

Parotid saliva flow rate, calcium, phosphorus, and magnesium concentrations in relation to dental caries experience in children

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ABSTRACT

Flow rate, Ca, P, and Mg concentrations were measured in resting parotid saliva collected from 207 children (mean age 8.96 years) in relation to dental caries experience. DMFS values were one-third higher in boys than in girls, and this increase was accompanied by significantly lowered Ca ($P < 0.01$) and P ($P < 0.05$) concentrations in saliva. With all subjects divided into two DMFS groups, both P and Ca were decreased in the high DMFS group; the 9% decrease in Ca level was not significant.

Introduction

Saliva is an important factor in the maintenance of oral health. Beneficial effects are derived from the cleansing action of a copious flow of saliva and by interaction and exchange between the chemical constituents of saliva and the tooth surface.

By virtue of its chemical composition, human saliva is capable of rehardening buffer-softened enamel surfaces.¹ Since this reparative capacity is related to the mineral constituents of the fluid bathing the teeth, these components have received considerable research attention. Between-subject comparison of salivary constituents is plagued by the fact that alterations in rate of flow bring about marked changes in chemical composition. For this, as well as several other reasons, studies are few that have demonstrated even a statistically significant correlation between salivary components and dental health status.

It has been suggested that salivary flow rate may be a contributing factor in caries incidence.²⁻³ This relationship has been unquestionably authenticated in studies involving desalivated animals and in observations on markedly xerostomic patients, such as those under psychotherapy or receiving radiotherapy for lesions of the head and neck area.⁴⁻⁸

Utilization of whole saliva for biochemical studies is complicated by the fact that many of the constituents of this fluid are not of salivary origin. Further, it is extremely difficult to collect a true unstimulated whole saliva sample since movement of the oral musculature to expel the sample usually constitutes stimulation. Many of these complications may be obviated by collection of unstimulated samples from the parotid gland. If an appropriate device is employed, if it is positioned with an absolute minimum of manipulation, and if subject activity is carefully monitored, it is possible in most instances to collect what may be properly classified as the resting secretion.

Such a procedure was utilized in collecting unstimulated parotid saliva from 3786 subjects and a significant decrease in rate of flow was found to be related to dental caries experience.⁹ It was also demonstrated that chloride,¹⁰ bicarbonate,¹¹ glucose,¹² and sodium and potassium¹³ concentrations in this fluid were not significantly related to DMFS. In one study,¹⁴ however, it was shown that phosphorus concentration was inversely related to dental caries experience and that this relationship was particularly significant when subjects with DMFS rates of 10 and below were compared to those with DMFS scores exceeding 40.

Since subjects in this previous study were mature young adult males, it appeared appropriate to conduct an experiment including phosphorus evaluation in youngsters during the very caries-prone years. The present study was designed to evaluate primarily the relationships between dental caries experience and flow rate, and the concentrations of calcium, phosphorus and magnesium.

Materials and methods

Subjects were 207 children (99 boys, 108 girls) between the ages of 3 and 16 years accepted as teaching

cases at the University of Texas Dental Branch. Parotid fluid sampling was undertaken at 8:00 a.m. with the subjects in a fasting state and seated comfortably in a quiet area. A metal collection device¹⁵ was placed over the orifice of the right Stensen's duct with a minimum of manipulation. Saliva was collected in calibrated tubes and the volume read to the nearest 0.05 ml.

No exogenous stimulation was used and every effort was made to obtain as nearly as possible the resting secretion of the parotid gland. Collection time varied from 7 to 58 min depending upon the time needed to collect an adequate sample. The children viewed films on toothbrushing, watched television, or read during the collection period. Complete clinical and roentgenologic examinations served to establish the DMFS score. Teeth were not scored as missing unless extracted as a result of carious involvement.

Salivary flow rate was estimated by dividing volume by collection time. Calcium and magnesium were measured with an atomic absorption spectrophotometer after dilution of saliva 1:10 with an aqueous solution containing 0.89% lanthanum oxide and 0.4% hydrochloric acid. Phosphorus concentration was measured as inorganic phosphate by the method of Fiske and SubbaRow as adapted to automated equipment.¹⁶ Concentrations of calcium, phosphorus, and magnesium were converted to minute secretion rates (milligrams per 100 ml \times 10 \times flow rate = micrograms per minute), thus providing an additional variable for analysis.

Conventional analyses of variance, *t*-tests and the Duncan Multiple Range test were applied to search for overall differences between DMFS groups, and to identify specific means that did differ significantly. A

correlation matrix evolved as a portion of a stepwise regression analysis which sought DMFS predictors and provided concentration-flow rate relationships.

Results

Table 1 presents means and standard deviations for all variables with all 207 children in the analysis. A comparison based upon sex is also provided. Caries experience was significantly ($P < 0.01$) higher in boys than in girls. This one-third higher DMFS was accompanied by significantly lower concentrations of calcium ($P < 0.01$) and phosphorus ($P < 0.05$). There was also an 11% lower magnesium level, but this did not reach the level of statistical significance.

Table 2 outlines the effect of age on DMFS score, flow rate, and the concentration and secretion rates for calcium, phosphorus, and magnesium. Age effects significant at the 0.05 level were noted for flow rate, magnesium concentration, and the minute secretion rates for calcium and phosphorus; effect of age on magnesium secretion rate was significant at the 0.01 level.

Subjects were then divided for analysis into two widely varying DMFS groups—less than 10 DMFS (mean 4.2; S.D. = 3.06) *vs.* 10 or more DMFS (mean 17.2; S.D. = 5.57). The decrease in parotid saliva phosphorus concentration from 39.1 mg/100 ml (S.D. = 16.20) to 34.8 mg/100 ml (S.D. = 12.55) associated with the more than 300% increase in average caries experience in the high DMFS group was significant at the 0.05 level. The parallel 9% decrease in calcium concentration from 4.6 mg/100 ml (S.D. = 1.83) to 4.2 mg/100 ml (S.D. = 1.54) did not reach the 0.05 level ($t = 1.69$). Magnesium values did not differ significantly.

Table 1. Effect of sex on caries experience and parotid saliva variables in 207 children

Variable	All subjects (N = 207)		Boys (N = 99)		Girls (N = 108)		Males vs. females significance
	Mean	S.D.	Mean	S.D.	Mean	S.D.	
Age	8.96	2.46	9.02	2.18	8.90	2.71	N.S.
DMFS	10.2	7.83	11.7	8.33	8.8	7.10	<0.01
Flow Rate (ml/min)	0.034	0.028	0.035	0.024	0.033	0.032	N.S.
Calcium (mg/100 ml)	4.4	1.71	4.1	1.46	4.7	1.87	<0.01
Phosphorus (mg/100 ml)	37.1	14.77	34.7	12.07	39.4	16.61	<0.05
Magnesium (mg/100 ml)	0.33	0.18	0.31	0.18	0.35	0.17	N.S.
Calcium (μ g/min)	1.3	1.00	1.3	0.82	1.3	1.15	N.S.
Phosphorus (μ g/min)	11.1	8.39	11.0	6.54	11.2	9.84	N.S.
Magnesium (μ g/min)	0.11	0.10	0.10	0.07	0.11	0.12	N.S.

Table 2. Effect of age on caries experience and parotid saliva variables in 207 children

Variable	Age in years							
	3-6 (N = 33)		7-8 (N = 54)		9-10 (N = 64)		11-16 (N = 56)	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
DMFS	6.1	6.93	10.6	8.45	12.7	8.41	9.4	5.90
Flow Rate (ml/min)	0.032	0.024	0.029	0.024	0.036	0.029	0.039	0.033
Calcium (mg/100 ml)	3.7	1.38	4.5	1.55	4.7	1.99	4.3	1.63
Phosphorus (mg/100 ml)	39.7	15.58	36.1	14.19	36.0	13.62	38.3	16.21
Magnesium (mg/100 ml)	0.25	0.13	0.33	0.17	0.34	0.20	0.36	0.18
Calcium (μ g/min)	1.0	0.81	1.2	0.99	1.4	0.93	1.5	1.17
Phosphorus (μ g/min)	10.4	6.50	9.5	7.34	11.2	7.32	13.0	10.95
Magnesium (μ g/min)	0.07	0.05	0.10	0.11	0.11	0.08	0.14	0.12

Table 3. Effect of parotid flow rate on concentrations of calcium, phosphorus, and magnesium (N = 207)

Flow rate grouping	No. of subjects	Parotid saliva constituents					
		Calcium		Phosphorus		Magnesium	
		Mean	S.D.	Mean	S.D.	Mean	S.D.
<i>ml/min</i>		<i>mg/100 ml</i>		<i>mg/100 ml</i>		<i>mg/100 ml</i>	
<0.011	30	5.8	2.13	48.9	18.83	0.45	0.10
0.011-0.020	57	4.8	1.43	43.7	16.06	0.37	0.17
0.021-0.030	39	4.4	1.33	31.0	9.79	0.35	0.19
0.031-0.050	39	3.7	1.40	27.2	7.78	0.30	0.16
0.051-0.080	26	3.7	1.48	30.1	7.59	0.26	0.18
>0.080	16	3.0	1.29	14.6	7.33	0.25	0.16

Subjects were also divided into six differing flow rate groups to ascertain the effect of rate of flow on calcium, phosphorus, and magnesium concentrations (Table 3). A significant negative relationship at least at the 0.01 level, was found between flow rate and calcium ($r = -0.459$), flow rate and phosphorus ($r = -0.443$), and flow rate and magnesium level ($r = -0.409$). Thus, subjects with higher rates of resting flow tended to have lower concentrations of each of these variables in the saliva.

Discussion

It is unquestionably true that, among other probable mechanisms, saliva protects against cariogenic challenge by counteracting demineralization or encouraging remineralization. Foremost among the constituents of saliva that would be expected to enhance this

potential are calcium, magnesium, phosphorus, and fluoride.¹⁷

Considerable research attention has been directed toward calcium and phosphorus levels in saliva in relation to caries experience, but Afonsky¹⁸ concluded from his review that while there is a tendency for higher average calcium and phosphorus values in caries-free persons, no conclusive evidence has been presented to support the premise that the concentration of either is of importance in caries prevention of susceptibility.

Shannon *et al.*¹⁴ showed that unstimulated parotid fluid phosphorus concentration was inversely related to dental caries incidence in 514 young adults, and that when the phosphorus values for subjects with DMFS rates of 10 or less were compared to those with 41 or higher, significant differences were found. Unfortunately, the importance of this finding was mini-

mized by overlapping individual values, and it was emphasized that this negated the possibility of using phosphorus levels in diagnosing caries susceptibility.

The present study demonstrates that an inverse caries-parotid saliva phosphorus relationship is also present in children. Although overlapping values again preclude a caries susceptibility test, these corroborative findings point out that the salivary phosphorus definitely is implicated in caries incidence.

DMFS scores were significantly ($P < 0.01$) higher in boys than in girls. This higher rate of caries experience has been reported by others conducting surveys in children in this same institution. Asarch¹⁹ examined an equally divided group of 94 boys and girls and reported DMFS means of 11.34 and 7.66, respectively ($P < 0.05$). For girls, in association with the healthier oral state, the levels of calcium and phosphorus in saliva were significantly ($P < 0.01$ and $P < 0.05$, respectively) higher than was the case in boys. This result lends credence to the previously reported correlations between these variables.

No significant flow rate differences were noted between male and female children in the present study. Previous reports have established a sex-related difference in stimulated whole saliva flow rate¹⁸ and an inverse flow rate-caries relationship⁹ in adults. Thus, flow rate differences would be expected. Further, the age effects in children ranging from 3 to 16 years on flow rate, magnesium concentration, and the secretion rates for calcium, phosphorus, and magnesium all point to definite differences between the parotid glands of children and adults.

Differences, however, are confounded by the finding that unstimulated parotid glands of children and adults manage the secretion of calcium, phosphorus, and magnesium similarly. The concentrations of calcium, phosphorus, and magnesium in unstimulated saliva are inversely related to flow rate. Thus, individuals who tend to flow faster in the absence of exogenous stimulation have lower calcium, phosphorus, and magnesium concentrations. This may be explained by the resorptive movement of sodium in the duct system.

It has been proposed that the parotid glands elaborate an acinar fluid which is essentially plasma-like with respect to osmolarity and electrolyte composition.²⁰ During the passage of the acinar fluid down the duct system, sodium is reabsorbed as potassium is secreted.

However, the sodium of the final fluid remains relatively constant over a wide range of very low flow rates due to simultaneous proportional reabsorption of water.²¹ This decrease in water content, proportional to the decrease in rate of flow, increasingly concentrates the remaining constituents, including calcium, phosphorus, and magnesium, and produces the inverse flow rate-constituent relationship. This con-

cept is substantiated by the finding that sodium levels remain constant as atropine administration reduces flow rate and increases calcium, phosphorus, and magnesium concentration.²² Thus, although glandular mechanisms appear to operate similarly in children and adults, the final product appears to be affected by the maturity of the gland.

However, the main point of this study is confirmation of the finding that saliva phosphorus is related to caries experience. Clark and Levine,²³ as early as 1927, showed that ingestion of inorganic phosphate is followed by a rapid excretion of phosphate in whole saliva. Bates²⁴ demonstrated an increase in parotid saliva phosphate concentration following infusion of an orthophosphate solution. This suggests that dietary phosphorus intake may have an important caries-preventive role.

Summary

Resting parotid saliva samples were collected from 207 children in the 3-16 year age group (mean age 8.96 years) and determinations made of rate of flow and concentrations of calcium, magnesium, and phosphorus.

Caries experience was one-third higher in boys than in girls. This increase in DMFS was accompanied by significantly lower concentrations of salivary calcium ($P < 0.01$) and phosphorus ($P < 0.05$). Magnesium level was also lower by 11% (NS).

When subjects were divided into two widely varying DMFS groups the decrease in phosphorus associated with the high DMFS was significant at the 0.05 level. There was an associated 9% decrease in calcium level (NS).

The concentrations of calcium, phosphorus, and magnesium in unstimulated parotid saliva were all negatively correlated ($P < 0.01$) with rate of salivary flow.

While none of these test variables could be employed as an index of caries susceptibility in individual patients, it is clear that the presence of elevated levels of calcium and phosphorus in the saliva of children is protective against dental caries. This is a solid base from which clarifying experiments can be designed.

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