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AUTHOR(S):

Shin, Jung-ho; Takada, Daisuke; Kunisawa, Susumu; Imanaka, Yuichi

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Effects of periodontal management for patients with type 2 diabetes on healthcare expenditure, hospitalization and worsening of diabetes: an observational study using medical, dental and pharmacy claims data in Japan

Jung-ho Shin | Daisuke Takada | Susumu Kunisawa | Yuichi Imanaka

Department of Healthcare Economics and Quality Management, Graduate School of Medicine, Kyoto University, Kyoto, Japan

Correspondence
Yuichi Imanaka, Department of Healthcare Economics and Quality Management, Graduate School of Medicine, Kyoto University, Yoshida Konoe-cho, Sakyo-ku, Kyoto 606-8501, Japan.
Email: imanaka-y@umin.net

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Abstract

Aims: To investigate the effects of regular periodontal management for people with type 2 diabetes on total healthcare expenditure, hospitalization and the introduction of insulin.

Materials and methods: We collected data of individuals who were prescribed diabetes medications during the fiscal year 2015 from the claims database of a prefecture in Japan. We fitted generalized linear models that had sex, age, comorbidities and the status of periodontal management during the previous two years as predictors.

Results: A total of 16,583 individuals were enrolled. The annual healthcare expenditure in the third year was 4% less (adjusted multiplier 0.96, 95% confidence interval [CI] 0.92–1.00) in the group receiving periodontal management every year. The adjusted odds ratio (aOR) for all-cause hospitalization was 0.90 (95% CI: 0.82–0.98). The aOR of introducing insulin in the third year for those who had not been prescribed insulin during the previous two years (n = 13,222) was 0.77 (95% CI: 0.64–0.92) in the group receiving periodontal management every year.

Conclusion: Regular periodontal management for diabetic people was associated with reduced healthcare expenditure, all-cause hospitalization and the introduction of insulin therapy.

KEYWORDS
acute myocardial infarction, healthcare expenditure, ischaemic stroke, periodontal disease, periodontal management, type 2 diabetes

1 | INTRODUCTION

The links between periodontal and systemic diseases have been studied for more than 50 years (Genco & Sanz, 2020). In 2012, the European Federation of Periodontology and the American Academy of Periodontology held a joint workshop; this led to three potential mechanisms being suggested for these links: metastatic infections, inflammation and inflammatory injury, and adaptive immunity (Van Dyke & Winkelhoff, 2013). Independent associations between severe periodontitis and cardiovascular diseases, the most studied links in this field, are supported by a considerable body of evidence (Sanz et al., 2020).

Regarding diabetes, a bidirectional relationship between diabetes and periodontal diseases has been suggested: diabetes is

associated with increased prevalence and progression of periodontal diseases, and periodontal diseases are associated with poorer glycaemic control in patients with diabetes (Taylor, 2001). A recent review suggested plausible mechanisms for these relationships, such as elevations in the levels of several cytokines (Sanz et al., 2018a; Sanz et al., 2018b). The global prevalence of diabetes among people aged 20–79 years is estimated to be 9.3% (International Diabetes Federation, 2019). In Japan, the prevalence of diabetes, which is defined as individuals with HbA1c values ≥6.5% (48 mmol/mol) or who are taking more than one medication for diabetes, was 13.1% for all ages and 19.7% for those aged ≥65 years (Ministry of Health, Labour, and Welfare, 2020).

On the other hand, the prevalence of mild periodontitis is 45%–50% among all adults and more than 60% in adults aged >65 years (Genco & Sanz, 2020). In Japan, the prevalence of periodontitis was 53.6% among those aged ≥20 years and 62.7% for people aged ≥65 years in 2016 (Ministry of Health, Labour, and Welfare, 2017). The prevalence increased between 2011 and 2016; in 2011, the prevalence was 41.7% for those aged ≥20 years and 56.3% for individuals aged ≥65 years (Ministry of Health, Labour, and Welfare, 2017). A recent meta-analysis showed that periodontal treatment reduced HbA1c levels by approximately 0.40% (range: 0.27%–0.65%) after 3 months (Madianos & Koromantzos, 2018). Also, in patients with type 2 diabetes, a higher HbA1c level was reported to be a strong predictor of stroke and acute myocardial infarction (Rawshani et al., 2018). Given the high prevalence of periodontitis and the bidirectional relationships between periodontitis and diabetes, the management of periodontitis for individuals with diabetes could reduce the economic burden of diabetes and related conditions. Several studies have investigated the relationship between periodontal treatment and healthcare costs for people with diabetes. However, the results of these studies have differed; some studies reported that periodontal treatment resulted in a reduction in healthcare costs (Jeffcoat et al., 2014; Nasseh et al., 2017), whereas another study reported increased overall medical costs (Albert et al., 2006).

Thus, the purpose of this study was to investigate the association between periodontal management and total healthcare expenditure of patients with type 2 diabetes. We also focused on what led to any differences in healthcare expenditure. To study this, we investigated the effects of periodontal management on all-cause hospitalization, hospitalization due to acute myocardial infarction or ischaemic stroke, and the introduction of insulin treatment as a surrogate measure of worsening diabetes.

Clinical Relevance

Scientific rationale for study: A bidirectional relationship between diabetes and periodontal diseases has been suggested.

Principal findings: We showed that regular periodontal management was associated with a reduction in total healthcare expenditure, all-cause hospitalizations, hospitalizations due to ischaemic stroke and the introduction of insulin. However, the proportion of individuals with diabetes who received regular periodontal management was not sufficiently high, considering the high prevalence of periodontitis among this group.

Practical implications: Physicians who involve in diabetes care and oral health professionals who involve in periodontal care should make further efforts to provide patients with adequate care for both conditions.

2 | METHODS

2.1 | Data sources

We used claims data from the National Health Insurance (NHI) and the Medical Care System for the Elderly Aged 75 or Over of a prefecture in Japan. Enrolment in health insurance is mandatory in Japan. The two major health insurance schemes in Japan are Employees' Health Insurance and the NHI. Those insured by the NHI, which is controlled by municipalities, include those who are not eligible for Employees' Health Insurance, such as individual proprietors, pensioners and irregular employers. The Medical Care System for the Elderly Aged 75 or Over is the only healthcare insurance scheme for the elderly aged 75 years or more (Ministry of Health, Labour, and Welfare). In 2015, the population of this prefecture was about 1.4 million (Portal Site of Official Statistics of Japan (e-Stat), 2016). The population structure and density of this prefecture are similar to the rest of Japan. The proportion of people aged ≥65 years and the population density per km^2 of this prefecture and the rest of Japan are similar; the differences were within 10% of those of Japan as a whole, which were 26.7% and 340.8 per km^2 in 2015, respectively (Portal Site of Official Statistics of Japan (e-Stat), 2016).

2.2 | Study population

We included people aged ≥35 years who were prescribed medication for type 2 diabetes in the fiscal year 2015, which began on 1 April 2015 and ended on 31 March 2016, and who had claims data for at least 3 years. Medication for type 2 diabetes included sulfonylureas, meglitinides, dipeptidyl peptidase-4 (DPP-4) inhibitors, biguanides, thiazolidinediones, alpha-glucosidase inhibitors, sodium-glucose transporter (SGLT) 2 inhibitors and glucagon-like peptide-1 receptor agonists (GLP-1 receptor agonists). We used this population for our main analyses. For the analysis of relationships between periodontal management and the introduction of insulin in the third year, we excluded those who were prescribed insulin during the previous 2 years.

2.3 | Exposure

The periodontal management in this study included probing, scaling, root planing, subgingival curettage, periodontal surgery and supportive periodontal therapy, which were identified by the corresponding claim codes. We created two categorical variables regarding the statuses of periodontal management: one for the frequency of management and the other for the level of intensity of management. The frequencies of periodontal management were divided into four categories according to the timing of the treatments: (a) during both the first and second years, (b) during either the first or the second year, (c) other dental treatments during the previous two years and (d) no dental treatment during the previous two years. Those in categories (c) and (d) by this categorization did not receive any periodontal management during the two years. The level of intensity of periodontal management was divided into two groups: (a) maintenance care only and (b) treatment for periodontitis. Individuals in the maintenance care group received probing, scaling and/or supportive periodontal therapy, whereas individuals in the treatment for periodontitis group received root planing, subgingival curettage and/or periodontal surgery during the first two years.

2.4 | Outcomes of interest

The primary outcome of interest was total healthcare expenditure in the third year. Total healthcare expenditure data, including copayments, were collected from medical, dental and pharmacy claims. The secondary outcomes of interest included all-cause hospitalizations, hospitalizations due to acute myocardial infarction, hospitalizations due to ischaemic stroke and introduction of insulin therapy during the third year (a surrogate for the increasing severity of diabetes).

2.5 | Statistical analyses

To investigate associations between outcomes in the third year and the statuses of periodontal management during the first two years, we fitted a generalized linear model (GLM) assuming a gamma distribution with a logarithmic link function for healthcare expenditure; this is one of the most reliable models for skewed healthcare data (Malehi et al., 2015); we used logistic regression models for hospitalizations and the introduction of insulin. The predictors in the models included sex, age strata, comorbidities and the statuses of periodontal management. We incorporated two types of variables for exposure: (a) the frequency of periodontal management only (four categories) and (b) the combination of the frequency (four categories) and the level of intensity (two categories) of periodontal management, that is a total of six categories. For the healthcare expenditure model, the quintiles of healthcare expenditure during the first two years were also incorporated as independent variables, because these account for the likelihood an individual will use healthcare services (Nasseh et al., 2017). For the outcome of introducing insulin in the third year, we excluded those who were prescribed insulin during the first two years. We fitted a logistic regression model for this outcome.

Comorbidities were defined as all diagnoses included in the medical and dental claims during the first two years. We then coded indicator variables of 32 comorbidities composing Gagne's combined comorbidities (Gagne et al., 2011), using Quan's coding algorithms (Quan et al., 2005). These 32 indicator variables outperformed other comorbidity measures for predicting hospital charges for various populations in Japan (Shin et al., 2020). Among the 32 comorbidities, we excluded 'diabetes without complications'.

2.6 | Sensitivity analyses

In the first sensitivity analysis, we divided the 'either the first or the second year' group of the exposure variable for the main analysis into two: 'the first year only' and 'the second year only'. We fitted the same models as the main analysis with this variable. In this analysis, we investigated whether the effects of periodontal management differed by the timing of periodontal management.

In the main analyses, the frequency of periodontal management was defined as once per year. However, there is currently no consensus on the appropriate interval between periodontal management consultations (Lamont et al., 2018). In the second sensitivity analyses, we divided the 'both the first and second years' group of the first exposure variable for the main analyses into two; one contained those who received periodontal management during every 6-month period, and the other contained those who received periodontal management every year, but not during every 6-month period. We repeated the same analyses as the main analyses using these categories for periodontal management.

In the third sensitivity analyses for the outcome of healthcare expenditure, we incorporated log-transformed individual-level expenditures as predictors, in place of the quintiles, during the previous two years. We then fitted a GLM using the remaining predictors used in the main analysis.

SAS® software version 9.4 (SAS Institute Inc.) was used for all analyses.

2.7 | Ethical approval

This study was conducted in accordance with the Ethical Guidelines for Medical and Health Research Involving Human Subjects of the Ministry of Health, Labour and Welfare, Japan. The Ethics Committee, Graduate School of Medicine, Kyoto University, approved this study (approval number: R0438).

3 | RESULTS

3.1 | Study population

The study populations comprised 16,583 individuals in the main study population and 13,222 individuals in the population for the analyses of insulin introduction during the third year, in which those who were prescribed insulin during the previous two years were excluded (Figure 1). Table 1 shows the characteristics of the study population (Table S1 shows these characteristics by the frequency and the intensity level of periodontal management). The number of those who received any treatment for periodontal management during both the first and second years was 4127 (24.9%); 9165 (55.3%) individuals did not receive any treatment for periodontal management during the first two years. Among those who received periodontal management during both the first and the second years (n = 4127), 1830 individuals (44.3%) received periodontal management during each 6-month period of the first two years. Among those who received periodontal management (n = 7418), 4007 (54.0%) individuals received maintenance care only and 3411 (46.0%) individuals received treatment for periodontitis. Individuals who received periodontal management every year received treatment for periodontitis more than maintenance care (58.0% vs. 42.0%), whereas those who received periodontal management in either the first or the second year received more maintenance care (69.1%).

3.2 | Annual healthcare expenditure

Table 2 shows annual healthcare expenditure by the frequency of periodontal management (Table S2 presents expenditure by the frequency and the intensity level of periodontal management). Total healthcare expenditure for those who received periodontal management during both the first and second years was lower than that for other groups. In particular, the expenditure for inpatients was the most prominent. The mean expenditure for inpatient service of the 'both the first and second years' group was 20% less than that of the whole study population during the first two years and 17% less in the third year.

3.3 | The effect of periodontal management on healthcare expenditure

The estimated healthcare expenditure was 4%–6% less (adjusted multiplier, which is an exponentiated regression coefficient, 0.94–0.96) in the periodontal management groups than that in the no dental treatment group (Table 3 and Table S3). The total healthcare expenditure of the previous two years was a potent predictor; the first quintile was estimated to spend 43% less (adjusted multiplier 0.57) in the third year, and the fifth quintile was estimated to spend 105% more (adjusted multiplier 2.05).

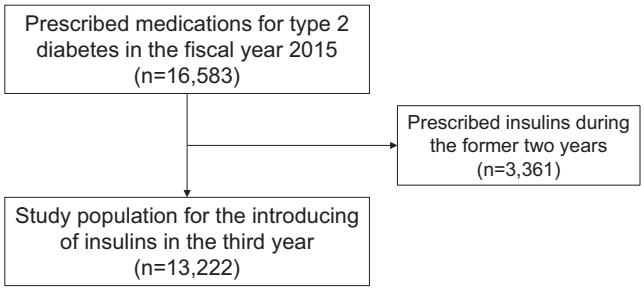

FIGURE 1 Flowchart showing the selection of study populations

3.4 | The effect of periodontal management on hospitalizations and the introduction of insulin

The adjusted odds ratios (aORs) for hospitalizations and the introduction of insulin are presented in Table 3 and Tables S4–S7. The aOR for all-cause hospitalization was 0.90 (95% confidence interval, CI: 0.82–0.99), while the aORs for hospitalizations due to acute myocardial infarction and ischaemic stroke were 1.06 (95% CI: 0.54–2.06) and 0.60 (95% CI: 0.44–0.81), respectively, in the group receiving periodontal management every year. The aOR for the introduction of insulin in the third year for those who were not prescribed insulin during the first two years was 0.77 (95% CI: 0.64–0.92) in the 'both the first and second years' group. The number of individuals included in this analysis was 13,222, because we excluded individuals who were prescribed insulin during the first two years.

3.5 | The effects of differences in periodontal management on each outcome

Table 4 and Tables S8–S12 show the adjusted multipliers and aORs of the combinations of the frequency and the level of periodontal management. All groups with periodontal management tended to exhibit reduced healthcare expenditure in the third year (adjusted multiplier 0.93–0.97). Regardless of the intensity level of management, periodontal management during both the first and second years was associated with reduced all-cause hospitalization (aOR 0.88–0.91) and hospitalization due to ischaemic stroke (aOR 0.56–0.62). Treatments for periodontitis in both the first and the second years were associated with a reduced introduction of insulin during the third year (aOR 0.73).

3.6 | Sensitivity analyses

Tables S13-S17 summarize the results of the first sensitivity analyses. Comparing the results of the main analyses, the results of the first sensitivity analyses where we divided the 'either the first and second year' group into 'the first year only' and 'the second year only' were not considerably different.

Tables S18–S22 present the results of the second sensitivity analyses. The results between the 'every 6-month' group and the 'every year' group were not considerably different; compared with

TABLE 1 Characteristics of the study population

	All	Periodontal management		No periodontal management	
		Both the first and second years	Either the first or the second year	Other dental treatment	No dental treatment
N	16,583	4127	3291	3382	5783
Sex					
M	9047 (54.6%)	2299 (55.7%)	1795 (54.5%)	1864 (55.1%)	3089 (53.4%)
F	7536 (45.4%)	1828 (44.3%)	1496 (45.5%)	1518 (44.9%)	2694 (46.6%)
Age, years old					
Mean ± SD	73.0 ± 9.3	72.3 ± 8.4	72.4 ± 9.1	74.6 ± 9.0	73.0 ± 10.1
Median (1Q, 3Q)	75 (67, 80)	75 (67, 78)	75 (66, 79)	76 (68, 81)	75 (67, 80)
35–44	168 (1.0%)	28 (0.7%)	34 (1.0%)	25 (0.7%)	81 (1.4%)
45–54	437 (2.6%)	93 (2.3%)	95 (2.9%)	58 (1.7%)	191 (3.3%)
55–64	1646 (9.9%)	411 (10.0%)	359 (10.9%)	265 (7.8%)	611 (10.6%)
65–74	5487 (33.1%)	1523 (36.9%)	1129 (34.3%)	1009 (29.8%)	1826 (31.6%)
75–84	7333 (44.2%)	1866 (45.2%)	1440 (43.8%)	1616 (47.8%)	2411 (41.7%)
85-	1512 (9.1%)	206 (5.0%)	234 (7.1%)	409 (12.1%)	663 (11.5%)
Comorbidities					
Myocardial infarction	991 (6.0%)	223 (5.4%)	188 (5.7%)	218 (6.4%)	362 (6.3%)
Congestive heart failure	4085 (24.6%)	852 (20.6%)	779 (23.7%)	921 (27.2%)	1533 (26.5%)
Cardiac arrhythmias	3550 (21.4%)	888 (21.5%)	715 (21.7%)	759 (22.4%)	1188 (20.5%)
Valvular disease	1062 (6.4%)	250 (6.1%)	221 (6.7%)	227 (6.7%)	364 (6.3%)
Cerebrovascular disease	4964 (29.9%)	1226 (29.7%)	998 (30.3%)	1108 (32.8%)	1632 (28.2%)
Dementia	1239 (7.5%)	214 (5.2%)	248 (7.5%)	286 (8.5%)	491 (8.5%)
Pulmonary circulation disorders	96 (0.6%)	29 (0.7%)	23 (0.7%)	15 (0.4%)	29 (0.5%)
Peripheral vascular disorders	3722 (22.4%)	971 (23.5%)	740 (22.5%)	833 (24.6%)	1178 (20.4%)
Hypertension	13,295 (80.2%)	3154 (76.4%)	2628 (79.9%)	2791 (82.5%)	4722 (81.7%)
Paralysis	228 (1.4%)	53 (1.3%)	41 (1.2%)	63 (1.9%)	71 (1.2%)
Other neurological disorders	1005 (6.1%)	242 (5.9%)	198 (6.0%)	222 (6.6%)	343 (5.9%)
Chronic pulmonary disease	5832 (35.2%)	1560 (37.8%)	1145 (34.8%)	1238 (36.6%)	1889 (32.7%)
Diabetes with chronic complications	7606 (45.9%)	1870 (45.3%)	1505 (45.7%)	1619 (47.9%)	2612 (45.2%)
Hypothyroidism	1172 (7.1%)	315 (7.6%)	205 (6.2%)	266 (7.9%)	386 (6.7%)
Renal failure	1374 (8.3%)	265 (6.4%)	255 (7.7%)	321 (9.5%)	533 (9.2%)
Liver disease	5553 (33.5%)	1443 (35.0%)	1146 (34.8%)	1119 (33.1%)	1845 (31.9%)
Peptic ulcer disease	4716 (28.4%)	1233 (29.9%)	941 (28.6%)	1024 (30.3%)	1518 (26.2%)
AIDS/HIV	8 (0.0%)	2 (0.0%)	2 (0.1%)	2 (0.1%)	2 (0.0%)
Any malignancy, including lymphoma and leukaemia, except for malignant neoplasm of skin	3029 (18.3%)	817 (19.8%)	635 (19.3%)	653 (19.3%)	924 (16.0%)
Metastatic cancer	281 (1.7%)	88 (2.1%)	55 (1.7%)	57 (1.7%)	81 (1.4%)
Rheumatoid arthritis/collagen vascular diseases	947 (5.7%)	259 (6.3%)	213 (6.5%)	191 (5.6%)	284 (4.9%)
Coagulopathy	357 (2.2%)	85 (2.1%)	71 (2.2%)	81 (2.4%)	120 (2.1%)
Obesity	143 (0.9%)	35 (0.8%)	27 (0.8%)	26 (0.8%)	55 (1.0%)
Weight loss	174 (1.0%)	50 (1.2%)	23 (0.7%)	45 (1.3%)	56 (1.0%)
Fluid and electrolyte disorders	3250 (19.6%)	703 (17.0%)	651 (19.8%)	731 (21.6%)	1165 (20.1%)
Blood loss anaemia	105 (0.6%)	19 (0.5%)	20 (0.6%)	27 (0.8%)	39 (0.7%)
Deficiency anaemia	2453 (14.8%)	542 (13.1%)	481 (14.6%)	528 (15.6%)	902 (15.6%)

(Continues)

TABLE 1 (Continued)

	All	Periodontal management		No periodontal management	
		Both the first and second years	Either the first or the second year	Other dental treatment	No dental treatment
Alcohol abuse	196 (1.2%)	46 (1.1%)	56 (1.7%)	38 (1.1%)	56 (1.0%)
Drug abuse	8 (0.0%)	2 (0.0%)	2 (0.1%)	1 (0.0%)	3 (0.1%)
Psychoses	505 (3.0%)	93 (2.3%)	119 (3.6%)	99 (2.9%)	194 (3.4%)
Depression	1301 (7.8%)	318 (7.7%)	294 (8.9%)	295 (8.7%)	394 (6.8%)
Annual healthcare expenditures of the previous two years					
Mean ± SD (1000 JPY)	996 ± 1303	923 ± 1115	1003 ± 1269	1039 ± 1320	916 ± 1292
Median (1Q, 3Q)	535 (320, 1053)	543 (347, 996)	548 (334, 1075)	565 (338, 1147)	452 (266, 943)
1st quintile (≤JPY 278,730)	3316 (20.0%)	584 (14.2%)	587 (17.8%)	576 (17.0%)	1569 (27.1%)
2nd quintile (≤JPY 425,725)	3317 (20.0%)	919 (22.3%)	617 (18.7%)	634 (18.7%)	1147 (19.8%)
3rd quintile (≤JPY 647,760)	3317 (20.0%)	931 (22.6%)	712 (21.6%)	675 (20.0%)	999 (17.3%)
4th quintile (≤JPY 1,245,835)	3317 (20.0%)	917 (22.2%)	655 (19.9%)	746 (22.1%)	999 (17.3%)
5th quintile	3316 (20.0%)	776 (18.8%)	720 (21.9%)	751 (22.2%)	1069 (18.5%)
Annual healthcare expenditures of the third year					
Mean ± SD (1000 JPY)	1092 ± 1655	1002 ± 1496	1014 ± 1459	1170 ± 1667	1058 ± 1742
Median (1Q, 3Q)	502 (306, 997)	513 (328, 930)	493 (310, 958)	533 (324, 1116)	438 (263, 909)
All-cause hospitalization in the third year					
Previous two years	5706 (34.4%)	1307 (31.7%)	1170 (35.6%)	1266 (37.4%)	1963 (33.9%)
Third year	5649 (34.1%)	1269 (30.7%)	1115 (33.9%)	1302 (38.5%)	1963 (33.9%)
Admission due to AMI in the third year					
Previous two years	92 (0.6%)	20 (0.5%)	18 (0.5%)	22 (0.7%)	32 (0.6%)
Third year	71 (0.4%)	16 (0.4%)	15 (0.5%)	17 (0.5%)	23 (0.4%)
Admission due to ischaemic stroke in the third year					
Previous two years	413 (2.5%)	70 (1.7%)	93 (2.8%)	102 (3.0%)	148 (2.6%)
Third year	410 (2.5%)	66 (1.6%)	81 (2.5%)	107 (3.2%)	156 (2.7%)
Insulins					
Previous two years	3361 (20.3%)	699 (16.9%)	685 (20.8%)	746 (22.1%)	1231 (21.3%)
Third year	3201 (19.3%)	684 (16.6%)	626 (19.0%)	716 (21.2%)	1175 (20.3%)
Introducing insulins in the third year[a]					
N	13,222	3428	2606	2636	4552
Introduced in the third year	989 (7.5%)	210 (6.1%)	191 (7.3%)	229 (8.7%)	359 (7.9%)

Abbreviations: 1Q, 1st quartile; 3Q, 3rd quartile; JPY, Japanese Yen; SD, standard deviation.

[a]Individuals who were not prescribed insulin during the first two years were excluded.

the results of the no dental treatment group, the healthcare expenditure, hospitalization and introduction of insulin in the third year were reduced in these two groups. The healthcare expenditure was less in the 'every year' group (adjusted multiplier 0.95 vs. 0.97), whereas all-cause hospitalization was less in the 'every 6-month' group (aOR 0.84 vs. 0.95).

In the third sensitivity analysis, which incorporated individual-level healthcare expenditure during the previous two years as a predictor, the results were not considerably different from those of the main analyses. The adjusted multipliers of the periodontal management groups were 0.93–0.96 (Tables S23–S24).

4 | DISCUSSION

We investigated the effects of two years of periodontal management on healthcare expenditure, all-cause hospitalization, hospitalization due to acute myocardial infarction, hospitalization due to ischaemic stroke and the introduction of insulin in the third year. Periodontal management for two years, regardless of its interval, was associated with reduced healthcare expenditure in the third year. Periodontal management in both the first and second years was associated with reductions in all-cause hospitalization and hospitalization due to ischaemic stroke. It was also

TABLE 2 Annual healthcare expenditure by the frequency of periodontal management.

	All	Periodontal management		No periodontal management	
		Both the first and second years	Either the first or the second year	Other dental treatment	No dental treatment
Annual healthcare expenditure during the previous two years					
Mean ± SD (1000 JPY)	996 ± 1303	923 ± 1115	1003 ± 1269	1039 ± 1320	916 ± 1292
Median (1Q, 3Q)	535 (320, 1053)	543 (347, 996)	548 (334, 1075)	565 (338, 1147)	452 (266, 943)
Medical					
Mean ± SD (1000 JPY)	895 ± 1248	792 ± 1060	895 ± 1216	932 ± 1266	853 ± 1243
Median (1Q, 3Q)	453 (271, 917)	432 (266, 815)	451 (274, 938)	486 (285, 961)	414 (249, 846)
Inpatient					
Mean ± SD (1000 JPY)	380 ± 897	303 ± 745	405 ± 902	423 ± 967	371 ± 901
Median (1Q, 3Q)	0 (0, 330)	0 (0, 251)	0 (0, 376)	0 (0, 394)	0 (0, 307)
Outpatient					
Mean ± SD (1000 JPY)	514 ± 751	489 ± 650	490 ± 673	510 ± 708	482 ± 748
Median (1Q, 3Q)	343 (232, 511)	346 (238, 514)	344 (231, 497)	348 (234, 522)	317 (213, 466)
Dental					
Mean ± SD (1000 JPY)	29 ± 48	62 ± 60	40 ± 43	31 ± 51	0
Median (1Q, 3Q)	16 (0, 45)	51 (33, 78)	30 (15, 52)	21 (7, 42)	0 (0, 0)
Pharmaceutical					
Mean ± SD (1000 JPY)	71 ± 174	68 ± 164	69 ± 160	76 ± 184	63 ± 169
Median (1Q, 3Q)	10 (0, 72)	14 (1, 73)	11 (1, 75)	12 (1, 73)	5 (0, 58)
Annual healthcare expenditure in the third year					
Mean ± SD (1000 JPY)	1092 ± 1655	1002 ± 1496	1014 ± 1459	1170 ± 1667	1058 ± 1742
Median (1Q, 3Q)	502 (306, 997)	513 (328, 930)	493 (310, 958)	533 (324, 1116)	438 (263, 909)
Medical					
Mean ± SD (1000 JPY)	976 ± 1612	862 ± 1455	892 ± 1415	1048 ± 1618	972 ± 1707
Median (1Q, 3Q)	400 (242, 832)	390 (245, 734)	386 (233, 784)	430 (256, 930)	364 (222, 791)
Inpatient					
Mean ± SD (1000 JPY)	457 ± 1306	378 ± 1217	395 ± 1141	523 ± 1340	485 ± 1386
Median (1Q, 3Q)	0 (0, 143)	0 (0, 0)	0 (0, 85)	0 (0, 335)	0 (0, 151)
Outpatient					
Mean ± SD (1000 JPY)	519 ± 817	484 ± 659	497 ± 748	525 ± 821	487 ± 827
Median (1Q, 3Q)	329 (214, 506)	338 (226, 511)	326 (213, 490)	333 (215, 520)	301 (195, 462)
Dental					
Mean ± SD (1000 JPY)	30 ± 66	53 ± 66	35 ± 51	30 ± 103	10 ± 32
Median (1Q, 3Q)	5 (0, 43)	38 (17, 72)	14 (0, 53)	8 (0, 40)	0 (0, 0)
Pharmaceutical					
Mean ± SD (1000 JPY)	87 ± 195	87 ± 203	87 ± 188	92 ± 211	76 ± 170
Median (1Q, 3Q)	12 (0, 103)	17 (0, 102)	12 (0, 107)	12 (0, 105)	6 (0, 86)

Abbreviations: 1Q, 1st quartile; 3Q, 3rd quartile; JPY, Japanese Yen; SD, standard deviation.

associated with reduced introduction of insulin during the third year.

Our results showing reductions in healthcare expenditure associated with periodontal management are in line with those of previous studies (Jeffcoat et al., 2014; Nasseh et al., 2017). One study reported that a periodontitis treatment group spent more on medical costs than a gingivitis treatment group, dental maintenance service group, other dental services group and no dental service group (Albert et al., 2006). In this earlier study, the data relating to medical costs and periodontal treatment were collected during the same 2-year period. Our study, studies by Jeffcoat et al. (2014) and Nasseh et al. (2017) collected data relating to medical costs following a period of periodontitis treatment of several years. Thus, these three studies investigated the consequences of periodontal treatment,

TABLE 3 Association between each outcome and the frequency of periodontal management

	aM/aOR	95% CI	*p*
OUTCOME: healthcare charges in the third year			
Management for periodontitis			
Both the first and second years	0.96	(0.92–1.00)	.035*
Either the first or the second year	0.94	(0.90–0.97)	<.001*
Other dental treatments	1.05	(1.01–1.09)	.024*
None	1.00	(Reference)	
OUTCOME: all-cause hospitalization in the third year			
Management for periodontitis			
Both the first and second years	0.90	(0.82–0.99)	.026*
Either the first or the second year	0.99	(0.90–1.09)	.856
Other dental treatments	1.11	(1.01–1.23)	.027*
None	1.00	(Reference)	
OUTCOME: hospitalization due to acute myocardial infarction in the third year			
Management for periodontitis			
Both the first and second years	1.06	(0.54–2.06)	.869
Either the first or the second year	1.16	(0.59–2.30)	.670
Other dental treatments	1.14	(0.59–2.19)	.702
None	1.00	(Reference)	
OUTCOME: hospitalization due to ischaemic stroke in the third year			
Management for periodontitis			
Both the first and second years	0.60	(0.44–0.81)	<.001*
Either the first or the second year	0.89	(0.67–1.18)	.423
Other dental treatments	1.02	(0.79–1.32)	.889
None	1.00	(Reference)	
OUTCOME: introducing insulins in the third year[a]			
Periodontal management			
Both the first and second years	0.77	(0.64–0.92)	.005*
Either the first or the second year	0.93	(0.77–1.12)	.425
Other dental treatments	1.02	(0.86–1.22)	.812
None	1.00	(Reference)	

Abbreviations: aM, adjusted multiplier which is an exponentiated regression coefficient; aOR, adjusted odds ratio; CI, confidence interval.

[a]Individuals who were not prescribed insulin during the first two years were excluded.

*$p < .05$.

TABLE 4 Association between each outcome and the frequency and the intensity level of periodontal management

	aM/aOR	95% CI	*p*
OUTCOME: healthcare charges in the 3rd year			
Healthcare charges during the previous two years			
Periodontal management			
Both the first and second years			
Maintenance care only	0.97	(0.92–1.01)	.166
Treatments for periodontitis	0.96	(0.91–1.00)	.051
Either the first or the second year			
Maintenance care only	0.93	(0.89–0.98)	.003*
Treatments for periodontitis	0.94	(0.88–1.00)	.037*
Other dental treatments	1.05	(1.01–1.09)	.024*
No dental treatment	1.00	(Reference)	
OUTCOME: all-cause hospitalization in the third year			
Periodontal management			
Both the first and second years			
Maintenance care only	0.88	(0.78–1.00)	.044*
Treatments for periodontitis	0.91	(0.82–1.02)	.113
Either the first or the second year			
Maintenance care only	1.02	(0.91–1.14)	.772
Treatments for periodontitis	1.02	(0.80–1.09)	.393
Other dental treatments	1.11	(1.01–1.23)	.027*
No dental treatment	1.00	(Reference)	
OUTCOME: hospitalization due to acute myocardial infarction in the third year			
Periodontal management			
Both the first and second years			
Maintenance care only	1.07	(0.44–2.60)	.875
Treatments for periodontitis	1.05	(0.47–2.34)	.907
Either the first or the second year			
Maintenance care only	1.03	(0.46–2.32)	.944
Treatments for periodontitis	1.43	(0.55–3.69)	.463
Other dental treatments	1.14	(0.59–2.19)	.702
No dental treatment	1.00	(Reference)	
OUTCOME: hospitalization due to ischaemic stroke in the third year			

(Continues)

TABLE 4 (Continued)

	aM/ aOR	95% CI	p
Periodontal management			
Both the first and second years			
Maintenance care only	0.56	(0.37–0.86)	.008*
Treatments for periodontitis	0.62	(0.44–0.89)	.010*
Either the first or the second year			
Maintenance care only	1.02	(0.64–1.21)	.416
Treatments for periodontitis	1.02	(0.60–1.43)	.736
Other dental treatments	1.11	(0.79–1.32)	.890
No dental treatment	1.00	(Reference)	
OUTCOME: introducing insulins in the third year[a]			
Periodontal management			
Both the first and second years			
Maintenance care only	0.83	(0.66–1.06)	.144
Treatments for periodontitis	0.73	(0.58–0.91)	.005*
Either the first or the second year			
Maintenance care only	0.90	(0.73–1.12)	.358
Treatments for periodontitis	0.98	(0.73–1.30)	.874
Other dental treatments	1.02	(0.86–1.22)	.812
No dental treatment	1.00	(Reference)	

Abbreviations: aM, adjusted multiplier which is an exponentiated regression coefficient; aOR, adjusted odds ratio; CI, confidence interval.

[a]Individuals who were not prescribed insulins during the previous two years were excluded.

*$p < .05$.

whereas the study by Albert et al. compared the treatment costs for comorbid conditions of individuals with diabetes between those who had periodontitis and those who did not. Our results showed that the crude healthcare expenditure of those who received maintenance care only during both the first and second years was the lowest (Table S2).

In addition, we investigated possible contributory factors for the differences in total healthcare expenditure. Our results suggest the reduction in hospitalizations, especially those caused by ischaemic stroke, might be one of the drivers for reducing healthcare expenditure. The associations between periodontal diseases and cardiovascular diseases, including ischaemic stroke, are well established (Sanz et al., 2020). We showed that periodontal management for as little as two years, regardless of the severity of periodontitis, was associated with a reduction in hospitalizations due to ischaemic stroke. However, we did not see any association of periodontal management on acute myocardial infarction. The reason for this may be the small number of events recorded. Further studies are needed to clarify this effect.

Our results showed that periodontal management for two years was associated with reduced odds for the need to introduce insulin in the third year. The periodontal management group showed reduced odds for the need to introduce insulin. This effect was not observed after one year of periodontal management. Although a short-term (3 months) effect of periodontal treatment on reducing HbA1c was demonstrated, no long-term effect on reducing HbA1c was evident (Madianos & Koromantzos, 2018). Our results suggest that repeated periodontal treatment could be beneficial for glycaemic control in people with diabetes.

Our results showed the 55.3% of people with type 2 diabetes did not receive any periodontal management, including periodontal examinations, during two years. A Japanese national survey in 2016 reported that 53.6% of people aged ≥20 years had periodontitis (Ministry of Health, Labour, and Welfare, 2017). The prevalence was 62.7% for those aged ≥65 years, among whom the prevalence of diabetes was also elevated. Given the prevalence of periodontitis is higher among people with diabetes (Soskolne & Klinger, 2001), the proportion of people receiving regular periodontal management may be suboptimal. The Consensus Report and Guidelines of the International Diabetes Federation and the European Federation of Periodontology recommend physicians provide oral health education for all individuals who have diabetes, as part of their overall educational program (Sanz et al., 2018a; Sanz et al., 2018b). The guidelines also recommend oral health professionals inform patients who have not been diagnosed with diabetes but who have risk factors for type 2 diabetes about their risk of having diabetes and refer them to a physician (Sanz et al., 2018a; Sanz et al., 2018b). Further efforts for cooperation between physicians and oral health professionals are desirable.

Our study has some limitations. First, the data we used did not contain clinical information or any possible confounders, such as socioeconomic status. Second, we only used claims data from the NHI and the Medical Care System for the Elderly Aged 75 or Over. The Medical Care System for the Elderly Aged 75 or Over covers all residents aged ≥75 years, but the NHI does not. However, the NHI covered 71.3% of the population aged between 65 and 74 in 2018 (Ministry of Health, Labour, & Welfare, 2019). Given the higher prevalence of diabetes among the elderly, our study population might be sufficient for the study of diabetes. Third, we identified individuals with type 2 diabetes based on their prescribed medication. A small number of individuals with type 1 diabetes, such as slowly progressive insulin-dependent diabetes mellitus, might be included in our study population. Fourth, we could not determine the prevalence of periodontitis for people with diabetes who did not receive any periodontal treatment. However, we showed the beneficial effects of periodontal management did not differ by the level of intensity of periodontal management. Moreover, receiving periodontal management every year, or even every half-year, did not increase total

healthcare expenditure, including dental costs. These results suggest the effect of periodontal management on outcomes seen in our study might also be applied to individuals with diabetes who do not have active periodontitis.

5 | CONCLUSION

Regular periodontal management for people with type 2 diabetes was associated with reduced healthcare expenditure, which included medical, dental and pharmacy costs, all-cause hospitalization, hospitalization due to ischaemic stroke and introduction of insulin therapy, regardless of the severity of periodontitis. Further efforts to ensure cooperation between physicians and oral health professionals are desirable.

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CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest regarding the publication of this article.

AUTHORS' CONTRIBUTIONS

Jung-ho Shin involved in conceptualization, methodology, software, validation, formal analysis, investigation, data curation, writing–original draft preparation, and writing–review and editing. Daisuke Takada involved in conceptualization, methodology, validation, investigation, and writing–review and editing. Susumu Kunisawa involved in conceptualization, validation, resources, data curation, writing–review and editing, and project administration. Yuichi Imanaka involved in conceptualization, validation, resources, writing–review and editing, supervision, project administration and funding acquisition.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID

Jung-ho Shin https://orcid.org/0000-0003-0201-4847
Yuichi Imanaka https://orcid.org/0000-0003-4613-2159

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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