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ORIGINAL ARTICLE

Salivary flow rate and periodontal infection – a study among subjects aged 75 years or older

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OBJECTIVE: To analyse the relation of stimulated and unstimulated salivary flow rates to periodontal infection in home-dwelling elderly people aged 75 years or older.

SUBJECTS AND METHODS: This study was based on a subpopulation of 157 (111 women, 46 men) home-dwelling, dentate, non-smoking elderly people (mean age 79.8, SD 3.6 years) from the Geriatric Multidisciplinary Strategy for the Good Care of the Elderly Study). The data were collected by interview and oral clinical examination.

RESULTS: Persons with very low (<0.7 ml min^{-1}) and low stimulated salivary flow rates (0.7–<1.0 ml min^{-1}) had a decreased likelihood of having teeth with deepened (≥4 mm) periodontal pockets, RR: 0.7, CI: 0.5–0.9 and RR: 0.7, CI: 0.5–0.9, respectively, when compared with those with normal stimulated salivary flow. Persons with a very low unstimulated salivary flow rate (<0.1 ml min^{-1}) had a decreased likelihood of having teeth with deepened (≥4 mm) periodontal pockets, RR 0.8, CI: 0.6–1.0, when compared with subjects with low/normal unstimulated salivary flow.

CONCLUSIONS: In a population of dentate, home-dwelling non-smokers, aged 75 years or older, low stimulated and unstimulated salivary flow rates were weakly associated with a decreased likelihood of having teeth with deep periodontal pockets.

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Keywords: salivary flow rate; periodontal infection; elderly people

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Introduction

The antimicrobial constituents of saliva, such as IgA, IgG, IgM, lysozyme, lactoperoxidase, lactoferrin, mucins and histatins, as well as bacterial clearance act as defence mechanisms against oral pathogens. In a situation where salivary flow is decreased, bacterial clearance is decreased and normal microbial homoeostasis is unbalanced. For example, counts of *Candida* (Shimizu *et al*, 2008) and cariogenic microbes like *Lactobacillus* and *Streptococcus mutans* (Almståhl and Wikström, 2005) are elevated in persons with a decreased salivary flow rate.

Reduced salivary flow has also been found to relate to clinical outcomes such as dental caries (Dawes, 2008), fungal infections (Dawes, 2008), lower number of teeth (Flink *et al*, 2008), tooth loss (Caplan and Hunt, 1996) and a variety of subjective symptoms (Turner and Ship, 2007). The results of studies focusing on the relationship between reduced salivary flow and periodontal disease are inconclusive; some studies have found an association (Crow and Ship, 1995; Farsi *et al*, 2008; Márton *et al*, 2008), whereas in others, no association has been found (Sewón *et al*, 1990; Ship *et al*, 1991; Almståhl and Wikström, 1999; Hirotomi *et al*, 2006, 2008; Koss *et al*, 2009). To our knowledge, only two studies have been conducted among elderly people (Hirotomi *et al*, 2006, 2008).

Elderly people often suffer from hyposalivation due to medication (Cassolato and Turnbull, 2003; Scully, 2003; Wolff *et al*, 2008) or various systemic diseases (von Bültzingslöwen *et al*, 2007). For reasons of reduced bacterial clearance and unbalanced microbial homoeostasis, it can be hypothesized that a reduced salivary flow rate is a risk factor for periodontal infection. The aim of this study was to analyse the relation of

stimulated and unstimulated salivary flow rates to periodontal infection in elderly people.

Material and methods

Study population
This study is based on a subpopulation of 157 home-dwelling, dentate, non-smoking elderly people (111 women, 46 men, mean age 79.8, SD 3.6 years) from the GeMS intervention study (Geriatric Multidisciplinary Strategy for the Good Care of the Elderly). Originally, 1000 participants aged 75 years or older on the first of November 2003 were randomly drawn from the Population Register Centre from the total population of elderly living in the city of Kuopio, in eastern Finland. Written informed consent was obtained from the participants or their relatives. The study protocol was approved by the ethics committee of Kuopio University Hospital and the University of Kuopio.

Interview and geriatric clinical examination
A trained nurse and a geriatrician carried out a clinical examination and interviewed the participants about their health status and health behaviour. If the subject was unable to answer the questions, a close relative or caregiver provided the information, and if the person was unable to visit the municipal health centre, a trained nurse and a geriatrician made a home visit to conduct the interview and examination. Medical records from the municipal health centre, home nursing service, local hospitals and Kuopio University Hospital were also used.

Oral clinical examination
An oral clinical examination was performed during the years 2004–2005 on participants belonging to the intervention group (n = 354) (27 refused and 23 died before the oral examination). Thus, the oral clinical examination was conducted on 354 subjects. After restriction to home-dwelling, dentate (at least one clinically visible tooth or tooth root) non-smoking subjects, the final study population consisted of 157 subjects for whom unstimulated or stimulated salivary flow rate was measured.

During the dental appointment, two dentists performed the oral clinical examination. The dentists were calibrated before the data collection period by examining seven subjects together, and the clinical examinations were performed in a standardized manner based on written instructions. As a result of the high age of the participants and the length of the examination, repeated examinations were not conducted. The clinical oral examinations were conducted in a dental unit with dental chair, saliva suction, a syringe and the unit lamp, using a WHO colour-coded periodontal probe, a mouth mirror and a gauze pad. If the subject preferred a dental visit outside of the dental clinic, the dentist made a home visit with a dental nurse or dental hygienist. No radiograph was taken if not clinically indicated.

Outcome variable
The number of teeth with periodontal pockets with a pocket depth ≥4 mm was used as an outcome variable to measure the presence of periodontal infection. The periodontal pockets were probed on the distopalatal/lingual and mesiobuccal approximal surfaces of all teeth.

Explanatory variables
The subjects were asked to abstain from eating and drinking for 1 h before the measurement of unstimulated and stimulated salivary flow rates. Among person with dentures, collection of unstimulated saliva was carried out without dentures and collection of stimulated saliva, with dentures.

Unstimulated salivary flow rate was measured using the draining method (Navazesh, 1993). To measure the unstimulated salivary flow rate, the subjects were asked to sit straight and bend their head slightly forward. The subjects were first asked to swallow, and then to drool saliva for 5 min into a centrifuge tube. To collect the stimulated saliva samples, the participants were first advised to swallow, then asked to chew a paraffin wax capsule for 30 s and then to spit or swallow saliva. After clearing the mouth of saliva, the paraffin wax was chewed and the saliva stimulated through mastication was drained for 5 min into a glass centrifuge tube.

The stimulated salivary flow rate was classified as <0.7 ml min^{-1} (very low), $0.7-<1.0$ ml min^{-1} (low) and ≥ 1.0 ml min^{-1} (normal), and unstimulated salivary flow as <0.1 ml min^{-1} (very low), 0.1–0.2 ml min^{-1} (low) and over 0.2 (normal) based on the literature (Flink *et al*, 2008). In our study, the unstimulated salivary flow rate categories 0.1–0.2 ml min^{-1} and over 0.2 ml min^{-1} were combined because there were too few participants in the 0.1–0.2 ml min^{-1} category of unstimulated salivary flow rate. Correlation coefficient between stimulated and unstimulated salivary flow rate was 0.61.

Other variables
After light drying with air syringes, dental plaque on the buccal and palatal surfaces of all teeth was recorded on the basis of visual observation. Dental plaque was classified into three categories: less than 20%, 20–50%, more than 50% of the examined tooth. Dental calculus (including both supra- and/or subgingival calculus) was measured while probing periodontal pockets on the distopalatal/lingual and mesiobuccal approximal surfaces of all teeth. Dental calculus was classified in two ways; more than 20% *vs* less, and more than 50% *vs* less, of the examined tooth.

Dental visits were classified as regularly *vs* symptom-based or never. Tooth brushing frequency was asked during the oral clinical examination and it was classified as tooth brushing twice a day or more often *vs* once a day or more seldom.

The Lawton Instrumental Activities of Daily Living Scale (IADL) was used to assess independent living skills and functional status (Lawton and Brody, 1969). It was measured by means of an IADL questionnaire,

which included eight domains. The sum IADL score ranged from 0 (low) to 8 (high), and the IADL score was classified into two groups (IADL score 0–6 *vs* 7–8).

Body mass index (BMI), (body weight in kilograms/height in meters^2) was categorized as BMI <30 *vs* BMI ≥ 30. Diabetes was determined on the basis of information obtained from the geriatric clinical examination, a recorded medical diagnosis or reimbursable medication. Rheumatoid diseases were determined on the basis of a recorded medical diagnosis.

Duration of education was dichotomized as 7 years or more *vs* less than 7 years. Smoking habits were asked as to whether the respondents had never smoked, smoked previously but stopped, smoked occasionally or smoked daily. The study was restricted to non-smokers. The descriptive statistics related to the salivary flow rate are presented in Table 1.

Statistical methods

Poisson multivariate regression models were used to estimate relative risk (RR) and 95% confidence intervals (CI). The models were adjusted for age, gender, education, presence of dental plaque, dental visits, tooth brushing frequency, diabetes, BMI, physical activity (IADL score) and number of teeth (offset variable). The SPSS 16.0 software for Windows (SPSS Inc, 2008) was used in the statistical analyses.

Results

In our population, 33% had a decreased stimulated and 30% a decreased unstimulated salivary flow rate. On average, those who had low salivary flow more often had various diseases, such as diabetes and rheumatoid arthritis, more often were obese, more often had lowered physical activity and used more drugs (Table 1).

Unadjusted risk estimates for the explanatory variables are presented in Table 2. After controlling for confounding factors, persons with very low (<0.7 ml min^{-1}) and low stimulated salivary flow rates (0.7– <1.0 ml min^{-1}) had a decreased likelihood of having teeth with deepened (≥4 mm) periodontal pockets, RR: 0.7, CI: 0.5–0.9 and RR: 0.7, CI: 0.5–0.9, respectively, when compared with those with a normal stimulated salivary flow rate. Those with a very low unstimulated salivary flow rate (<0.1 ml min^{-1}) had a decreased likelihood of having teeth with deepened (≥4 mm) periodontal pockets, RR 0.8, CI: 0.6–1.0, when compared with subjects with a low/normal unstimulated salivary flow rate (Table 3.).

Table 1 Basic characteristics of the study population by different categories of stimulated and unstimulated salivary flow rate

	Stimulated salivary flow rate[a]			*Unstimulated salivary flow rate*[b]	
Variable	*<0.7 ml min^{-1}* n = *30/153*	*0.7–<1.0 ml min^{-1}* n = *20/153*	*≥1.0 ml min^{-1}* n = *103/153*	*<0.1 ml min^{-1}* n = *47/156*	*≥0.1 ml min^{-1}* n = *109/156*
Sociodemographic variables					
Gender, proportion of men (*n*, %)	4/30 (13.3)	3/20 (15.0)	36/103 (35.0)	8/47 (17.0)	38/109 (34.9)
Age (mean ± SD)	82.2 ± 4.1	81.6 ± 3.6	80.0 ± 3.4	80.3 ± 3.8	80.3 ± 3.8
≥85 years (*n*, %)	7/30 (23.3)	4/20 (20.0)	9/103 (8.7)	9/47 (19.1)	12/109 (11.0)
Education ≥7 years (*n*, %)	16/29 (55.2)	12/20 (60.0)	57/101 (56.4)	27/46 (58.7)	59/107 (55.1)
Dental variables					
Number of teeth (mean ± SD)	14.6 ± 8.2	12.5 ± 7.9	15.8 ± 8.0	14.0 ± 8.1	15.6 ± 8.0
Proportion of participants with ≥1 tooth with periodontal pockets ≥4 mm (*n*, %)	15/30 (50.0)	11/20 (55.0)	62/103 (50.2)	27/47 (57.4)	62/109 (56.9)
Number of teeth with periodontal pockets ≥4 mm (mean ± SD)	2.4 ± 3.5	2.6 ± 3.7	2.7 ± 3.9	2.3 ± 3.1	2.8 ± 4.0
Number of teeth with periodontal pockets ≥4 mm (median)	0.5	1.0	1.0	1.0	1.0
Number of carious teeth (mean ± SD)	1.7 ± 2.7	1.0 ± 1.9	1.0 ± 1.9	1.3 ± 2.0	1.2 ± 2.1
Dental plaque					
<20% of teeth with dental plaque (*n*, %)	7/30 (23.3)	6/20 (30.0)	41/103 (39.8)	13/47 (27.7)	40/109 (36.7)
20–50% of teeth with dental plaque (*n*, %)	8/30 (26.7)	3/20 (15.0)	27/103 (26.2)	11/47 (23.4)	27/109 (24.8)
>50% of teeth with dental plaque (*n*, %)	15/30 (50.0)	11/20 (55.0)	35/103 (34.0)	23/47 (48.9)	42/109 (38.5)
Dental calculus					
>20% of teeth with dental calculus (*n*, %)	21/30 (70.0)	16/20(60.0)	78/102 (76.5)	31/47 (66.0)	83/108 (76.1)
>50% of teeth with dental calculus (*n*, %)	12/30 (40.0)	6/20 (30.0)	43/102 (41.7)	18/47 (38.3)	46/108 (42.6)
Dental visits (*n*, %)	15/29 (51.7)	10/20 (50.0)	65/103 (63.1)	25/45 (55.6)	66/109 (60.6)
Tooth brushing twice a day (*n*, %)	19/30 (63.3)	13/20 (65.0)	74/103 (71.8)	30/47 (63.8)	76/109 (69.7)
General health-related variables					
Diabetes (*n*, %)	10/30 (33.3)	2/20 (10.0)	6/103 (5.8)	10/47 (21.3)	8/109 (7.3)
BMI ≥30 (*n*, %)	10/29 (34.5)	5/19 (26.3)	19/103 (18.4)	10/44 (22.7)	24/108 (22.2)
IADL score 0–6 (*n*, %)	11/30 (36.7)	5/19 (26.3)	16/103 (15.5)	16/47 (34.0)	19/108 (17.6)
Rheumatoid diseases (*n*, %)[c]	4/30 (13.4)	1/20 (0.5)	12/103 (11.7)	6/47 (12.8)	11/109 (10.1)
Number of drugs (mean ± SD)	7.4 (3.7)	3.8 (2.2)	4.3 (2.8)	6.5 (3.7)	4.1 (2.7)

[a]Stimulated salivary flow rate was missing from 4 participants.
[b]Unstimulated salivary flow rate was missing from 1 participant.
[c]Data in 2006.

Table 2 Factors related to the number of teeth with periodontal pockets ≥4 mm deep. Unadjusted relative risks (RR) with 95% confidence intervals (CI) of Poisson regression models

Variable	n	*Number of teeth with periodontal pockets ≥4 mm Unadjusted RR (95% CI)*
Stimulated salivary flow	153	
≥1.0 ml min^{-1}		1.0
0.7–<1.0 ml min^{-1}		1.2 (0.9–1.6)
<0.7 ml min^{-1}		0.9 (0.7–1.2)
Unstimulated salivary flow	156	
≥0.1 ml min^{-1}		1.0
<0.1 ml min^{-1}		0.9 (0.7–1.1)
Age, continuous	157	1.01 (0.99–1.04)
Gender	157	
female		1.0
male		0.8 (0.7–1.0)
Education	154	
≥7 years		1.0
<7 years		0.9 (0.7–1.1)
Dental plaque	157	
<20% of teeth with dental plaque		1.0
20–50% of teeth with dental plaque		1.6 (1.2–2.1)
>50% of teeth with dental plaque		1.7 (1.3–2.1)
Dental visits	155	
regularly		1.0
symptom-based or never		1.8 (1.5–2.2)
Tooth brushing	157	
twice a day		1.0
once a day or more seldom		1.3 (1.1–1.6)
Diabetes	157	
no		1.0
yes		1.0 (0.7–1.3)
BMI	153	
<30		1.0
≥30		1.3 (1.1–1.7)
IADL score	156	
7–8		1.0
0–6		1.1 (0.9–1.4)

Table 3 Relation between the stimulated salivary flow rate and unstimulated salivary flow rate and the number of teeth with periodontal pockets ≥4mm deep. Adjusted relative risks (RR) with 95% confidence intervals (CI) of Poisson regression models[a]

Variable	*Number of teeth with periodontal pockets ≥4 mm RR (95% CI) Total study population* n = *157*	*Number of teeth with periodontal pockets ≥4mm RR (95% CI) Persons with ≥10 teeth* n = *103*
Stimulated salivary flow		
≥1.0 ml min^{-1}	1.0	1
0.7–<1.0 ml min^{-1}	0.7 (0.5–1.0)	0.3 (0.2–0.6)
<0.7 ml min^{-1}	0.7 (0.5–0.9)	0.8 (0.6–1.1)
Unstimulated salivary flow		
≥0.1 ml min^{-1}	1.0	1
<0.1 ml min^{-1}	0.8 (0.7–1.0)	0.7 (0.6–0.9)

[a]Adjusted for age, gender, education, dental plaque, dental visits, tooth brushing, diabetes, BMI, IADL score.

When the data were restricted to those with 10 or more teeth, it was found that persons with very low and low stimulated salivary flow rates had a decreased likelihood of having teeth with deepened periodontal pockets, RR: 0.3, CI: 0.2–0.6 and RR: 0.8, CI: 0.6–1.1, respectively, when compared with those with a normal stimulated salivary flow rate. Those with a very low unstimulated salivary flow rate had a decreased likelihood of having teeth with deepened periodontal pockets, RR 0.7, CI: 0.6–0.9, when compared with subjects with a low/normal unstimulated salivary flow rate (Table 3.).

Discussion

Our hypothesis was that a reduced salivary flow rate posed a risk factor for periodontal infection by reducing bacterial clearance and having an effect on microbial homoeostasis. Our results showed, however, that a low salivary flow rate was not associated with an increased likelihood but was in fact weakly associated with a decreased likelihood of having teeth with deepened periodontal pockets. We did not study how low salivary flow was connected to periodontal health, but there are plausible biological mechanisms such as decreased formation of dental calculus or changes in the composition of dental biofilm, for instance.

In our data, those who had reduced salivary flow had more dental plaque and slightly although statistically non-significantly less dental calculus than those with normal salivary flow. One possibility is that calculus formation is reduced among those with low salivary flow. This would be in accordance with earlier studies, where hyposalivation has been found to be related to lower pH in saliva (Bardow *et al*, 2001) and a lower salivary output of bicarbonate, sodium, potassium, calcium and phosphate (Almståhl and Wikström, 2003), which in turn may lead to decreased saturation of calcium phosphates and decreased formation of supragingival calculus.

Another explanation for why those with low salivary flow had less periodontal pockets could be that the bacterial composition of dental plaque may differ between those who had low salivary flow and those with normal salivary flow. One environmental factor affecting the composition of dental plaque is the pH in the oral cavity. It is known that gram-negative periodontal pathogens, such as *Bacteroides intermedius*, *Fusobacterium nucleatum* (Bradshaw *et al*, 1989), *Prevotella nigrescens* (Bradshaw and Marsh, 1998) and *Aggregatibacter actinomycetemcomitans* (Haase *et al*, 2006), favour neutral or alkaline pH. Thus, it is understandable that the acid environment related to a low salivary flow rate is not a suitable milieu for periodontal pathogens.

Despite the fact that the participants of the study were old, the rate of participation in the oral clinical examination was fairly high (70.8%), which was achieved by means of visits outside of the dental clinic. The study population consisted of 75-year-old or older home-dwelling, non-smoking residents of the city of Kuopio, meaning the participants did not differ essentially in relation to age, ethnic origin, physical capacity and smoking history. In addition, we adjusted for

potential confounders such as age, gender, education, presence of dental plaque, dental visits, tooth brushing frequency, diabetes, BMI, physical activity and number of teeth (as an offset variable).

Further strengths were that thorough clinical examinations were carried out by a multiprofessional team including two dentists, a geriatrician and a nurse. The dental examiners were calibrated before the data collection period by examining seven subjects together, and written instructions for the clinical examination were used. However, concordance within examiners (interexaminer kappa) and repeatability (intra-examiner kappa) could not be assessed.

We used the number of teeth with deepened periodontal pockets (with a cut-off value of 4 mm) as an outcome. The use of a continuous outcome means our outcome variable focused on not only the presence but also the extent of the infection of the periodontium. In addition, the use of a continuous outcome variable made it possible for us to reduce the effect of misclassification related to measurement error.

We combined the low (0.1–0.2 ml min^{-1}) and normal (over 0.2 ml min^{-1}) unstimulated salivary flow rate categories because there were too few participants (six persons) in the low unstimulated salivary flow rate category. Combining these categories means the risk estimate for the very low salivary flow category could have been slightly lower if the reference category were normal unstimulated salivary flow instead of the combined low and normal salivary flow rate category. This 0.1 value has widely been used as a cut-off value for low unstimulated salivary flow rate (Ericsson and Hardwick, 1978; Dormenval *et al*, 1998; Nederfors, 2000).

It is known that salivary flow is affected by the circadian rhythm (Ferguson and Botchway, 1979, Flink *et al*, 2005). In this study, the salivary flow rate measurements were performed during the oral clinical examination, but not at the same time of day, which may cause random error in the saliva flow rate measurements. However, as the measurements were most probably unrelated to periodontal condition, it is unlikely that the results would be essentially biased.

Lastly, although the Poisson regression model takes into account the number of teeth, it is possible that the number of teeth confounds the association between salivary flow and periodontal infection. To exclude this possibility, we restricted data to those with 10 or more teeth. These results are consistent with the results among the total study population, which increases the credibility of the findings.

Conclusions

About one-third of the dentate population 75 years old and older suffered from low salivary flow. As in other populations, low salivary flow was associated with medications and various diseases. Despite several other adverse effects of low salivary flow, such as dental caries, burning mouth syndrome and denture stomatitis, it does not appear to mean an increased risk for periodontal infection.

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References

Almståhl A, Wikström M (1999). Oral microflora in subjects with reduced salivary secretion. *J Dent Res* **78:** 1410–1416.

Almståhl A, Wikström M (2003). Electrolytes in stimulated whole saliva in individuals with hyposalivation of different origins. *Arch Oral Biol* **48:** 337–344.

Almståhl A, Wikström M (2005). Microflora in oral ecosystems in subjects with hyposalivation due to medicines or of unknown origin. *Oral Health Prev Dent* **3:** 67–76.

Bardow A, Nyvad B, Nauntofte B (2001). Relationships between medication intake, complaints of dry mouth, salivary flow rate and composition, and the rate of tooth demineralization *in situ*. *Arch Oral Biol* **46:** 413–423.

Bradshaw DJ, Marsh PD (1998). Analysis of pH-driven disruption of oral microbial communities *in vitro*. *Caries Res* **32:** 456–462.

Bradshaw DJ, McKee AS, Marsh PD (1989). Effects of carbohydrate pulses and pH on population shifts within oral microbial communities *in vitro*. *J Dent Res* **68:** 1298–1302.

von Bültzingslöwen I, Sollecito TP, Fox PC *et al* (2007). Salivary dysfunction associated with systemic diseases: systematic review and clinical management recommendations. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* **103**(Suppl)**:** S57.e1–15.

Caplan DJ, Hunt RJ (1996). Salivary flow and risk of tooth loss in an elderly population. *Community Dent Oral Epidemiol* **24:** 68–71.

Cassolato SF, Turnbull RS (2003). Xerostomia: clinical aspects and treatment. *Gerodontology*. **20:** 64–77.

Crow HC, Ship JA (1995). Are gingival and periodontal conditions related to salivary gland flow rates in healthy individuals? *J Am Dent Assoc* **126:** 1514–1520.

Dawes C (2008). Salivary flow patterns and the health of hard and soft oral tissues. *J Am Dent Assoc* **139**(Suppl)**:** 18S–24S.

Dormenval V, Budtz-Jørgensen E, Mojon P, Bruyère A, Rapin CH (1998). Associations between malnutrition, poor general health and oral dryness in hospitalized elderly patients. *Age Ageing* **27:** 123–128.

Ericsson Y, Hardwick L (1978). Individual diagnosis, prognosis and counselling for caries prevention. *Caries Res* **1** (Suppl)**:** 94–102.

Farsi N, Al Amoudi N, Farsi J, Bokhary S, Sonbul H (2008). Periodontal health and its relationship with salivary factors among different age groups in a Saudi population. *Oral Health Prev Dent* **6:** 147–154.

Ferguson DB, Botchway CA (1979). Circadian variations in the flow rate and composition of whole saliva stimulated by mastication. *Arch Oral Biol* **24:** 877–881.

Flink H, Tegelberg A, Lagerlöf F (2005). Influence of the time of measurement of unstimulated human whole saliva on the diagnosis of hyposalivation. *Arch Oral Biol* **50:** 553–559.

Flink H, Bergdahl M, Tegelberg A, Rosenblad A, Lagerlöf F (2008). Prevalence of hyposalivation in relation to general health, body mass index and remaining teeth in different age groups of adults. *Community Dent Oral Epidemiol* **36:** 523–531.

Haase EM, Bonstein T, Palmer RJ Jr, Scannapieco FA (2006). Environmental influences on Actinobacillus actinomycetemcomitans biofilm formation. *Arch Oral Biol* **51:** 299–314.

Hirotomi T, Yoshihara A, Ogawa H, Ito K, Igarashi A, Miyazaki H (2006). A preliminary study on the relationship between stimulated saliva and periodontal conditions in community-dwelling elderly people. *J Dent* **34:** 692–698.

Hirotomi T, Yoshihara A, Ogawa H, Ito K, Igarashi A, Miyazaki H (2008). Salivary spinability and periodontal disease progression in an elderly population. *Arch Oral Biol* **53:** 1071–1076.

Koss MA, Castro CE, Salúm KM, López ME (2009). Changes in saliva protein composition in patients with periodontal disease. *Acta Odontol Latinoam* **22:** 105–112.

Lawton MP, Brody EM (1969). Assessment of older people. Self-maintaining and instrumental activities of daily living. *Gerontologist* **9:** 179–186.

Márton K, Madléna M, Bánóczy J *et al* (2008). Unstimulated whole saliva flow rate in relation to sicca symptoms in Hungary. *Oral Dis* **14:** 472–477.

Navazesh M (1993). Methods for collecting saliva. *Ann N Y Acad Sci* **20:** 72–77.

Nederfors T (2000). Xerostomia and hyposalivation. *Adv Dent Res* **14:** 48–56.

Scully C (2003). Drug effects on salivary glands: dry mouth. *Oral Dis* **9:** 165–176.

Sewón L, Söderling E, Karjalainen S (1990). Comparative study on mineralization–related intraoral parameters in periodontitis–affected and periodontitis-free adults. *Scand J Dent Res* **98:** 305–312.

Shimizu C, Kuriyama T, Williams DW *et al* (2008). Association of oral yeast carriage with specific host factors and altered mouth sensation. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* **105:** 445–451.

Ship JA, Fox PC, Baum BJ (1991). How much saliva is enough? 'Normal' function defined. *J Am Dent Assoc* **122:** 63–69.

SPSS Inc (2008). *SPSS 16.0 for Windows*. SPSS Inc.: Chicago, IL, USA.

Turner MD, Ship JA (2007). Dry mouth and its effects on the oral health of elderly people. *J Am Dent Assoc* **138**(Suppl)**:** 15S–20S.

Wolff A, Zuk-Paz L, Kaplan I (2008). Major salivary gland output differs between users and non-users of specific medication categories. *Gerodontology* **25:** 210–216.