Comparison of Salivary Ion Activity Product for Hydroxyapatite (IPHA), Alkaline Phosphatase and Buffering Capacity of Adults According to Age and Caries Severity

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KEY WORDS
Dental Caries; Ion Activity; Saliva; Buffering

ABSTRACT

Statement of Problem: Tooth caries is influenced by different biochemical characteristics of saliva. As hydroxyapatite is the main component of enamel, salivary ion activity product for hydroxyapatite (IPHA) as well as alkaline phosphatase may be attributed to dental caries.

Purpose: The aim of the present study was to compare salivary buffering capacity, alkaline phosphatase and IPHA of adults according to the dental caries and age.

Materials and Method: One hundred and twenty 19 to 44 years old male individuals were divided into four groups according to the dental caries rate and age: group 1: 19-35 years old low dental caries (DMFT <5); group 2: 19-35 years old high dental caries (DMFT 5<); group 3: 35-44 years old low dental caries (DMFT <11) and 35-44 years old high dental caries (DMFT 11<). Five millilitre of unstimulated saliva was collected, and then buffering capacity, the level of alkaline phosphatase activity and IPHA was determined for each sample. Data was analyzed by soft ware SPSS using two-way ANOVA, Friedman and Mann-Whitney tests.

Results: Mean and standard deviation of buffering capacity of group 1 to 4 was 2.66±0.54, 2.64±0.56, 2.70±0.70 and 2.26±0.82, respectively. The difference was not significance ($p=0.305$). Mean and standard deviation of alkaline phosphatase activity of group 1 to 4 was 5.82±2.91, 5.30±1.52, 4.77±1.82 and 4.55±1.61, respectively. There was no significant difference ($p=0.692$). Mean and standard deviation of IPHA of group 1 to 4 was 29.39±0.61, 29.51±0.76, 29.14±0.56 and 29.75±0.75, respectively. The difference was significant ($p=0.049$).

Conclusion: Based on the results of the present study, buffering capacity and the level of alkaline phosphatase couldn’t affect dental caries, independently. However, the higher value of IPHA may be attributed to the higher dental caries rate. Ageing decreases alkaline phosphatase activity.


Introduction

Tooth caries, a common chronic infectious disease of the oral cavity, is considered as a complex phenomenon and is involved with different important factors including saliva characteristics, tooth surface morphology, oral hygiene. Different biochemical characteristics of
saliva such as salivary flow rate, buffering capacity, inorganic component, as well as proteins may affect the development of dental caries [1-2].

The normal structure of enamel is mainly consisted of hydroxyapatite, which contains a high degree of calcium and phosphate. It is expected that saliva might be effective on enamel maturation and remineralisation [3-4], with respect to its high level of calcium and phosphate [5-6]. However, spontaneous precipitation of these ions from saliva to tooth structure cannot occur [2]. Studies show that there are factors which may influence the function of calcium and phosphate on tooth remineralisation. Alkaline phosphatase, a salivary protein, may increase the concentration of salivary phosphate and the balance of demineralisation to remineralisation process of enamel. It seems that the function of this protein relatively depends on the salivary pH and buffering capacity [7].

To show the degree of saturation of the solutions, many authors used the ion activity product for hydroxyapatite (IPHA) calculated by employing the equation: \[ \text{IPHA} = \{\text{Ca}^{2+}\}^5 \{\text{PO}_4^{3-}\}^3 \{\text{OH}^-\} \] [8-10]. Different factors such as pH, buffering capacity, and temperature have shown, in an in-vitro experiment, to be effective on the IPHA [11]; however, it seems that there is a relationship between the values of IPHA and de- and remineralisation of the enamel [12].

To the best of our knowledge no clinical study has been performed yet to evaluate the relationship between the IPHA of saliva and tooth caries experience. Therefore it seems necessary to conduct a study to compare the IPHA, reflecting salivary calcium and phosphate concentration [12], alkaline phosphatase; which may balance enamel remineralisation [4], as well as buffering capacity; that may affect alkaline phosphatase function and the quantity of ion activity product for hydroxyapatite [7,12], regarding the caries risk and age.

The aim of the present study was to compare salivary IPHA, alkaline phosphatase, as well as buffering capacity of saliva in adults concerning the tooth caries prevalence.

Materials and Methods

Study population

In this observational cross sectional study [13], 120 men with age range of 19 to 44 years who were seeking for routine dental care in oral medicine department of Hamadan dental school, Hamadan, Iran, were participated. Respecting the previous studies [12, 14], those who had positive history of illnesses or treatments which could cause alteration in salivary rate and composition including diabetes, rickets, deformed osteitis, periodontal disease, history of radiotherapy or chemotherapy, dehydration, using antibiotic in recent two weeks, and mouth breath, were excluded from the study. The only inclusion criterion was regular teeth brush, for at least once in 24 hours. Informed consent was obtained from each individual, before any data collection and examination of the oral health status.

Dental examination

Data was collected by interview and clinical examination. An examiner was trained and informed with WHO instructions on tooth caries diagnosis. Prior to examination, teeth were isolated by cotton rolls. With patients sitting on the dental unit, a WHO periodontal probe and a No.4 flat mouth mirrors were used for each dental examination. Teeth lost or restored due to trauma, orthodontic treatment or aesthetic reasons were not considered as missed or filled teeth. Decayed (D), missed (M) and filled teeth were detected and DMFT were calculated.

According to the mean DMFT values of Iranian population of different ages reported in the previous studies [15-16], participants were divided into low and high risk groups; those with DMFT value higher than the mean DMFT of aged-matched population considered as high risk group and vice versa. Regarding the DMFT value and the age, participants were divided into four groups as follows; group 1 was composed of 30 low risk male individuals with age range of 19-35 years (DMFT<5), group 2 (was included 30 high risk men with age range of 19-35 years (DMFT>5), group 3 consisted of 30 low risk male individuals with 35 to 44 years old (DMFT<11) and finally 30 high risk men with age range of 35-44 years old (DMFT>11) were placed in to group 4.

Saliva collection and salivary buffering capacity

To reduce circadian effect, saliva collection was done between 9 and 11 am. Five millilitres of unstimulated saliva was collected in centrifuge tubes (HAILUN, Jiansu, China) after 2 hours with subjects being prevented of eating, drinking or brushing. Collected samples were delivered to the biochemistry lab. in 2 hours.
Shortly after delivering, 0.5 ml of each sample was used to measure the pH value within 30 seconds after the placement of pH-sensitive electrode (HANNA instruments®, Inc. Michigan, USA). Buffering capacity was determined by modified Ericsson method [19]. Regarding the salivary pH, after adding 1.5 ml of 5 mmol/L hydrochloric acid into the 0.5 ml saliva; samples were ranked to have: (1) low (pH<4.5); (2) medium (4.5<pH<5.5); and (3) high buffering capacity (pH 5.5) [20-21].

Measurement of total salivary calcium and phosphate concentration
In order to measure ion activity product for hydroxyapatite (IPHA); salivary calcium and phosphate concentrations were needed to be measured. For measuring calcium concentration, colorimetric method using Cresolphthalein complexone and produces purple solution in which the colour intensity is proportional to the calcium concentration. To examine the colour intensity, the light absorption of the solution was measured by spectrophotometer (JENWAY, Staffordshire, UK) in 570 nanometre wavelength, and finally calcium concentration was calculated in mg/dL [20].

Measuring salivary phosphate concentration was basically similar to that of calcium; however, two different solutions containing ammonium molibdate and sulphuric acid used to produce coloured solution. Light absorption of the solutions was measured by spectrophotometer in 340 nanometre wavelength and phosphate concentration was calculated in mg/dL [22].

Measurement of alkaline phosphatase concentration
The level of alkaline phosphatase activity (unit/L) was measured by kinetic method. In this method alkaline phosphatase converts 4-nitrophenyl phosphate into 4-nitrophenol and produces a yellow solution. The light absorption which matches up to the activity of alkaline phosphatase was assessed by spectrophotometer in 405 nanometre (nm) wavelength [4, 20].

Calculation of ion activity product for hydroxyapatite (IPHA)
As it is clear that the pH + pOH are 14 [23], after measurement of the pH of the samples, pOH was used to calculate the concentration of $\{\text{OH}^-\}$. $\text{IPHA}$ was calculated by placement of the concentration of calcium$^2+$, phosphate$^3-$ and OH$^-\$ in the following equation: $\text{IPHA} = \{\text{Ca}^{2+}\} \times \{\text{PO}_4^{3-}\} \times \{\text{OH}^-\}$, in which any value in the curly brackets shows the ion activity in saliva. In the present study, like the previous one [12], the negative logarithms of $\text{IPHA}$ ($\text{pIPHA}$) have been used for convenience in order to determine the enamel solubility. All calculations were done by current Microsoft Office Excel soft ware.

Statistical analysis
Data was analyzed by SPSS version 13.00 software. The mean salivary alkaline phosphatase and $\text{pIPHA}$ were compared among four experimental groups using Two-way ANOVA. In order to compare salivary buffering capacity of the groups, Friedman and Mann-Whitney tests were used. $P$-value of <0.05 was considered statistically significant in all analysis.

Results
The mean age of the individuals participated in the present study was 32.95±8.09. The mean numbers of decayed (D), missed (M) and filled (F) teeth, as well as DMFT for each experimental group are shown in Table 1. Salivary parameters including the average of salivary flow rate, pH, calcium and phosphate concentration of the four groups are illustrated in Table 2, separately.

<table>
<thead>
<tr>
<th>Experimental group</th>
<th>Mean D ± SD</th>
<th>Mean M ± SD</th>
<th>Mean F ± SD</th>
<th>Mean DMFT ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.24±1.10</td>
<td>0.93±0.50</td>
<td>1.96±1.62</td>
<td>3.70±1.51</td>
</tr>
<tr>
<td>2</td>
<td>2.76±2.47</td>
<td>1.71±1.5</td>
<td>4.46±2.68</td>
<td>8.70±2.34</td>
</tr>
<tr>
<td>3</td>
<td>1.80±1.42</td>
<td>2.52±2.50</td>
<td>3.60±2.11</td>
<td>7.90±1.90</td>
</tr>
<tr>
<td>4</td>
<td>4.50±4.07</td>
<td>6.06±4.71</td>
<td>5.06±4.08</td>
<td>15.60±2.96</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Experimental group</th>
<th>Mean FR ± SD</th>
<th>Mean pH ± SD</th>
<th>Mean Ca ± SD</th>
<th>Mean Ph ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.84±0.29</td>
<td>6.62±0.70</td>
<td>4.86±1.02</td>
<td>9.76±2.03</td>
</tr>
<tr>
<td>2</td>
<td>0.81±0.38</td>
<td>6.59±0.68</td>
<td>4.73±0.68</td>
<td>10.16±2.99</td>
</tr>
<tr>
<td>3</td>
<td>0.64±0.29</td>
<td>6.90±0.40</td>
<td>5.00±1.01</td>
<td>10.53±2.09</td>
</tr>
<tr>
<td>4</td>
<td>0.62±0.37</td>
<td>6.49±0.60</td>
<td>4.56±0.79</td>
<td>10.66±2.06</td>
</tr>
</tbody>
</table>
The results of Two-way ANOVA showed that the difference between the experimental groups were significant ($p=0.049$). Although, $PI_{PHA}$ was significantly different according to the DMFT ($p=0.003$), there was no significant difference between $PI_{PHA}$ of participants with different ages. The changes of $I_{PHA}$ according to the DMFT values of different age groups are shown in Figure 1.

The mean level of alkaline phosphatase activity of group one to four was 5.82±2.91, 5.30±1.52, 4.77±1.82 and 4.55±1.61, respectively. Two way ANOVA analysis showed that regarding the age, the difference was significant ($p=0.018$), however, neither the difference among four experimental groups ($p=0.692$) nor between high and low dental caries risk groups ($p=0.318$) was significant.

In the present study, similar to the previous study [24], total or rest saliva was used because of its long time contact with the teeth. Total saliva, compared to the limited secretion of stimulated saliva; is imparted in our mouth for approximately 14 hours a day [25]. As there is hormonal and physiological difference between two genders, we selected our subjects to be only male individuals in order to reduce inter and intra group differences. Regarding the possible effects of aging on salivary secretion and composition, the population participated in the present study were placed into two groups according to their age [26].

The balance between demineralisation and remineralisation of teeth surface depends on the salivary calcium and phosphate saturation [27]. Due to the controversial results of the previous studies which were conducted to evaluate the relationship between salivary calcium and phosphate concentration and tooth caries [28-30], in the present study; $pI_{PHA}$ was measured considering its ability to reflect calcium and phosphate saturation together and also its relationship with buffering capacity [11]. According to the results of the present study, the amount of $I_{PHA}$ is significantly different between low and high dental caries risk groups in all ages, but the difference is more prominent in older adults (Figure 1). Earlier in-vitro experiments reported different values for $pI_{PHA}$ ranging from 51.8 to 58.8 depended on the different condition, including temperature [9]. To the best of our knowledge, no clinical study was performed to evaluate the relation between $pI_{PHA}$ and tooth caries; however, Auichi et al. [11] reported that the mean value of $pI_{PHA}$ was 40 and was related to the salivary buffering capacity. In the present study the mean $pI_{PHA}$ was 29.45. Compared to previous study [9], the
results of the present study showed a lower amount of pIPHA. This difference may be contributed to the different variants such as gender of the participants whom the salivary samples were collected from, as well as initial pH of saliva.

The mean level of alkaline phosphatase activity in the present study was 5.11 unit/L and similar to the finding of Shaharabi et al [4] and Afshar et al [31] showed no significant difference between low and high dental-caries risk groups. Previous studies on salivary alkaline phosphatase activity showed different results. Contrary to our findings, Gandhy et al [12] reported that higher level of alkaline phosphatase activity is related to rampant caries. Based on our searching, no study compared the salivary alkaline phosphatase activity in different ages; however the results of this study showed that the older is patient, the lower is alkaline phosphatase activity.

Three different buffering capacity including bicarbonates, phosphates and proteins are responsible for salivary buffering [32]. Different factors such as hormones, metabolic conditions and general health could affect this capacity. So in the current study all participants were men with no systemic diseases in order to decrease the influence of the factors that could alter the results. In this study Ericson method [2] was used to evaluate salivary buffering capacity. According to this method, salivary pH after adding acid was considered as an appraisal factor for buffering capacity [2].

Results of the present study were similar to the findings of Monezgo et al. [33] and Gabris et al. [34]. It showed that there is no significant difference in buffering capacity of saliva according to dental caries risk. On the contrary, Lundgren et al. [35] observed that lower buffering capacity increased root caries prevalence. This differing result could be due to dissimilar methods of the two studies. Of these inconsistencies, structural difference between the root and crown, unstimulated or stimulated saliva could be declared. Age as well as gender was another difference of methods between these two studies [36].

Opposite to the results of the current study, Ruiz et al. [37] explained that buffering capacity could be deliberated as a predictive factor for dental caries prevalence. Different gender of the participants could be the cause of different results delivered by these two studies respecting the Heintze [36] study which reported sex hormones could affect the buffering capacity and it was higher in male subjects.

The results of the present study similar to the results of Palomares et al. [25], Kitasako et al. [38] and Farsi et al. [39], showed that there is no relationship between age and salivary buffering capacity.

Based on the current findings, salivary buffering capacity and alkaline phosphatase had no significant relationship with dental caries rate in male adults. Although salivary alkaline phosphatase activity reduces with age, no significant change occurs in buffering capacity. According to the results of the present study, since there is a significant relation between pIPHA and dental caries, it could be considered as a predictor of dental caries; however performing further research in a wider population, regarding the age, sex and race is suggested.

**Conclusion**
Based on the results of the present study, although buffering capacity and the level of alkaline phosphatase is not related to the severity of dental caries, IPHA index in individuals with higher teeth caries prevalence is higher than those with lower caries prevalence. Ageing decreases the level of alkaline phosphatase activity.

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