59, and 13.71. The normal control group was 14.

\textbf{pH of saliva and plaque}

In the repeated measurement group \((n = 11),\) the \(\text{pH(P)}, \text{pH(S)}, \text{pH(total)}, \text{pH(B)},\) and \(\text{pH(p)}\) are demonstrated in Fig. 1. The \(\text{pH(P)}\) was 6.60 before radiotherapy, and declined steadily to the lowest 6.00 \((P = 0.148)\) 6 months after radiotherapy, and then began to increase; \(\text{pH(S)}\) declined from 6.88 to 6.26 \((P = 0.003)\) 1 month after radiotherapy, to the lowest 6.11 \((P < 0.0001)\) at 3 months, and returned to 6.55 12 months after radiotherapy; \(\text{pH(total)}\) declined from 6.93 to 6.20 \((P = 0.0002)\) 1 month after radiotherapy, to the lowest 6.13 \((P = 0.0001)\) 2 months after radiotherapy, and returned to 6.80 12 months after radiotherapy; \(\text{pH(B)}\) declined from 7.60 to 7.07 before and 1 month after radiotherapy \((P = 0.003)\). Then it increased to 7.60 9 months after radiotherapy; \(\text{pH(p)}\) declined from 6.69 to 6.33 before and 1 month after radiotherapy \((P = 0.053)\). Then it increased to 6.90 12 months after radiotherapy; \(\text{Buffering}\) the score of buffering capacity declined from 11 to 8.50 1 month after radiotherapy, to the lowest 7.29 \((P < 0.0001)\) 2 months after radiotherapy, and then increased.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure1.png}
\caption{The \(\text{pH(P)}, \text{pH(S)}, \text{pH(total)}, \text{pH(B)},\) and \(\text{pH(p)},\) and buffering capacity were analyzed in the repeated measurement group; \(\text{pH(P)}\) declined from 6.60 to 6.09 \((P = 0.002)\) 1 month after radiotherapy, to the lowest 6.00 \((P = 0.148)\) 6 months after radiotherapy, and then began to increase; \(\text{pH(S)}\) declined from 6.88 to 6.26 \((P = 0.003)\) 1 month after radiotherapy, to the lowest 6.11 \((P < 0.0001)\) 3 months, and returned to 6.55 12 months after radiotherapy; \(\text{pH(total)}\) declined from 6.93 to 6.20 \((P = 0.0002)\) 1 month after radiotherapy, to the lowest 6.13 \((P = 0.0001)\) 2 months after radiotherapy, and returned to 6.80 12 months after radiotherapy; \(\text{pH(B)}\) declined from 7.60 to 7.07 before and 1 month after radiotherapy \((P = 0.003)\). Then it increased to 7.60 9 months after radiotherapy; \(\text{pH(p)}\) declined from 6.69 to 6.33 before and 1 month after radiotherapy \((P = 0.053)\). Then it increased to 6.90 12 months after radiotherapy; \(\text{Buffering}\) the score of buffering capacity declined from 11 to 8.50 1 month after radiotherapy, to the lowest 7.29 \((P < 0.0001)\) 2 months after radiotherapy, and then increased.}
\end{figure}
months after radiotherapy. There was no difference between before and 9 months after radiotherapy (P > 0.05; Fig. 1A). The pH(S) was 6.88, higher than pH(P), before radiotherapy, and declined to the lowest 6.11 (P < 0.0001) at 3 months after radiotherapy. Even though it returned to 6.55, there was a significant difference between before and 12 months after radiotherapy (P = 0.018; Fig. 1B). The pH(total) was 6.93, higher than pH(P)/pH(S), before radiotherapy, and declined to the lowest 6.13 (P = 0.0001) at 2 months after radiotherapy. There was no difference between before and 12 months after radiotherapy (P > 0.05; Fig. 1C). The pH(B) declined from 7.60 to 7.07 before and 1 month after radiotherapy (P = 0.003). There was no difference between before and 9 months after radiotherapy (P > 0.05; Fig. 1D). The pH(p) declined from 6.69 to 6.33 before and 1 month after radiotherapy (P = 0.053). There was no difference between before and 12 months after radiotherapy (P > 0.05; Fig. 1E). In the single measurement group (n = 51), the pH(P), pH(S), pH(total), pH(B), and pH(p) are demonstrated in Table 5. According to the univariate linear regression model, the average pH(P) decreased 0.002 with age, decreased 0.018 in male patients, and increased 0.074 with time. The average pH(S) decreased 0.011 with age, decreased 0.068 in male patients, and increased 0.098 with time. The average pH(total) decreased 0.005 with age, decreased 0.116 in male patients, and increased 0.128 with time. The average pH(p) decreased 0.005 with age, decreased 0.216 in male patients, and increased 0.053 with time. Concerning the influence of time-period, four groups: pretreatment, < 1 year after radiotherapy, 1–5 years after radiotherapy, and > 5 years after radiotherapy were analyzed. The pH(P) in each group was 6.60, 6.24, 6.27, and 6.40 respectively, and there were no significant differences in all groups (Fig. 4A). The pH(S) in each group was 6.88, 6.49, 6.63, and 6.68 respectively, and there were no significant differences in all groups (Fig. 4B). The pH(total) in each group was 6.93, 6.24, 6.54, and 6.59 respectively, and statistically significant difference was reached between pretreatment and < 1 year after radiotherapy group (Fig. 4C). The pH(B) in each group was 7.6, 7.16, 7.35, and 6.97 respectively, and statistically significant differences were reached between pretreatment group, < 1 year after radiotherapy group and > 5 years after radiotherapy group (Fig. 4D). The pH(p) in each group was 6.69, 6.53, 6.57, and 6.70 respectively, and there were no significant differences in all groups (Fig. 4E).

**Stimulated salivary flow rate**

In the repeated measurement group, the flow rate (mL/5 min) was 7.18 before radiotherapy. It declined steeply to 2.71 (P < 0.0001) 1 month after radiotherapy, and to the lowest 1.5 at 2 months after radiotherapy. Although it increased slowly at 3 months after radiotherapy, it still could not return to the pretreatment level (P < 0.0001; Fig. 2). In the single measurement group, the flow rate decreased 0.009 with age, increased 1.156 in male patients, and decreased 0.197 with time (Table S2). Concerning the influence of time-period, four groups: pretreatment, < 1 year after radiotherapy, 1–5 years after radiotherapy, and > 5 years after radiotherapy were analyzed. The flow rate in each group was 7.18, 2.19, 3.78, and 1.47 respectively, and the latter three groups showed significant differences with pretreatment group (Fig. 4F).

<table>
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<tr>
<th>Variable</th>
<th>β</th>
<th>SE</th>
<th>P value</th>
<th>95% CI Lower bound</th>
<th>95% CI Upper bound</th>
</tr>
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<tbody>
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<td>pH(P)</td>
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<td></td>
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<tr>
<td>Age</td>
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<td>0.008</td>
<td>0.760</td>
<td>−0.018</td>
<td>0.013</td>
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<td>0.047</td>
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<td>pH(S)</td>
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<tr>
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<td>0.008</td>
<td>0.169</td>
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<tr>
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<td>0.045</td>
<td>0.002</td>
<td>0.193</td>
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<tr>
<td>pH(total)</td>
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<tr>
<td>Age</td>
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<td>pH(B)</td>
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<tr>
<td>Age</td>
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<td>0.696</td>
<td>−0.514</td>
<td>0.763</td>
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</table>

P < 0.05, significant difference.

B = regression estimated value; Buffering = buffering capacity; CI = confidence interval; pH(B) = pH of stimulated saliva; pH(P) = pH of dental plaque; pH(P) = pH of parotid gland; pH(S) = pH of submandibular gland; pH(total) = pH of total resting saliva; SE = standard error; Time = time period after radiotherapy.

a The time period was not normally distributed and so took the logarithmic form.

**Saliva buffering capacity**

In the repeated measurement group, the score was 11 before radiotherapy. It declined steeply to 8.50 at 1 month after radiotherapy, to lowest 7.29 (P < 0.0001) at 2-months after radiotherapy, and then increased. There was no significant difference between before and 5 months after radiotherapy (P > 0.05; Fig. 1F). In the single measurement group, the score increased 0.005 with age, increased 0.588 in male patients, and increased 0.125 with time (Table S5). Concerning the influence of time-period, four groups: pretreatment, < 1 year after radiotherapy, 1–5 years after radiotherapy, and > 5 years after radiotherapy were analyzed. The score in each group was 11, 7.94, 10.11, and 8.46 respectively, and...
statistically significant differences were reached between the pretreatment group, < 1 year after radiotherapy, and > 5 years after radiotherapy groups (Fig. 4G).

Pearson correlation coefficient

As shown in Fig. 3, pH(p) had a positive linear correlation with pH(P), pH(S), and pH(total). Statistically significant differences were found between pH(p) and pH(S), and with pH(total) respectively.

Discussion

Dysfunctions due to radiosensitivities of salivary glands might be differentiated into the early radiation event to alter cell signal transduction and the late radiation exposure to damage acinar progenitor cells in stem cells niche. Therefore we investigated salivary gland function changes of HCN patients in different time-intervals after radiotherapy. In the repeated measurement group, individual difference can be excluded because baseline data are from the same patient before radiotherapy, but patients are not easily kept for a long time. In the single measurement group, data from more patients for a longer time after radiotherapy can be easily collected, but interindividual variation may interfere with results because baseline data are from other normal patients. Many articles indicated that there were relatively large interindividual differences with respect to salivary functional changes, which was the reason why we performed

Figure 2  Salivary flow rate was analyzed by a mixed model in the repeat measurement group. Salivary flow rate was 7.18 before radiotherapy. It decreased steeply to 2.71 (P < 0.0001) at 1 month after radiotherapy and to the lowest 1.5 at 2 months after radiotherapy. Even though it increased to around 3.5 10–12 months after radiotherapy, it still could not return to the original level.

Figure 3  Pearson correlation coefficients indicated that pH(P), pH(S), and pH(total) had a statistically significant positive correlation with pH(p). The correlation coefficient of pH(p) with pH(S) was 0.66030 (P < 0.05). The correlation coefficient of pH(p) with pH(total) was 0.81178 (P < 0.05). pH(p) = pH of dental plaque; pH(P) = pH of parotid gland saliva; pH(S) = pH of submaxillary gland; pH(total) = pH of total resting saliva.
consecutive repeated measurements to figure out more accurate data. In our results, salivary flow rate decreased steeply from 7.18 to 2.71 ($P < 0.0001$) 1-month after radiotherapy and it could not return to the original level (Fig. 2). It was also reported that salivary flow rate reduced 50–70% after radiotherapy.\(^1\) According to Blanco et al.,\(^19\) salivary flow rate recovered from 2.15 to 3.15 (6–12 months after radiotherapy), which was consistent with...
our results (from 2.19 to 3.5). Besides, Möller et al.\textsuperscript{20} also reported that flow rate would slowly recover 4-months after radiotherapy but cannot return to the original level. From the results of the single measurement group, age, sex, and time-interval after radiotherapy were all not significant predictor factors for salivary flow rate. Most articles only reported the data of total saliva or stimulated parotid gland saliva.\textsuperscript{21} We further surveyed different types of saliva. Traditionally, the Lashley cup was put into the Stenson’s duct opening for parotid gland saliva and micropipette was put in the Wharton’s duct opening for submaxillary gland saliva collection. The acid base titrations, pH test strips, and handheld portable pH meters were mentioned for pH measurement,\textsuperscript{22–24} whereas the Modified Ericsson method, Dentobuff method, and Strip method were mentioned for buffering capacity.\textsuperscript{25–27} We used the GC Saliva-Check Buffer kit for its advantages of non-invasiveness, simplicity, and elegance.\textsuperscript{28} For patients who have fragile buccal mucosa, it is very important to collect their saliva gently. The advantages of this kit are ease of use, direct chair-side testing, simple symbols for tracking results, and adjunctives for caries risk assessment. However, it does not include bacterial testing and caries-risk predictability. To keep following patients who experienced radiotherapy for a long time, treating them gently and carefully was very important. From our results, pH(P), pH(S), and pH(total) all declined steeply at 1 month after radiotherapy, which was the same tendency with our salivary flow rate results. However, pH of saliva could recover back to near the original level (Fig. 1A–C). The high correlation of salivary flow rate and pH ($R = 0.71$) could explain our results.\textsuperscript{20} Besides, the value and tendency of pH(total) were more similar to pH(S) than pH(P) (Fig. 5). It might be because the total saliva was $\sim 65–80\%$ composed of saliva from submaxillary and sublingual glands.\textsuperscript{19} However, pH(P) was overall lower than pH(S) and pH(total), and pH(P) also later recovered back until 6 months after radiotherapy. This might be because serous acinar cells in parotid glands are more easily damaged by radiotherapy than mucous acinar cells in submaxillary glands.\textsuperscript{11,29} The lower flow rate of the parotid gland might also lead to its low pH value. Some articles indicated that salivary acinar and duct cells deteriorated then the secretion $\text{HCO}_3^-$ was reduced.\textsuperscript{4,21,30} Therefore, we hypothesized that the low saliva pH was due to accumulated acidic plaque which could not be neutralized by bicarbonate. Our results showed that pH(p) was higher than pH(P) and only slightly lower than pH(total) and pH(S) before radiotherapy, which means that the parotid gland was damaged more easily than the submaxillary gland. We also found that pH(p) was even higher than pH(total) and pH(S) for 1 year after radiotherapy (Fig. 6), which indicated that after a long time the buffering capacity of saliva was changed. It was difficult to prove our hypothesis. Because the pH of dental plaque was affected by complicated multifactors,\textsuperscript{8} more accurate pH measuring methods shall be performed to further examine our hypothesis. Our results also indicated that the pH of stimulated saliva, pH(B), was much higher than pH(P), pH(S), and pH(total) at every time point (Fig. 7). This might be because the bicarbonate was mostly produced by parotid gland into stimulated saliva.\textsuperscript{31} According to our results, to enhance stimulated saliva secretion would be very useful in oral hygiene improvements for
HCN patients after radiotherapy. The buffering capacity was inversely proportional to the caries rate. Our results indicated that the buffering capacity declined steeply at 1 month after radiotherapy but recovered back partially; whereas Möller et al indicated the buffering capacity and flow rate were irreversibly reduced after radiotherapy. Development of radiotherapy from traditional isocentric cobalt-60 into intensity modulated radiation therapy (IMRT) might help to decrease the radiation exposure and provide the possibility of buffering capacity recovery. The application of IMRT since 2006 in National Taiwan University Hospital might be the reason. During these decades, IMRT is an advanced form of three-dimensional conformal radiotherapy (3D-CRT). It uses the 3D treatment planning capabilities, such as computed topography, magnetic resonance imaging, on a slice-by-slice basis as opposed to drawing beam portals on a simulator radiograph. It appears to offer several advantages including a significant reduction in irradiated volume for normal salivary glands. It is anticipated that this reduction would translate into overall reductions in acute and potentially late treatment-related toxicity. According to our results, pH(B) and buffering capacity had a high correlation. As during the period of 4 months after radiotherapy, both pH(B) and buffering capacity were down to low levels, oral hygiene education would be very important (Fig. 8). Finally, according to the results of the single measurement group, the time period after radiotherapy was a significant predictor influencing the pH of submaxillary gland and whole resting saliva, which demonstrated their correlation again. Moreover, although we could not tell that the lower pH of saliva was due to dental plaque, results of Pearson’s correlation coefficient indicated that pH(P), pH(S), and pH(total) had a statistically significant positive correlation with pH(p) (Fig. 4). To reduce pellicle and plaque accumulation would be important in oral hygiene maintenance for HCN patients after radiotherapy.

Conflicts of interest

The authors have no conflicts of interest relevant to this article.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jds.2015.01.004.

References


