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Assessing oral health and the minimally important differences in oral health-related quality of life of non-diabetic and diabetic patients: a cross-sectional study

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ABSTRACT

Background: Non-diabetics and diabetics might have different oral health problems and impacts on their oral health-related quality of life (OHRQoL). Comparison of oral health status and coping strategies between these patients, and evaluation of factors associated with OHRQoL might facilitate better treatment planning for improved patient-centred outcome.
Methods: One hundred and eleven non-diabetics and 107 diabetics attending a public hospital were clinically examined and evaluated for coping strategies (abbreviated coping orientation to problems experienced) and OHRQoL [short-form oral health impact profile (OHIP-14S)]. Factors associated with OHRQoL were analysed through correlation/partial correlation. Minimally important differences (MID) of OHIP-14S were calculated to confirm associations between attachment loss, caries, and tooth loss with OHRQoL.
Results: Non-diabetics had worse periodontal status. Diabetics had more missing teeth. Non-diabetics and diabetics employed maladaptive coping to manage oral health problems. Overall, non-diabetics reported worse OHRQoL. Determination of MID showed that non-diabetics with high-severe attachment loss and <20 teeth experienced poorer OHRQoL. Diabetics with caries, high-severe attachment loss, and <25 teeth experienced poorer OHRQoL.
Conclusion: Different factors were associated with OHRQoL of non-diabetics and diabetics. Delivery of treatment aimed at maintaining teeth in a periodontally healthy and caries free state, and provision of more chewing units might help improve OHRQoL of diabetics. © 2024 Australian Dental Association.

Keywords: Dental caries, diabetes mellitus, minimal clinically important difference, oral health, periodontitis, quality of life, tooth loss.

Abbreviations and acronyms: BOP = bleeding on probing; Brief-COPE = abbreviated coping orientation to problems experienced questionnaire; CAL = clinical attachment loss; DM = type 2 diabetes mellitus; DMFT = decayed, missing, filled teeth index; DSC = Diabetic Specialist Clinic; ES = effect size; FPG = fasting plasma glucose; GOC = General Outpatient Clinic; HbA1c = glycated haemoglobin; ICDAS = International Caries Detection and Assessment System; MID = minimally important difference; MWU = Mann–Whitney *U* test; NA = not applicable; NDM = non-diabetes mellitus; OHIP-14S = Chinese short-form oral health impact profile; OHRQoL = oral health-related quality of life; Pl = plaque accumulation; PPD = probing pocket depth; Q1–Q3 = interquartile range; SD = standard deviation; SEm = standard error of measurement; STROBES = Strengthening the Reporting of Observational Studies in Epidemiology.

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CLINICAL RELEVANCE

Different factors might be associated with the oral health-related quality of life of non-diabetic and diabetic patients. Non-diabetic patients associated their oral health-related quality of life with high-severe attachment loss, and having less than 20 teeth. Diabetic patients associated their oral health-related quality of life with caries, high-severe clinical attachment loss, and having less than 25 teeth. Regardless of diabetic status, provision of periodontal treatment to maintain teeth and prosthetic treatment to replace missing teeth could improve oral health-related quality of life. For diabetic patients, delivery of dental treatment aimed at maintaining teeth in a caries-free and periodontally healthy state, and the provision of more chewing units, might be the best effort to improve their oral health-related quality of life.

INTRODUCTION

Oral health and diabetes are interlinked through the body's underlying inflammatory pathways and shared risk indicators/factors[1] such as oral microbiome, medications taken, dietary habits, and smoking.[2–5] As such, diabetes mellitus patients are prone to various oral diseases/conditions[2–5] that might impact their daily function.[6]

Multiple research groups had established a synergistic relationship between periodontitis and DM,[4,7,8] and patients with both diseases are at enhanced risk of experiencing severe periodontal breakdown and impaired glucose metabolism.[4,7,8] Similarly, individuals with DM have been shown to exhibit higher caries rate[2,3,5] and experience more tooth loss.[9–11]

Oral health-related quality of life (OHRQoL) measures are essential to evaluate how patients are personally affected by an oral disease/condition and what they expect from treatment.[12,13] Many oral diseases/conditions, such as caries and periodontitis, can impair one's physical abilities, psychological well-being, and social function.[14–16] Results regarding the impact of type 2 diabetes mellitus (shortened to DM within the context of this study) on OHRQoL have been ambiguous. Mohamed *et al.*[17] reported that poorly controlled DM patients had poorer periodontal conditions and worse OHRQoL than those without DM [non-DM (NDM)]. However, Irani *et al.*[18] found that although DM led to worse periodontal conditions, it did not impact OHRQoL. It was postulated that the physiological and psychological burden of a chronic systemic disease might mask the effects of oral health issues on daily function.[18,19] Hence, a comparison of coping strategies between DM and NDM patients, and evaluation of their association with OHRQoL might shed light on how these patients psychologically cope[20] to deal with oral health problems. Understanding the psychological barriers in patients when dealing with oral health problems[21,22] might facilitate dental treatment planning for improved outcome.

To better treat dental patients, factors that are associated with their OHRQoL should be evaluated so that more problem-focused strategies can be put in place. NDM and DM patients might have different priorities when it comes to OHRQoL. To determine these factors, it is thus essential to first evaluate the influence of the added burden of DM on patient's periodontal status, dental health, coping strategies, and OHRQoL, and compare them to NDM patients. Once any differences/similarities in the abovementioned variables are established, factors that might have an association with OHRQoL of NDM and DM participants can be assessed through conventional statistical methods and confirmed through calculation of the minimally important differences (MID) in OHRQoL scores.[23,24]

The first aim of this study was to assess periodontal status, dental health [decayed, missing, and filled teeth index (DMFT)],[25] coping strategies [abbreviated coping orientation to problems experienced questionnaire (Brief-COPE)],[26] and OHRQoL [Chinese short-form oral health impact profile (OHIP-14S)][27] in patients with DM, and to compare these results with patients without DM. The null hypothesis is that there are no statistically significant differences in periodontal status, dental health, coping strategies, and OHRQoL between DM and NDM patients. The second aim of this study was to evaluate factors associated with OHRQoL in DM and NDM participants. The null hypothesis is that there are no differences in factors associated with OHRQoL between DM and NDM participants.

MATERIALS AND METHODS

Study design

This was a cross-sectional study done according to the STROBES (Strengthening the Reporting of Observational Studies in Epidemiology)[28] guidelines.

Ethics approval and consent

The study protocol was approved by the Institutional Review Boards of the University of Hong Kong/Hospital Authority Hong Kong West Cluster (UW 11-380) and the Hong Kong East Cluster Research Ethics Committee (HKEC-2011-076). Participants were informed regarding all aspects of the study and signed a written consent prior to study commencement. Personal identifiers were removed from all collected data.

Study participants

The sample size calculation was based on the median difference in OHIP-14S scores between NDM and DM. To achieve 90% power to detect a significant difference using the Mann–Whitney *U* test at a 5% significance level (alpha = 0.05) and assuming a moderate effect size of 0.50, 90 participants per group (ratio of NDM:DM = 1:1) will be required. Considering an estimated recruitment success rate of 60%, at least 300 participants will need to be screened (150 NDM and 150 DM), or until the required sample size is fulfilled. The power analysis was carried out using G*Power 3.1.9.7 (a program developed by Axel Buchner, Edgar Erdfelder and Franz Faul).[29,30]

Participant recruitment was carried out at both the Diabetic Specialist Clinic (DSC) and General Outpatient Clinic (GOC), Tung Wah Eastern Hospital

(TWEH), Hospital Authority, Hong Kong. At the same time, a clinical examination was performed at the Periodontology Clinic, Faculty of Dentistry, Prince Philip Dental Hospital (PPDH), the University of Hong Kong, between March 2012 and April 2014.

Inclusion/exclusion criteria

Diabetic participants were recruited and referred by the diabetologist in charge (SCS) at TWEH according to the World Health Organization criteria for diabetes [fasting plasma glucose (FPG) ≥7.0 mmol/L; two-hours plasma glucose post-oral glucose load ≥11.1 mmol/L; casual glucose ≥11.1 mmol/L with symptoms or with glycated haemoglobin (HbA1c) higher than 6.5%].[31] Medical conditions (FPG, HbA1c, history of DM, and current medications) of participants were provided during the referral. NDM patients were recruited from the TWEH free walk-in GOC for episodic diseases with relatively mild symptoms. Convenient sampling was employed.

For both DM and NDM participants, participants were (i) of Chinese ethnicity, (ii) 35–65 years old, (iii) able to provide written consent, and (iv) present with at least 2 teeth in each quadrant.

Participants were excluded if they were (i) pregnant or lactating, (ii) presented with a history of significant valvular heart disease or on anticoagulant therapy, (iii) presented with concurrent systemic disease which might require antibiotic cover for periodontal examination, (iv) received antimicrobial therapy and/or non-steroidal anti-inflammatory drugs within the preceding 6 months.

Over the designated once-per-month, half-day participants recruitment, the research team anticipated roughly a total attendance of 250 or 300 potentially eligible participants to DSC or GOC, respectively, at TWEH. Written information was given and the respective clinic attendees were all invited to join the study.

At the end of recruitment, 181 patients from DSC and 218 patients from GOC indicated their willingness to partake in the study by providing contact information and filling up an entry in the booking system for an appointment at PPDH.

Clinical examination

All consented participants underwent clinical examination. Parameters recorded were decayed (D), missing (M) and filled (F) teeth (DMFT), plaque accumulation (Pl%) and bleeding on probing (BOP%) recorded in percentage, probing pocket depths (PPD), and clinical attachment loss (CAL) in millimetre. Decayed teeth were determined as a code 3 [Localized enamel breakdown (without clinical visual signs of dentinal involvement)] or higher according to the International Caries Detection and Assessment System (ICDAS).[32]

Periodontal measurements were measured at six sites per tooth (mesio-buccal, mid-buccal, disto-buccal, mesio-lingual, mid-lingual, and disto-lingual). Teeth excluded were third molars, impacted teeth, retained roots, grossly broken-down teeth, and teeth that were difficult to examine because of inaccessibility (e.g., severe malocclusion). All measurements were performed by two calibrated examiners (AC, STN) using a manual probe (PCP-UNC15, Hu-Friedy, Chicago, IL). The examination was repeated in every tenth participant to assess inter-examiner reliability.

All screened individuals with dental problems, regardless of participation in the study, were referred for dental treatment at PPDH.

Questionnaires

Questionnaires were administered through a face-to--face interview with one trained research assistant.[33] Instructions were explained and the interviewer stood by to clarify any queries. For those marginally literate participants, questionnaires were completed in an interviewer-assisted format. The questionnaire contained the following elements.

Demographic data

A questionnaire on demographic data was administered.

Oral health-related quality of life

Oral health-related quality of life was evaluated via the Chinese version of OHIP-14S.[27] The OHIP-14S is a 14-item self-completed questionnaire divided into seven domains – functional limitation, physical discomfort, psychological discomfort, physical disability, psychological disability, social disability, and handicap. A Likert response format (0 = never, 1 = hardly ever, 2 = occasionally, 3 = fairly often, 4 = very often) was employed. The sum of all responses gave a total OHIP-14S score (range 0–56). Higher scores indicate worse OHRQoL.

Coping strategies

The Brief-COPE inventory[26,34] was used to assess coping strategies. The Brief-COPE uses a 4-point Likert scale ('I haven't been doing this at all' to 'I've been doing this a lot'), assessing 14 coping methods (listed in Table 1).[26] Each coping strategy was assessed and analysed individually.

Table 1. Background and characteristics of study participants

Variables	NDM (n = 111)		DM (n = 107)		Test
	Mean	SD	Mean	SD	
Age (Years)	54.4	7.4	54.7	6.5	*t*-test
	n	%	n	%	
Gender					
Male (1)	47	42.3	58	54.2	χ^2
Female (2)	64	57.7	49	45.8	
			Mean	SD	
DM history					
Years with DM		NA	10.9	7.6	NA
Fasting plasma glucose (mmol/L)		NA	8.3	3	NA
HbA1c (%)		NA	7.8	1.5	NA
	n	%	n	%	
Educational level					
Primary school (1)	19	17.1	19	17.8	χ^2
Secondary school (2)	75	67.6	59	55.1	
Tertiary or above (3)	17	15.3	29	27.1	
Household income*					
≤9999 or refuse to answer (1)	30	27	36	33.6	χ^2
10 000–14 999 (2)	21	18.9	15	14.0	
15 000–24 999 (3)	39	35.1	15	14.0	
≥25 000 (4)	21	19	41	38.3	
Oral health-related quality of life	Median	Q1–Q3	Median	Q1–Q3	
OHIP-14S*	10	4–18	6	2–12	MWU
Functional limitation	2	1–3	2	0–3	MWU
Physical pain*	2	1–4	2	0–4	MWU
Psychological discomfort*	1	0–3	1	0–3	MWU
Physical disability*	2	0–3	1	0–2	MWU
Psychological disability	1	0–3	1	0–2	MWU
Social disability	0	0–0	0	0–0	MWU
Handicap*	0	0–1	0	0–0	MWU
Brief COPE	Median	Q1–Q3	Median	Q1–Q3	
Active coping	6	6–8	7	6–8	MWU
Planning	7	6–8	7	6–8	MWU
Use of instrumental social support	6	5–6	6	5–6	MWU
Humour	6	5–6	5	4–6	MWU
Use of emotional support	5	4–6	5	4–6	MWU
Positive re-interpretation	6	6–7	7	6–8	MWU
Acceptance	7	6–8	7	6–8	MWU
Denial	4	3–5	4	3–5	MWU
Distraction*	6	5–6	6	5–7	MWU
Focus on venting of emotions	6	5–7	6	5–7	MWU
Behavioural disengagement	4	3–5	4	3–5	MWU
Substance use	2	2–3	2	2–3	MWU
Religion	4	3–6	4	2–6	MWU
Self-blame	5	4–6	5	4–6	MWU
Oral conditions	Median	Q1–Q3	Median	Q1–Q3	
Plaque accumulation in % (Pl%)*	82.7	69.9–88.7	86.5	76.8–92	MWU
	Mean	SD	Mean	SD	
Bleeding on probing in % (BOP%)	55.3	23.4	60.4	22	*t*-test
Mean clinical attachment loss (mm)*	4.2	2.7	3.5	1.2	*t*-test
Decayed teeth (D)	0.6	1.2	0.6	1.9	*t*-test
Missing teeth (M)*	3	3.7	4.1	3.6	*t*-test
Filled teeth (F)	4.2	3.6	3.5	3.7	*t*-test
DMFT	7.7	5.5	8.2	6.2	*t*-test

Brief COPE = abbreviated Coping Orientation to Problems Experienced; DM = diabetes mellitus; DMFT = decayed, missing, filled teeth; MWU = Mann–Whitney *U* test; NA = not applicable; NDM = non-diabetic; OHIP-14S = Chinese short-form Oral Health Impact Profile; Q1–Q3 = interquartile range; SD = standard deviation.
*Statistically significant differences between groups.

Statistical analysis

Statistical analysis was performed using the statistical software package IBM SPSS version 22.0 (SPSS, Chicago, IL). The level of significance was $P \leq 0.05$. The normality of data was assessed through Kolmogorov–Smirnov test. To determine factors associated with OHRQoL, partial correlation analysis (controlling for any independent variables that might show initial differences between NDM and DM participants) and Spearman's correlation analysis were carried out with OHIP-14S and number of teeth present as dependent variables. Independent variables are listed in Tables 2 and 3.

Participants were grouped into those with low-moderate mean full mouth CAL (mean CAL ≤3.0 mm) and those with high-severe mean full mouth CAL (mean CAL >3.0 mm)[6,33,35]; those with no decayed teeth and those with ≥1 decayed tooth, those with <25 teeth and ≥25 teeth[36]; those with <20 teeth and ≥20 teeth,[37] for subgroup analyses.

Table 2. Correlation analysis of variables associated with OHIP-14S of NDM and DM participants*

Variables	NDM (n = 111)		DM (n = 107)	
	r	*P*-value	*r*	*P*-value
Age	−0.003	0.979	−0.012	0.905
Education level	−0.090	0.349	−0.225	0.020
Household income	−0.096	0.318	−0.140	0.152
Brief COPE				
Active coping	0.122	0.201	−0.166	0.088
Planning	0.021	0.828	0.019	0.849
Use of instrumental social support	−0.175	0.066	0.049	0.615
Humour	−0.067	0.485	0.113	0.246
Use of emotional support	0.020	0.831	0.076	0.438
Positive re-interpretation	−0.037	0.700	0.041	0.674
Acceptance	0.009	0.926	0.060	0.541
Denial	0.219	0.021	0.114	0.244
Distraction	0.125	0.190	0.170	0.081
Focus on venting of emotions	0.079	0.407	0.222	0.022
Behavioural disengagement	0.081	0.396	0.182	0.060
Substance use	0.067	0.483	0.112	0.251
Religion	0.062	0.516	0.111	0.256
Self-blame	0.110	0.252	0.217	0.025
Oral conditions				
Plaque accumulation in % (Pl%)	0.093	0.330	0.293	0.002
Bleeding on probing in % (BOP%)	0.129	0.176	0.363	<0.001
Mean clinical attachment loss (mm)	0.200	0.035	0.243	0.012
Decayed teeth	0.058	0.548	0.247	0.010
Missing teeth	0.143	0.135	0.234	0.015
Filled teeth	0.025	0.797	0.137	0.161

Brief COPE = abbreviated Coping Orientation to Problems Experienced inventory; DM = diabetes mellitus; NDM = non-diabetic; OHIP-14S = Chinese short-form Oral Health Impact Profile.
*Spearman's correlation.

Table 3. Correlation analysis of variables associated with number of teeth present of NDM and DM participants*

Variables	NDM (n = 111)		DM (n = 107)	
	r	*P*-value	*r*	*P*-value
Age	−0.383	<0.001	−0.476	<0.001
Education level	0.110	0.252	0.199	0.040
Household income	−0.027	0.775	0.395	<0.001
Oral health-related quality of life				
OHIP-14S	−0.143	0.135	−0.234	0.015
Functional limitation	−0.192	0.043	−0.359	<0.001
Physical pain	0.002	0.981	−0.196	0.043
Psychological discomfort	−0.115	0.231	−0.109	0.263
Physical disability	−0.169	0.076	−0.194	0.046
Psychological disability	−0.125	0.191	−0.086	0.381
Social disability	0.032	0.735	−0.047	0.632
Handicap	0.073	0.445	−0.163	0.093
Oral conditions				
Plaque accumulation in % (Pl%)	0.094	0.325	−0.097	0.319
Bleeding on probing in % (BOP%)	−0.035	0.719	−0.271	0.005
Mean clinical attachment loss (mm)	−0.282	0.003	−0.497	<0.001
Decayed teeth	0.002	0.987	−0.204	0.035
Filled teeth	−0.289	0.002	−0.134	0.167

Brief COPE = abbreviated Coping Orientation to Problems Experienced inventory; DM = diabetes mellitus; NDM = non-diabetic; OHIP-14S = Chinese short-form Oral Health Impact Profile.
*Spearman's correlation.

Categorization into groups with <25 teeth and ≥25 teeth was based on an 18-year retrospective study among Chinese patients, which reported that a majority (66%) of participants with at least one systemic disease had <25 teeth.[36] Having less than 25 teeth was reported to have a negative impact on OHRQoL.[38] Categorization into groups with <20 teeth and ≥20 teeth was based on a previous study, which reported that participants with less than twenty teeth experienced worse OHRQoL, regardless of occluding units.[37]

Minimally important differences (MIDs) of OHIP-14S for various subgroups were determined through a distribution-based approach.[24] The standard error of measurement (SEm) was calculated by multiplying the standard deviation of the mean OHIP-14S score (of the reference group) by the square root of one minus the reliability of the OHIP-14S (0.86).[27] A difference in the score (between groups) that falls within the SEm was considered a measurement error; therefore, the SEm value was taken as the MID.[24] For effect size (ES), Cohen's d was determined by calculating the difference in mean OHIP-14S between groups and dividing the result by the group's standard deviation. The Effect size (ES) was expressed as a ratio and interpreted through benchmark values of small (0.2), moderate (0.5), and large (0.8) effects.[39]

RESULTS

Inter-examiner reliability

Results from duplicate examinations on 22 participants showed that inter-examiner reliability (kappa) on dental (DMFT) and periodontal (PPD in mm and CAL in mm) statuses were 0.705 and 0.703/0.790, indicating substantial agreement, respectively.

Socio-demographic characteristics and clinical data

A total of 181 patients from DSC (raw response rate of 72.4%) and 218 patients from GOC (raw response rate of 72.7%) indicated their willingness to partake in this study by providing contact information as well as filling up an entry into the booking system for screening appointment at PPDH. Of the 112 DM patients who eventually attended the dental hospital, 4 attended but refused to provide consent and 1 was excluded due to severe heart disease. This gave 107 DM participants who completed the study or 59.1% recruitment success. For the NDM group, 124 attended the dental hospital, 8 refused to provide consent, 5 were excluded because 2 had valvular heart disease, 1 had severe heart disease, 1 had a cerebral vascular accident, and 1 was with Parkinsonism. Eventually, 111 NDM participants completed the study or 50.9% recruitment success. Demographic characteristics and clinical data of all participants are shown in Table 1.

Oral health-related quality of life and coping strategies

OHIP-14S, OHIP-14S domain scores, and coping strategies (Brief-COPE) between DM and NDM participants are reported in Table 1. NDM participants applied distraction less often than DM participants. NDM participants also fared worse in terms of OHIP-14S. The MID in OHIP-14S (mean ± SD) between NDM (12.1 ± 10.2) and DM (8.6 ± 8.9) participants was 3.3 points, the ES was 0.4 indicating a small effect.[39] The difference in mean OHIP-14S between these two subgroups was 3.5. This was larger than the MID (3.3), meaning that the difference in score was not a result of measurement error and can be considered clinically meaningful.[23] For NDM participants, 47 (42.3%) had OHIP-14S 3.3 points above the mean OHIP-14S of DM participants (8.6). The mean OHIP-14S score for these 47 NDM participants was 21.3 ± 9.1 (range: 12–51). In terms of OHIP-14S domains (mean ± SD), these 47 participants were mainly affected in terms of physical pain (4.6 ± 2.1), psychological discomfort (3.6 ± 2.3), physical disability (3.6 ± 1.9), psychological disability (3.5 ± 2.2), functional limitation (3.5 ± 1.6), handicap (1.3 ± 1.5), and social disability (1.1 ± 1.6).

Results for partial correlation analysis for factors that were associated with OHIP-14S of all participants (n = 218) are shown in Table S1. Positive correlations were found between OHIP-14S and denial, venting of emotions, behavioural disengagement, substance use, religion, and decayed teeth (Table S1).

The factors associated with OHIP-14S of NDM and DM participants are shown in Table 2.

Clinical attachment loss and OHRQoL

For NDM and DM participants, higher mean CAL was positively associated with higher OHIP-14S (Table 2). To further evaluate the effect of CAL on OHRQoL, NDM participants were grouped into those with low-moderate mean full mouth CAL and those with high-severe mean full mouth CAL. Data for these groups were normally distributed (Kolmogorov-Smirnov test, $P = 0.288$), independent sample t-test was used to compare OHIP-14S between those with mean low-moderate CAL (n = 51) versus high-severe CAL (n = 60). There was a statistically significant difference ($P = 0.030$) in OHIP-14S (mean ± SD) between those with low-moderate CAL (9.9 ± 7.6) and those with high-severe CAL (13.9 ± 11.7). The OHIP-14S MID between NDM participants with low-moderate CAL and those with high-severe CAL was 2.8 points, the ES was 0.5 indicating a moderate effect.[39] The difference in mean OHIP-14S between these two subgroups was 4.1. This was larger than the MID (2.8), meaning that the difference in score was not a result of measurement error and can be considered clinically meaningful.[23] For NDM participants with high-severe CAL, 43 (71.7%) had OHIP-14S 2.8 points above the mean OHIP-14S of those with low-moderate CAL (9.9). The mean OHIP-14S score for these 43 NDM participants was 20.2 ± 9 (range: 13–51). In terms of OHIP-14S domains (mean ± SD), these 43 participants were mainly affected in terms of: physical pain (4.8 ± 2.1), physical disability (3.8 ± 1.8), psychological disability (3.7 ± 2.2), psychological discomfort (3.7 ± 2.3), functional limitation (3.6 ± 1.6), handicap (1.3 ± 1.5), and social disability (1.2 ± 1.6).

Similarly, DM participants were also grouped into those with low-moderate mean full mouth CAL (n = 47) and those with high-severe mean full mouth CAL (n = 60). Data were normally distributed (Kolmogorov-Smirnov test, $P = 0.476$). There was a statistically significant difference ($P = 0.044$) in OHIP-14S (mean ± SD) between those with low-moderate CAL (7.0 ± 7.4) and those with high-severe CAL (9.9 ± 9.8). The OHIP-14S MID between DM participants with low-moderate CAL

and those with high-severe CAL was 2.8 points, the ES was 0.4 indicating a small effect.[39] The difference in mean OHIP-14S between these two subgroups was 2.9. This was larger than the MID (2.8), meaning that the difference in score was not a result of measurement error and can be considered clinically meaningful.[23] For DM participants with high-severe CAL, 25 (41.7%) had OHIP-14S 2.8 points above the mean OHIP-14S of those with low-moderate CAL (7.0). The mean OHIP-14S score for these 25 DM participants was 18.8 ± 9.2 (range: 10–42). In terms of OHIP-14S domains (mean ± SD), these 25 participants were mainly affected in terms of: physical pain (4.1 ± 2.1), functional limitation (3.5 ± 1.7), psychological discomfort (3.5 ± 2.2), physical disability (3.0 ± 2.4), psychological disability (3.0 ± 1.7), handicap (0.9 ± 1.4), and social disability (0.8 ± 1.1).

Decayed teeth and OHRQoL

To further evaluate the associations between decayed teeth and OHRQoL in DM participants, DM participants were grouped into those with no decay versus those with ≥1 decayed tooth. Data for these groups were normally distributed (Kolmogorov-Smirnov test, $P = 0.203$), independent sample t-test was used to compare OHIP-14S between those with no decayed teeth (n = 79) and those with ≥1 decayed tooth (n = 28). There was a statistically significant difference ($P = 0.030$) in OHIP-14S (mean ± SD) between those with no decayed teeth (7.2 ± 6.9) compared to those with ≥1 decayed tooth (12.7 ± 12.2). The OHIP-14S MID between DM participants with no decayed teeth and DM participants with ≥decayed teeth was 2.6 points, the ES was 0.8 indicating a large effect.[39] The difference in mean OHIP-14S between these two subgroups was 5.5. This was larger than the MID (2.6), meaning that the difference in score was not a result of measurement error and can be considered clinically meaningful.[23] For DM participants with ≥1 decayed tooth, 13 (46.4%) of them had OHIP-14S 2.6 points above the mean OHIP-14S of those with no decayed teeth (7.2). The mean OHIP-14S score for these 13 participants was 22.9 ± 10.8 (range: 11–42). In terms of OHIP-14S domains (mean ± SD), these 13 DM participants were mainly affected in terms of: physical pain (4.4 ± 2.8), physical disability (4.3 ± 2.4), psychological discomfort (mean 4.2 ± 2.4), functional limitation (3.9 ± 2.1), psychological disability (3.4 ± 2.3), handicap (1.5 ± 1.7), and social disability (1.2 ± 1.4).

NDM participants were also grouped into those with no decay (n = 76) versus those with ≥1 decayed tooth (n = 35). Data were normally distributed (Kolmogorov-Smirnov test, $P = 0.546$). There was no statistically significant difference ($P = 0.274$) in OHIP-14S (mean ± SD) between those with no decay (11.3 ± 9) and those with ≥1 decayed tooth (13.6 ± 12.4).

Number of teeth present

Factors associated with number of teeth present of all participants (n = 218) are shown in supplementary Table S2, with functional limitation of OHIP-14S, and substance use negatively associated with number of teeth present.

Factors associated with number of teeth present for NDM and DM participants are shown in Table 3 and Table S3.

To further scrutinize the associations between the number of teeth present and OHRQoL of NDM versus DM participants, partial correlation analysis on the number of teeth present, OHIP-14S and all seven domains was performed. Functional limitation remained negatively associated with number of teeth present in both NDM/DM participants (Table S4).

Participants were categorized into subgroups with <25 teeth and ≥25 teeth. For NDM participants, data for these subgroups were normally distributed (Kolmogorov–Smirnov test, $P = 0.259$), independent sample t-test was used to compare OHIP-14S between those with <25 teeth (n = 32) and ≥25 teeth (n = 79). There was no statistically significant difference ($P = 0.474$) in OHIP-14S (mean ± SD) between those with <25 teeth (13.2 ± 8.9) compared to those with ≥25 teeth (11.6 ± 10.7).

As the comparison of OHIP-14S using 25 teeth as a cut-off point was not statistically significant, NDM participants were further categorized into subgroups with <20 teeth and ≥20 teeth.[37] Data for these subgroups were normally distributed (Kolmogorov–Smirnov test, $P = 0.300$). Independent sample *t*-test was employed to compare OHIP-14S between those with <20 teeth (n = 11) and ≥20 teeth (n = 100). There was a statistically significant difference ($P = 0.028$) in OHIP-14S (mean ± SD) between those with <20 teeth (17.6 ± 10.8) compared to those with ≥20 teeth (11.5 ± 10). The OHIP-14S MID between NDM participants with <20 teeth and those with ≥20 teeth was 4 points, the ES was 0.6 indicating a moderate effect. The difference in mean OHIP-14S between these two subgroups was 6.1 which was larger than the MID (4.0), meaning that the difference in score was not a result of measurement error and can be considered clinically meaningful.[23] For NDM participants with <20 teeth, 6 (54.5%) of them had OHIP-14S 4 points above the mean OHIP-14S of those with ≥20 teeth (n = 105, 11.5). The mean OHIP-14S score for these 6 participants was 25 ± 9.1 (range: 17–41). In terms of OHIP-14S (mean ± SD) domains, these 6

participants were mainly affected in terms of: physical pain (5 ± 2.4), psychological disability (5.0 ± 1.8), physical disability (4.7 ± 2.7), psychological discomfort (mean 4.3 ± 2.4), functional limitation (4.0 ± 2.1), handicap (1.0 ± 0.9), and social disability (1.0 ± 1.3).

DM participants were similarly categorized into subgroups with <25 teeth and ≥25 teeth. Data for these subgroups were normally distributed (Kolmogorov–Smirnov test, $P = 0.133$), independent sample t-test was used to compare OHIP-14S between those with <25 teeth (n = 40) and ≥25 teeth (n = 67). There was a statistically significant difference ($P = 0.018$) in OHIP-14S (mean ± SD) between those with <25 teeth (11.6 ± 11.1) compared to those with ≥25 teeth (6.9 ± 6.8). The OHIP-14S MID between DM participants with <25 teeth and those with ≥25 teeth was 4.2 points, the ES was 0.4 indicating a small effect.[39] The difference in mean OHIP-14S between these two subgroups was 4.7. This was larger than the MID (4.2), meaning that the difference in score was not a result of measurement error and can be considered clinically meaningful.[23] For DM participants with <25 teeth, 15 (37.5%) of them had OHIP-14S 4.2 points above the mean OHIP-14S of those with ≥25 teeth (6.9). The mean OHIP-14S score for these 15 participants was 23.1 ± 9.7 (range: 13–42). In terms of OHIP-14S domains (mean ± SD), these 15 DM participants were mainly affected in terms of physical pain (4.9 ± 2.3), functional limitation (4.4 ± 1.5), psychological discomfort (mean 4.2 ± 2.6), physical disability (3.9 ± 2.6), psychological disability (3.3 ± 2.3), handicap (1.5 ± 1.6), and social disability (0.9 ± 1.6).

Participants with DM were further categorized into subgroups with <20 teeth and ≥20 teeth. Data for these subgroups were not normally distributed (Kolmogorov-Smirnov test, $P = 0.032$). Mann–Whitney U test was employed to compare OHIP-14S between those with <20 teeth (n = 18) and ≥20 teeth (n = 89). There was a statistically significant difference ($P = 0.005$) in OHIP-14S between those with <20 teeth [median (interquartile range) = 12 (5.75–17.5); mean ± SD = 13.3 ± 9.5] compared to those with ≥20 teeth [median (interquartile range) = 5 (2–11); mean ± SD = 7.7 ± 8.5]. The OHIP-14S MID between DM participants with <20 teeth and those with ≥20 teeth was 3.6 points, the ES was 0.6 indicating a moderate effect. The difference in mean OHIP-14S between these two subgroups was 5.6, which was larger than the MID (3.6), meaning that the difference in score was not a result of measurement error and can be considered clinically meaningful.[23] For DM participants with <20 teeth, 9 (50%) of them had OHIP-14S 3.6 points above the mean OHIP-14S of those with ≥20 teeth (7.7). The mean OHIP-14S score for these 9 participants was 20.7 ± 7.8 (range: 13–37). In terms of OHIP-14S domains (mean ± SD), these 9 participants were mainly affected in terms of: physical pain (4.3 ± 2.1), functional limitation (4.1 ± 1.2), physical disability (3.7 ± 2.3), psychological discomfort (3.6 ± 2.7), psychological disability (3 ± 2.2), handicap (1.2 ± 1.4), and social disability (0.8 ± 1.4).

DISCUSSION

This cross-sectional study set out to evaluate any differences/similarities in dental health status, periodontal status, coping strategies, and OHRQoL of NDM and DM participants, and to identify factors that were associated with the OHRQoL of NDM and DM participants so that a more problem-focused and perhaps patient-centred approach can be suggested when treating these patients.

Within the limits of this study, there were significant differences in mean full mouth CAL, number of missing teeth, and coping strategies between NDM and DM participants, rejecting the first null hypothesis. Factors associated with the OHRQoL of NDM and DM participants were different, with mean CAL being the only shared factor associated with OHIP-14S for both groups. Thus, the second null hypothesis was rejected as well.

Coping has been defined as the cognitive and behavioural efforts undertaken by each individual to manage the internal and external demands of stressful situations.[40] Regarding coping, DM participants engaged in distraction more often than NDM participants. Distraction was explained as turning to work or other activities to take my mind off things/doing something to think about it less.[41] Such behaviour supports previous findings by Irani *et al.*,[18] which suggest that DM patients might focus more on managing their systemic conditions and pay less attention to oral health problems.

When the OHRQoL of all participants were analysed for associations with coping strategies, OHIP-14S was associated with denial, venting of emotions, behavioural disengagement, substance use, and religion, all of which might be classified as dysfunctional or maladaptive coping.[41,42] When analysed separately, OHRQoL of NDM participants was associated with denial while OHRQoL of DM participants was associated with venting emotions and self-blame, which were all dysfunctional/maladaptive coping methods. Dysfunctional or maladaptive coping is usually employed when a stressor is deemed uncontrollable. The individual involved resolves to actions aimed at minimizing the stress brought upon by the situation.[41,43] Association of the aforementioned dysfunctional/maladaptive coping with OHRQoL might

reflect the feeling of helplessness when oral health problems such as periodontal disease, caries, and tooth loss arise. Using maladaptive coping strategies to deal with oral health problems might be a generalized misconception that oral disease/conditions are not manageable factors.[44] Perhaps, proper education and positive reinforcement that oral disease/conditions can be prevented, treated, and most of the time, rehabilitated, might change the perception of a layperson (be it NDM or DM). This might motivate them to seek treatment and continue maintaining oral health in the long run.

As opposed to previous evidence,[8,18] the current group saw NDM participants showing worse periodontal status in terms of CAL compare to those with DM. However, DM participants experienced more tooth loss compared to their NDM counterparts. This might partly explain why DM participants presented with lower CAL than NDM participants as most periodontally involved teeth might have been lost over the years. Furthermore, this study employed convenience sampling and did not specifically screen for participants with periodontitis. As such, periodontitis patients with DM in TWEH might have been missed or have refused to participate. The debilitating effects of periodontitis on OHRQoL were still observable in the current group of participants, where OHIP-14S was associated with CAL in both NDM and DM participants. To further substantiate the impact of periodontitis on OHRQoL, the calculation of the MID and ES was employed. In a clinical setting, objective surrogate parameters such as PPD, CAL, and BOP% are usually used to determine disease severity. When subjective measures such as OHRQoL are used, it is often difficult to conclude if statistical significance equals clinical/practical significance.[45,46] Most OHRQoL instruments provide an overall score with no specific scale to determine if patients' OHRQoL is mildly, moderately, or severely affected by a disease/condition. The MID is the smallest score difference considered important from both the clinician's and patient's point of view.[23] The determination of the MID[23] and effect size[46] provides a better interpretation of OHIP-14S results and allows determination of which oral condition is closely associated with OHRQoL.[23,37,47] Forty-three NDM and twenty-five DM participants with high-severe CAL reported OHIP-14S scores higher than those with low-moderate CAL, with differences equal or higher than the MID. Physical pain was the most frequently affected domain in both NDM and DM participants with high-severe CAL, meaning that these 68 (32% of 218) participants who had high-severe CAL associated their oral pain with deteriorations in periodontal health.

Within the limits of this study, even though NDM participants fared worse in terms of periodontal health compared to DM participants, both groups associated poorer OHRQoL with worse periodontal status. The sequelae of periodontitis, such as gum swelling, pain/sensitivity, tooth mobility, drifting of teeth, and eventual loss of teeth, are readily perceivable by individuals[15,47–49] and might lead to psychological impacts.[13,21,50] Although CAL is not easily reversible, providing periodontal therapy and maintenance of a healthy periodontium might have a positive effect on OHRQoL.[51,52]

The presence of decayed teeth was associated with poorer OHRQoL in DM participants, and this was evaluated via the determination of the MID of those with ≥1 decayed tooth. Caries was associated with deteriorations in OHRQoL of DM participants in terms of worse physical pain, followed by physical disability, psychological discomfort, functional limitation, and psychological disability. Although the caries experience of the evaluated DM participants was relatively low, having carious teeth, even on just a single tooth, appeared to be associated with impaired daily function in those examined. This was in contrast to NDM participants whose OHRQoL showed no association with decayed teeth. Such results possibly reflect differences in the perceived importance of oral function between the two groups. DM participants who might practice a more stringent and specific diet control[53] with emphasis on reducing softer processed foods[54] and increased fibre intake[55] might find it difficult to chew if their oral function was restricted by pain or even food impaction due to caries. Dissimilar to periodontitis, in which initial signs and symptoms might go unnoticed,[50] the discomfort from untreated caries can be enervating from the start.[16,56] Even the need to seek dental treatment due to dental caries has been reported to be associated with poor OHRQoL.[16] DM participants who are already burdened with a chronic systemic disease might have felt that having discomfort from dental caries was an added inconvenience and associated it with their OHRQoL. Better oral hygiene practices and periodic preventive dental checkups could prove beneficial in reducing caries risk and improving OHRQoL in the long run.[57]

Tooth loss is a reflection of accumulated oral pathologies, including caries and periodontitis, over time.[58] Although the reasons for tooth loss within the study population could not be clearly established, the impact of having more missing teeth had significant associations with functional limitations for both NDM and DM participants.

Within this study, DM participants with <25 teeth and those with <20 teeth experienced poorer OHRQoL mainly due to physical pain and functional limitation. Eating forms an integral part of Chinese culture,[59] and chewing difficulties due to tooth loss not only affect the physical and psychological satisfaction of eating[60] but might be a considerable hindrance

to patients with DM who need to maintain strict dietary control.[53,58,61] For NDM participants, having <25 teeth was not associated with poorer OHRQoL. However, when the number of teeth dropped to <20, NDM participants with <20 teeth experienced worse OHRQoL than those with ≥20 teeth. Their most affected domains were physical pain and psychological disability.

Having an increasing number of missing teeth would be restrictive to one's daily function.[16,62] Käyser,[63] who introduced the concept of a shortened dental arch, suggested that a minimum of four occluding units (one unit = a pair of occluding premolars) was enough for daily masticatory needs.[63] Even though the number of occluding pairs was not evaluated in this study, the idea of maintaining a shortened dental arch[63] might be applicable to NDM patients, but not to individuals with DM. The dietary needs of individuals with DM might necessitate a bilateral molar occlusion or more for proper function. This can be assumed from the difference in OHIP-14S domains affected in NDM and DM participants. DM participants with <25/20 teeth and poor OHRQOL reported worse scores in physical pain and functional limitation, while NDM participants with <20 teeth and poor OHRQOL reported worse scores in physical pain and psychological disability. DM participants appear to associate tooth loss more with diminished daily function, and losing just three teeth (excluding third molars) seems to be associated with worse OHRQoL. The actual need for bilateral molar occlusion in DM participants cannot be established in the current cross-sectional study. Such associations might be the basis for future clinical trials aimed at minimizing tooth loss and with efforts to rehabilitate DM patients to ≥25 teeth/prosthesis to determine if having more occluding units is essential for optimal OHRQoL.

LIMITATIONS

Several limitations must be addressed. The cross-sectional nature of this study did not allow long-term evaluation of periodontal health, dental health, OHRQoL, and the coping behaviour of participants. Evaluating the coping strategies of participants at a single time point might reflect their short-term psychological state and not their long-term psychological traits,[21,64] which might be why no apparent pattern or relationship in coping strategies and OHRQoL can be seen. The effects of dental treatment (e.g., periodontal therapy) on glycaemic control and OHRQoL were also not assessed. Such information might prove helpful in the management of DM patients, for example, focusing treatment towards the maintenance or provision of more chewing units and restoration of carious teeth, might improve OHRQoL in DM patients in the long run.

The OHIP-14S is not a condition-specific OHRQoL instrument and might not completely capture the impact associated with periodontal status, caries, and tooth loss on the daily lives of participants screened.[14] Future studies employing a condition-specific index to evaluate the impacts of identified risk indicators of poor OHRQoL might be considered to clarify the influence of oral conditions on daily function.[47,65]

Reasons for tooth loss were not determined as most participants were new to PPDH without prior records, and might not recall details related to their missing teeth. For subgroup analyses, 25 and 20 remaining teeth, without considering the number of occluding units were used as an arbitrary cut-off point to predict the impact of missing teeth on OHRQoL. This was based on published evidence noting a significant drop in OHRQoL once the number of teeth present dropped below twenty-five[38] and twenty,[37] even when occlusion was not assessed. Such observations hold within a Chinese community where the number of teeth in the mouth serves not only one's functional needs but also plays an essential role in psychosocial demands and cultural beliefs.[66,67] The dietary habits of NDM and DM participants were not evaluated. Perhaps such information might shed light on the different functional needs between NDM and DM participants, and allow better comprehension of factors that are associated with their OHRQoL so that proper treatment can be carried out. The prosthetic status of participants was not evaluated. The impact of replacing missing teeth with fixed prosthetics or removable dentures could not be assessed. A population study on 8,155 Koreans reported that removable prostheses were associated with poorer masticatory function and worse diabetic control.[68] Such results and the observation that poor OHRQoL of DM participants was associated with inferior periodontal health, caries, and missing teeth might be used as a guide when treating patients with DM.

CONCLUSION

Within the limits of this study, NDM participants fared worse in their OHRQoL compared to DM participants, mirroring results by Irani *et al.*[18] However, participants with DM associated OHRQoL to many of their oral conditions, with those showing higher attachment loss (≥3 mm mean full mouth CAL), presented with more missing teeth (≥4 missing teeth), and had dental caries (≥1 decayed teeth), experiencing worse OHRQoL. Individuals with DM might need more teeth/prostheses for better chewing function. Delivery of treatment aimed at maintaining teeth and provision of more chewing units, while controlling for

known risks[68–70] might be the best effort to improve OHRQoL of DM patients.

Furthermore, OHRQoL of NDM and DM participants was associated with dysfunctional/maladaptive coping strategies. The pessimistic impression that their oral conditions cannot be treated or improved might be the reason for such negative perceptions towards oral health. More problem-focused motivational and interventional approaches might be needed to improve OHRQoL of dental patients regardless of DM status.

Future long-term clinical research on management strategies to alleviate oral problems that matter most to patients might shed light on how OHRQoL can be improved in NDM and DM patients.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

AUTHOR CONTRIBUTIONS

A Chen: Conceptualization; Investigation; Data curation; Writing – original draft. **ST Ng:** Conceptualization; Investigation; Data curation. **V Goh:** Formal analysis; Data curation; Visualization; Writing – review & editing. **KWS Yeung:** Formal analysis; Data curation. **YC Tsang:** Formal analysis. **Q Wang:** Data curation. **WK Leung:** Conceptualization; Methodology; Validation; Investigation; Resources; Data curation; Visualization; Project administration; Funding acquisition; Writing – original draft; Writing – review & editing; Supervision. **S-C Siu:** Methodology; Validation; Investigation; Resources; Project administration.

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ETHICS APPROVAL STATEMENT

The study protocol was approved by the Institutional Review Boards of the University of Hong Kong/Hospital Authority Hong Kong West Cluster (UW 11-380) and the Hong Kong East Cluster Research Ethics Committee (HKEC-2011-076).

INFORMED CONSENT STATEMENT

Informed consent was obtained from all study participants involved in the study.

Data availability statement

The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy reasons.

SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article:

Table S1. Partial correlation analysis of variables associated with OHIP-14S of all participants (n = 218).

Table S2. Partial correlation analysis of variables associated with the number of teeth present in all participants (n = 218).

Table S3. Correlation analysis between the number of teeth present and coping strategies.

Table S4. Partial correlation analysis between the number of teeth present, OHIP-14S, and domains.

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