Association of Root Surface Caries with Periodontal Parameters in Type 2 Diabetes Patients

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Abstract

Background: Mounting evidence has demonstrated a reciprocal association between diabetes mellitus and periodontal diseases, characterized by loss of alveolar bone, gingival recession and root exposure. Recently, studies showed that type 2 diabetes patients were at high risk to development root caries. This essay aims to clarify the relationship between root surface caries (RC) and periodontal parameters in diabetes patients, as well as evaluate relevant risk factors in Type 2 diabetes mellitus (T2DM). **Materials and Methods:** A total of 132 qualified adult patients with T2DM and periodontitis were recruited to this study. Radiographic data were collected to calculate alveolar bone loss (ABL). Subjects were assigned to three groups according to tertiles of ABL to make a comparison. Decayed and/or filled teeth (DFT) were calculated for both coronal and root surface as the caries indices of the remaining teeth. The plaque index (PLI), gingival recession (GR), probing depth (PD) at six sites per tooth, number of missing teeth, number of retained root remnants, and number of teeth with furcal lesions were recorded during clinical examinations. Blood analyses were carried out for glycated hemoglobin (HbA1c), fasting glucose. Correlation analysis, analysis of covariance (ANCOVA), and logistic regression were used to analyse the data. **Results:** By analyzing covariance, the research found that subjects with increased ABL have significantly higher numbers of missing teeth, root surface caries DFT, teeth with furcal lesions ($P < 0.05$). There is a significant positive correlation between root surface caries DFT and ABL, GR, coronal caries DFT ($P < 0.05$), respectively. ABL, coronal caries and age became significant predictor variables for Root Surface DFT (≥ 3) ($P < 0.05$). **Conclusion:** Root surface caries were associated with ABL, GR and coronal caries in periodontitis with T2DM as well as ABL, coronal caries and age became risk factors for predicting the occurrence of RC. **Key Words:** Association, Root Caries, Diabetes mellitus, Periodontitis

Background

According to the International Diabetes Federation, 425 million people are affected with diabetes mellitus worldwide, with 109.6 million of them living in China[1, 2]. Type 2 diabetes mellitus (T2DM) poses a serious health problem, in addition to several systematic complications of diabetes, it is also linked to the progression of periodontal disease which is characterized by loss of alveolar bone, gingival recession and deep periodontal pocket, resulting in a greater number of exposed root surfaces at risk of root caries (RC) and missing teeth [2, 3].

Mounting evidence has demonstrated a reciprocal association between diabetes mellitus and periodontal disease [4, 5]. Increased systemic blood glucose concentrations may not only result in the proliferation of anerobic microorganisms associated with periodontal pockets, but also induce inflammatory responses in periodontal disease [6, 7]. Loss of attachment leading to gingival recession (GR) is commonly seen in periodontitis, which can lead to root exposure to oral environment [8, 9]. Then an unfavorable oral environment, with high levels of pathogenic bacteria and rate of carbohydrate fermentation, may alter the balance of the remineralization/demineralization cycles in favor of RC development [10, 11].

Root caries, like coronal caries, is a biofilm/sugar-dependent disease where caries process is caused by bacteria-induced acidification as a result of metabolism of dietary carbohydrates [12]. Unlike coronal caries, lesion of RC mainly locates in the proximal supragingival sites often within 2 millimeters of cemento-enamel junctions. Because there are a considerable amount of organic materials that make up root surfaces, not only does bacterial acidification occur, but also organic material degradation caused by proteases [13–15] in root caries. So there is particular concern over the risk of RC that are faced by patients with a history of periodontitis and resective surgery, especially in multi-rooted teeth [16].

Studies have shown a higher prevalence of root caries in diabetes patients [17–19]. Meanwhile, individuals with T2DM were reported to need greater caries prevention and periodontal treatment [20]. While others indicated no effect of diabetes on the prevalence of RC [21–23]. Most of these studies focused on the comparison of RC in diabetes with non-diabetic counterparts, or compared RC with coronal caries in patients with diabetes. Whether it is accumulated exposure or biological effect that causes the association between the RC and periodontitis among patients with T2DM needs further investigation. The risk factors leading to RC with periodontitis of T2DM patients need to be explored. Therefore, the objective of this cross-sectional study is to verify the relationship between RC and periodontal parameters, such as ABL, GR and PD in periodontitis with T2DM, and to explore the relevant predictor factors in Type 2 diabetes mellitus (T2DM).

Methods

From November 2012 to May 2013, patients attending diabetes-oriented educational classes at 5 diabetes centers in Guangzhou City, China, were invited to participate in this study. A total of 132 patients (71 males and 61 females; aged 36 to 85 years) accepted the invitation. All subjects had been diagnosed with T2DM with the adoption of the criteria of the World Health Organization [24]. At the beginning of this study, patients also received a diagnosis of chronic periodontitis under the criteria of the American Academy of Periodontology [25], with at least fourteen natural teeth. Patients were excluded if they had contracted at least one systemic disease other than diabetes mellitus, had received antibiotics or other medicines in previous 4 weeks, had contracted other oral mucosal diseases, had had complete or removable partial dentures, had contracted an active infection other than periodontitis, pregnancy or lactation, had been receiving periodontal treatment within the last six months, or they refused to provide written informed consent.

HbA1c was tested immediately by boronate-affinity chromatography, and coefficient of variation (CV) of the method for HbA1c ranged from 1.2–2.8%. Fasting plasma glucose levels were assessed by an automated enzymatic method.

Clinical parameters including coronal and root surface caries and periodontal parameters were recorded. Coronal and root surface caries were assessed using a combination of visual and tactile criteria, decayed and/or filled teeth (DFT) for the remaining teeth were calculated for both coronal and root surface caries indices [26]. A single previously calibrated examiner (intra-examiner Kappa value ranged from 80–87%)

made full-mouth assessment for periodontal condition, excluding the third molars, with a Williams manual probe. Clinical variables at six sites (mesio-buccal, mid-buccal, disto-buccal, mesio-lingual, mid-lingual and disto-lingual) per tooth were recorded, including plaque index (PLI), pocket probing depth (PD), gingival recession (GR) and clinical attachment level (CAL). The number of missing teeth, the number of retained root remnants, and the number of teeth with furcal lesions were also recorded. All parameters were examined by one researcher. The intra-examiner calibration was performed with 97%, 95% and 95% agreement for coronal caries, root surface caries and PLI, respectively.

Before receiving periodontal therapy, each patient was taken 14 periapical films for periodontal analysis and medical record. We obtained the films for assessing alveolar bone level. The distance that was first measured was from the cemento-enamel junction (CEJ) to the point of alveolar bone ridge where periodontal ligament started to be of equal width. The second distance was from CEJ to the root apex along the tooth surface. The former was divided by the latter, and the ratio was reported to be as a % for each site. For this report, only sites with a $\geq 20\%$ bone loss were analyzed. The percentages of sites with bone loss $\geq 20\%$ out of the total number of measured sites were calculated and defined as alveolar bone loss (ABL) for each subject. The numbers of teeth with radiolucent periapical lesions and teeth with furcal lesions were also recorded by the same radiologist (XML, the intra-examiner κ value was 82–88%) [27].

The correlations among HbA1c, fasting plasma glucose, ABL, PD, GR and root surface DFT and coronal surface DFT were analysed by Spearman's rho test, respectively. For comparison, subjects were divided into three groups according to tertiles of the ABL. Mild ABL ranged from 12.24–48.94%, moderate ABL ranged from 48.98–69.57%, and severe ABL ranged from 70.27–100%. To determine the differences in the numbers of teeth with RC, coronal caries, furcal lesions, radiolucent periapical lesions, missing teeth and retained root remnants, analysis of covariance (ANCOVA) was performed after adjustment for age, gender, smoking, duration of diabetes mellitus.

All statistical analyses were two-tailed with a significance level at 0.05 and calculated using software SPSS 19.0 (SPSS, Chicago, IL).

Results

The study subjects consisted of 71 (53.8%) males and 61 (46.2%) females with a mean age of 60.16. The mean number of years after they were diagnosed with diabetes mellitus was 8.65 years. There were no significant differences among the three groups in terms of age, gender, disease course, smoking history and other demographic parameters and information at their first visit ($P > 0.05$) (Table 1).

Table 1
The Demographic Parameters of the Study Subjects by Tertiles of Alveolar Bone Loss

Variable	Mild ABL (N = 44) Mean ± SD/n(%)	Moderate ABL (N = 44) Mean ± SD/n(%)	Severe ABL (N = 44) Mean ± SD/n(%)	F/P
Age (years)	58.36 ± 10.36	59.93 ± 9.72	61.50 ± 11.26	0.988/0.375
Duration of diabetes mellitus (years)	8.48 ± 5.99	8.39 ± 6.15	8.70 ± 6.23	0.032/0.969
Gender				
Male	21(47.7)	22(50.0)	28(63.6)	0.307/0.247
Female	23(52.3)	22(50.0)	16(36.4)	
Mean PLI	0.84 ± 0.62	1.60 ± 4.86	0.99 ± 0.45	0.885/0.415
Mean PD(mm)	2.24 ± 0.39	2.53 ± 0.50	2.96 ± 0.79	16.906/0.00
Mean GR(mm)	1.03 ± 0.54	1.46 ± 0.57	1.93 ± 0.82	20.397/0.00
Frequency of tooth-brushing				
≥ 2 times/day	40(90.9)	39(88.6)	37(84.1)	0.410/0.665
1 time/day	4(9.1)	4(9.1)	7(15.9)	
≤1 time/day	0	1(2.3)	0	
Frequency of using dental floss				
Never	39(88.6)	40(90.9)	44(100)	1.940/0.148
≥ 1 time/day	0	1(2.3)	0	
Occasionally	5(11.4)	3(6.9)	0	
Education level				
≤ 6 years	5(11.4)	8(18.2)	6(13.8)	0.775/0.463
7–9 years	9(20.7)	10(22.8)	15(34.2)	
10–12 years	14(41.8)	13(29.5)	12(27.3)	
13–15 years	11(25.0)	4(9.1)	6(13.8)	
≥ 16 years	5(11.4)	9(20.5)	5(11.4)	
Smoking status				
ANCOVA was performed after adjustment for age, gender, smoking, duration of diabetes mellitus, difference is significant at the 0.05 level*.				

Variable	Mild ABL (N = 44) Mean $\pm$ SD/n(%)	Moderate ABL (N = 44) Mean $\pm$ SD/n(%)	Severe ABL (N = 44) Mean $\pm$ SD/n(%)	F/P
Never smoker	36(81.8)	37(84.1)	29(65.9)	2.681/0.072
Ex-smoker	0	1(2.3)	2(4.6)	
Current-smoker	8(18.2)	6(13.8)	13(29.5)	
Financial stress Yes No	28(63.6) 16(36.4)	18(40.9) 26(59.0)	27(61.4) 17(38.6)	2.684/0.062
HbA1c (%)	7.20 $\pm$ 1.30	7.27 $\pm$ 1.43	7.46 $\pm$ 1.60	0.380/0.684
Fasting plasma glucose (mmol/l)	7.81 $\pm$ 2.29	7.81 $\pm$ 2.43	8.10 $\pm$ 2.20	0.239/0.788
ANCOVA was performed after adjustment for age, gender, smoking, duration of diabetes mellitus, difference is significant at the 0.05 level*.				

In correlation analysis, neither root surface DFT nor coronal caries DFT was associated with HbA1c and fasting plasma glucose ($P > 0.05$), though the number of missing teeth was associated with HbA1c ($r = -0.175$, $P = 0.045$). Meanwhile root surface DFT was associated with coronal surface DFT ($r = 0.412$, $P = 0.000$) after controlling for age, duration of diabetes mellitus, gender, smoking, education level, frequency of tooth-brushing, frequency of using dental floss, mean PLI, the number of teeth with coronal caries, the number of missing teeth, and the number of teeth with furcal lesions.

In correlation analysis of periodontal parameters, root surface DFT, the number of missing teeth and the teeth with furcal lesions were associated with mean CAL ($r = 0.189$, $P = 0.030$) ($r = 0.388$, $P = 0.000$) ($r = 0.173$, $P = 0.047$) and GR ($r = 0.172$, $P = 0.049$) ($r = 0.181$, $P = 0.037$) ($r = 0.388$, $P = 0.000$), but not mean PD ($P > 0.05$).

Significant difference was found among the three ABL groups regarding root surface DFT ($P = 0.028$), teeth with furcal lesions ($P = 0.000$) and number of missing teeth ($P = 0.000$) (Table 2).

Table 2 The state of tooth and periapex by ABL severity in oral.

	Mild ABL (n = 44) Mean ± SD	Moderate ABL (n = 44) Mean ± SD	Severe ABL (n = 44) Mean ± SD	F	P
Number of missing teeth	2.30 ± 2.12	3.61 ± 3.33	5.70 ± 4.31	11.437	0.000*
Root surface DFT	1.89 ± 1.54	2.43 ± 1.93	2.93 ± 1.91	3.70	0.028*
Coronal surface DFT	2.18 ± 1.90	2.05 ± 1.61	2.43 ± 1.69	0.560	0.573
Number of retained root remnants	0.69 ± 0.11	1.04 ± 0.16	0.75 ± 0.11	0.520	0.596
Number teeth with furcal lesions	1.07 ± 1.17	1.82 ± 1.21	2.23 ± 1.34	9.853	0.000*
Number of teeth with radiolucent periapical lesions	1.13 ± 0.17	1.06 ± 0.16	1.16 ± 0.18	0.237	0.790
ANCOVA was performed after controlling for age, gender.* The mean difference is significant at the 0.05 level.					

In multiple logistic-regression models using root surface DFT (≥ 3) as a dependent variable, the ABL became a significant predictor variable for elevated root surface DFT in all three models, after adjusting for possible confounders. Age and coronal surface DFT were significant confounders (Table 3).

Table 3 The Logistic Regression Models with Dependent Variables: Root Surface DFT (≥ 3)

	Model 1		Model 2		Model 3	
	P	OR	P	OR	P	OR
Age (years)	0.029*	1.061	0.040*	1.058	0.051	1.056
Male	0.112	2.489	0.121	2.463	0.114	2.548
Frequency of tooth-brushing	0.432		0.471		0.461	
≥ 2 times/day	1.000	0.000	1.000	0.000	1.000	0.000
1 time/day	1.000	0.000	1.000	0.000	1.000	0.000
Frequency of using dental floss	0.816		0.878		0.890	
≥ 1 time/day	1.000	0.000	1.000	0.000	1.000	0.000
Occasionally	0.523	0.492	0.690	0.563	0.629	0.581
Education levels (n)	0.104	—	0.117		0.114	
≤ 6 years	0.999	0.000	0.999	0.000	0.999	0.000
7 to 9 years	0.999	0.000	0.999	0.000	0.999	0.000
10 to 12 years	0.999	0.000	0.999	0.000	0.999	0.000
13 to 16 years	0.999	0.000	0.999	0.000	0.999	0.000
Smoking	0.234		0.218		0.224	
Never smoker	0.137	16.297	0.142	15.778	0.157	14.688
Current smoker	0.291	7.283	0.326	6.398	0.357	5.849
Mean PLI	0.346	0.826	0.455	0.806	0.454	0.809
Number of retained root remnants			0.463	1.239	0.466	1.237
Number of missing teeth					0.772	1.022
Coronal surface DFT	0.000*	1.912	0.000*	1.919	0.000*	1.905
Alveolar Bone Loss	0.015*	16.173	0.013*	17.443	0.030*	15.074

OR = odds ratio; — = not applicable.

Model 1 was adjusted for age, gender, frequency of tooth-brushing, frequency of using dental floss, education levels, smoking, and mean PLI with a -2 log likelihood = 115.628, Cox and Snell R² = 0.368, and Nagelkerke R² = 0.499; Model 2 was additionally adjusted for the number of retained root remnants with a -2 log likelihood = 115.066, Cox and Snell R² = 0.370, and Nagelkerke R² = 0.503; Model 3 was additionally adjusted for number of missing teeth with a -2 log likelihood = 114.982, Cox and Snell R² = 0.371, and Nagelkerke R² = 0.503.

* The mean difference is significant at the 0.05 level

	Model 1		Model 2		Model 3	
	P	OR	P	OR	P	OR
Constant	1.000	0.000	1.000	0.000	1.000	0.000
OR = odds ratio; – = not applicable.						
Model 1 was adjusted for age, gender, frequency of tooth-brushing, frequency of using dental floss, education levels, smoking, and mean PLI with a -2 log likelihood = 115.628, Cox and Snell R2 = 0.368, and Nagelkerke R2 = 0.499; Model 2 was additionally adjusted for the number of retained root remnants with a -2 log likelihood = 115.066, Cox and Snell R2 = 0.370, and Nagelkerke R2 = 0.503; Model 3 was additionally adjusted for number of missing teeth with a -2 log likelihood = 114.982, Cox and Snell R2 = 0.371, and Nagelkerke R2 = 0.503.						
* The mean difference is significant at the 0.05 level						

Discussion

This study has demonstrated that the DFT severity of root surface is strongly positively correlated with increased ABL and coronal caries in T2DM patients.

It is well-known that root surface exposure to oral cavity is a prerequisite for root surface caries. CAL and GR have been recognized as relevant factors in the onset and occurrences of RC [28]. Meanwhile, gingival recession in periodontal disease which resulted from alveolar bone loss is the main cause of such exposure [29]. Analysis of ancient skeletal remains shows that the occurrence of root caries is correlated with alveolar bone loss [30]. So the main etiologic factors for onset of RC is “exposure”, subsequently the presence of bacteria and fermentable carbohydrates on the root surface cause the progression of RC [31]. Recent studies have provided supportive findings to suggest that coronal caries could contribute to the occurrence of carious cavities and further trigger root caries [26, 32, 33].

However, root surface DFT was not associated with mean PD in this study. In our previous study, periodontal pocket, as a result of chronic gingival inflammation including considerable inflammatory cells and cytokines, has demonstrated that increased PD is significantly associated with glycemic control in T2DM patients [34]. From anatomical structure and pathological points of view, PD does not necessarily directly cause the exposure of root surface [35]. And the relationship between the periodontal pocket and root caries could be further explored.

There are biologically plausible explanations that diabetes mellitus is linked to the progression of periodontal disease at risk for RC [36]. While results of the present study do not support the direct association between RC and HbA1c. Some research has suggested that oral microenvironment may be exacerbated by T2DM, showing elevated gingival crevicular glucose levels, subsequently cariogenic bacteria accumulation and reproduction accelerate, and consequently salivary flow slows, leading to RC [19, 37, 38]. Nevertheless, so far no studies have suggested that the patients with T2DM have higher

content of susceptible bacteria of root caries [39]. It needs larger-scaled randomized controlled trial (RCT) investigation into the controversial findings so as to confirm inter-relationship between RC and T2DM.

In addition, other epidemiological studies have supported the notion that diabetes may serve as a precursor to natural tooth loss. Some findings are consistent with the evidence from the studies [40, 41]. However, negative correlation between the number of missing teeth and HbA1c were found in this study. There is evidence which shows that the relationship between diabetes and periodontal diseases is bidirectional. For example, periodontitis could have a negative effect on glycemic control[42]. Tooth loss, so that major inflammatory cytokines correlating with T2DM decrease, is likely cause a reduction in HbA1c. More research is needed to confirm the association between tooth loss and T2DM.

Age has been confirmed to be a key variable with regard to diagnostic, aetiological, and intervention research of caries and periodontitis [11, 43], which is consistent with the logistic regression outcomes of this study. It is evident that patients with periodontal diseases, caries susceptibility and elder age with T2DM deserve particular attention and extra oral healthcare.

Abbreviations

RC: Root surface caries; T2DM: Type 2 diabetes mellitus; ABL: Alveolar bone loss; DFT: Decayed and/or filled teeth; PLI: Plaque index; GR: Gingival recession; PD: Probing depth; HbA1c: Glycated hemoglobin; ANCOVA: Analysis of covariance; CV: Coefficient of variation; CAL: Clinical attachment level; CEJ: Cemento-enamel junction.

Declarations

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Availability of data and materials

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

Authors' contributions

LC and SZ proposed the experimental hypothesis and design, and wrote the manuscript. DL analyzed the data and revised the manuscript. MI and FT collected the clinical samples and provided the clinical

diagnosis, XL as a radiologist, contributes to image analysis. All authors read and approved the final manuscript.

Consent for publication

Not Applicable.

Conflicts of interest

The authors report no conflicts of interest related to this study.

Ethics statement and consent to participate

The present study was performed in accordance with the Declaration of Helsinki. Ethics approval was gained from the Ethical Committee of Southern Medical University before implementation of the study, and written informed consent was obtained from all participants at the beginning of the study.

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