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Associations between oral sugar clearance, dental caries, and related factors among 71-year-olds

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Abstract

Objective. To investigate the associations between oral sugar clearance and the prevalence of dental decay. ***Material and Methods.*** A total of 92 (44 F, 48 M) 71-year-old subjects in Göteborg, Sweden were consecutively chosen from a representative cohort study. The subjects were examined for: 1) caries-related status, 2) oral function, 3) salivary conditions, 4) cariogenic micro-organisms, and 5) oral sugar clearance. A factor analysis was used to investigate the possible existence of latent variables within these five areas. The latent variables from the factor analyses were used to study the associations between clearance and caries in multivariate regression models. ***Results.*** Only one latent variable relating to oral sugar clearance was found. In the regression model with the latent variable related to oral sugar clearance as a dependent variable and gender plus the latent variables related to oral function and salivary conditions as an independent variable, there were associations with gender and some latent variables reflecting oral function and one reflecting glucose in saliva ($R^2 = 0.20/0.17$). Three latent variables relating to caries-related status were found and these were associated with the number of teeth, the percentage of filled tooth surfaces, and the percentage of decayed tooth surfaces (DS%). In the regression analysis using the latent variable associated with DS% as a dependent variable, this variable was related to the latent variables of oral sugar clearance and to some reflecting oral function, as well as glucose in saliva ($R^2 = 0.28$). ***Conclusions.*** Oral sugar clearance appears to be independently associated with the prevalence of dental caries in the elderly.

Key Words: *Cariogenic micro-organisms, dental caries, oral function, saliva, sugar clearance*

Introduction

Oral sugar clearance (OSC) is the reduction in the concentration of sugar in saliva over time. OSC is dependent on the amount of sugar and the efficiency of its removal, depending on the properties of the product and on the physiological and anatomical features of the individual [1]. Different physiological impairments have been seen to reduce OSC [2–4] and the elderly appear to be among those in the population that are vulnerable to a reduction in OSC [2,4].

In some studies, OSC has been found to correlate to dental caries [2–4], but this factor has rarely been included in studies of caries risk models [5–10], with only a few exceptions [11]. Several studies have revealed associations between OSC and oral function, salivary secretion, buffer capacity, and cariogenic micro-organisms [2–4,12,13]. However, none of these studies has analyzed whether the inclusion of OSC improves the ability to predict the prevalence of dental caries.

Several other factors are associated with dental caries apart from OSC that could be related to oral function, salivary conditions, and cariogenic micro-organisms. General health is associated with both salivary secretion rate [14,15] and oral function [2–4,16–18]. Other possible caries risk factors are diet [19–23], social factors [5,6,24], tobacco habits [6], and oral hygiene [7–9,11]. This makes it questionable whether including OSC improves dental caries models or whether it only acts as an intermediate factor.

To analyze the influence of different factors, a sample with sufficient variation regarding the variables under investigation would be needed. The elderly appear to be such a group [1,4].

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The aim of this study was to investigate the associations between OSC and dental caries in a sample of dentate elderly people and to evaluate the possible benefit of including oral clearance in caries models, together with other covariates such as oral function, salivary conditions, and cariogenic microflora.

Material and methods

Within the framework of the geriatric and gerontological studies of elderly people in Göteborg (H70), a consecutive sample of 120 individuals was chosen from the investigation of 70-year-olds in 1992–93 [25]. The number of subjects was based on the assumption of a drop-out rate of about 20% and the ability to detect a correlation of 0.25 as statistically significant. The criterion for including a subject was a minimum of 10 teeth, with at least 4 in each jaw. The sample was primarily chosen as a sample with sufficient variation regarding the different variables and also as a reasonably representative sample of 70-year-olds. The results of the H70 examinations were not available until one year after the examination and the subjects were consequently 71 years of age when the study was carried out. A total of 94 persons participated and the reasons for not participating were failure to reply (4 subjects), lack of interest (11 subjects), inability to participate (10 subjects), and dental fear (1 subject). There were no statistically significant differences between drop-outs ($n = 26$) and participants regarding gender or number of teeth. Of the 94 participants, one person did not complete the examinations and one had a very severe caries status (regarded as an outlier), which meant that both were excluded from the analyses. A total of 92 persons (44 F, 48 M, 77% of the original sample) were therefore included in the present study. Of these, 86 had visited a dentist for a regular check-up during the previous year, 5 between 1 and 2 years, and 1 between 2 and 3 years. There were no statistically significant correlations between the time of the last check-up and dental decay ($p = 0.74$).

The participants were instructed not to brush their teeth on the day of the examinations. The examinations took 2 h and started with the oral examination and functional tests, which continued for around 1 h. These were directly followed by the salivary tests and thereafter the OSC test, which therefore took place 1.5 h after the start of the examinations.

One of the authors (T.A.) conducted the oral examination, oral muscular co-ordination ability test, chewing efficiency test, and measurements of chewing movements. A specially trained laboratory technician collected the saliva samples and measured OSC. The different variables were divided into five groups (here called “areas”): 1) caries-related status, 2) oral function, 3) salivary conditions, 4) cariogenic micro-organisms, and 5) oral sugar clearance.

Area 1: caries-related status

The teeth were examined using a mirror, probe, and two bitewing radiographs. Only manifest, presumably active, carious lesions extending well into the dentine were recorded as carious lesions. The following variables were used: DMFS, DMFT, DS, DT, FS and FT, MS, MT, number of teeth, number of healthy surfaces, Eichner Index (measure of present occluding areas, from 1 = all 28 teeth in occlusion, to 10 = zero natural teeth), and the modified Eichner Index (also including artificial teeth in bridges as occluding teeth [26]). Furthermore, some relative measurements, such as filled or decayed surfaces as a percentage of all present tooth surfaces (FS%, FT%, DS%, and DT%), were used. As DS and DT were highly skewed, their logarithms were also included [lg (DS + 1) and lg (DT + 1)]. From the oral examination, a total of 18 variables were used in the subsequent analyses (Table I).

Area 2: oral function

Three different measurements of oral function were used: 1) oral muscular co-ordination ability, 2) masticatory efficiency, and 3) mandibular movements.

Oral muscular co-ordination ability (MA test). The subjects were asked to assemble a pair of cubic test pieces (a matrix with a round hole and a patrix with a round tap) in their mouth according to Landt [27]. The subjects shut their eyes, the pair of test pieces was placed in their hands and their hands were guided towards their mouths. The subjects picked up the test pieces with their lips and a stopwatch was started. The time required for assembling the matrix and patrix was expressed in seconds (if the subject failed within a maximum time of 60 s, a value of 120 s was recorded). The test was repeated three times and the mean value was used in the subsequent analyses (Table I).

Masticatory efficiency. This was measured using a method based on a sieve system [28]. A roasted almond was chewed for 10 s and was then spat into a sieve with a 0.7 mm mesh. The mouth was rinsed once and the subjects then spat into the sieve again. The sieve was then rinsed and the pieces of almond that remained in the sieve were collected and weighed. This was performed after the collections had been dried for at least 24 h. The original method was extended, as the fraction of particles smaller than 0.7 mm was also weighed to enable the calculation of the part that was retained in the

Table I. Variables used in the factor analyses of different areas.

Decayed surfaces (DS)
Missing surfaces (MS)
Filled surfaces (FS)
Decayed teeth (DT)
Missing teeth (MT)
Filled teeth (FT)
Eichner Index
Modified Eichner Index
DMFT
DMFS
Number of teeth
Number of sound surfaces
DS %
DT %
FS %
FT %
Lg DS
Lg DT
Oral function area
(MA test)
Mean time for assembling round pieces
(Chewing efficiency test)
Percentage of parts <0.7 mm in the first chewing test
Percentage of parts <0.7 mm in the second chewing test
Percentage of parts >0.7 mm in the first chewing test
Percentage of parts >0.7 mm in the second chewing test
Percentage of parts retained in the first chewing test
Percentage of parts retained in the second chewing test
Mean percentage of parts <0.7 mm in both chewing tests
Mean percentage of parts >0.7 mm in both chewing tests
Mean percentage of parts retained in both chewing tests
(Selspot test)
Angle opening, mean and CV
Angle closing, mean and CV
Distance opening, mean and CV
Distance closing (lg), mean and CV
Amplitude, mean and CV
Max. position laterally, mean and CV
Max. position vertically, mean and CV
Time opening phase (lg), mean and CV
Time closing phase, mean and CV
Time occlusion phase (lg), mean and CV
Time duration chewing cycle (lg), mean and CV
Velocity max. opening phase, mean and CV
Velocity max. closing phase, mean and CV
Velocity mean opening phase, mean and CV
Velocity mean closing, mean and CV
Saliva area
Secretion rate unstimulated saliva
Secretion rate stimulated saliva
Buffer capacity unstimulated saliva
Buffer capacity stimulated saliva
Glucose concentration in unstimulated saliva
Caries-related microbiology area
Streptococcus mutans CFU/ml
Streptococcus sobrinus CFU/ml
Lactobacilli CFU/ml
Candida albicans CFU/ml
Lg *Streptococcus mutans* CFU/ml
Lg *Streptococcus sobrinus* CFU/ml
Lg *Lactobacilli* CFU/ml
Lg *Candida albicans* CFU/ml
Streptococcus mutans CFU/ml/remaining tooth
Streptococcus sobrinus CFU/ml/remaining tooth
Lactobacilli CFU/ml/remaining tooth
Candida albicans CFU/ml/remaining tooth
Streptococcus mutans CFU/ml/FS
Streptococcus sobrinus CFU/ml/FS
Lactobacilli CFU/ml/FS
Candida albicans CFU/ml/FS
Oral sugar clearance area
Glucose concentration after 3 min
Glucose concentration after 7 min
Glucose concentration after 11 min
Glucose concentration after 16 min
Glucose concentration after 21 min
Glucose concentration after 31 min
Clearance AUC (31 min)
Clearance time

mouth. The procedure was performed twice and six variables were used in the analyses (Table I).

Mandibular movements. Movements of the mandible during chewing were measured with an optoelectronic device intended for 3-dimensional recording (Selspot Co., Partille, Sweden) [29]. The system consisted of three units: 1) light-emitting diodes (LED) with driver electronics, 2) a position-sensitive detector in a camera, and 3) a computer with a camera interface. Duplicate recordings of a masticatory sequence were made during 20 s of chewing a roasted almond. A single masticatory cycle was divided into three separate phases: opening, closing, and occlusal level phase. A total of 15 measurements relating to total cycle duration, time of the three different phases, the mean and maximum velocity of opening and closing, the distances of opening and closing, and the angle in relation to the sagittal plane when the mandible approaches and leaves the intercuspal position were used. As every person completed several chewing cycles, the results per person for all 15 measurements from the computer program are presented as the mean and standard deviation. Instead of standard deviation, the coefficient of variation (CV = standard deviation divided by the mean) was used in the analyses, leading to a total of 30 variables (Table I). Four of the variables displayed highly skewed distributions and their logarithms were therefore used instead of the original values.

Area 3: saliva conditions

Unstimulated and paraffin-stimulated whole saliva samples were collected as described by Heintze et al. [15]. Unstimulated saliva was collected during 15 min and stimulated saliva during 5 min. Buffer capacity was determined electrometrically according to Ericsson [30]. Three milliliters of 0.005 M HCl were added to 1 ml of stimulated saliva. After 20 min of aeration, the final pH was determined electrometrically. The amount of glucose in unstimulated saliva was measured using an enzymatic method (see below). Five variables were used in the subsequent analyses (Table I).

Area 4: cariogenic micro-organisms

The paraffin-stimulated saliva samples were dispersed for 30 s on a Whirlimixer and serial 10-fold dilutions were made in 0.05 M phosphate buffer (pH 7.3); 25 µl of appropriate dilutions were plated on mitis salivarius bacitracin agar plates (MSB) for the growth of *mutans streptococci*, on Rogosa selective lactobacillus agar plates (SL) for the growth of *lactobacilli* and on Sabouraud dextrose agar plates for the growth of *Candida*. The MSB agar plates were incubated aerobically for 72 h at 37°C. All the colonies were counted on SL agar as *lactobacilli*, whereas on MSB agar, only colonies exhibiting the typical morphology of *Streptococcus mutans* and *S. sobrinus* were counted [31]. On Sabouraud dextrose agar, only colonies exhibiting the typical morphology of *Candida* were counted. The results were expressed as colony-forming units (CFU) and as the logarithms of CFU/ml, CFU/ml per remaining tooth and CFU/ml per FS. A total of 16 variables were used in the analyses (Table I).

Area 5: oral sugar clearance

The method described by Hase et al. [2] was used. The subjects were asked to chew and swallow a glucose tablet equivalent to 3 g glucose (Dextrosol® Naturell; CPC Food AB, Kristianstad, Sweden). The glucose concentration in saliva was measured sublingually using a paper disc (diameter 4 mm), punched from filter paper (Millipore AP 25; Millipore Corp., Bedford, Mass, USA) and was capable of absorbing approximately 20 µl saliva. The disc was removed from the mouth after 10 s when it had become thoroughly soaked with saliva. It was then placed in 1 ml distilled water and boiled. This procedure was carried out before (0 min) and 3, 7, 11, 16, 21, and 31 min after the intake of the tablet. After boiling, the tubes were frozen and stored until they were analyzed. The tubes were then thawed and centrifuged and the glucose concentration was analyzed enzymatically (GOD Perid®; Boehringer Mannheim GmbH Diagnostica, Mannheim, Germany) and expressed as mmol/l. The salivary glucose concentration from the different measurements up to 31 min was used to calculate the area under the constructed concentration-time curve (AUC) and salivary sugar clearance time corresponding to the time it takes for the salivary glucose concentration to drop to 5 mM [2]. As all clearance-related variables were highly skewed, logarithmic values were used, leading to eight OSC for the analyses (Table I).

Statistical analyses

The analyses were conducted in two stages. The first consisted of a factor analysis within each of the five "areas". Within each "area", all the variables were included in the analysis and the factor scores that were obtained were used in the next stage. This second stage involved the estimation of two multiple regression models, including the factors as independent variables and factors of OSC and dental caries, respectively, as dependent variables. Before the multiple regression analyses were carried out, all the variables were univariately analyzed using partial regression with gender as the controlling factor.

The principal component method was used to extract factors, and Varimax with Kaiser normalization was used as the rotation method. As a primary cut-off limit, an eigenvalue of more than 1 was used. In some cases, the eigenvalues were lowered until at least 75% of the variation was explained by the model. The different factors were identified in accordance with the variable or variables with which they had the highest correlation. In the following presentation, all factors are given as "Fa". The factor scores for the individuals were calculated according to the regression technique.

The two regression models included the latent variables related to OSC and dental caries as dependent variables, using gender and the other latent variables as independent variables. The independent latent variables included in the model of OSC were those related to oral function and salivary conditions. The independent latent variables included in the model of dental caries were all the other factors. Three different linear multiple regression analyses were performed, the first including all variables in the model, the second using forward stepwise procedures, and the third using backward stepwise procedures. Both of the stepwise procedures were carried out until all the remaining factors in the final models were statistically significant ($p < 0.05$).

The statistical analyses were done with the SPSS statistical package version 10.0 (SPSS, Chicago, Ill., USA).

Results

Measurements

The subjects had a mean of 20 teeth with 55 filled tooth surfaces (FS) (the quintiles had 13/32, 17/47, 20/56, 23/63, and 26/78; mean teeth/mean FS). There were no signs of active caries among 55 of the 92 subjects (60%) (the frequency distributions were 55/0, 11/1, 13/2, 6/3, 2/4, 1/5, 2/6, 1/8, and 1/10; *n*/DS). The mean DS value was 1.1 (Table II). Twelve of the subjects (13%) had removable partial dentures.

Table II. Mean, standard deviation and median of variables representing the five areas.

Area	Mean	± SD	CV[1]	Median
Caries-related status				
DS	1.1	1.8	164%	0.0
FS	55.3	16.6	30%	56.0
MS	39.6	21.2	54%	37.0
DMFS	94.9	21.7	23%	98.0
Number of teeth	19.9	4.5	23%	20.5
Number of sound surfaces	35.1	22.2	63%	31.5
Oral function				
MA test				
Mean oral muscular coordination ability (s)	32.7	23.7	72%	24.5
Chewing efficiency				
Parts larger than 0.7 mm after chewing (%)	51.0	21.3	42%	51.3
Parts smaller than 0.7 mm after chewing (%)	31.6	7.6	24%	30.3
Parts retained in the mouth after chewing (%)	15.3	9.9	65%	15.1
Mandibular movements				
Angle open (°)	64.2	13.7	21%	66.2
Angle closed (°)	58.9	13.8	23%	61.5
Distance open (mm)	16.4	5.3	32%	16.3
Distance closed (mm)	19.0	12.7	67%	17.0
Amplitude (mm)	11.3	3.8	34%	10.7
Time duration chewing cycle (s)	0.62	0.38	61%	0.5
Velocity open (mm/s)	96.3	37.4	39%	91.6
Saliva				
Secretion stimulated saliva (ml/min)	2.3	1.3	57%	2.0
Buffer capacity stimulated saliva (pH)	5.3	1.5	28%	5.3
Secretion unstimulated saliva (ml/min)	0.4	0.3	75%	0.3
Buffer capacity unstimulated saliva (pH)	3.5	1.6	46%	3.7
Cariogenic micro-organisms				
Streptococcus mutans (lg CFU/ml)	5.1	1.0	20%	5.2
Streptococcus sobrinus (lg CFU/ml)	2.3	1.8	78%	2.3
Lactobacilli (lg CFU/ml)	4.1	1.3	32%	4.2
Candida (lg CFU/ml)	3.1	1.1	35%	2.3
Oral sugar clearance				
Sugar clearance AUC (mmol*min)	367.3	1538.9	419%	48.3
Sugar clearance time (min)	7.5	7.5	100%	5.4

[1]CV = Coefficient of variation (SD/mean value).

Eleven of the 92 subjects (12%) needed more than 1 min to assemble the matrix and patrix in the MA test and 15 (16%) needed less than 15 s. The mean time was 33 s (SD 24 s) (Table II).

The parts of the almonds that were still larger than 0.7 mm after 10 s of chewing weighed 51% of the original weight of the almonds. Pieces smaller than 0.7 mm weighed 32% of the original weight and the remainder (16%) of the weight of the almonds was retained (Table II). Two of the subjects were not able to chew the almond at all, but 11 succeeded in reducing more than 75% of the almonds to pieces smaller than 0.7 mm in 10 s.

The measurements of mandibular movements showed that the mean amplitude during chewing was 11 mm, the mean length of a chewing cycle was 0.6 s, and the mean velocity during opening was 96 mm/s (Table II).

The mean secretion rate for unstimulated saliva was 0.4 ml/min, while that for stimulated saliva was 2.3 ml/min. Five (5%) of the subjects had a stimulated saliva secretion rate below 0.7 ml/min and 6 (6%) had an unstimulated saliva secretion rate below 0.1 ml/min. A buffer capacity below 5.0 was found in 40% of the participants. Four (4%) participants had a detectable level of glucose in unstimulated saliva (prior to chewing the glucose tablet).

Eighteen (20%) of the elderly subjects had $>10^6$ CFU/ml of *mutans streptococci*. Most of them were *S. mutans* (mean log value 5.1 CFU/ml) and only a small percentage of subjects were *S. sobrinus* (mean 2.3 CFU/ml). Nineteen (21%) had $>10^5$ CFU/ml of *Lactobacilli* spp. (mean log value 4.1 CFU/ml) and 42 (46%) had detectable amounts of *Candida* (mean log value 3.1 CFU/ml).

The mean clearance time was 7.5 min and the mean AUC[31] was 367 min × mmol/l. Both variables had highly skewed distributions.

Latent variables within areas (Table III)

Three different latent variables related to "caries-related status" were found; the first was associated mainly with the number of teeth, the second with the FS% and the third with DS%.

Table III. Results of the five factor analyses of latent variables within the five areas. The variables are given in order of impact on factors. Only variables with correlations of $r > 0.5$ are presented.

	Factor									
	1	2	3	4	5	6	7	8	9	Communalities and explainedvariance
Caries-related status										
Missing surfaces	−0.94									0.98
Number of teeth	0.94									0.98
Filled surfaces %		0.93								0.91
Number of sound surfaces		−0.87								0.97
Decayed surfaces lg			0.97							0.97
Decayed surfaces %			0.96							0.95
Explained variance by the fact model (%)										86.3
Oral Function										
Velocity mean open CV *	0.78									0.76
Total time duration CV	0.79									0.87
Velocity max open		0.93								0.96
Distance open		0.86								0.93
Parts larger than 0.7 mm after chewing			−0.93							0.90
Parts smaller than 0.7 mm after chewing			0.81							0.77
Parts retained in the mouth after chewing			0.55							0.76
Time closed lg				0.89						0.87
Distance closed lg				0.63						0.92
Amplitude		0.67		0.56						0.81
Total time duration lg				0.77	0.55					0.96
Time open lg					0.84					0.84
Amplitude CV						0.88				0.91
Maximal position vertically CV						0.83				0.89
Angle open							−0.85			0.84
Angle open CV							0.83			0.80
Angle closed								−0.75		0.86
Angle closed CV								0.80		0.76
Time MA test									0.81	0.68
Explained variance by the factor model (%)										80.6
Saliva										
Secretion rate stimulated saliva	0.84									0.76
Buffering capacity unstimulated saliva	0.85									0.74
Secretion rate stimulated saliva		0.78								0.68
Buffering capacity stimulated saliva		0.84								0.72
Glucose in saliva			0.99							0.98
Explained variance by the factor model (%)										77.5
Cariogenic micro-organisms										
Candida albicans lg	0.93									0.93
Candida / FS	0.93									0.94
Streptococcus sobrinus lg		0.98								0.97
Streptococcus sobrinus / tooth		0.97								0.97
Streptococcus mutans lg			0.89							0.79

Table III (*Continued*)

	Factor									Communalities and explainedvariance
	1	2	3	4	5	6	7	8	9	
Streptococcus mutans / tooth			0.92							0.77
Lactobacilli lg				0.82						0.87
Lactobacilli / tooth				0.82						0.90
Explained variance by the factor model (%)										79.6
Oral Sugar clearance										
Clearance time lg	0.85									0.73
Clearance AUC lg	0.96									0.91
Explained variance by the factor model (%)										80.1

*CV = Coefficient of variation.

The factor analysis of the oral function area resulted in nine latent variables. The first two were related to mandibular movement variables, primarily to the coefficient of variation (CV) of velocity and time duration, and to velocity and distance. The third included all three variables from the chewing efficiency test. The fourth to the eighth latent variables were mandibular movement variables with time, time of opening, amplitude CV, angle of opening, and angle of closing. The ninth variable was correlated to the MA test.

The factor analysis of saliva area produced three latent variables related to unstimulated saliva, stimulated saliva, and glucose in unstimulated saliva.

The 16 variables relating to the area of the cariogenic micro-organisms were reduced to 4 latent variables according to the factor analysis. The first was mainly related to *Candida*, the second to *S. sobrinus*, the third to *S. mutans,* and the last to lactobacilli.

The eight variables in the oral glucose clearance test had one latent variable in common.

The latent variables relating to "decayed surfaces" and "oral sugar clearance" were chosen as dependent variables in the multiple regression models.

Univariate associations between latent variables

The latent variable relating to the OSC area appeared to be correlated to 13 other latent variables – all 3 latent variables relating to salivary conditions, 5 relating to oral function, 3 to cariogenic micro-organisms, and 2 to caries-related status.

The latent variables relating to DS% appeared to be correlated to 7 other latent variables, i.e. 1 latent variable from salivary conditions, 3 from oral function, 2 from cariogenic micro-organisms, and the latent variable relating to OSC.

Regression models of OSC and dental caries

After the stepwise procedures in the OSC regression model, 5 variables were still statistically significant after the forward procedure (Table IV) and 4 after the backward procedure. The latent variable with the highest partial correlation was the one with a smaller and more varied angle during opening. Glucose in saliva was related to slower clearance, whereas greater chewing efficiency was related to faster clearance. Being female and needing a long time to assemble the pieces of the MA test were associated with slower clearance (Table IV). The latent variable related to the MA test was not included in the final model using the backward procedure.

In the regression model with the latent variable related to DS% as the dependent variable, slow clearance was the strongest indicator, together with an increased amount of glucose in saliva, an increased amount of lactobacilli, and an increased

Table IV. Final multiple linear regression models with latent variables of oral sugar clearance and dental caries as dependent variables. The results come from forward stepwise multiple linear regressions. In both models, gender, latent variables of oral function and salivary conditions were included as independent variables. When dental caries was the dependent variable, the latent variables of oral sugar clearance and caries-related oral microbiology were also included as independent variables.

Dependent variable	Independent variables	Partial correlation	*p*-value
[Fa]Clearance[1]	[Fa]Angle open	–0.34	0.002
	[Fa]Glucose in saliva	0.31	0.005
	[Fa]Chewing efficiency	–0.28	0.010
	Gender (female)	0.23	0.037
	[Fa]MA	0.23	0.038
	Adj R^2 0.20 (total model[2] =0.20)		
[Fa]Decayed surfaces	[Fa]Clearance	0.35	0.001
	[Fa]Glucose in saliva	0.33	0.002
	[Fa]Lactobacilli	0.27	0.014
	[Fa]Total time	0.22	0.048
	Adj R^2 0.30 (total model[2] =0.32)		

[1] [Fa]Latent variable from factor analyses; [2]total model including both significant and non-significant variables.

chewing cycle time (Table IV). Both the forward and backward procedures resulted in the same model.

Discussion

The main finding in this study was that the strongest predictor of the prevalence of dental decay in this sample of dentate elderly people was OSC. The result underlines the potentially important role of OSC in dental caries that has been found in other studies [1,3,4]. Other factors that were independently associated with caries were oral function and the level of glucose in saliva. All three of these factors (clearance, oral function, glucose in saliva) are rarely used in caries risk models [5–11]. However, studies of caries among elderly people have found that cariogenic micro-organisms play an important role [5–8,10,11], as do caries experience [5–8,11], salivary flow rate [12,13], oral hygiene [7–9,11], and sugar intake [7,9,11]. Some of these factors were included in the present study and both lactobacilli and *S. mutans* were associated with the number of DS, but only lactobacilli qualified in the final model (Table IV). The results of this study may indicate that factors other than those normally used are important in studies of dental caries, at least among the elderly.

As a result of the findings in other studies [2–4], the associations between different functional variables and OSC were expected, whereas associations between dental decay and oral function have not previously been studied and are therefore interesting observations. Of the 9 latent variables found in the factor analysis of oral function, 8 were related to oral clearance or decayed surfaces and 3 qualified in the final models. This further underlines the importance of studying the relationship between oral function and caries. The study further points to the elderly as a group in which this relationship could be studied.

Our results do not follow the model of Lagerlöf et al. [32], as OSC in our study was not directly associated with salivary secretion rate. The reason for this could be that we used solid tablets that required some chewing and the model suggested by Lagerlöf et al. only applies to solutions. Another possibility is that oral function variables may act as intermediate factors in the models as they were related both to salivary secretion rate and to OSC, thereby concealing the effect. The difference in results could also be due to other differences such as those between healthy younger adults and elderly individuals.

The findings regarding the level of glucose in saliva prior to the OSC test were unexpected. As it was independently statistically significantly related to both caries and OSC, it seems unlikely that this finding is only due to chance. As the subjects were supervised during the 1.5 h before the OSC test, we know that they did not eat anything containing glucose during that time. Furthermore, none of them was diagnosed with diabetes and none of them had elevated blood glucose levels one year before our study. This is perhaps an indication that some people who eat often and at the same time have impaired oral clearance may therefore have glucose in their saliva. This would explain the relationship both to OSC and to dental caries.

There is always a problem with drop-outs and whether or not they distort the results. This population was selected as a sub-sample from a larger sample of people who had attended a previous medical examination. The drop-outs between the first (the medical) and second examination (used in the present study) did not influence the mean or the variation in the number of teeth in the subjects in the final sample. Compared with other studies, the stimulated salivary secretion rate of 2.3 ml/min is higher than the 1.8 ml/min found among 75-year-olds [33] and the 1.0–1.4 ml/min found among 70-year-olds who had fasted overnight [34]. This could indicate a somewhat healthier population than the average, which is not unexpected, as only those with more than 10 teeth were included in the study [16]. The mean time for the MA test was longer than that in the control group in the study by Engvall & Birkhed [3] but shorter than the time found by Lundgren et al. [4] among 92-year-olds, which were findings that were also expected. Tzakis et al. [28] used the same chewing efficiency test among young adults (aged 20–31 years) and they were more efficient than the elderly people in the present study. Seventy percent of the chewed particles were smaller than 0.7 mm after 10 s in the younger group compared with 49% in this study. The results for mandibular movements were all close to those found previously among dentate elderly people [29], including a total cycle duration of 0.66 s compared with 0.62 s in the present study. The results for the sample used in this study therefore appear to be in line with expectations based on previous studies among dentate elderly Swedish people, at least in terms of salivary conditions and oral function.

However, to analyze associations, sufficient variation is required within the sample. In Table II, most variables have coefficients of variation between 20% and 70%, which appears to be sufficient. However, as almost all our subjects used fluoride-containing dentifrice, brushed their teeth daily, and were all healthy enough to participate in the examination, the importance of these three aspects could not be analyzed. The results are therefore only applicable if these factors are, for example, borne in mind.

There are risks associated with using factor analysis, such as losing important information and difficulty interpreting the results. However, most of the expected associations based on the results of other studies were found, such as those between dental caries and *S. mutans* and between OSC and dental caries. Some of the results also emphasize the advantage of analyzing latent variables. First, the analyses reduce the risk of including highly correlated variables in the models, such as those between secretion rate and buffer capacity, thereby reducing the risk of misinterpreting the estimated models. Second, including all the variables makes it possible to find those that may present dimensions not accounted for in the traditionally used variables, such as the intra-individual variation found in mandibular movements and the level of glucose in saliva before the OSC test (Table III).

The findings from the present investigation suggest that more attention should be focused on the importance of OSC, especially in the elderly. There is perhaps a need for an easy chair-side method to evaluate OSC, such as a dip-slide test like the one that is used to evaluate glucose in urine, to make it easier to test OSC in large population studies. Furthermore, there may be a need to develop different types of treatment to increase clearance. One of these treatments could be a method like the one suggested by Hase et al. [35].

The conclusions from this study are that there were relatively strong associations (12% of the variation) between the prevalence of dental caries and OSC. Even though the measurements used in this study do not reflect every aspect of dental caries, they do underline the importance of regarding oral clearance as a possible independent risk factor for dental caries, at least among the elderly, and indicate that it may be worthwhile including OSC in caries risk studies.

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