Oral Health Status of Low-income, Middle-aged to Elderly Hong Kong Chinese with Type 2 Diabetes Mellitus

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Purpose: To study oral health conditions, diabetic medical complications and their association in type 2 diabetes mellitus (DM).

Materials and Methods: Cross-sectional survey of 364 type 2 DM patients (63.6 ± 10.1 years, 54% female) and 161 controls (64.1 ± 10.6 years, 53% female) with or without essential hypertension, predominantly low-income, attending a hospital were recruited. Periodontal disease (Community Periodontal Index [CPI]) and dental status (decayed, missing and filled teeth [DMFT]) were recorded. Fasting plasma glucose and, for DM patients, HbA1C and DM complications were recorded on enrolment and follow up, respectively.

Results: Many DM subjects had fair diabetic control. Both groups (control/DM) had poor oral health: DMFT = 14.5/16.8, CPI 4 = 36%/50%, (P <0.02) while DM subjects had less DT(adjusted) = 2.1/1.4 (P <0.01). Of the follow-up DM individuals, 294 (81%) had medical complication(s). Regression analyses showed association between advanced periodontal attachment loss (ALoss) and age, male gender, smoking and DM; MT and DMFT were associated with age, female gender, smoking, DM and hypertension. ALoss and DMFT were not associated with DM complications.

Conclusions: The oral health of the surveyed Chinese subjects was poor. Type 2 DM subjects were affected more by ALoss and MT but less DT. Subjects with hypertension had higher odds for MT.

Key words: dental caries, diabetes complications, diabetes mellitus, DMF index, periodontal disease, type 2 diabetes mellitus

Oral Health Prev Dent 2008; 6: 105-118. *Submitted for publication: 15.01.07; accepted for publication: 18.06.07.*

Periodontal disease is reported to be the sixth most common complication of diabetes mellitus (DM) (Loe, 1993), and links between these two conditions are emerging. Type 2 DM is characterised by peripheral insulin resistance with a production defect in insulin that varies in severity. China is one of the countries with the largest number of people suffering from DM. Chinese people who live in urbanised locations such as Hong Kong experience even higher environmental and lifestyle risks for the development of DM (Chan, 2000). It has been suggested that DM predisposes individuals who have inadequate oral hygiene to periodontal disease, through a combination of mechanisms including defective leukocyte function, altered collagen synthesis, chronic vascular pathology and compromised wound healing (American Academy of Periodontology, 1996). DM is also reported to be associated with salivary gland hypofunction, which is in turn associated with an increased risk of dental caries in DM patients (Moore et al, 2001a). Control of dental decay and periodontal disease is therefore particularly important in the overall management strategy of diabetes.

The relationship between DM and periodontal disease has been suggested to be bidirectional (Grossi and Genco, 1998), but proper substantiation is need-

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ed. Although many reports have explored the links between type 2 DM and dental caries or periodontal disease in isolation (Taylor et al, 2004), comprehensive reports concerning both oral problems and their associations with type 2 DM status and DM medical complications are uncommon.

Diabetic complications, both macrovascular and microvascular, are influenced by a variety of factors, including DM/hyperglycaemia duration, pathobiology of the diabetic state, behaviour or attitude towards health care and heredity (Ko et al, 1995; Young et al, 1998; Bachmann et al, 2003). DM and its complications are generally also considered risk indicators or risk factors for periodontal diseases or tooth loss (Persson et al, 2003; Ng and Leung, 2006). In addition, dental status such as decayed (D) and filled tooth (FT) surfaces in patients with insulin-dependent diabetes mellitus (IDDM) is reported to be associated with diabetic neuropathy (Moore et al, 2001b); in type 2 DM subjects, missing teeth (MT) and temporomandibular joint dysfunction have been found to be associated with diabetic neuropathy (Collin et al, 2000). Some studies have also reported that periodontitis is associated with DM complications such as renal, cardiovascular and ischemic heart disease, as well as retinopathy in IDDM or type 2 DM (Thorstensson et al, 1996; Noma et al, 2004; Saremi et al, 2005).

In Hong Kong, where the population is 6.9 million (Hong Kong Census and Statistics Department, 2005), the prevalence of type 2 DM is about 10% (Lam et al, 2000). Despite being known as a high-income city, only about one quarter of the Hong Kong population are regular dental attendees (Lo and Schwarz, 1994a; Dental Service Head Office, 2002). A study by Cruz and co-workers regarding oral health among Asian-Americans in New York City (Cruz et al, 2001) reported that the low income status of the Chinese cohorts was associated with poor perceived, as well as actual, dental health status. Low-income DM subjects were also reported to commonly experience cardiovascular comorbidities (Robbins et al, 2005). Dentally underserved, low-income DM individuals would therefore potentially provide a reasonable platform for studying the association between oral health status, type 2 DM and DM complications.

The objective of this prospective cross-sectional study was therefore to investigate the oral health conditions of a group of dentally underserved Hong Kong Chinese patients with type 2 DM and to assess whether patients' dental and periodontal conditions are associated with diabetic control and concurrent diabetic medical complications. The null hypotheses for this study were as follows: (i) DM confers no extra burden on dental health in mainly low-income, older Hong Kong Chinese patients with DM; and (ii) oral health status of DM subjects is not associated with DM control or any concurrent diabetic medical complications.

MATERIALS AND METHODS

Study participants

The target sample size was at least 400 cases plus controls, with reference to previously published surveys similar to the present study (Bacic et al, 1989; Sandberg et al, 2000). Patients with type 2 DM were conveniently recruited from the specialist referral outpatient clinic of the Tung Wah Eastern Hospital (TWEH), Hong Kong, whereas controls without DM were also conveniently recruited from the TWEH free walk-in General Outpatient (GOP) Clinic during the study period. Patient turnover for both clinics is approximately 60 to 70 each per half-day session.

Patients were recruited on six consecutive Mondays with the morning or afternoon session randomly allocated to the selection of only patients or only controls by a coin toss performed by a medical member of the team. Based on past records, the proportions of first-time attendees were 10% or 50% for the DM and GOP Clinic, respectively. Approximately half of the GOP Clinic attendees were those with chronic disease, principally essential hypertension, who were receiving regular follow-up and oral hypotensive therapy.

Inclusion criteria for both DM group and controls were as follows. Participants had to be: (i) of Chinese ethnicity, (ii) ≥ 41 years old, and (iii) require no antibiotic prophylaxis for periodontal examination. In addition, the control subjects had: (iv) no systemic disease except essential hypertension, and (v) no DM, i.e. fasting plasma glucose (FPG) < 7.0 mmol/l (Alberti and Zimmet, 1998). FPG data of controls were reviewed 1 month after their recruitment period to confirm eligibility of control subjects. Also the gender and age proportion of subjects in DM or control group were adjusted if needed.

Ethics

The ethical principles defined by the World Medical Association Declaration of Helsinki were followed in this study and all participants gave written informed consent. Approval for the study was granted by the Ethics Committee of the Faculty of Dentistry, The University of Hong Kong.

Data collection

Patient background and dental examination

A self-administered questionnaire was used to collect data on educational level, family income, smoking habits, oral hygiene practices, time since last dental visit and the presence of any medical conditions that might indicate antibiotic prophylaxis before periodontal examination. The subjects were then interviewed individually in a room by a dentist who was not involved in the dental examination to check and follow up for non-responses in the questionnaire and to ascertain that DM subjects fulfilled the selection criteria (i) to (iii) and that controls fulfilled the selection criteria (i) to (iv) before enrolment. The subjects were also reminded not to disclose their medical history to the dental examiners.

Dental examinations were conducted in a separate room at TWEH by four examiners calibrated as described by Schwarz et al (2001); two dentists exclusively assessed caries status (FCSC, CSPT) and two exclusively assessed periodontal disease status (LJ, WKL) according to standard World Health Organization (WHO) protocols (WHO, 1997). The dental status classification (DMFT score), examination procedures, dental instruments and diagnostic criteria used were those recommended by the WHO (1997). In addition, the number of edentulous patients and the use of dental prostheses were recorded according to the WHO Oral Health Assessment Form (WHO, 1997). Periodontal status summarising the condition at six sextants per mouth was assessed using the Community Periodontal Index (CPI) according to WHO criteria (WHO, 1997) and periodontal attachment loss (ALoss) as described by Corbet et al (2001). The latter classification system is scored as follows:

- score 0 = ALoss of 0 to 3 mm (cemento-enamel junction [CEJ] not visible and CPI score 0–3)
- score 1 = ALoss of 4 to 5 mm (CEJ within the black band on the CPI probe)
- score 2 = ALoss of 6 to 8 mm (CEJ between the black band and the 8.5-mm ring)
- score 3 = ALoss of 9 to 11 mm (CEJ between the 8.5- and 11.5-mm rings)
- score 4 = ALoss of 12 mm or more (CEJ beyond the 11.5-mm ring)
- score X = excluded sextant, < 2 teeth present
- score not recordable (CEJ not detectable owing to calculus or restoration).

Chronic periodontitis was defined as a CPI score of 4 in any one sextant (WHO, 1997). Plaque control of subjects was not recorded. Oral hygiene instructions were given to each subject immediately after the examination.

Assessment of DMFT, or CPI and ALoss scores was performed by any one of the two calibrated dentists and repeated by his partner every tenth patient. Dental examination results were discussed and reviewed by the full dental team immediately after each survey day. Calibration exercises at the Prince Philip Dental Hospital were performed on the Friday before each survey day to ensure consistency of the examination techniques throughout the study.

Current medical status

The hypertension status of controls, and DM control, hypertension status and medical complications of DM patients were assessed by the endocrinology team of the research group (SCS, KWW), who were not involved with the dental examination. The medical data, except FPG for controls, were disclosed to the dental examiners only after all dental and medical surveys had been completed, subjects' eligibility confirmed and age proportion of control subjects adjusted. Blood pressure of all recruited subjects was taken on the day of recruitment followed by a recall medical appointment. A fasting blood sample was taken for FPG determination for all subjects, and an extra blood sample was taken for glycosylated haemoglobin (HbA1c) level determination for DM subjects. Diabetic complications of new DM attendees would be calculated within 6 months of recruitment. At the follow-up visit, the presence of current DM complications, if any, were recorded. Cerebrovascular accident (CVA) was defined as a history of CVA or signs of cerebrovascular infarction or haemorrhage detected by brain magnetic resonance imaging or computed tomography (Fauci et al, 1998), with or without full patient recovery. Coronary heart disease (CHD) was defined on the basis of clinical features and an abnormal electrocardiogram, and was confirmed by exercise tolerance testing, coronary angiography and/or previous history of heart failure. In addition, CHD was diagnosed if the patient had received concurrent CHD treatment or had a relevant history requiring hospital admission, such as myocardial infarction, revascularisation or angina (Thomas et al, 2003).

Diabetic nephropathy was defined as microalbuminuria of 30 to 300 mg/day (in the absence of urinary tract infection and cardiac failure), proteinuria or macroalbuminuria > 300 mg/day (Young et al, 1998). Diabetic neuropathy was defined on the basis of clinical features; abnormal results from nerve conduction studies, vibration or reflex tests; biothesiometry > 25; or a history of amputation due to neuropathy (Parta-

nen et al, 1995; Fauci et al, 1998). Diabetic retinopathy was detected from retinal photographs that had been taken with a nonmydriatic 45° retinal camera (CR-45UAF camera; Canon, Kanagawa, Japan) and interpreted by a calibrated ophthalmologist as described previously (Siu et al, 1998). Hypertension was defined as a blood pressure (systolic/diastolic) > 150/90 mm Hg (WHO, 1999) for untreated subjects taking no medications after resting in a seated position for at least 5 minutes, or as having a history of hypertension and concurrently taking oral hypotensive medications. Peripheral vascular disease (PVD) was defined on the basis of clinical history, such as intermittent claudication, amputation after podiatry tests or clinical absence of a peripheral pulse (Dargis et al, 1999).

Owing to practical reasons, no repeated test was carried out for medical examinations. Machine read data for blood tests, complicated or invasive diagnostic tests results were reviewed, discussed, and confirmed as a result of agreement between the two members of the endocrinology team.

Data analysis

Theoretical model

The theoretical model supporting the strategy for statistical analysis used is as follows. DM status is known to impact negatively on the healing response of those who have the disease, which will then affect the health of the periodontium, which regularly faces chronic inflammation. The effect of DM on human salivary gland function would also affect the dental health of DM subjects. DM complications are events that may occur in time, particularly when metabolic control of the disease is less than optimal. Poor DM control is likely to affect oral health. The analyses were therefore designed to focus on working out the associations between poor dental or periodontal health with known risk factors such as age, smoking habit, dental habits, DM and DM complications. The data analysis strategy was carried out as described below.

Statistical analysis

All data were analysed using the Statistical Package for Social Sciences, version 11.5 (SPSS, Chicago, IL, USA). Standard descriptive statistics (mean, standard deviation, frequency) were used to describe the demographic characteristics of subjects, the pattern of dental habits and dental service utilisation, blood pressure and oral health status. Chi-square test or Fisher exact test was used for comparing categorical variables, and *t* test and/or analysis of variance (ANOVA) was used for comparing continuous variables in multi-group comparisons. Logistic regression was used to determine, among the pooled DM and control data, the risk factors for the binary variables CPI (CPI score = 4) and ALoss scores (ALoss score ≥ 2). The associations between poor periodontal health, DM control and DM complications in test subjects were also studied. Caries experience of subjects stratified in terms of gender or DM status and adjusted for age was analysed using analysis of covariance (ANCOVA) and a stepwise linear regression model. Any associations between caries experience, DM control and DM complications in diabetes subjects were also evaluated. A significance level of 0.05 was adopted.

RESULTS

Participation rate

Of the total of 402 DM patients who attended the DM clinic, 385 fulfilled the recruitment criteria (excluded patients: 12 subjects < 41 years old or with type 1 DM; 3 required prophylactic antibiotics before periodontal examination; 2 were non-Chinese); 364 consented to participate (participation rate, 95%; 54% female), of whom 43 (12%) were first-time attendees. Of the total of 387 control patients attending the GOP Clinic, 207 fulfilled recruitment criteria (excluded patients: 110 subjects < 41 years old; 43 receiving concurrent medical treatment other than oral hypotensive agents; 21 with FPG ≥ 7.0 mmol/l; 3 required prophylactic antibiotics before periodontal examination; 3 were non-Chinese); 190 consented to participate (participation rate, 92%, 54% female), 96 (51%) of whom were new patients. The proportion of DM patients who were 41 to 60 years old was smaller than that of the non-DM group (124/364 or 34.1% vs 85/190 or 44.7%, P = 0.018, Chi-square test). The corresponding 41- to 60-year-old subgroup of control subjects were thus arranged according to ascending age order, then the corresponding size of this subgroup was reduced by deleting the first followed by every third subjects from the list. A total of 29 individuals were deleted, leaving the corresponding subjects of similar proportion to that of the test group (56/161 or 34.8%, P = 0.95, Chi-square test).

With 161 controls and 364 patients, and assuming the risk of 60% in the DM group, the minimum odds ratio (OR) detectable is 1.73 with an 80% power and a 5% level of significance.

Table 1 Background characteristics of study participants

Characteristic	Categories	Non-DM (n = 161)	DM (n = 364)	Test	Statistics	P-value
Age (years)	Mean ± SD	64.1 ± 10.6	63.6 ± 10.1	*t*	0.46	NS
	Range	41–85	41–85			
Gender	Male	75 (46.6)	168 (46.2)	χ^2	0.01	NS
	Female	86 (53.4)	196 (53.8)			
Education	No/primary	83 (51.6)	218 (59.9)	χ^2	3.70	NS
	Secondary	62 (38.5)	110 (30.2)			
	Post-secondary	16 (9.9)	36 (9.9)			
Monthly household income (HK$)[a]	≤ 4,999	128 (79.5)	287 (78.8)	χ^2	4.34	NS
	5,000–9,999	13 (8.1)	47 (12.9)			
	≥ 10,000	20 (12.4)	30 (8.2)			
Smoking habit	Non-smoker	115 (71.4)	266 (73.1)	χ^2	0.75	NS
	Ex-smoker	28 (17.4)	66 (18.1)			
	Smoker	18 (11.2)	32 (8.8)			
Hypertension	No	85 (52.8)	127 (34.9)	χ^2	14.87	< 0.0001
	Yes	76 (47.2)	237 (65.1)			
Tooth brushing habit	< 2 times daily	49 (30.4)	136 (37.4)	χ^2	2.35	NS
	≥ 2 times daily	112 (69.6)	228 (62.6)			
Flossing habit	No	151 (93.8)	344 (94.5)	χ^2	0.11	NS
	Yes	10 (6.2)	20 (5.5)			
Time lapsed since last dental visit	≤ 1 year	43 (26.7)	146 (40.1)	χ^2	17.24	< 0.0001
	2 years	48 (29.8)	63 (17.3)			
	3 years	26 (16.1)	39 (10.7)			
	≥ 4 years	44 (27.3)	116 (31.9)			
CPI[b]		n = 153	n = 308			
	0, 1, 2, or 3	98 (64.1)	155 (50.3)	χ^2	7.78	< 0.005
	4	55 (35.9)	153 (49.7)			
ALoss[c]		n = 150	n = 303			
	0 or 1	89 (59.3)	149 (49.2)	χ^2	4.15	< 0.05
	≥ 2	61 (40.7)	154 (50.8)			
Caries experience (mean ± SD)	DT	2.1 ± 2.7	1.3 ± 2.2	*t*	3.27	< 0.001
	FT	2.0 ± 2.8	1.6 ± 2.7	*t*	1.55	NS
	MT	10.5 ± 8.4	13.9 ± 10.5	*t*	3.59	< 0.0001
	DMFT	14.5 ± 8.6	16.8 ± 9.8	*t*	2.52	< 0.02
		n = 156	n = 317			
	DT/DMFT%[d]	16.5 ± 20.1	11.8 ± 17.0	*t*	2.51	< 0.02

Results are No. (%) unless otherwise indicated
DM, diabetes mellitus (type 2)
NS, not significant
[a]US$ 1 = HK$ 7.8
[b]CPI, Community Periodontal Index score; n = 153 controls and 308 DM patients. Reasons for exclusion: (i) complete edentulism: 2 male and 3 female controls, 18 male and 29 female DM patients; (ii) insufficient teeth in any one sextant: 1 male and 2 female controls, 4 male and 5 female DM patients.
[c]ALoss, periodontal attachment loss score (see the main text for definitions); n = 150 controls and 303 DM patients. Reasons for exclusion: (i) complete edentulism: 2 male and 3 female controls, 18 male and 29 female DM patients; (ii) unable to score any one sextant: 1 male and 5 female controls; 6 male and 8 female DM patients.
[d]n = 156 controls and 317 DM patients. Reason for exclusion: complete edentulism: 2 male and 3 female controls, 18 male and 29 female DM patients.

Participants' profiles

Demographic characteristics and smoking habits
The control and DM subjects had similar demographic characteristics (Table 1), such as mean age, gender and education proportions. The majority of both groups could be considered to have a low socioeconomic status: approximately 80% of each had a mean household monthly income of HK$ 4,999 or less (< US$ 7,700 per year). Similar proportions of each group smoked (about 1 in 10) (Table 1).

Table 2 Periodontal status of study participants

	CPI		ALoss	
	Non-DM	DM	Non-DM	DM
n[a]	153	308	150	303
Percentage of subjects with highest score				
0	0.0	0.0	11.3	9.2
1	0.0	0.0	48.0	39.9
2	12.5	11.0	30.0	33.3
3	51.6	39.3	8.0	12.9
4	35.9[b]	49.7	2.7	4.6
Mean number of sextants with score				
0	0.0	0.0	1.9[c]	1.5
1+2+3+4	5.1	4.8	2.8	2.9
2+3+4	5.1	4.8	0.7[c]	1.0
3+4	2.9	3.1	0.1	0.2
4	0.7	1.1	0.0	0.1
X	0.9	1.2	1.3	1.6

CPI, Community Periodontal Index
ALoss, periodontal attachment loss score (see the main text for definitions)
DM, diabetes mellitus (type 2)
[a]See Table 1 for reasons for exclusion
[b]Significantly different from DM group, Fisher exact test, $P < 0.02$
[c]Significantly different from DM group, ANOVA, $P \leq 0.018$

Table 3 Adjusted caries experience of study participants

Caries experience	Categories	Mean (SD)	Statistics	P-value[a]
DT	Male	1.91 (0.16)	F = 3.94	< 0.05
	Female	1.50 (0.15)		
	Non-DM	2.06 (0.18)	F = 10.41	< 0.001
	DM	1.35 (0.12)		
FT	Male	1.54 (0.17)	F = 3.70	NS
	Female	1.98 (0.16)		
	Non-DM	1.97 (0.20)	F = 3.03	NS
	DM	1.55 (0.13)		
MT	Male	11.06 (0.57)	F = 7.33	< 0.01
	Female	13.10 (0.54)		
	Non-DM	10.29 (0.68)	F = 19.28	< 0.0001
	DM	13.87 (0.45)		
DMFT	Male	14.51 (0.55)	F = 8.26	< 0.005
	Female	16.58 (0.51)		
	Non-DM	14.32 (0.65)	F = 9.88	< 0.005
	DM	16.77 (0.43)		
DT/DMFT%[b]	Male	17.73 (1.24)	F = 15.72	< 0.0001
	Female	11.20 (1.16)		
	Non-DM	16.76 (1.43)	F = 6.88	< 0.01
	DM	12.17 (1.00)		

Data have been adjusted for age; DM = diabetes mellitus (type 2)
[a]ANCOVA
[b]Exclusions due to complete edentulism: 2 male and 3 female controls, 18 male and 29 female DM patients

Dental background

More than 6 in 10 of patients in both groups brushed their teeth at least twice a day, but more than 9 in 10 did not floss (Table 1). Although the mean (± standard deviation) time since the last dental visit was similar for both groups (control vs DM: 2.5 ± 1.2 years vs 2.4 ± 1.4 years), the distribution of patients by duration since last visit was significantly different, with DM patients most commonly reporting that they visited a dentist within the last 12 months (Table 1). About 3 in 10 patients in both groups had not been to a dentist for 4 or more years.

In addition, the two groups showed significantly different distributions when classified by periodontal status (Table 1). Half of the type 2 DM subjects and 36% of control subjects had chronic periodontitis (highest CPI score of 4, Table 1). No subject had a healthy periodontium, i.e. CPI score of 0 or 1. The detailed periodontal status of the subjects is shown in Table 2.

Controls had more decayed teeth and a higher DT/DMFT%, i.e. DMFT burden due to DT, than DM patients but fewer missing teeth and a lower DMFT score (Table 1). These differences persisted after adjustment for age (Table 3).

When the two groups were combined (n = 525) and data were analysed by sex, men had a higher adjusted DT score and DT/DMFT% but lower MT and DMFT scores than women (Table 3).

Furthermore, fewer controls (n = 56, 34.8%) than DM subjects (n = 171, 47.0%) wore removable partial dentures (P = 0.001, Chi-square test). Forty-seven (13%) type 2 DM subjects and 5 (3%) control subjects were totally edentulous (P < 0.001, Chi-square test).

Inter-examiner reliability

Examinations for DMFT (FCSC vs CSPT), CPI and ALoss (LJ vs WKL) were repeated on a total of 71 randomly selected test or control subjects. Inter-examiner reproducibility of clinical dental examination results (percentage agreement) was never below 89%. Results from these duplicate examinations showed that inter-examiner reliability on dental status as well as periodontal status was good (Kappa = 0.83 for DMFT) or very good (weighted Kappa = 0.75 for CPI and 0.86 for ALoss).

Medical status

Of the 43 DM patients who attended the DM clinic for the first time, two failed to appear for the subsequent medical follow-up. Of the 362 DM patients who were successfully evaluated for their medical history, the mean age of DM onset was 55.3 ± 10.7 years and the mean time since diagnosis was 7.9 ± 1.3 years. The mean HbA1c and FPG levels were 7.9 ± 1.3% and 8.5 ± 2.7 mmol/l, respectively.

Diabetic complications found among the surveyed DM participants, in ascending order of prevalence, were CVA (3.6%), PVD (6.4%), CHD (13.3%), neuropathy (29.8%), retinopathy (34.3%), nephropathy (44.5%), periodontitis (49.7%) and hypertension (65.5%). Hypertension was significantly more common among the 364 DM patients than among the 161 controls (Table 1). Medical treatment for hypertension in the DM and control groups was more or less the same: oral hypotensive drugs such as diuretics, β-blockers and calcium channel blockers, whichever was appropriate, along with diet modification. However, all hypertensive DM patients were also routinely given angiotensin-converting enzyme inhibitor I for renal protection. Among the 362 DM patients who were successfully followed up, 81% had one or more DM complications and 16% had four or more DM complications. Of the 41 followed-up patients who attended the DM clinic for the first time, 68% had one or more medical complications: 2% had CVA, 7% had CHD, 10% had neuropathy, 20% had retinopathy, 37% had nephropathy and 51% had hypertension. Two-thirds of these first time attendees had a highest CPI score of 4.

Odds for advanced periodontal attachment loss

Periodontal parameters such as the highest CPI score and highest ALoss score were dichotomised for odds assessment as follows. The highest combined CPI scores of 2 or 3 were classed as non-periodontitis (gingivitis or moderate periodontal disease; no participants had a highest score of 0 or 1) and a highest score of 4 was classified as advanced periodontal disease. Highest combined ALoss scores of 0 or 1 were classed as normal or noncases (minimal periodontal attachment loss) and a highest score of 2 or more was classed as advanced periodontal attachment loss (probing attachment level ≥ 6 mm in any one sextant examined).

CPI scores

Results of the univariate analysis to identify factors associated with having a highest CPI score of 4 are shown in Table 4. Young individuals and women had a significantly reduced likelihood of having a highest CPI score of 4, whereas smokers and ex-smokers and DM patients had a significantly increased likelihood. A stepwise logistic regression analysis was then performed with these risk factors as independent variables to eliminate possible confounding effects. As shown in Table 4, smoking and DM were the only fac-

Table 4 Odds ratios for study participants with Community Periodontal Index (CPI) score = 4

Variable	Categories	Unadjusted (univariate)[a] OR	P-value	95% CI	Adjusted[b] OR	P-value	95% CI
Age		0.98	0.018	0.96–1.00	0.98	0.041	0.96–1.00
Gender	Male	1.00	0.011			NS	
	Female	0.62		0.43–0.90			
Education	No/Primary	1.00	0.276				
	Secondary	1.13		0.76–1.68			
	Post-secondary	0.66		0.35–1.24			
Smoking habit	Non-smoker	1.00	0.002		1.00	0.001	
	Ex-smoker	1.81		1.11–2.95	1.98		1.20–3.27
	Smoker	2.78		1.43–5.40	2.74		1.39–5.43
Type 2 DM	No	1.00	0.006		1.00	0.004	
	Yes	1.76		1.18–2.62	1.84		1.22–2.77
Hypertension	No	1.00	0.556				
	Yes	0.90		0.62–1.30			
Tooth brushing habit	< 2 times daily	1.00	0.907				
	≥ 2 times daily	0.98		0.66–1.45			
Flossing habit	No	1.00	0.860				
	Yes	1.07		0.51–2.25			
Monthly household income (HK$)[c]	≤ 4999	1.00	0.426				
	5000–9999	1.39		0.79–2.43			
	≥ 10,000	0.86		0.47–1.58			
Time lapsed since last dental visit	≤ 1 year	1.00	0.455				
	2 years	1.49		0.91–2.43			
	3 years	1.19		0.64–2.20			
	≥ 4 years	1.22		0.77–1.93			

OR, odds ratio
CI, confidence interval
NS, not significant.
[a]OR for each factor was computed from logistic regression
[b]Adjusted ORs were computed with stepwise logistic regression with variables that were significant (P < 0.05) in the univariate analysis
[c]US $1 = HK $7.8

tors that remained significantly associated with having a highest CPI score of 4; adjusted ORs were as follows: 1.98 for ex-smokers, 2.74 for smokers and 1.84 for DM patients. These ORs also served as the age-adjusted ORs for ex-smokers, smokers and DM patients. No association was found between having a highest CPI score of 4 and diabetic control or diabetic medical complications among DM subjects.

ALoss scores

Results of the univariate analysis to identify factors associated with having a highest ALoss score ≥ 2 are shown in Table 5. Female sex and flossing were associated with a reduced likelihood of having a highest ALoss score ≥ 2, whereas older age, previous and current smoking, DM and a longer time since the last dental visit were all associated with an increased likelihood. Stepwise logistic regression analysis (Table 5) indicated that smokers and DM patients had elevated odds (OR = 2.86 and 1.71, respectively) of having a highest ALoss score ≥ 2, whereas women had decreased odds (OR = 0.58). No significant association was found between a highest ALoss score ≥ 2 and diabetic control or diabetic medical complications among DM subjects.

Odds for caries experience

Stepwise linear regression results for DT, FT, MT, DMFT and DT/DMFT%, were treated as dependent variables, with age, gender, education, smoking, DM status, hypertension, brushing habit, flossing habit, monthly household income and years lapsed since last dental

Table 5 Odds ratios for study participants with highest periodontal attachment loss (ALoss) score[a] ≥ 2

Variable	Categories	Unadjusted (univariate)[b] OR	P-value	95% CI	Adjusted[c] OR	P-value	95% CI
Age		1.02	0.048	1.00–1.04	1.03	0.008	1.01–1.05
Gender	Male	1.00	< 0.0001		1.00	0.014	
	Female	0.48		0.33–0.70	0.58		0.38–0.90
Education	No/primary	1.00	0.304				
	Secondary	0.74		0.49–1.10			
	Post-secondary	0.79		0.43–1.46			
Smoking habit	Non-smoker	1.00	0.001		1.00	0.02	
	Ex-smoker	1.90		1.16–3.11	1.39		0.80–2.41
	Smoker	3.07		1.54–6.11	2.86		1.35–6.08
Type 2 DM	No	1.00	0.042		1.00	0.012	
	Yes	1.51		1.02–2.24	1.71		1.13–2.59
Hypertension	No	1.00	0.578				
	Yes	0.90		0.62–1.31			
Tooth brushing habit	< 2 times daily	1.00	0.099				
	≥ 2 times daily	0.72		0.48–1.07			
Flossing habit	No	1.00	0.022			NS	
	Yes	0.38		0.17–0.87			
Monthly household	≤ 4,999	1.00	0.593				
income(HK$)[d]	5,000–9,99	1.08		0.62–1.91			
	≥ 10,000	0.75		0.41–1.37			
Time lapsed since	≤ 1 year	1.00	0.017			NS	
last dental visit	2 years	1.26		0.77–2.06			
	3 years	1.11		0.60–2.06			
	≥ 4years	2.11		1.32–3.37			

OR, odds ratio
CI, confidence interval
NS, not significant
[a]See the main text for definitions
[b]OR for each factor was computed from logistic regression
[c]Adjusted OR were computed with stepwise logistic regression with variables that were significant (P < 0.05) in the univariate analysis
[d]US $1 = HK $7.8

visit as independent variables, presented in Table 6. The coefficients in the regression model were interpreted as factors increasing (positive coefficient) or decreasing (negative coefficient) values of the corresponding dependent variables. Coefficients for the independent categorical variables should be interpreted as the values affecting the corresponding dependent variable when changing from baseline category.

Increasing age had a significant positive effect on DT number whereas DM subjects and flossing had significant effect in reducing the DT number. When comparing the size of the two coefficients, flossing habit (-1.0) had a greater effect in reducing the DT number than the DM status (-0.7).

Increasing age and a greater time since the last dental visit had significant effects in reducing the FT number. On the hand, better brushing and flossing habits were significantly associated with an increase in the FT number. Flossing habit (2.0) appeared to exert the larger effect.

Similar results were obtained for MT and DMFT. Increasing age, female, smoker, DM status, and hypertension had significant positive effects in increasing the numbers of MT and DMFT. Smoking had the largest effect on MT (5.4) and DMFT (4.3) among the significant factors above.

The results in Table 6 show that female gender, DM status and flossing habit (largest effect, -7.7) were significantly associated with reducing DT/DMFT%, while a longer time lapsed the last dental visit was significantly associated with increasing the DT/DMFT% (9.4).

No association was detected between DT, FT, MT, DMFT or DT/DMFT% and diabetic control or diabetic medical complications among DM subjects.

Table 6 Results from stepwise linear regression analysis (adjusted) of caries experience with other factors[a]

Variable	Categories	DT Coefficient	DT P-value	FT Coefficient	FT P-value	MT Coefficient	MT P-value	DMFT Coefficient	DMFT P-value	DT/DMFT%[b] Coefficient	DT/DMFT%[b] P-value
Age		0.03	< 0.002	-0.05	< 0.0001	0.47	< 0.0001	0.44	<0.0001		
Gender	Male					Base		Base		Base	
	Female					2.79	< 0.001	2.57	<0.005	-4.98	< 0.005
Smoking	Non-smoker					Base		Base			
	Ex-smoker					0.24	NS	0.04	NS		
	Smoker					5.43	< 0.0001	4.27	<0.001		
Type 2 DM	No	Base				Base		Base		Base	
	Yes	-0.72	< 0.001			3.40	< 0.0001	2.23	<0.005	-4.08	< 0.02
Hypertension	No					Base		Base			
	Yes					1.67	< 0.04	1.77	<0.025		
Tooth brushing	< 2 times daily			Base							
habit	≥ 2 times daily			0.55	< 0.02						
Flossing habit	No	Base		Base						Base	
	Yes	-1.03	< 0.025	1.96	< 0.0001					-7.69	< 0.03
Time lapsed	≤ 1 year			Base						Base	
since last	2 years			-0.68	< 0.02					4.03	NS
dental visit	3 years			-1.35	< 0.0001					6.42	< 0.02
	≥ 4 years			-1.58	< 0.0001					9.42	< 0.0001

Base, reference group
NS, not significant
[a]Adjusted OR were computed with stepwise logistic regression with variables that were significant ($P < 0.05$) in the univariate analysis, i.e. education and monthly household income were not significant and hence were not listed.
[b]Exclusions due to complete edentulism: 2 male and 3 female controls, 18 male and 29 female DM patients.

DISCUSSION

This case-control study used convenience sampling to select middle-aged to elderly subjects attending two outpatient clinics of a charitable hospital, TWEH. The TWEH, together with two other general hospitals, serves the east side of Hong Kong Island, which is home to a population of approximately 0.8 million. Within the district, six other GOP clinics and two other specialist DM clinics are operated by the government, or the Hospital Authority provides outpatient services for the residents. The TWEH DM and GOP clinics provide medical services for free, as they are subsidised by a hospital charity; the other clinics charge nominal fees for medical consultation and prescribed drugs. Numerous other private general or specialist medical offices are located within the region and operate on a fee-for-service basis.

As a consequence of the target population served by the two study clinics, almost 80% of selected DM and control patients who were surveyed earned a fairly low annual family income of < US$ 7,700 (Table 1), compared with about 15% in the general population of Hong Kong (Hong Kong Census and Statistics Department, 2005). Educational and family income profiles of the DM and control patients were very similar, indicating minimal selection bias between these two groups of older Chinese adults of predominantly low socioeconomic status.

The present study recorded CPI together with ALoss, because there is evidence that simultaneous measurement of CPI and clinical attachment level leads to a better estimation of the prevalence of periodontitis than the CPI protocol alone (Agerholm and Ashley, 1996; Plancak et al, 2004). Using the CPI 10 index teeth recording approach, Benigeri et al (2000) demonstrated that the CPI method, compared with full-mouth probing pocket depth (PPD) measurement, underestimated the prevalence of periodontal disease by 12% among 2110 35- to 44-year-old Canadian subjects. An earlier study reported that 44% of 169 25- to 64-year-old farm-workers in Athens had at least one pocket with a PPD ≥ 6 mm as detected by partial CPI, compared with 47% when a standard full-mouth periodontal examination was used (Diamanti-Kipioti et al, 1993). The periodontal data in this study, therefore, should be interpreted with caution considering this known limitation.

The mean time lapsed since the last dental visit was equally long for DM and control groups (2.5 ± 1.0 years), although a significantly larger proportion of the DM group had visited a dentist within the previous 12

months. The finding that dental visits were irregular among participants concurs with the practices of the general population of Hong Kong (Lo and Schwarz, 1994a; Dental Service Head Office, 2002). Both test and control cohorts had poor oral health as well as a low socioeconomic background (Table 1). From this group of predominantly low-income and dentally underserved subjects, this study comprehensively surveyed the associations, among other known risk indicators for poor dental health, between DM, DM control, or DM complications and their concurrent oral health status.

The diabetic status of the type 2 DM recruits in the present study appeared to be fairly well controlled (HbA1c = 7.9 ± 1.3%). Their prevalence of medical complications was similar to those reported for Hong Kong Chinese (Chan, 2000). The present study did not detect any association between DM medical complications and caries or periodontal disease, apparently substantiating the study's second null hypothesis of no association between poor oral health and DM medical complications. However, the study findings did not support the study's first null hypothesis: type 2 DM patients presented with a lower age-adjusted DT score and DT/DMFT% but higher MT and DMFT scores, and a larger proportion of DM patients than controls had chronic periodontitis, increased attachment loss and hypertension.

The control group seemed to be affected more by caries than the general population. For example, control patients in the 65- to 74-year age group had DT/FT scores of 2.1/2.0, compared with published figures of 1.4/0.5 (Lo and Schwarz, 1994b) or 1.3/1.2 (Dental Service Head Office, 2002). The corresponding figure for 65- to 74-year-old patients with type 2 DM was 1.1/1.3. However, among the 65- to 74-year-old controls, MT/DMFT scores appeared slightly lower than those of the local population: 10.5/14.5 vs 17.0/18.9 (Lo and Schwarz, 1994b) or 15.1/17.6 (Dental Service Head Office, 2002). Type 2 DM patients in the same age group had a mean MT of 17.8 and a mean DMFT of 20.3, which are similar to those of the local population (Lo and Schwarz, 1994b; Dental Service Head Office, 2002).

The distribution of patients according to their highest CPI scores showed that both groups were affected more by periodontitis than the general population; for example, among 65- to 74-year-olds, the proportion of subjects with highest CPI score of 4 was 37.7% in controls and 44.2% in the DM group, compared with 15% (Holmgren et al, 1994) and 11% (Dental Service Head Office, 2002), respectively, in the local population. Analyses of US population data yielded similar findings: subjects of a low socioeconomic status, especially the elderly, had poorer dental and periodontal health (Drury et al, 1999).

We also found more decayed teeth among control patients than among DM patients. Similarly, the proportion of the DMFT burden caused by DT (DT/DMFT%) was also higher in controls (Table 3). These results indicate that controls had a higher unmet need for DT prevention and treatment and that, in general, type 2 DM patients (whose DM was controlled fairly well) probably had a lower risk of dental caries. Similar findings have been reported in a predominantly low socioeconomic Hispanic group of type 2 DM patients in the US (Lalla et al, 2004). A Finnish study (Collin et al, 1998b) also reported that among non-IDDM subjects, the prevalence of caries remained the same as that among controls, although the same group found a partial loss of caries-protective properties of saliva samples from DM subjects (Meurman et al, 1998). In contrast, a later Swedish study found increased rates of xerostomia, periodontitis and initial caries lesions in patients with type 2 DM compared with healthy controls (Sandberg et al, 2000). Therefore, further studies are needed to clarify the relationship between type 2 DM status on salivary gland function and dental caries.The DM cohort also had more missing teeth and an increased severity of periodontal disease than did the controls (Tables 1–3). A similar observation regarding MT was also reported among Yugoslavian type 2 DM subjects (Bacic et al, 1989). The same study found no association between caries experience, duration of DM, diabetic control or diabetic complications. However, unlike in the present study, they did not record the periodontal status of the subjects surveyed.

A study on the periodontal health of low-income, underserved and predominantly Hispanic subjects found that DM status was associated with an increased extent and frequency of radiographic alveolar bone loss, reduced number of restored teeth and previous endodontic treatment or prosthesis (Lalla et al, 2004). In a survey conducted on the west coast of North America among adults with a similar age range to those in the present study (Persson et al, 2003), those without DM had a smaller proportion of sites with PPD ≥ 5 mm than DM patients, as demonstrated in the present study. An increased prevalence of periodontitis and radiographic bone loss in non-IDDM has also been reported in a study of elderly Finnish subjects by Collin et al (1998a). Although no oral radiographic examination was performed in the current study, the findings suggest that in Hong Kong, low-income middle-aged to elderly patients with type 2 DM of a predominantly low

socioeconomic status seem to experience more severe periodontal disease than those without DM.

The type 2 DM patients studied had higher odds of periodontal attachment loss than controls (Table 5). This result is in line with that from a current community study showing increased odds of periodontal attachment loss among Hong Kong Chinese subjects who reported a history of DM (Ng and Leung, 2006). The same study also reported increased odds as well as a wide 95% confident interval regarding advanced periodontal attachment loss in association with smoking, a phenomenon also observable in the present study (Table 5). Existing knowledge regarding the pathogenesis of periodontal disease in DM patients and the impact of diabetic control, with or without smoking on periodontal health are, however, insufficient to explain the underlying mechanism (American Academy of Periodontology, 1996) or the association between DM complications and periodontitis. For example, a recent meta-analysis failed to demonstrate positive effects of periodontal treatment on diabetic glycaemic control (Janket et al, 2005).

In a case-control study that followed up the periodontal and medical conditions of 39 pairs of IDDM patients with or without periodontal disease over a median of 6 years, having periodontitis was associated with a significantly higher prevalence of proteinuria, cardiovascular disease and PVD (Thorstensson et al, 1996). It would be interesting to know whether a similar phenomenon is seen in patients with type 2 DM. The results of the present preliminary cross-sectional investigation, however, do not substantiate any association between type 2 DM or its medical complications and periodontitis.

Among surveyed test and control patients, hypertension was associated with increased (adjusted) odds of MT (Table 6). In agreement, a recent study of a group of postmenopausal Japanese women who had a similar age range to that in this study found that MT was associated with an increased risk of hypertension (Taguchi et al, 2004). It is important to note that for the cohort of low-income, middle-aged to elderly Chinese adults in the present study, the significant association between hypertension and MT was not limited to women. A recent large-scale epidemiological study performed in Spain showed that hypertension or prehypertension was associated with risk markers of insulin resistance (Cordero et al, 2006), thereby indicating that blood pressure, body mass index and metabolic syndrome are closely related. The current study, however, did not record the body mass index, diet or other relevant risk markers, so it was not possible to detect the relationship between DM or insulin resistance and hypertension among the participants. Nevertheless, the observed association between DM, hypertension and MT perhaps indirectly demonstrates a link between the two systemic diseases through a dental context. Further research is needed to substantiate this notion.

Although it is practically impossible to revert the diabetic status, diabetic complications and hypertensive status of patients with type 2 DM adults, their dental or periodontal health can be maintained effectively with preventive approaches (Rodrigues et al, 2003). Oral health habits and diabetes treatment adherence are correlated (Syrjälä et al, 2004), so appropriate modification of oral health behaviour may improve adherence to DM control measures and perhaps antihypertensive management as well. It is therefore tempting to speculate that improving oral health and controlling periodontal disease may reduce the detrimental effects of dental or periodontal inflammation and their corresponding systemic effects, thereby reducing the morbidity and mortality of diabetic complications in type 2 DM patients. However, one must be cognisant that this case-control study only reported the strength of association between the various factors investigated and poor oral health among our cohorts. While a one to one age- and sex-matching design may increase the power of the study and at the same time reduce the minimum odds ratio detectable, further more robust studies are needed to verify the above-suggested hypothesis.

In conclusion, this study shows that middle-aged to elderly Hong Kong Chinese patients of a predominantly low socioeconomic status with type 2 DM are prone to periodontal disease or periodontal attachment loss and, compared with age- and sex-matched controls, are more likely to have lower DT but higher MT and DMFT scores. Increased MT and DMFT scores are associated with hypertension, whereas poor periodontal health is associated with smoking, increasing age, DM and male gender. Physicians should be cognisant of the dental and oral complications of underserved elderly patient populations and collaborate with oral health care workers to provide comprehensive dental care with emphasis on prevention and smoking cessation programmes for patients from poor backgrounds with type 2 DM and/or hypertension.

ACKNOWLEDGEMENTS

This study was supported by a CRCG grant (10204278), The University of Hong Kong, and a grant from the Research Grants Council of the Hong Kong Special Administrative Region, China (HKU 7331/00M) to WKL. We thank Dr. Trevor Lane for manuscript editing.

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