SCREENING FOR TYPE 2 DIABETES MELLITUS AND PREDIABETES USING POINT-OF-CARE TESTING FOR HBA_{1C} AMONG THAI DENTAL PATIENTS

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Abstract. Diabetes mellitus type 2 (DM) is associated with oral diseases. Some studies indicated that patients who seek dental treatment could have undiagnosed hyperglycemic condition. The aim of this study was to assess the prevalence of undiagnosed hyperglycemia and selected associated factors among Thai dental patients. Dental patients without a history of hyperglycemia were recruited from the Special Clinic, Faculty of Dentistry, Mahidol University, Bangkok, Thailand and His Majesty the King's Dental Service Unit, Thailand. The patients were randomly selected and a standardized questionnaire was used to collect demographic data from each patient. Blood pressure, body mass index (BMI), and waist circumference were recorded for each subject. The number of missing teeth, periodontal status, and salivary flow rate were also investigated. HbA_{1c} was assessed using a finger prick blood sample and analyzed with a point-of-care testing machine. Hyperglycemia was defined as a HbA_{1c} ≥5.7%. The prevalence of hyperglycemia among participants was calculated and multivariate logistic regression analysis was used to identify risk factors. A total of 724 participants were included in the study; 33.8% had hyperglycemia. On multiple logistic regression analysis, older age, family history of DM, being overweight (BMI ≥23 kg/m^2), having central obesity and having severe periodontitis were significantly associated with hyperglycemia. The high prevalence of hyperglycemia in this study of dental patients suggests this setting may be appropriate to screen for patients with hyperglycemia.

Keywords: diabetes mellitus, prevalence, epidemiology, dental clinics, risk factors, hyperglycemia

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INTRODUCTION

Poorly controlled diabetes mellitus type 2 (DM) is associated with damage to multiple organs, including the eyes, kidneys, nerves, heart and blood vessels

(American Diabetes Association, 2004). About a quarter of new patients diagnosed with DM already have retinopathy or microalbuminuria (Engelgau *et al*, 2000). Microvascular and macrovascular complications can sometimes be present even in patients with prediabetes who have chronic hyperglycemia (Saudek *et al*, 2008). The number of people aged ≥20 years estimated to have DM world-wide is expected to increase from 171 million in 2000 to 366 million by 2030 (Wild *et al*, 2004). The Thai National Health Examination Survey IV (NHES IV) estimates the age-adjusted prevalence of impaired fasting glucose (IFG) and undiagnosed DM among Thais aged ≥20 years to be 10.6% and 2.3%, respectively (Aekplakorn *et al*, 2011). The International Diabetes Federation estimated that world-wide, half the cases of DM are remain undiagnosed (Whiting *et al*, 2011). These data suggest the importance of identifying DM earlier.

Three methods have commonly been used to diagnose DM: a fasting plasma glucose (FPG) ≥126 mg/dl on 2 separate occasions on different days, symptoms of DM with a random plasma glucose level ≥200 mg/dl or a two-hour postprandial plasma glucose level ≥200 mg/dl (American Diabetes Association, 2013). The HbA_{1c} test has recently been used to diagnose prediabetes and DM with a cut-off levels of 5.7-6.4% and ≥6.5%, respectively (American Diabetes Association, 2013). The factors favoring the use of HbA_{1c} test are: 1) the HbA_{1c} test does not require the patient to be fasting; 2) HbA_{1c} reflects longer-term glycemic levels; 3) the HbA_{1c} result is standardized; and 4) errors caused by non-glycemic factors affecting HbA_{1c} are infrequent. Using rapid testing at the point-of-care can minimize patient inconvenience and possibly detect more cases earlier. HbA_{1c} has been used to screen for prediabetes and undiagnosed DM in the dental setting in some studies(Genco *et al*, 2014; Herman *et al*, 2015).

Several factors have been found to be associated with an increased risk for developing DM, including increasing age, obesity and lack of physical activity (Aekplakorn *et al*, 2006; American Diabetes Association, 2013). DM is more common among individuals with a family history of the disease, dyslipidemia, hypertension, impaired fasting glucose and impaired glucose tolerance (American Diabetes Association, 2004). Many studies have documented the relationship between oral health and DM (Mealey and Rethman, 2003; Mealey and Ocampo, 2007; Lamster *et al*, 2008). A strong association between periodontal disease and uncontrolled DM has been reported (Taylor, 2001). Oral findings suggestive of DM include periodontal disease, mouth dryness (xerostomia and hyposalivation) and a burning sensation in the mouth (Li *et al*, 2011).

The relationship between periodontal disease and diabetes shows the importance of screening for DM among dental patients (Strauss *et al*, 2010). Measuring blood glucose levels in the dental clinic can provide valuable information for both patients and dentists. Patients with abnormal glucose levels can be referred for further diagnosis and treatment (Barasch *et al*, 2012). In one study from the United States, 1,022 dental patients aged ≥45 years who were not aware of their diabetic status were screened using a HbA_{1c} test (Genco *et al*, 2014); 416 (40.7%) had a HbA_{1c} level ≥5.7% and were referred to their physicians for further evaluation. Of these 12.3% were diagnosed as having DM, 23.3% as having prediabetes and 64.4% as not having DM. These data suggest screening for diabetes in the dental

setting is possible and may be of benefit to patients.

There are no published reports of screening for hyperglycemia in the dental setting in Thailand. Therefore, we aimed to determine the prevalence of undiagnosed hyperglycemia and its associated risk factors among Thai dental patients using point-of-care testing for HbA_{1c}.

MATERIALS AND METHODS

Study population

This study was performed in two clinical settings. The first setting was the Special Clinic of the Faculty of Dentistry, Mahidol University (SCMU), Bangkok, Thailand. This clinic, associated with the dental school, is devoted to the diagnosis and care of outpatients and served by several dental specialists working in cooperation. At this clinic 446 patients were recruited into this study; these patients primarily resided in urban areas. The second setting was His Majesty the King's Dental Service Unit (MDSU), which is the largest mobile dental service unit in Thailand. This unit provides dental service to people in suburban areas of Thailand. In this second setting, 278 patients were included; these patients primarily resided in suburban areas.

All patients were randomly selected from the 2 dental settings for participation in this study. Inclusion criteria were patients aged ≥25 years who had no previous history of hyperglycemia who sought dental treatment at either the SCMU or the MDSU. The patients must have been able to fill out a demographic investigation form and a questionnaire. Exclusion criteria were patients who had been diagnosed with severe anemia or polycythemia, pregnant women, patients who had conditions that cause secondary DM, such as Cushing's syndrome, acromegaly, hemochromatosis, pancreatitis or cystic fibrosis, patients who were on systemic corticosteroids, and patients who were taking glucose-lowering medication(s) or were on chemotherapy. Patients who had been treated for an oral cancer either with surgery or radiation therapy were also excluded. In total, 724 patients aged ≥25 years were included in this study.

Demographic data collection

A standardized questionnaire was used to collect data regarding patient gender, age, education level, marital status, current work and financial status, smoking and alcohol consumption and a family history of DM. Also recorded were a personal history of medical illnesses, including hypertension, cardiovascular disease, hyperlipidemia and gout. If the patient had one or more of these diseases, they were considered to have a medical illness.

Body weight was measured with a mechanical balance to the nearest 1.0 kg. Height was measured in bare feet to the nearest 0.01 m. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared. Overweight was defined as a BMI ≥23 kg/m^2 (WHO/IASO/IOTF, 2000).

In each subject, waist circumference was measured midway between the inferior margin of the last rib and the iliac crest at the end of expiration with an inelastic plastic fiber tape measured to the nearest 0.5 cm. while the subject stood balanced on both feet (WHO, 2008). A waist circumference ≥90 cm in males and ≥80 cm in females was defined as central obesity (WHO/IASO/IOTF, 2000).

Systolic and diastolic blood pressures were measured using an automatic sphygmomanometer (Omron HEM-7221,

Omron Healthcare, Kyoto, Japan) in the right arm with the patient in a seated position after the participant had rested for at least 5 minutes. Hypertension was defined as a systolic blood pressure (SBP) ≥140 mmHg or a diastolic blood pressure (DBP) ≥90 mmHg (Mancia *et al*, 2007) or by history in cases where the patient had a history of hypertension.

Periodontal examination

Each subject received a complete periodontal examination by an experienced dentist. Periodontal examination was performed at the dental clinic using mouth mirrors and manual periodontal probes (North Carolina periodontal probe UNC-15 Hu Friedy Manufacturing, Chicago, IL) with an artificial dental unit light. Probing depth (PD) was defined as the distance between the gum margin and the base of the gum sulcus that could be explored by a periodontal probe to the nearest whole millimeter. Gum recession was measured for all teeth except the third molar in 6 locations (mesiobuccal, midbuccal, distobuccal, mesiolingual, midlingual and distolingual). The clinical attachment level (CAL) was calculated from the PD and gum recession as the distance from the cementoenamel junction to the base of the periodontal sulcus. Each participant was given instructions regarding dental treatment needs if they were found to have periodontal disease.

Participant periodontal status was classified into 3 levels: 1) severe, 2) moderate, and 3) mild or no periodontitis, based on the extent and severity of periodontal disease using the criteria of the Centers for Disease Control (CDC) Periodontal Disease Surveillance Workgroup (Page and Eke, 2007). These criteria defined severe periodontitis as having ≥2 interproximal sites with a CAL ≥6 mm (not on the same tooth) and ≥1 interproximal site with PD ≥5 mm; moderate periodontitis as having ≥2 interproximal sites with a CAL ≥4 mm (not on the same tooth) or ≥2 interproximal sites with a PD ≥5mm (not on the same tooth); individuals who did not fulfill the above criteria were classified as having no or mild periodontitis.

Evaluation of salivary flow rate

An unstimulated salivary flow rate was measured using a Modified Schirmer Test (MST). Patients were asked to sit in an upright position and to swallow to clear secretions from the mouth. The edge of the Schirmer test strip was placed on the floor of the patient's mouth with the patient's tongue raised and gently retracted and kept in the mouth for 3 minutes. The length of the strip that was moist, indicated by a blue dye, was then measured. Hyposalivation was defined as the length of moisture of ≤25 millimeters (Fontana *et al*, 2005).

Glycemic measurement

Since there are a number of different methods for measuring HbA_{1c}, the National Glycohemoglobin Standardization Program (NGSP) has obviated this problem by publishing a standardization for the various HbA_{1c} methods. However, the American Diabetes Association (ADA) has recommended that only NGSP-certified methods be used to measure HbA_{1c} (Curt *et al*, 2000). The DCA Vantage (Siemens Medical Solutions Diagnostics, Tarrytown, NY) based on latex agglutination inhibition immunoassay methodology provides results within 6 minutes and is NGSP-certified. This method is comparable with other laboratory-based methods (Lenters-Westra and Slingerland, 2010). The DCA vantage was used for this study. A finger stick blood sample was used for the test. A point-of-care HbA_{1c} level <5.7% was considered normal, 5.7-6.4% was con-

Table 1
Prevalence of hyperglycemia by study site.

	Total *N* = 724 No. (%)	Special Clinic, Mahidol University *n* = 446 No. (%)	King's Dental Service Unit *n* = 278 No. (%)
Normal	479 (66.2)	291 (65.2)	188 (67.6)
Hyperglycemia (HbA_{1c} ≥5.7%)	245 (33.8)	155 (34.7)	90 (32.3)
Prediabetes (HbA_{1c} 5.7-6.4%)	204 (28.2)	133 (29.8)	71 (25.5)
DM (HbA_{1c} ≥6.5%)	41 (5.6)	22 (4.9)	19 (6.8)

sidered to be prediabetes and ≥6.5% was considered to be DM (American Diabetes Association, 2013). Hyperglycemia was defined as a HbA_{1c} ≥5.7%.

Subjects identified as having prediabetes were advised to control their diet, lose weight, increase their physical activity and repeat the blood test annually. Subjects identified as having DM were referred to their physician for further evaluation and management.

Statistical analysis

The prevalence of hyperglycemia was calculated for the whole study group and the subgroups. Differences in variables between subjects with and without hyperglycemia were assessed using the χ^2 test and the *t*-test for categorical and continuous variables, respectively.

Demographic and clinical variables associated with hyperglycemia with a *p*-value <0.25 on bivariate analysis were included in multiple logistic regression analysis. On multiple logistic regression analysis, backward stepwise analysis was used to select variables included in the final model. The probabilities for entry and removal of factors were set to $p < 0.05$ and $p \geq 0.1$, respectively. All analyses were completed using STATA (STATA statistical software, version 14.0; College Station, TX).

Ethical considerations

This study was approved by the Institutional Review Board, Faculty of Medicine, Chulalongkorn University (Reference Number: 388/2005), the Committee on Human Rights and Human Experimentation, Faculty of Dentistry/ Faculty of Pharmacy, Mahidol University (MU-DT/PY-IRB 2013/010.1902), and the Ethics Committee of the Maharat Nakhon Ratchasima Hospital. All participants gave written informed consent prior to participation in the study.

RESULTS

A total of 724 subjects were included in this study: 446 from the SCMU and 278 patients from the MDSU. The prevalence of hyperglycemia (HbA_{1c} ≥5.7%) was 33.8%; 28.2% were identified as having prediabetes (HbA_{1c} between 5.7-6.4%) and 5.6% were identified as having DM (HbA_{1c} ≥6.5%). The prevalences of hyperglycemia at the SCMU and MDSU were 34.7% and 32.3%, respectively (Table 1). The prevalences of hyperglycemia, prediabetes and DM were not significantly different between the 2 study sites.

The clinical characteristics of the normal and hyperglycemic subjects are shown in Table 2. Normal and hypergly-

Table 2
Clinical characteristics of study subjects.

Characteristics	Normal No. (%)	Hyperglycemia No. (%)	*p*-value
Age (years) (*n*=723)	478	245	<0.001
25-35	90 (18.8)	18 (7.4)	
36-45	85 (17.8)	25 (10.2)	
46-55	137 (28.7)	74 (30.2)	
56-65	111 (23.2)	83 (33.9)	
>65	55 (11.5)	45 (18.4)	
Gender (*n*=724)	479	245	0.117
Male	108 (22.6)	43 (17.6)	
Female	371 (77.5)	202 (82.5)	
Education level (*n*=724)	479	245	0.081
None/primary education	138 (28.8)	80 (32.7)	
Secondary education	83 (17.3)	54 (22.0)	
Higher education	258 (53.9)	111 (45.3)	
Marital status (*n*=724)	479	245	0.001
Single	164 (34.2)	53 (21.6)	
Married	275 (57.4)	159 (64.9)	
Separated	40 (8.4)	33 (13.5)	
Working (*n*=723)	479	244	0.007
No	137 (28.6)	94 (38.5)	
Yes	342 (71.4)	150 (61.5)	
Household income (*n*=718)	476	242	0.349
Living comfortably	281 (59.0)	133 (55.0)	
Coping	176 (37.0)	102 (42.2)	
Difficult	19 (4.0)	7 (2.9)	
Smoking status (*n*=723)	478	245	0.628
Never smoked	433 (90.6)	226 (92.2)	
Former smoker	18 (3.8)	6 (2.5)	
Current smoker	27 (5.7)	13 (5.3)	
Current alcohol use (*n*=723)	478	245	0.186
No	389 (81.4)	209 (85.3)	
Yes	8 (18.6)	36 (14.7)	
History of medical illness (*n*=720)	477	243	0.003
No	307 (64.4)	129 (53.1)	
Yes	170 (35.6)	114 (47.0)	
Family history of diabetes (*n*=723)	479	244	0.003
No	330 (68.9)	141 (57.8)	
Yes	149 (31.1)	103 (42.2)	
History of hypertension (*n*=716)	472	244	<.001
No	317 (67.2)	122 (50.0)	
Yes	155 (32.8)	122 (50.0)	
Body Mass Index (kg/m^2) (*n*=721)	477	244	<.001
<23	177 (37.1)	44 (18.0)	
≥23	300 (62.9)	200 (82.0)	

Table 2 (Continued).

Characteristics	Normal No. (%)	Hyperglycemia No. (%)	*p*-value
Presence of central obesity (*n*=716)	473	243	<.001
No	197 (41.7)	44 (18.1)	
Yes	276 (58.4)	199 (81.9)	
Oral characteristics			
Hyposalivation (*n*=715)	473	242	0.128
No	460 (97.3)	230 (95.0)	
Yes	13 (2.7)	12 (5.0)	
Fully edentulous (*n*=715)	473	242	0.15
No	461 (97.5)	231 (95.5)	
Yes	12 (2.5)	11 (4.5)	
Number of missing teeth (*n*=692)[a]	4.24 (4.9)	5.73 (5.7)	0.001
Periodontal status (*n*=701)[a]	467	234	0.013
No or mild periodontitis	234 (48.9)	99 (40.4)	
Moderate periodontitis	193 (40.3)	105 (42.9)	
Severe periodontitis	52 (10.9)	41 (16.7)	

[a]Fully edentulous subjects excluded.

cemic subjects were similar in regard to gender, education level, income, smoking status and alcohol consumption. However, participants with hyperglycemia were significantly more likely to be older (82.5% *vs* 63.4%, $p<0.001$), married (64.9% *vs* 57.4%, $p<0.05$), have a medical illness (47.0% *vs* 35.6%, $p<0.05$) have a family history of DM (42.2% *vs* 31.1%, $p<0.05$), have hypertension (50.0% *vs* 32.8%, $p<0.001$), be overweight (82.0% *vs* 62.9%, $p<0.001$) have central obesity (81.9% *vs* 58.4%, $p<0.001$), have more missing teeth (5.73 *vs* 4.24 teeth, $p<0.001$) and have severe periodontitis (16.7% *vs* 10.9%, $p<0.05$).

Table 3 shows the risk factors associated with hyperglycemia on multiple logistic regression analysis; these were age ≥56 years (OR=3.47; 95%CI: 1.85-6.51), having a secondary level education (OR=1.76; 95%CI: 1.07-2.90), having a family history of DM (OR=1.69; 95%CI: 1.19-2.41), being overweight (OR=1.64; 95%CI: 1.03-2.61), having central obesity (OR=2.53; 95%CI: 1.60-3.99) and having severe periodontitis (OR=1.86; 95%CI: 1.10-3.17).

DISCUSSION

In this study, the prevalence of hyperglycemia was investigated among dental patients from Thai urban and suburban areas and 33.8% had hyperglycemia. In 2009, the data from the NHES IV conducted among 18,629 Thai adults aged ≥20 years found the prevalences of impaired fasting glucose (IFG), defined as having a fasting plasma glucose (FPG) from 5.6 to 6.9 mmol/l, and undiagnosed DM, defined as having a FPG ≥7.0 mmol/l, to be 10.6% and 2.3%, respectively (Aekplakorn *et al*, 2011). In that study, the prevalence of DM was significantly higher among urban than rural residents ($p<0.001$) (Aekplakorn *et al*, 2011). In our study, the prevalences of prediabetes and DM were 28.2% and 5.6%,

Table 3
Multivariate logistic regression analysis of risk factors associated with hyperglycemia (n=690).

Factors	Adjusted OR	95% CI	p-value
Age in years			
25-35	1.00	Reference	
36-45	1.17	0.58-2.39	0.658
46-55	2.10	1.13-3.91	0.019
56-65	3.47	1.85-6.51	<0.001
>65	3.69	1.83-7.46	<0.001
Education level			
None/primary education	1.00	Reference	
Secondary education	1.76	1.07-2.90	0.027
Higher education	1.37	0.90-2.09	0.146
Family history of diabetes			
No	1.00	Reference	
Yes	1.69	1.19-2.41	0.004
Body Mass Index (kg/m^2)			
<23	1.00	Reference	
≥23	1.64	1.03-2.61	0.038
Central obesity			
No	1.00	Reference	
Yes	2.53	1.60-3.99	<0.001
Periodontal status			
No or mild periodontitis	1.00	Reference	
Moderate periodontitis	1.28	0.88-1.85	0.199
Severe periodontitis	1.86	1.10-3.17	0.021

but there were no significant differences between urban and suburban patients. The high prevalence of hyperglycemia found among our study subjects may be due to the study population of dental subjects. Many studies have reported an association between oral diseases and DM (Mealey and Rethman, 2003; Lamster *et al*, 2008). Therefore, patients who sought dental care in our study might have been more likely to have DM. Although our study found no significant difference in the prevalence of hyperglycemia between urban and suburban areas. This may be due to different study populations since we studied dental patients. Urban and suburban dental patients may have had similar risks for hyperglycemia.

Opportunistic screening for hyperglycemia, such as with any contact with a health care system, including screening dental patients, has been suggested previously (Strauss *et al*, 2010; Lalla *et al*, 2011; Herman *et al*, 2015). American Diabetes Association guidelines (2004) recommend screening for DM in those aged ≥45 years, those with a first-degree relative with DM, those with a hypertension or cardiovascular disease and those with a BMI ≥25 kg/m^2. Genco *et al* (2014) examined 1,022 dental patients aged ≥45 years from 11 general and periodontal specialty dental

offices and a dental clinic in a community health center in Rhode Island, USA. Screening for DM was performed by asking ADA Risk Test questions followed by a point-of-care capillary HbA_{1c} test. Of those 1,022 participants screened, 416 (40.7%) had a HbA_{1c} ≥5.7%. Genco *et al* (2014) found 38.8% of participants from private dental offices and 48.1% from a community health service clinic had a HbA_{1c} ≥5.7%. Herman *et al* (2015) examined 181 subjects from a dental clinic in Michigan, USA through initial random glucose screening and then HbA_{1c} testing and found 60 patients (33.15%) had a HbA_{1c} ≥5.7%. Tentolouris *et al* (2013) screened 398 Greek dental subjects using a point-of-care HbA_{1c} level and found the prevalences of HbA_{1c} ≥5.7%, ≥6.0% and ≥6.5% to be 54%, 34% and 12%, respectively. These data suggest dental patients not only can be, but should be screened for DM in the dental setting.

In our study, older age, family history of DM, overweight (BMI ≥23 kg/m^2) and central obesity were associated with hyperglycemia. Several studies have used these parameters to screen dental patients for hyperglycemia (Strauss *et al*, 2010; Lalla *et al*, 2011; Tentolouris *et al*, 2013; Herman *et al*, 2015). Tentolouris *et al* (2013) reported risk factors associated with hyperglycemia were age, overweight (BMI >25 kg/m^2), family history of DM and central obesity. They also found severe periodontitis to be associated with hyperglycemia (OR=1.86; 95%CI: 1.10-3.17). Borrell *et al* (2007) found American subjects with a self-reported family history of DM, a personal history of hypertension, high cholesterol or clinical evidence of periodontal disease had a 27-53% chance of having undiagnosed DM. Lalla *et al* (2011) reported a prospective study aiming to develop a prediction protocol for screening unrecognized hyperglycemia in a dental clinic. Using the data from the screening, predication model for undiagnosed DM was established. When 2 dental parameters including severe periodontitis and number of missing teeth were added to the prediction model, the correct identification of patients with prediabetes and undiagnosed DM was 73%. These data suggest severe periodontitis may be used to predict which patients may have hyperglycemia.

Many studies have reported DM to be a risk factor for periodontitis and tooth loss (Oliver and Tervonen, 1993, 1994; Mealey, 1999). The mechanism for periodontitis associated with DM involves vascular changes, neutrophilic dysfunction and impaired collagen synthesis (Manouchehr-Pour *et al*, 1981). DM can cause vascular changes in all tissues, including capillaries of periodontal structures (Ray, 1948; Russell, 1966). These changes have been postulated to impair the biological functions of oxygen diffusion, leukocyte migration and immune factor activities, contributing to the progression of periodontitis and tooth loss (Murrah, 1985). Oliver and Trevonen (1994) and Ainamo and Ainamo (1996) found patients with well controlled DM do not lose more teeth than healthy individuals and the risk for periodontitis in patients with DM can be reduced by minimizing plaque accumulation with daily oral hygiene and professional dental removal of calculus (Oliver and Trevonen, 1994; Ainamo and Ainamo, 1996). Early diagnosis of hyperglycemia may help prevent severe periodontitis and tooth loss.

Our study had limitations. Diagnosis of hyperglycemia was based on a single HbA_{1c} test. Repeat testing and physician consultation are needed to diagnose DM. Patients with anemia were excluded from

the study on the basis of self-reports only, not blood tests. Undiagnosed anemia may influence the prevalence of hyperglycemia in this study.

Our findings suggest screening patients for hyperglycemia in the dental setting is possible. Oral health care providers should take an active role in hyperglycemia screening among high risk patients to try to prevent oral complications of hyperglycemia.

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