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Retrospective analysis of the effects of non-communicable diseases on periodontitis treatment outcomes

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ABSTRACT

Purpose: We retrospectively analysed patients' dental and periodontal status according to the presence of non-communicable diseases (NCDs) and the effects of NCDs on periodontal treatment outcomes. Factors influencing disease recurrence were investigated using decision tree analysis.

Methods: We analysed the records of patients who visited the Department of Periodontology, Pusan National University Dental Hospital from June 2014 to October 2019. As baseline subjects, 1,362 patients with periodontitis and who underwent full-mouth periodontal examinations before periodontal treatment were selected. Among them, 321 patients who underwent periodontal examinations after the completion of periodontal treatment and 143 who continued to participate in regular maintenance were followed-up.

Results: Forty-three percent of patients had a NCD. Patients without NCDs had more residual teeth and lower sum of the number of total decayed, missing, filled teeths (DMFT) scores. There was no difference in periodontal status according to NCD status. Patients with a NCD showed significant changes in the plaque index after periodontal treatment. The decision tree model analysis demonstrated that osteoporosis affected the recurrence of periodontitis.

Conclusions: The number of residual teeth and DMFT index differed according to the presence of NCDs. Patients with osteoporosis require particular attention to prevent periodontitis recurrence.

Keywords: Chronic periodontitis; Decision trees; Non-communicable diseases; Osteoporosis; Periodontitis

INTRODUCTION

Non-communicable diseases (NCDs) are chronic non-infectious diseases, the most common of which are cardiovascular disease (CVD), cancers, chronic respiratory diseases, and diabetes mellitus (DM) [1]. These diseases result from a combination of genetic, physiological, environmental, and behavioural factors. Due to changes in lifestyle, diet, and stress, the incidence of various NCDs is increasing, as is the proportion of patients

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Conceptualization: Ji-Young Joo, Eun-Kyung Kim; Data curation: Eun-Kyung Kim, Hyun-Joo Kim; Formal analysis: Eun-Kyung Kim, Yunhwan Noh; Funding acquisition: Ji-Young Joo, Hae-Ryoun Park; Investigation: Ji-Young Joo; Methodology: Ji-Young Joo, Hyun-Joo Kim, Hae-Ryoun Park, Ju-Youn Lee, Youngseuk Cho; Project Administration: Ji-Young Joo; Writing - original draft: Ji-Young Joo, Eun-Kyung Kim, Hyun-Joo Kim; Writing - review & editing: Ji-Young Joo, Eun-Kyung Kim, Hae-Ryoun Park, Ju-Youn Lee, Youngseuk Cho, Yunhwan Noh.

with multiple NCDs [2]. According to recent papers, lifestyle-related comorbidities such as hypertension (HT), DM, CVD, rheumatoid arthritis, erectile dysfunction, osteoporosis, obesity, cerebral infarction, respiratory disease, cancer, and Alzheimer's disease are classified as NCDs and are the focus of active research [2-4].

Periodontal disease (PD) is a combination of bacterial infection and inflammatory reaction. Because PD is mainly caused by bacteria in plaque, periodontal treatment is usually successful when accompanied by thorough debridement and good oral hygiene. However, the rate and severity of progression may vary depending on the host's immune and inflammatory reactions. Therefore, to improve the outcome of periodontal treatment, it is important for periodontal professionals to educate patients both to manage oral hygiene and to control risk factors that affect periodontal health.

Recent studies have provided some evidence that the correlation between PD and major NCDs is bidirectional. PD and NCDs share many risk factors, such as older age, active smoking, stress, and uncontrolled blood pressure and glucose levels [5,6]. Therefore, a new strategy aiming to control common risk factors in order to achieve synergistic prevention, treatment, and management of both diseases is emerging.

It is known that the immune and inflammatory responses of the host have an important effect on the severity of periodontitis and treatment outcomes [7]. We hypothesized that patients with chronic diseases who are not systemically healthy may have more severe periodontitis and worse outcomes of periodontal treatment. Therefore, in this study, we considered NCDs as a disease group including systemic unhealthy states. The purpose of this study was to investigate the effects of NCDs on dental status, the severity of periodontitis, and the outcomes of periodontal treatment through clinical dental and periodontal indexes based on hospital records. In addition, NCDs influencing disease recurrence were investigated through decision tree analysis.

MATERIALS AND METHODS

Study design and data collection
The study population included patients who visited the Department of Periodontology at Pusan National University Dental Hospital between June 2014 and October 2019. The patients underwent full-mouth periodontal examinations before periodontal treatment and were diagnosed with periodontitis according to the American Academy of Periodontology 1999 classification. Among them, patients who underwent periodontal examinations after periodontal treatment were selected. The periodontal examinations performed at this time were carried out only when an experienced periodontist determined that periodontitis was resolved. Lastly, patients who were compliant with follow-up checks after periodontal treatment were identified. In each step, patients were divided into subgroups according to the presence or absence of NCDs (**Figure 1**). After the completion of periodontal treatment, periodontitis was considered to have recurred if inflammatory signs appeared during the supportive periodontal therapy (SPT) period and more than non-surgical periodontal treatment was performed.

In periodontal examinations, the most representative clinical variables for diagnosing periodontitis were used, including the periodontal pocket depth (PPD), gingival recession
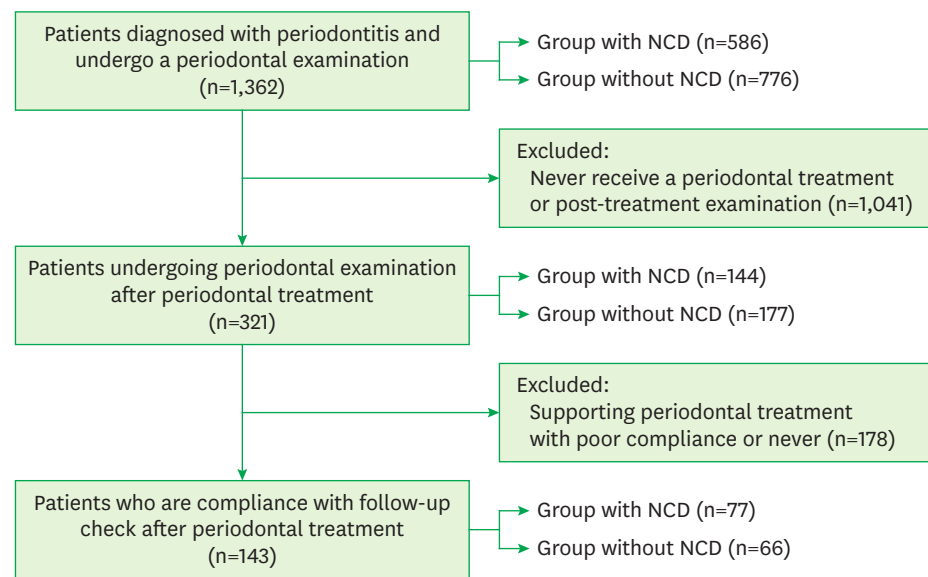
Figure 1. Flow chart of the inclusion and exclusion of patient data for the retrospective analysis. NCD: non-communicable disease.

(REC), clinical attachment level (CAL), bleeding on probing (BOP), and plaque index (PI). The number of total, decayed (DT), missing (MT), and filled teeth (FT) was used to assess dental status. The sum of the number of total decayed, missing, filled teeths (DMFT) score was calculated by summing the number of DTs, MTs, and FTs.

The presence of NCDs was investigated based on the initial chart of each patient's electronic dental record. Generally, only patients' medical histories diagnosed by the relevant specialists were recorded in the past medical history section of the initial examination records. The following diseases were considered as NCDs: HT, DM, hyperlipidaemia, CVD, osteoporosis, cancer, renal disease, liver disease, arthritis, respiratory disease, and Alzheimer's disease. Patients with more than 1 disease were included in the group for each disease.

These data were extracted by referring to the hospital record chart of the Pusan National University Dental Hospital.

The study protocol was approved by the Institutional Review Board of Pusan National University Dental Hospital (PNUDH-2019-047).

Statistical analysis

Data are presented as mean±standard deviation for continuous variables and as numbers and percentages for categorical variables. Descriptive statistics were generated for NCDs and variables related to periodontal and dental status. The independent t-test was used to analyse differences in variables representing dental and periodontal status according to the presence of NCDs. Statistical significance was set at $P<0.05$.

The χ^2 automatic interaction detection analysis, a decision tree algorithm, was used to identify the most important risk factors associated with NCDs from a pool of several potential risk factors that were extracted from patients' electronic dentistry records.

The decision tree was created using the following procedure: the most significant risk factor (the one with the largest χ^2 value) was used to divide the entire patient population into ≥2 subgroups. These groups were subsequently subdivided by the next most significant risk factor. The analysis continued in a step-by-step manner to select the most influential variable at each stage until there no significant risk factors remained [8]. In other words, a node was separated if the P value met the adjusted significance value (P=0.000); if it did not, it was considered a terminal node. Analyses were performed using SPSS software (version 23.0; IBM Corp., Armonk, NY, USA).

RESULTS

Baseline characteristics of the study population

A total of 1,362 patients were included in this study, with a mean age of 52.98±9.98 years. The male-to-female ratio was 678:684. The number of patients with NCDs was 586 (43%). HT was the most common NCD (20.6%), followed by DM (9.8%), hyperlipidaemia (9.3%), and CVD (5.7%). Furthermore, 10.9% of the patients were smokers (**Table 1**).

Dental and periodontal status according to the presence of NCDs

Table 2 shows the dental and periodontal status according to the presence of NCDs at baseline. The number of residual teeth was 26.21±2.33 and 25.60±2.75 in patients without NCDs and patients with NCDs, respectively. The DMFT score was significantly higher in patients with NCDs (6.02±5.07) than in patients without NCDs (4.64±4.36). Regarding periodontal status, the PI was 48.54±21.16 in patients with NCDs and 48.75±19.64 in patients without NCDs.

Table 1. Baseline characteristics of the patients

Characteristics	Patients (n=1,362)
Age	52.98±9.98
Sex	
Male	678 (49.8)
Female	684 (50.2)
Non-communicable diseases	586 (43.0)
Hypertension	280 (20.6)
Diabetes mellitus	133 (9.8)
Osteoporosis	34 (2.5)
Renal disease	14 (1.0)
Respiratory disease	14 (1.0)
Liver disease	45 (3.3)
Cancer	35 (2.6)
Cardiovascular disease	78 (5.7)
Hyperlipidaemia	127 (9.3)
Rheumatoid arthritis	3 (0.2)
Dementia	3 (0.2)
Arthritis	19 (1.4)
Autoimmune disease	4 (0.3)
Urologic disease	26 (1.9)
Thyroid disease	35 (2.6)
Obstetric and gynaecologic diseases	18 (1.3)
Neurologic disease	10 (0.7)
Psychiatric problems	22 (1.6)
Smoking	149 (10.9)

Values are presented as mean±standard deviation or number (%).

Table 2. Dental and periodontal status according to the presence of NCDs

Status	NCDs		P value
	Yes (n=586)	No (n=776)	
Dental status			
Residual teeth	25.60±2.75	26.21±2.33	<0.001[a]
DT	0.49±1.05	0.44±0.96	0.124
MT	2.40±2.75	1.79±2.33	<0.001[a]
FT	3.12±3.10	2.41±2.61	<0.001[a]
DMFT	6.02±5.07	4.64±4.36	<0.001[a]
Periodontal status			
PPD	3.01±0.71	2.98±0.77	0.129
REC	0.61±0.58	0.55±0.54	0.276
CAL	3.58±0.94	3.52±0.92	0.494
BOP	0.70±0.45	0.70±0.45	0.723
PI	48.54±21.16	48.75±19.64	0.012[b]

Values are presented as mean±standard deviation.
DT: decayed teeth, MT: missing teeth, FT: filled teeth, DMFT: sum of the number of total decayed, missing, filled teeths, PPD: periodontal pocket depth, REC: gingival recession, CAL: clinical attachment level, BOP: bleeding on probing, PI: plaque index, NCD: non-communicable disease.
[a]Statistically significant difference ($P<0.001$); [b]Statistically significant difference ($P<0.05$).

Periodontal status after periodontal treatment according to the presence of NCDs

In total, 321 patients underwent periodontal examinations after periodontal treatment, and the number of patients with NCDs was 156 (48.6%). HT was the most common NCD in this group (19.3%), followed by hyperlipidaemia (11.5%) and DM (9.0%), and 7.5% of the patients were smokers (**Table 3**). **Table 4** shows the periodontal status and changes in periodontal variables after periodontal treatment according to the presence of NCDs. Patients with NCDs had higher PPD, REC, CAL, and PI, and those without NCDs had higher BOP; however, the differences were not statistically significant. When evaluating the magnitude of changes in

Table 3. Demographic characteristics of the patients who underwent periodontal examinations after periodontal treatment

Characteristics	Patients (n=321)
Age	53.50±9.17
Sex	
Male	137 (42.7)
Female	184 (57.3)
Non-communicable diseases	156 (48.6)
Hypertension	62 (19.3)
Diabetes mellitus	29 (9.0)
Osteoporosis	11 (3.4)
Renal disease	1 (0.3)
Respiratory disease	0 (0.0)
Liver disease	10 (3.1)
Cancer	10 (3.1)
Cardiovascular disease	16 (5.0)
Hyperlipidaemia	37 (11.5)
Rheumatoid arthritis	0 (0.0)
Dementia	0 (0.0)
Arthritis	6 (1.9)
Autoimmune disease	0 (0.0)
Urologic disease	6 (1.9)
Thyroid disease	12 (3.7)
Obstetric and gynaecologic diseases	7 (2.2)
Neurologic disease	3 (0.9)
Psychiatric problems	4 (1.2)
Smoking	24 (7.5)

Values are presented as mean±standard deviation or number (%).

Table 4. Analysis of periodontal status and changes in periodontal indices after periodontal treatment according to the presence of NCDs

Characteristics	NCDs		P value
	Yes (n=144)	No (n=177)	
Periodontal status			
PPD	2.26±0.53	2.25±0.47	0.465
REC	0.67±0.58	0.56±0.52	0.230
CAL	2.93±0.86	2.80±0.74	0.268
BOP	0.24±0.23	0.27±0.25	0.666
PI	21.99±14.65	20.46±12.50	0.675
Changes in periodontal indices			
ΔPPD	0.59±0.55	0.62±0.52	0.613
ΔREC	−0.01±0.36	−0.07±0.36	0.127
ΔCAL	0.58±0.66	0.57±0.523	0.823
ΔBOP	0.36±0.33	0.43±0.44	0.117
ΔPI	29.04±18.96	24.55±18.06	0.031[a]

Values are presented as mean±standard deviation.
Δ: amount of change, PPD: periodontal pocket depth, REC: gingival recession, CAL: clinical attachment level, BOP: bleeding on probing, PI: plaque index, NCD: non-communicable disease.
[a]Statistically significant difference (P<0.05).

periodontal variables, the differences between the 2 groups were not statistically significant, except for PI.

Table 5 shows the demographic characteristics of patients who were compliant with follow-up checks after periodontal treatment. This group included 143 patients, of whom 59 (41.3%) had NCDs. HT was the most common NCD (25.2%), followed by hyperlipidaemia (16.1%) and DM (9.1%), and 6.3% of the patients were smokers. **Table 6** shows the analysis of periodontitis recurrence after periodontal treatment according to the presence of NCDs. In patients with NCDs, the frequency of retreatment or additional tooth extraction was

Table 5. Demographic characteristics of the patients who were compliant with follow-up checks after periodontal treatment

Characteristics	Patients (n=143)
Age	53.98±8.87
Sex	
Male	71 (49.7)
Female	72 (50.3)
Non-communicable diseases	59 (41.3)
Hypertension	36 (25.2)
Diabetes mellitus	13 (9.1)
Osteoporosis	3 (2.1)
Renal disease	1 (0.7)
Respiratory disease	0 (0.0)
Liver disease	8 (5.6)
Cancer	5 (3.5)
Cardiovascular disease	10 (7.0)
Hyperlipidaemia	23 (16.1)
Rheumatoid arthritis	0 (0.0)
Dementia	0 (0.0)
Arthritis	4 (2.8)
Autoimmune disease	0 (0.0)
Urologic disease	4 (2.8)
Thyroid disease	3 (2.1)
Obstetric and gynaecologic diseases	3 (2.1)
Neurologic disease	1 (0.7)
Psychiatric problems	2 (1.4)
Smoking	9 (6.3)

Values are presented as mean±standard deviation or number (%).

Table 6. Analysis of periodontitis recurrence after treatment according to the presence of NCDs

Characteristics	NCDs		P value
	Yes (n=77)	No (n=66)	
Re-treatment after periodontal treatment	0.53±1.74	0.47±1.45	0.887
Tooth extraction after periodontal treatment	0.13±0.64	0.11±0.31	0.493

Values are presented as mean±standard deviation.
NCD: non-communicable disease.

higher during SPT after the completion of periodontal treatment, but the difference was not statistically significant.

Decision tree analysis to identify predictors of recurrence after periodontal treatment

In the decision tree model of the effect of NCDs on the recurrence of periodontitis after periodontal treatment, it was found that patients with osteoporosis had a higher risk of recurrence after periodontal treatment. After treatment, patients with osteoporosis had a frequency of recurrence of 5.00±7.81, whereas those without osteoporosis had a frequency of recurrence of 0.41±1.14 (**Figure 2**).

DISCUSSION

PD is an inflammatory condition that affects dental supporting tissues and is caused by an imbalance between the host response and oral bacterial community due to bacteria in biofilms. Periodontal bacterial lipopolysaccharides induce monocytes to produce inflammatory mediators such as tumour necrosis factor (TNF), prostaglandin, interleukins (ILs), and proteolysis enzymes. This inflammatory response is not only limited to periodontal lesions, but also affects other parts of the body [9].

Recent studies have shown that NCDs and PD have common pathogenic risk factors. Common risk factors include smoking, family history, obesity, hypercholesterolaemia, high blood pressure, diabetes, and alcoholism [10,11]. Control of these risk factors leads to improvements in both NCDs and PD. Martinez-Herrera et al. [12] showed that after non-surgical periodontal treatment, individuals with obesity had worse clinical outcomes
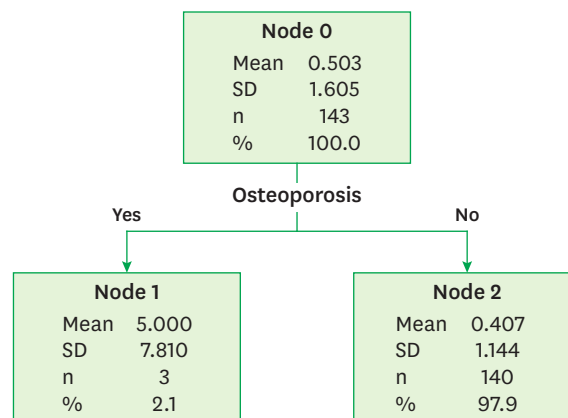
Figure 2. Decision tree model of the effects of non-communicable diseases on the frequency of recurrence after periodontal treatment.
SD: standard deviation.

than those without obesity. In a follow-up study, they assessed whether dietary weight loss interventions could improve the response to periodontal treatment in patients with obesity, and showed that individuals in the diet group had greater periodontal improvement than those without weight loss intervention [12]. Therefore, controlling risk factors can improve the therapeutic effect against both NCDs and PD, which share a similar pathogenesis and cellular mediators.

Although many studies have investigated the relationships between specific chronic diseases and PD, there are few studies on periodontal status and treatment effects according to the presence of NCDs covering all these diseases. This study investigated the relationship of the presence of NCDs based on health records with baseline dental and periodontal status and with post-treatment periodontal status and recurrence of periodontitis.

According to statistics from the Korean Health Insurance Review and Assessment Service (2019), HT was the most common chronic disease, followed by arthritis, mental and behavioural disorders, neurological disorders, diabetes, and liver disease [13]. In this study, HT was the most common NCD, followed by diabetes, hyperlipidaemia, and CVD (**Table 1**).

Severe periodontitis with few residual teeth may be considered a modifiable risk factor for the development of Alzheimer's dementia, vascular dementia, and mixed dementia [14]. In a Korean nationwide cohort study, Lee et al. [15] found that cardiovascular events and mortality increase in proportion to tooth loss. In this study, patients without NCDs had more residual teeth than those with NCDs, which is consistent with previous studies of specific diseases and residual teeth [16,17]. Brito et al. [16] found that patients with Crohn's disease and ulcerative colitis had a higher DMFT index and prevalence of periodontitis than their counterparts without those conditions. In this study, it was also shown that the DMFT index was higher in patients with NCDs than in those without NCDs. The DMFT index is an indicator of the incidence of DTs, MTs, and FTs and is one of the most widely used indices for presenting epidemiological data on caries [18]. Studies have investigated the relationships of the DMFT index and the number of residual teeth with specific diseases, but there have been no studies on the relationship between these parameters and NCDs in general, covering most lifestyle-related comorbidities. Based on our retrospective analysis, it can be suggested that people with NCDs may not have many sound residual teeth.

The relationships between specific systemic diseases and periodontitis have been addressed in many studies. Patients with HT have significantly more diseased pockets than those without HT, and the number of teeth was associated with the prevalence of myocardial infarction [19]. Cross-sectional studies have shown that patients with diabetes are more likely to experience periodontitis than healthy individuals of all ages. Another study showed that individuals with poor glycaemic control, especially smokers, had a higher progression of periodontitis and tooth loss than individuals with good glycaemic control and no diabetes [20]. In addition to diabetes, according to Sangwan et al. [20], patients with hyperlipidaemia had more markers of poor periodontal status, such as PPD and CAL, than those with normolipidaemia. However, in this study, no significant difference was observed in periodontal status according to the NCD group. NCDs include various non-infectious chronic diseases, but there are clear differences in pathogenesis and progression. Therefore, in a retrospective evaluation of periodontal status according to the presence of NCDs, defined as a category that includes a broad range of diseases in a single group, it is necessary to target more subjects or to perform periodontal and systemic disease evaluations prospectively.

In a prospective study, Teixeira et al. [21] identified associations of periodontitis with several systemic indicators for chronic NCDs. Some indicators showed significant associations with periodontitis, while others did not. The main limitation of that study was its cross-sectional design, which did not allow inferences of cause and effect between the variables. Longitudinal studies are needed to clarify the temporal relationship between periodontitis and chronic systemic diseases.

In the analysis of changes in periodontal indices after periodontal treatment, a statistically significant change in the PI was found in patients with NCDs. This reflects the need for more efforts to control plaque during SPT in patients with NCDs. This issue is critical for the effectiveness of the SPT programme. In addition, similar results were reported in previous studies examining the importance of motivation with respect to oral hygiene, considering that individuals have difficulty maintaining new habits over time [17].

Risk factors commonly known to cause tooth loss and recurrence of periodontitis include age, smoking, initial tooth prognosis, presence of an IL-1 polymorphism, and irregular SPT [22,23]. Matuliene et al. [24] studied the recurrence of periodontitis according to the periodontal risk assessment (RPA) as defined by Lang and Tonetti [25]. Smoking was the only important predictor of periodontitis recurrence among the 6 clinical parameters used in the RPA. Moreover, patients with a high-risk profile and low SPT compliance showed a higher recurrence of periodontitis and tooth loss [24,25]. These results are consistent with another study, which found that smoking and a high mean gingival bleeding index were associated with a higher risk of periodontitis recurrence in patients with aggressive periodontitis, and that regular SPT acted as a protective factor [26]. In this study, a high frequency of retreatment or additional extraction was observed during the SPT period after periodontal treatment in the group with NCDs, but the difference was not statistically significant.

In the present study, osteoporosis was found to affect the recurrence of periodontitis after periodontal treatment through a decision tree model analysis of NCDs. Patients with osteoporosis showed a high rate of loss of natural teeth, but there was no significant difference in periodontal measurements between healthy and osteoporotic groups [27]. Kim et al. [28] showed that a decrease in bone mineral density was significantly associated with higher odds of periodontitis. Genco and Borgnakke [29] suggested that osteoporosis may be a risk factor for periodontitis. Patients with osteoporosis show increased activity of inflammatory cytokines, such as RANKL, TNF-α, IL-β, and IL-6. This increase can stimulate osteoclastic activity, causing an increase in bone resorption and accelerating the progression of PD [30]. Further prospective research is needed to determine whether osteoporosis causes periodontitis recurrence.

Since this was a retrospective study based on hospital records, the study had to be performed based on limited data. This study also has several limitations inherent to retrospective analyses. First, the number of subjects decreased significantly after the completion of treatment compared to those evaluated before treatment. However, the number was sufficient to evaluate statistical significance. Second, the patients received different periodontal treatments according to the severity of periodontitis. However, the periodontal examination after treatment was performed when an experienced periodontist judged that periodontitis was resolved. Third, since NCDs include many diverse diseases, no significance was found in the relationship with periodontal clinical parameters. Therefore, it would be meaningful to group and evaluate disease groups with similar risk factors and mechanisms of development in future research.

In conclusion, this study showed differences in the number of remaining teeth and DMFT index according to the presence of NCDs. However, there was no significant difference in periodontal status. A close relationship was found between osteoporosis and the recurrence of periodontitis. Further studies are needed to investigate the correlation between NCDs and periodontitis.

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