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Prevalence of Xerostomia and the Salivary Flow Rate in Diabetic Patients*

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A – research concept and design; **B** – collection and/or assembly of data; **C** – data analysis and interpretation; **D** – writing the article; **E** – critical revision of the article; **F** – final approval of article; **G** – other

Abstract

Background. Diabetes is a metabolic disease characterized by hyperglycemia, which results from relative or absolute insulin deficiency. One of the first oral symptoms of diabetes is xerostomia.
Objectives. The aim of the study was to determine the prevalence of the xerostomia symptoms and salivary flow rate in diabetic patients according to the type of diabetes, the level of metabolic control and the duration of the disease.
Material and Methods. The study involved 156 adult patients of both sexes including 34 patients with diabetes type 1 (group C1), 59 with diabetes type 2 (group C2), and 63 generally healthy individuals as two control groups, sex- and age-matched to the diabetic group. The patients suffering from both types of diabetes were additionally subdivided according to the level of metabolic control and the duration of the disease. Xerostomia was diagnosed with the use of a specially prepared questionnaire and Fox's test. Moreover, the salivary flow rate of resting mixed saliva was measured.
Results. In type 1 diabetics, a significantly lower salivary flow rate in comparison to the age-matched control group (0.38 ± 0.19 mL/min vs. 0.53 ± 0.20 mL/min, $p < 0.01$) was found. However in type 2 diabetics, a slight lower salivary flow rate was noticed (on average, 20% lower). Dry mouth was far more frequently diagnosed in type 1 diabetics than in the control group.
Conclusions. In type 1 diabetics, in comparison to healthy subjects, a significantly lower resting flow rate of saliva and significantly higher prevalence of xerosomia were observed, but in type 2 diabetics, only a trend of such variability was observed (**Adv Clin Exp Med 2014, 23, 2, 225–233**).

Key words: diabetes mellitus type 1 and 2, xerostomia, salivary flow rate.

Diabetes is a metabolic disease characterized by hyperglycemia, which results from relative or absolute insulin deficiency. Absolute insulin deficiency is caused by the impairment of its biosynthesis and excretion of pancreatic islets by beta cells, while relative insulin deficiency is the result of the impairment of the reaction of cell, tissue and peripheral organs to insulin activity.

The World Health Organization has distinguished four basic types of the disease, of which the first two are the most frequent to occur. In the course of diabetes, especially with accompanying enduring hyperglycemia, systemic complications are bound to occur; therefore it is crucial to constantly monitor the therapy process. One of the markers used to control the effectiveness of diabetes treatment is testing for glycated hemoglobin content in blood (HbA1c) as a retrospective marker of metabolic control of diabetes. There is a linear correlation between the HbA1c level and the risk of complications [1, 2].

In diabetes, especially in the case of poorly controlled glycemia, oral lesions occur due to the increased level of glucose in the blood. Among others, the destruction of salivary glands has been reported. It manifests itself with impaired salivary secretion and may cause xerostomia, which leads to further damage of hard and soft oral tissues [3–5]. Xerostomia (dry mouth, oral dryness) manifests subjective symptoms of oral dryness, and hyposalivation being an actual reduction in salivary secretion. However, the feeling of dry

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mouth is not always related to hyposalivation, because normally-secreted saliva may be evaporated, leading to a sensation of dryness which occurs in subjects breathing through the mouth. Thus, it is essential to differentiate between primary (*xerostomia vera*) and symptomatic xerostomia (*xerostomia spuria*). The first is caused by reduced salivary gland secretion, but with clinically unchanged mucosa, or with accompanying mucosal atrophy, and visible pathologies involving the salivary glands. The latter occurs in subjects that experience oral dryness and a burning sensation in the mouth with proper function of the salivary glands, and a lack of objective symptoms. A subjectively-experienced feeling of dryness may often occur at a rate of secretion below 0.1–0.2 mL/min; therefore it is essential to differentiate between true xerostomia, related to the hypofunction of salivary gland secretion, and false xerostomia, since in the case of true xerostomia, there is a risk of the occurrence of oral pathologies [6].

The aim of the study was to evaluate the frequency of severity of the xerostomia symptoms and salivary flow rate in diabetic patients according to the type of disease, the level of metabolic control, and the duration of the disease as well.

Material and Methods

The study involved 156 adults of both sexes, out of which 34 had diabetes type 1 – group C1 (mean age 37.5 years, 18 female and 16 male), 59 with diabetes type 2 – group C2 (mean age 65.0 years, 28 female and 31 male), and 63 generally healthy individuals as two control groups K1 (n = 30, mean age 37 years, 16 female and 14 male) and K2 (n = 33, mean age 63.7 years, 16 female and 17 male), matched to the sex and age of the diabetic groups.

The patients suffering from both types of diabetes were additionally subdivided according to the metabolic control expressed by glycated hemoglobin level – HbA1c ≤ 8.5% and HbA1c > 8.5% – forming well-controlled subgroups of type 1 diabetics (subgroup A1), and poorly-controlled (subgroup B1), and type 2 diabetics (subgroup A2 and B2), respectively. The level of glycated hemoglobin was assayed with the use of a DCA 2000 Reagent Kit Siemens (Bayer) test.

Diabetics were also subdivided according to the duration of the disease – up to 10 years and over 10 years. They constituted subgroups of type 1 diabetics suffering from diabetes for less than 10 years – D1, and more than 10 years – E1, as well as respective subgroups of diabetics suffering from type 2 diabetes – D2 and E2.

Samples of resting mixed saliva were collected during the morning hours at least 1 hour after eating or drinking. The subjects sat with the head bent down and mouth open and the collected saliva from the mouth floor was taken by plastic pipette into a graded test tube, which was placed on ice. Based on the time needed for salivary sample collection and measurement of its volume, the salivary flow rate was calculated as mL/min (V).

Afterwards, each subject filled in a specially prepared questionnaire concerning afflictions with special attention paid to the presence of oral dryness symptoms. In order to diagnose xerostomia, Fox's test [7] was used. The test consists of 10 items, 4 [1–4] of which show a significant correlation with a reduced salivary flow. These questions concern a feeling of too little saliva in the oral cavity, a sense of oral dryness (xerostomia) while eating, difficulty swallowing and the need to wash down dry food with water.

Fox's test [7]

Items	Fox's test
1.	Do you need to sip liquids to aid in swallowing dry foods?
2.	Does your mouth feel dry when eating a meal?
3.	Do you have difficulty swallowing any foods?
4.	Does the amount of saliva in your mouth seem to be too little, too much, or you don't notice it?
5.	Does your mouth feel dry at night or on awakening?
6.	Does your mouth feel dry during the daytime?
7.	Do you keep a glass of water by your bed?
8.	Do you chew gum daily to relieve oral dryness?
9.	Do you use hard candies or mints daily to relieve oral dryness?
10.	Do you feel the need for frequent moistening the oral cavity?

The obtained data was analyzed (STATISTICA 9, StatSoft Polska, Kraków) with the use of a Mann-Whitney test with at significance level of $p < 0.05$.

Results

In comparison to healthy subjects, xerostomia diagnosed by Fox's test was observed in a significantly larger group of type 1 diabetics (C1 – 23.5% vs. K1 – 10.0%, $p < 0.05$), with a simultaneous decrease in salivary resting flow rate (C1 – 0.38 ± 0.19 mL/min; K1 – 0.53 ± 0.2 mL/min; $p < 0.01$) (Table 1).

Table 1. Salivary flow rate in diabetic and healthy subject

	Groups				**Significant difference**		
Salivary rate flow	**C1**	**C2**	**K1**	**K2**			
V (mL/min)	X ± SD	X ± SD	X ± SD	X ± SD	C1 vs. C2	C1 vs. K1	C2 vs. K2
	0.38 ± 0.19	0.36 ± 0.21	0.5 ± 0.2	0.45 ± 0.25	ns.	P < 0.01	ns.
Subgroups of diabetics with the different level of metabolic control of the disease							
	A1	A2	B1	B2	Significant difference		
V (mL/min)	X ± SD	X ± SD	X ± SD	X ± SD	A1 vs. A2	B1 vs. B2	
	0.38 ± 0.15	0.41 ± 0.25	0.37 ± 0.21	0.31 ± 0.16	ns.	ns.	
Subgroup of diabetics with the different duration of disease							
	D1	D2	E1	E2	Significant difference		
V (mL/min)	X ± SD	X ± SD	X ± SD	X ± SD	D1 vs. D2	E1 vs. E2	
	0.35 ± 0.2	0.26 ± 0.14	0.40 ± 0.18	0.4 ± 0.22	ns.	ns.	

C1 – patients with diabetes type 1, C2 – patients with diabetes type 2, K1 – control group to C1, K2 – control group to C2, X – arithmetic mean, SD – standard deviation, ns. – differences statistically not significant $p > 0.05$ V – salivary flow rate, A1 – diabetics type 1 and HbA1c ≤ 8.5% level, A2 – diabetics type 2 and HbA1c ≤ 8.5% level, B1 –diabetics type 1 and HbA1c > 8.5% level, B2 –diabetics type 2 and HbA1c > 8.5% level, D1 – patients with history of diabetes type 1 shorter than 10 years, D2 – patients with history of diabetes type 2 shorter than 10 years, E1 – patients with history of diabetes type 1 longer than 10 years, E2 – patients with history of diabetes type 2 longer than 10 years.

Moreover, comparing type 1 and 2 diabetics with subjects from the control group, it was observed that diabetic patients significantly more frequently complained about the feeling of oral dryness during the day (C1 – 38.2% vs. K1 – 20.0%; $p < 0.05$; C2 – 57.6% vs. K2 – 24.2%; $p < 0.05$), and during the night or after waking up (C1 – 20.6% vs. K1 – 10.0%; $p < 0.05$; C2 – 38.9% vs. K2 – 21.2%;

Table 2. Fox's test in patients with diabetes and healthy one

Groups / **Items**	**C1**		**C2**		**K1**		**K2**		**Significant difference**			
	n/N	**%**	**n/N**	**%**	**n/N**	**%**	**n/N**	**%**	**C1 vs. K1**	**C2 vs. K2**	**C1 vs. C2**	**K1 vs. K2**
1.	15/34	44.1	31/59	52.5	3/30	10.0	8/33	24.2	P < 0.05	P < 0.05	ns.	ns.
2.	9/34	26.5	16/59	27.1	9/30	30.0	7/33	21.2	ns.	ns.	ns.	ns.
3.	9/34	26.5	17/59	28.8	9/30	30.0	7/33	21.2	ns.	ns.	ns.	ns.
4.	8/34	23.5	15/59	25.4	9/30	30.0	7/33	21.2	ns.	ns.	ns.	ns.
5.	13/34	38.2	34/59	57.6	6/30	20.0	8/33	24.2	p < 0.05	p < 0.05	ns.	ns.
6.	7/34	20.6	23/59	38.9	3/30	10.0	7/33	21.2	p < 0.05	p < 0.05	ns.	ns.
7.	7/34	20.6	23/59	38.9	6/30	20.0	6/33	18.2	ns.	p < 0.05	ns.	ns.
8.	3/34	8.9	2/59	3.4	0/30	0	0/33	0	ns.	ns.	ns.	ns.
9.	3/34	8.9	1/59	1.7	0/30	0	0/33	0	ns.	ns.	ns.	ns.
10.	2/34	5.9	3/59	5.1	1/30	3.3	0/33	0	ns.	ns.	ns.	ns.
4A	8/34	23.5	15/59	25.4	3/30	10.0	7/33	21.2	p < 0.05	ns.S	ns.	ns.

C1 – patients with diabetes type 1, C2 – patients with diabetes type 2, K1 control group to C1 –, K2 – control group to C2, ns. – differences statistically not significant $p > 0.05$, 4A – number of patients which answered 4 main questions of the Fox's test positively (nr 1–4), n – number of confirmed responses, N – total number of respondents.

Table 3. Other symptoms of the dryness and ways of their overcoming in patients with diabetes and healthy one

No	Groups / Items	C1		C2		K1		K2		Significant difference		
		n/N	%	n/N	%	n/N	%	n/N	%	C1 vs. K1	C2 vs. K2	C1 vs. C2
1.	Other symptoms of the dryness											
	sensation of dryness of mucous membranes of the eye or the nose	8/34	23.5	14/59	23.7	4/30	13.3	6/33	18.2	ns.	ns.	ns.
	difficulty experience in speaking	5/34	17.7	9/59	15.2	5/30	16.7	4/33	12.1	ns.	ns.	ns.
	having problems in tasting food	14/34	41.1	14/59	23.7	3/30	10.0	4/33	12.1	P < 0.001	P < 0.001	ns.
2.	Ways of overcoming the dryness											
	necessity to drink water at night	7/34	20.6	23/59	38.9	6/30	20	6/33	18.2	ns.	P < 0.05	P < 0.05
	using humidifiers the air at home	4/34	11.7	8/59	13.5	0/30	0	2/33	6.1	ns.	ns.	ns.
	using humidifiers to mucous membranes	2/34	5.9	5/59	8.4	0/30	0	2/33	6.1	ns.	ns.	ns.

C1 – patients with diabetes type 1, C2 – patients with diabetes type 2, K1 – control group to C1, K2 – control group to C2, ns. – differences statistically not significant p > 0.05, n – number of confirmed responses, N – total number of respondents.

p < 0.05) (Table 2). Assessing symptoms of dryness other than those related to the oral cavity (Table 3), it was noted that type 1 and 2 diabetics significantly more frequently reported the occurrence of taste disorders (C1 – 41.1% vs. K1 – 10.0%, p < 0.001; C2 – 23.7% vs. K2 – 12.1%, p < 0.001), and type 2 diabetics significantly more often reported the necessity to drink water at night (C2 – 38.9% vs. K2 – 18.2; p < 0.05).

In subgroups of patients with well and poor diabetic control, there were no significant differences in the occurrence of the xerostomia symptoms assessed by Fox's test (Table 4), or significant differences in resting salivary flow rate (A1 – 0.38 ± ± 0.15 mL/min vs. A2 – 0.41 ± 0.25 mL/min; B1 – – 0.37 ± 0.21 mL/min vs. B2 – 0.31 ± 0.16 mL/min). Analyzing the coexistence of other symptoms of dryness (Table 5), it may be stated that type 1 diabetics from subgroup A1 significantly more frequently reported taste disorders in comparison to well controlled type 2 diabetics (A1 – 50% vs. A2 – 17.9%, p < 0.05). There were, however, no significant differences in salivary flow rate in type 1 and 2 diabetics in relation to the level of diabetic control (A1 – 0.38 ± 0.15 mL/min vs. A2 – 0.41 ± 0.25 mL/min; B1 – 0.37 ± 0.21 mL/min vs. B2 – 0.31 ± 0.16 mL/ /min).

Analyzing the results of Fox's test among diabetic patients according to the duration of the disease, no significant differences were found in the frequency of diagnosed xerostomia in subgroups of patients suffering from both types of the disease in the short and long term, as well as no significant differences in salivary flow rate (D1 – 0.35 ± 0.20 mL/min vs. D2 – 0.26 ± 0.14 mL/min; E1 – 0.40 ± 0.18 mL/min vs. E2 – 0.40 ± 0.22 mL/min). Patients suffering from diabetes for 10 years or more (Table 6) more frequently complained about oral dryness during the day (E1 – 35.0% vs. E2 – 64.1%; p < 0.05) and at night or after waking up (E1 – – 10.0% vs. E2 – 38.5%; p < 0.05), and reported the necessity to drink water at night (E1 – 15.0% vs. E2 – 41.1%; p < 0.05) (Table 7).

Discussion

The results of studies on the resting and stimulated flow rate of mixed saliva and the prevalence of xerostomia in type 1 and 2 diabetics does not provide conclusive results. A lack of differences in the secretion of unstimulated mixed saliva in children and adolescents suffering from diabetes in relation to healthy individuals was noted by Karjalainen et al. [8], and a statistically significant reduction was reported by Moreira et al. [9]. A lack of statistically significant differences in salivary secretion as compared with healthy individuals was reported

Table 4. Fox's test in subgroups diabetics with the different level of metabolic control of the disease

Subgroups / Items	A1		A2		Significant difference	B1		B2		Significant difference
	n/N	%	n/N	%		n/N	%	n/N	%	
1.	5/14	35.7	15/28	53.6	ns.	10/20	50.0	16/31	51.6	ns.
2.	1/14	7.1	7/28	25.0	ns.	8/20	40.0	9/31	29.1	ns.
3.	1/14	7.1	7/28	25.0	ns.	8/20	40.0	10/31	32.2	ns.
4.	1/14	7.1	6/28	21.4	ns.	7/20	35.0	9/31	29.1	ns.
5.	5/14	35.7	16/28	57.1	ns.	8/20	40.0	18/31	58.1	ns.
6.	3/14	21.4	10/28	35.7	ns.	4/20	20.0	13/31	41.9	ns.
7.	4/14	28.6	11/28	39.3	ns.	3/20	15.0	12/31	38.7	ns.
8.	1/14	7.1	1/28	3.6	ns.	2/20	10.0	1/31	3.2	ns.
9.	1/14	7.1	1/28	3.6	ns.	2/20	10.0	0/31	0.0	ns.
10.	1/14	7.1	1/28	3.6	ns.	1/20	5.0	2/31	6.4	ns.
4A	1/14	7.1	6/28	21.4	ns.	7/20	35.0	9/31	29.1	ns.

A1 – diabetics type 1 and HbA1c ≤ 8.5% level, A2 – diabetics type 2 and HbA1c ≤ 8.5% level, B1 – diabetics type 1 and HbA1c >8.5% level, B2 – diabetics type 2 and HbA1c > 8.5% level, ns. – differences statistically not significant $p > 0.05$, 4A – number of patients which answered 4 main questions of the Fox's test positively (no. 1–4), n – number of confirmed responses, N – total number of respondents.

Table. 5. Other symptoms of the dryness and ways of their overcoming in subgroups diabetics with the different level of metabolic control of the disease

No.	Subgroups / Items	A1		A2		Significant difference	B1		B2		
		n/N	%	n/N	%		n/N	%	n/N	%	
1.	Other symptoms of the dryness										
	sensation of dryness of mucous membranes of the eye or the nose	3/14	21.4	11/28	39.3	ns.	5/20	25.0	3/31	9.7	ns.
	difficulty experience in speaking	2/14	14.2	3/28	10.7	ns.	3/20	15.0	6/31	19.3	ns.
	having problems in tasting food	7/14	50	5/28	17.9	$P < 0.05$	7/20	35.0	9/31	29.1	ns.
2.	Ways of overcoming the dryness										
	necessity to drink water at night	4/14	28.5	11/28	39.2	ns.	3/20	15.0	12/31	38.7	ns.
	using humidifiers the air at home	0	0	3/28	10.7	ns.	4/20	20.0	5/31	16.1	ns.
	using humidifiers to mucous membranes	0	0	4/28	14.3	ns.	2/20	10.0	1/31	3.2	ns.

A1 – diabetics type 1 and HbA1c ≤ 8.5% level, A2 – diabetics type 2 and HbA1c ≤ 8.5% level, B1 – diabetics type 1 and HbA1c > 8.5% level, B2 – diabetics type 2 and HbA1c > 8.5% level, ns. – differences statistically not significant $p > 0.05$, n – number of confirmed responses, N – total number of respondents.

by Panchbhai et al. [10] examining adult diabetes type 1, and by Aydin [11] and Dodds and Dodds [12] examining type 2 diabetics. A lower secretion of stimulated and/or unstimulated saliva in diabetes type 1 and/or type 2, on the other hand, was demonstrated by Närhi et al. [13], Chavez et al. [3],

Table 6. Fox's test in subgroups diabetics with the different duration of the disease

Subgroups / Items	D1		D2		Significant difference	E1		E2		Significant difference
	n/N	%	n/N	%		n/N	%	n/N	%	
1.	7/14	50.0	9/20	45.0	ns.	8/20	40.0	22/39	56.4	ns.
2.	5/14	35.7	4/20	20.0	ns.	4/20	20.0	12/39	30.8	ns.
3.	5/14	35.7	5/20	25.0	ns.	4/20	20.0	12/39	30.8	ns.
4.	5/14	35.7	4/20	20.0	ns.	3/20	15.0	11/39	28.2	ns.
5.	6/14	42.8	9/20	45.0	ns.	7/20	35.0	25/39	64.1	$P < 0.05$
6.	5/14	35.7	8/20	40.0	ns.	2/20	10.0	15/39	38.5	$P < 0.05$
7.	4/14	28.6	7/20	35.0	ns.	3/20	15.0	16/39	41.1	$P < 0.05$
8.	3/14	21.4	1/20	5.0	ns.	0/20	0.0	1/39	2.6	ns.
9.	3/14	21.4	1/20	5.0	ns.	0/20	0.0	0/39	0.0	ns.
10.	2/14	14.3	1/20	50	ns.	0/20	0.0	2/39	5.1	ns.
4A	5/14	35.7	4/20	20.0	ns.	3/20	15.0	11/39	28.2	ns.

D1 – patients with history of diabetes type 1 shorter than 10 years, D2 – patients with history of diabetes type 2 shorter than 10 years, E1 – patients with history of diabetes type 1 longer than 10 years, E2 – patients with history of diabetes type 2 longer than 10 years, ns. – differences statistically not significant $p > 0.05$, 4A – number of patients which answered 4 main questions of the Fox's test positively (nr 1–4), n – number of confirmed responses, N – total number of respondents.

Table 7. Other symptoms of the dryness and ways of their overcoming in subgroups diabetics with the different duration of the disease

No	Subgroups / Items	D1		D2		Significant difference	E1		E2		Significant difference
		n/N	%	n/N	%		n/N	%	n/N	%	
1.	Other symptoms of the dryness										
	sensation of dryness of mucous membranes of the eye or the nose	3/14	21.4	4/20	20.0	ns.	5/20	25.0	10/39	25.6	ns.
	difficulty experience in speaking	4/14	28.6	5/20	25.0	ns.	1/20	5.0	4/39	10.2	ns.
	having problems in tasting food	7/14	50.0	5/20	25.0	ns.	7/20	35.0	9/39	23.1	ns.
2.	Ways of overcoming the dryness										
	necessity to drink water at night	4/14	28.6	7/20	35.0	ns.	3/20	15.0	16/39	41.0	$P < 0.05$
	using humidifiers the air at home	4/14	28.6	3/20	15.0	ns.	0,0	0.0	5/39	12.8	ns.
	using humidifiers to mucous membranes	1/14	7.1	2/20	10.0	ns.	1/20	5.0	3/39	7.6	ns.

D1 – patients with history of diabetes type 1 shorter than 10 years, D2 – patients with history of diabetes type 2 shorter than 10 years, E1 – patients with history of diabetes type 1 longer than 10 years, E2 – patients with history of diabetes type 2 longer than 10 years, ns. – differences statistically not significant $p > 0.05$, n – number of confirmed responses, N – total number of respondents.

Dodds et al. [14], Bernardi et al. [15], and Vaziri et al. [16]. Moreover, Ben-Aryeh et al. [17] noted a significantly lower resting flow rate of mixed saliva in type 1 diabetics as compared to diabetes type 2. Numerous factors, such as the method of collecting saliva (expectoration or drawing with the use of

a pipette from the mouth floor] and time of the day when saliva was collected, as well as the selection of patients as far as age, sex, body hydration, medicines, coexisting disease, body position and exposure to light are concerned, may have influenced the fact that dissimilar results were obtained. Our study has revealed a statistically significantly lower salivary flow rate in type 1 diabetics as compared to the age-matched control group (0.38 ± 0.19 mL/ /min vs. 0.53 ± 0.20 mL/min, $p < 0.01$), and only slightly lower salivary flow rate in type 2 diabetics (on average by 20% as compared with the respective control group). The secretion of saliva in type 1 and 2 diabetics was similar, and there were no significant differences between the two types of the disease, as compared to the level of diabetic control (good or poor), and the duration of the disease (up to 10 years and 10 years or more).

The causes of reduced salivary secretion in diabetic patients may be multiple. The prevalence of glycosuria caused by mild hyperglycemia results in fluid loss and dehydration of the body, and as a consequence, to decreased secretion of saliva. Moreover, in the course of diabetes, structural pathologies of complex etiologies with regard to salivary glands occur, which leads to disorders in the production of saliva [10]. The presence of pathologies with regard to salivary glands in diabetics with symptoms of xerostomia was confirmed in scintigraphic research by Kao et al. [18]. Furthermore, Chaveza et al. [3] reported that the level of diabetic control is a crucial mediating factor for the secretion of saliva since subjects with poor diabetic control showed a decreased stimulated flow rate of mixed saliva. It has been demonstrated that the coexistence of factors such as diabetic autonomic neuropathy, pathologies of capillaries and hormone imbalance, as well as disorders within the sympathetic and parasympathetic nervous system, may result in a decrease in the sensitivity of salivary glands to stimuli, and as a consequence, lead to an increase in salivary production [19–21]. Sabino-Silva et al. [22] in turn, studied SLC5A1, the gene responsible for biosynthesis of the protein that transports Na+ and glucose, and which is an agent in glucose exchange and in water transport. The gene expression has been modified in diabetic patients, which may cause pathologies in the parotid gland. Most probably, a high concentration of glucose that induces an increase in SLC5A1 gene expression causes a significant increase in mRNA SGLT1 in the parotid gland (by 50%), and the submandibular glands. An immunohistochemical assessment carried out on rats with induced diabetes revealed that the increase in SGLT1 gene expression results in the increase in the amount of protein in the basement membrane of salivary ducts (which were defined by the authors as water pumps) which stimulate reabsorption of water from primary saliva, and may constitute the main pathogenic mechanism explaining reduced production of saliva in diabetic patients.

The result of studies on the frequency of dry mouth in diabetes patients is inconclusive. Lack of differences in the prevalence of symptomatic xerostomia between diabetes type 1 and type 2 and healthy subjects was revealed by Ben-Aryeh et al. [17]. Moore et al. [19] in turn, noted a more frequent occurrence of xerostomia symptoms (24.1%) as well as reduced salivary secretion in type 1 diabetics suffering from neuropathy. Similarly, Busato et al. [23] reported significantly more frequent occurrence of xerostomia symptoms in type 1 diabetics as compared to healthy individuals (52.9% vs. 15.6%, $p < 0.01$). Vasconcelos et al. [24] in turn, reported a significantly more frequent occurrence of subjective oral dryness in type 2 diabetics as compared to healthy subjects (12.5% vs. 2.5%, $p = 0.000$). Carda et al. [25] observed a much greater prevalence of xerostomia, both in type 1 and 2 diabetics (76.4%) as compared to healthy individuals (18.7%), but without relating this data to salivary flow rate. Also Bajaj et al. [26] observed the prevalence of xerostomia with coexisting disorders of the secretory function of salivary glands in 14% of the diabetic patients. Yeh at al. [27] in turn, in studies carried out on mice with induced diabetes type 1, noted that hyperglycemia and xerostomia result in the impairment of the production of enamel matrix proteins, as well as in the inhibition of its mineralization process, which may favor caries development.

The diversified data concerning the frequency of xerostomia largely results from various diagnostic criteria. In order to identify xerostomia, our own research included Fox's test [7] which is useful to detect true secretory hypofunction. Four out of 10 items included in the test (feeling oral dryness during eating, the need to wash down dry food with water, difficulty in swallowing (dysphagia), and a sensation of too little saliva in the oral cavity) reveal a statistically significant correlation with the measured reduction of secreted saliva [28]. Therefore, in this study, xerostomia was identified when positive answers were given to these four questions. Based on this criterion in our study, dry mouth was far more frequently diagnosed in type 1 diabetics than in the control group (23.5% vs. 10.0%, $p < 0.05$; 25.4% vs. 21.2%, $p > 0.05$), with reduced secretion of saliva in diabetics as compared with control groups (0.38 ± ± 0.19 mL/min vs. 0.53 ± 0.2, $p < 0.01$; 0.36 ± 0.21 mL/min vs. 0.45 ± 0.25 ml/min, $p > 0.05$) and patients suffering from diabetes type 2 for a longer

time (10 years and more), as compared with type 1 diabetics, significantly more frequently declared symptoms of xerostomia: the feeling of dry mouth during the day (64.1% vs. 35.0%, $p < 0.05$), during the night or after waking up (38.5% vs. 10.0%, $p < 0.05$), and a need to have a glass of water at the nightstand (41.1% vs. 15.0%, $p < 0.05$), with a similar resting salivary flow rate. In diabetes type 1, the resting flow rate of mixed saliva was considerably lower, and the symptoms of xerostomia were significantly more frequent as compared to healthy subjects. Moreover, in both diabetic groups, irrespective of the type of the disease, it was reported that there was a higher frequency of the symptoms of dry mouth, and a lower salivary flow as compared with healthy subjects. However, the level of metabolic control of the disease and its duration did not significantly influence the salivary secretion. Saes Busato et al. [29] in turn, noted that 52.9% of type 1 diabetics complained about dry mouth, but only 9.8% of them proved to suffer from actually diminished salivary flow rate. 5.6% of the subjects had difficulty swallowing, and 23.5% reported a need to wash down food with water. 40.8% of diabetic patients had lower unstimulated salivary flow rate, but only half of them complained about dry mouth. 57% of the patients with normal secretion of saliva experienced xerostomia.

Our study has revealed a significantly lower flow rate of resting mixed saliva, and a significantly more frequent prevalence of xerostomia in type 1 diabetics as compared to healthy subjects. In type 2 diabetics, only a trend of such variability has been observed.

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