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# Influence of implant location on the prevalence of peri-implantitis in patients with peri-implantitis: a within-subjects comparison of healthy and peri-implantitis affected implants

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Running Title : Influence of implant location on peri-implantitis

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## ABSTRACT

The aim of this study was to analyze the influence of implant location on the prevalence of peri-implantitis by within-subjects comparison of healthy and peri-implantitis affected implants in patients with peri-implantitis.

To be included for this study, the patient should have at least one peri-implantitis affected implant and one healthy implant. Following clinical and radiographic assessments for peri-implantitis, 56 patients with 89 peri-implantitis affected implants and 249 healthy implants were included in this study. Influences of implant location variables including jaw position, tooth type, tooth position, and tooth adjacent to the implant on the prevalence of peri-implantitis were assessed using a multilevel analysis.

Implants placed in the maxillary jaw showed 2 times higher frequency of peri-implantitis than those placed in the mandibular jaw. Implants with absence of adjacent tooth were twice more likely to be affected by peri-implantitis than those with presence of an adjacent tooth. Sub-group analysis for the combination of jaw and position variables revealed that implants in the maxillary anterior position showed significantly higher prevalence rate of peri-implantitis than those in the mandibular anterior position.

Within limitations of the present study, patients showed significant increase in the prevalence rate of peri-implantitis when the implant was placed in the maxillary jaw or when tooth adjacent to the implant was absent. In addition, the presence of tooth seemed to provide positive effect on the occurrence of peri-implantitis at the adjacent implant.

Key words : Dental implant, Location, Peri-implantitis, Risk, Within-subject variation

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## INTRODUCTION

Implant-supported restoration now becomes a reliable prosthetic treatment option to overcome many shortcomings of conventional prosthetic rehabilitation. However, implants at certain locations such as in the maxillary posterior jaw show higher failure rate than those in other regions, especially when short implants are placed[1]. Poor bone quality and limited bone quantity of the maxillary jaw are blamed for its higher implant failure rate in comparison with the mandibular jaw[2,3].

Peri-implantitis has been suggested as one of main causes of implant loss along with occlusal overloading[4,5]. Patient- and implant-related risk factors for peri-implantitis have been extensively reported[6,7]. Among implant-related risk factors, implant location has been shown to influence the prevalence rate of peri-implantitis. However, the results regarding implant location were inconclusive[8].

The presence of tooth or implant adjacent to the implant in partially edentulous patient might lower the chance of peri-implantitis than that in totally edentulous patient due to a "protective effect" of the adjacent tooth or implant against occlusal force[9,10]. However, whether the protective effect for peri-implantitis is due to the presence of tooth or implant remains unclear.

If implant-related risk variables for peri-implantitis are evaluated by comparing peri-implantitis affected and healthy implants in different patients, implants might be under the influence of different patient-related risk variables. In addition, multiple healthy and peri-implantitis affected implants clustered in the same patient are more correlated than those in different patients in the analysis of implant-related risk. Hence, study design and data analysis should consider the influence of patient-related risk variables and correlation of data in a single patient[11,12].

The aim of the present study was to analyze the influence of implant location on the prevalence of peri-implantitis by within-subjects comparison of healthy implants and peri-implantitis affected implants in patients with peri-implantitis.

## MATERIALS AND METHODS

### 1. Patient Sample

Patients who presented evident peri-implant bone loss and/or clinical signs of peri-implantitis at one of his/her multiple implants when they visited the Department of Periodontology, Jeonbuk National University Dental Hospital, Jeonju, South Korea were recruited for this study. A total of 65 patients with 395 implants of which 127 implants initially suspected of having peri-implantitis were consecutively selected between January 2018 and February 2020. These patients were invited to participate in this cross-sectional study. To be included for this study, patient should have at least one peri-implantitis affected implant and one healthy implant following clinical and radiographic examination to diagnose healthy and peri-implantitis affected im-

plants. In addition, the implant should have been functionally loaded for more than one year. Implants in the totally edentulous jaws were excluded.

The study protocol was approved by the Institutional Review Board of Jeonbuk National University Hospital, Jeonju, South Korea (IRB No.: CUH 2017-04-007). All patients included in this study provided informed consent. The present study was conducted in accordance with STROBE checklist for cross-sectional studies and the 1975 Declaration of Helsinki revised in 2013.

### 2. Clinical Assessments

*Probing pocket depth* were recorded at mesial, facial, distal, and lingual site of all implants with a periodontal probe to the nearest 0.5mm (PCP15, Hu-Friedy Inc., Leimen, Germany). Following probing with a pressure of 0.25 N, *bleeding on probing* was assessed at the same sites. *Width of keratinized mucosa* at facial site of the implant was measured as the distance between the mucosal margin and the mucogingival junction with a periodontal probe to the nearest 0.5mm.

### 3. Radiographic Assessments

Periapical radiographs were taken with a digital system using a charge-coupled device (Xios XG Select, Dentsply Sirona Inc., New York, USA). The charge-coupled device was placed parallel to the implant and an X-ray beam (Heliodent plus, Dentsply Sirona Inc.) kept perpendicular to it. Bone level (BL) was measured as the distance from the top of the implant to the first bone-to-implant contact at the mesial and distal aspects of the implants. Measurements were performed with the use of image measurement program (NIH ImageJ, National Institutes of Health, Bethesda, MD), and the known implant length was used to calibrate magnification. One calibrated examiner (M.G.) who was not involved in the treatment performed all clinical and radiographic assessments.

### 4. Case definitions for healthy and peri-implantitis affected implants

Diagnosis of peri-implantitis was made if probing pocket depth at the implant was ≥ 6 mm with clinical signs of bleeding on probing or suppuration, and BL of the implant located ≥ 3 mm apical to the most coronal portion of the implant[13]. All other implants without peri-implantitis were considered as "healthy" implants for data analysis regardless of having "peri-implant mucositis".

### 5. Patient- and implant-related risk factors

Patients' records were reviewed to extract patient, implant, and implant location related risk factors for peri-implantitis. Patient-related risk factors included *age, sex* (male/female), *smoking* (yes/no), *systemic health condition in relation to heart disease, diabetes, osteoporosis, cancer, etc.* (healthy/compromised), *history of periodontal treatment* (yes/no), *implant maintenance therapy every* 6 months[14]

(yes/no), and *numbers of implants in each patient*. Implant-related risk factors included *follow-up period after functional loading, implant types* (bone level/tissue level, external/internal connection), and *prosthesis type* (single crown/fixed dental prosthesis [FDP]). Risk factors related to implant location included *jaw position* (maxilla/mandible), *tooth type* (non-molar/molar), *tooth position* (anterior:incisors, canine/ middle: premolars/ posterior: molars), and *tooth adjacent to implant* (presence/absence).

### 6. Study size

Sample size was calculated using a software (G* Power 3.1.9.7 for Windows 10) considering the following: a = 0.05; power = 0.8; detection of risk with an odds ratio (OR) ≥ 2.0, and a ratio of 1: 3 for matched cases to controls. Considering these calculations, at least 77 implants with peri-implantitis and 231 healthy implants should be included.

### 7. Data analyses

Descriptive statistics including mean values, standard deviations, ranges, and frequencies of variables were calculated with patient and implant as statistical units. The primary outcome variable of the study was the prevalence of peri-implantitis. Secondary outcome variables were probing pocket depth, bleeding on probing, width of keratinized mucosa, and marginal bone level at implant obtained at clinical and radiographic examinations for peri-implantitis. Because of cluster-correlated data resulting from patients having varying numbers of both healthy and peri-implantitis affected implants, multilevel analysis using generalized estimating equations (GEE) procedure was performed[11,12]. Effects of implant-related risk variables including implant location on binary outcome variables such as peri-implantitis affected/healthy implant and presence/absence of bleeding on probing were assessed using a binary logistic regression model. The influences of these risk variables on the occurrence of peri-implantitis were estimated by the univariate GEE analysis. Furthermore, multivariate GEE analysis was performed in a model that included implant location risk variables as explanatory variables. Exchangeable correlation structure was assumed as an indicative of the relationship between implant location variables and outcome variables. The result of GEE univariate analysis was presented as odds ratio (OR) with 95% confidence intervals (CIs). Influences of implant location on continuous outcome variables, pocket depth, width of keratinized mucosa, and peri-implant bone level were assessed using a linear regression model. Sub-group analysis of implant position (anterior vs. posterior) on the prevalence of peri-implantitis was made for maxillary jaw and mandibular jaw separately. In addition, a combination of jaw position and tooth position variables (i.e., maxillary anterior, maxillary posterior, mandibular anterior, and mandibular posterior) was assessed with respect to the prevalence rate of peri-implantitis. The influence of tooth presence adjacent to the implant on the prevalence rate was also further analyzed in relation to the number of

proximal tooth-facing surfaces at the implant. The significance of implant location variables influencing outcome variables was assessed using the Wald test based on robust standard error. P values less than 0.05 was considered to indicate statistical significance. Statistical analyses were performed with a statistical software program (Stata Corp., College Station, TX, USA).

## RESULTS

A total of 56 patients with 338 implants fulfilled the inclusion criteria for the study. According to the criteria for peri-implantitis, 89 implants were judged as having peri-implantitis and 249 implants were judged as healthy (Fig. 1).

Descriptive characteristics of patient, implant and implant location related risk factors are presented in Table 1. The mean age of patients was 62.2 years (range: 46 to 87 years). Most patients had a history of periodontal treatment. They were not following a regular implant maintenance therapy (IMT) program. The average follow up time after implant loading was 7.6 years (range: 1 to 19 years). Implant related variables other than implant location vari-

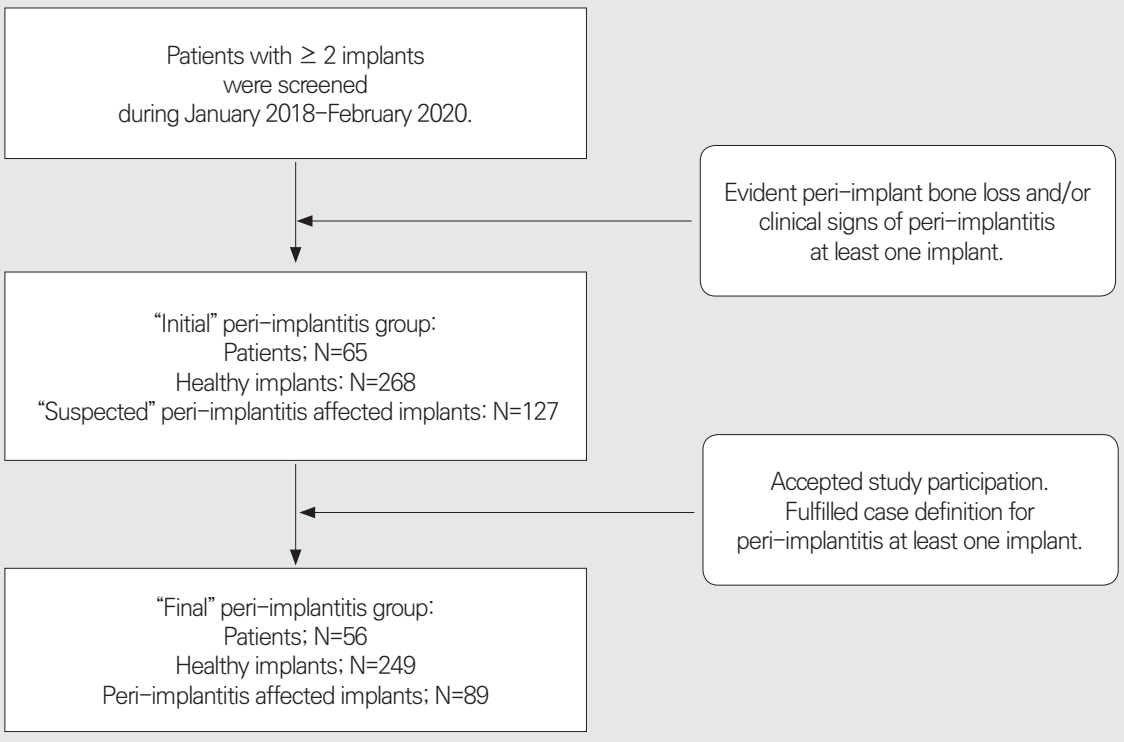


Figure 1. Selection processes of patient and implant groups.

Table 1. Description of patient, implant and implant location related risk variables for peri-implantitis

| Variable | Numbers | Mean (range) |
|---|---|---|
| Patient related | 56 | |
| Age, years | | 62.2 (46-87) |
| Male/Female | 36/20 | - |
| Smoker/Non-smokers | 9/47 | - |
| Systemically compromised/healthy conditions | 36/20 | - |
| History of periodontal treatment/No | 52/4 | - |
| Under regular IMT/No | 5/51 | - |
| Implants number per patient | | 6 (2-17) |
| Implant related | 338 | |
| Follow-up period, years | | 7.6 (1-19) |
| Implant types | | |
| Bone level/tissue level | 210/128 | - |
| External/internal connection | 21/317 | - |
| Implant supporting single crown/FPD | 103/235 | - |
| Implant location related | 338 | |
| Jaw position (maxilla/mandible) | 179/159 | - |
| Tooth position (anterior/middle/posterior) | 47/100/191 | - |
| Tooth type (non-molar/molar) | 147/191 | - |
| Tooth adjacent to implant (presence/absence) | 186/152 | - |
| Tooth-facing surfaces (no/1/2) | 152/158/28 | - |

Abbreviations: IMT, implant maintenance therapy, FDP, fixed dental prosthesis

ables were assessed in relation to the prevalence of peri-implantitis. None of included variables showed a statistically significant difference.

The majority of implants were installed in the posterior position in the dentition, especially in the mandibular molar position. While, the prevalence of the peri-implantitis was the highest in the maxillary canine position. It was the lowest in the mandibular canine position (Fig. 2).

Results of comparison of clinical and radiographic assessments at the implant with respect to implant location variables are presented in Table 2. Probing pocket depth and bleeding on probing were significantly deeper and more frequent at implants in the maxillary jaw and implants with absence of adjacent tooth than those in the mandibular jaw and with presence of adjacent tooth, respectively. Keratinized mucosa width was statistically significantly different between all included implant location variables. The peri-implant bone level was only significantly different between the presence and absence of tooth adjacent to the implant.

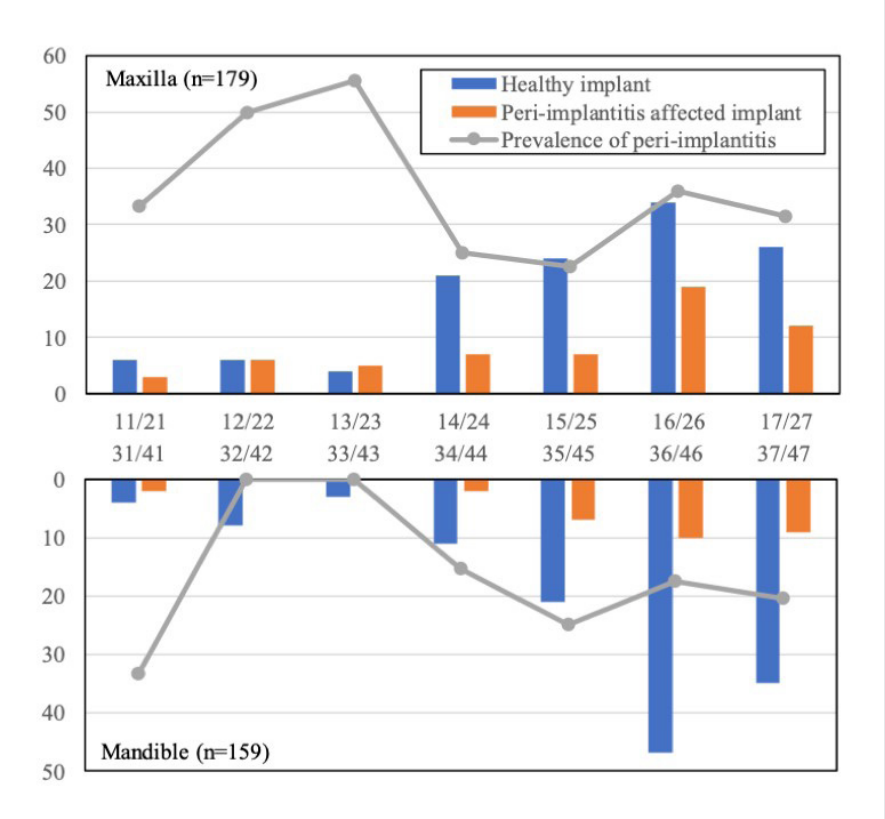


Figure 2. Numbers of healthy and peri-implantitis affected implants, and prevalence of peri-implantitis (%) according to implant positions following Fédération Dentaire Internationale tooth numbering system.

Among implant location variables, implants in the maxillary jaw and with absence of adjacent tooth showed significantly higher prevalence rate of peri-implantitis than those in the mandibular jaw and with presence of adjacent tooth, respectively in GEE univariate and multivariate analysis (Fig. 3). Implants placed in the maxillary jaw showed 2 times higher frequency of peri-implantitis than those in the mandibular jaw. Implants with absence of adjacent tooth were twice more likely to be affected by peri-implantitis than those with presence of an adjacent tooth (Table 3).

In subgroup analysis, the prevalence rate of peri-implantitis was not statistically different between anterior and posterior positions when jaw position was analyzed separately as maxillary and mandibular jaws. However, implants in the maxillary anterior position showed significantly higher prevalence of

Table 2. Comparison of probing pocket depth (PD), bleeding on probing (BoP), width of keratinized mucosa (WKM), and peri-implant bone level (PBL) at the implant(n=338) in relation to implant location variables. Mean ± standard deviation values in mm.

| Variables | PD | BoP (%) | WKM | PBL |
|---|---|---|---|---|
| Jaw | | | | |
| Maxilla | 4.1 ± 1.5* | 52.5* | 2.7 ± 2.1* | 1.7 ± 2.5 |
| Mandible | 3.7 ± 1.3 | 37.7 | 1.8 ± 1.4 | 1.1 ± 4.1 |
| Tooth type | | | | |
| Non-molar | 3.8 ± 1.3 | 44.6 | 2.6 ± 1.6* | 1.4 ± 2.3 |
| Molar | 4.0 ± 1.5 | 46.3 | 2.0 ± 2.0 | 1.5 ± 4.0 |
| Tooth position | | | | |
| Anterior | 4.0 ± 1.3 | 49.4 | 3.1 ± 1.3* | 2.0 ± 2.8 |
| Middle | 3.8 ± 1.4 | 49.5 | 2.4 ± 1.7 | 1.1 ± 1.9 |
| Posterior | 4.0 ± 1.5 | 42.3 | 2.0 ± 2.0 | 1.5 ± 4.0 |
| Tooth adjacent to implant | | | | |
| Presence | 3.7 ± 1.2 | 46.3 | 2.3 ± 1.8* | 1.0 ± 1.9 |
| Absence | 4.0 ± 1.5* | 47.9* | 2.2 ± 1.9 | 1.7 ± 3.8* |

*Difference by univariate generalized estimating equations: $P < 0.05$.

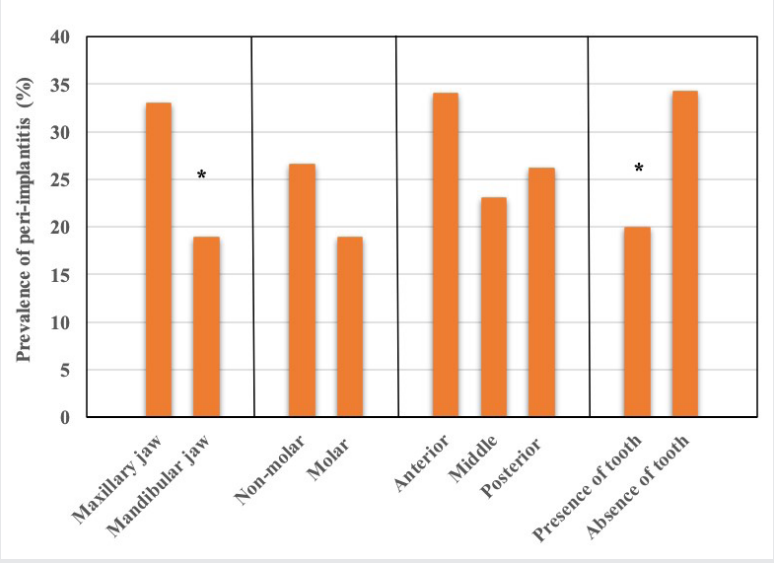


Figure 3. Comparison of implant location variables; *jaw position* (maxilla/mandible), *tooth type* (non-molar/molar), *tooth position* (anterior/middle/posterior), and *tooth adjacent to implant* (presence/absence) in relation to prevalence rate of peri-implantitis. Difference by univariate and multivariate generalized estimating equations is indicated as *$P < 0.05$.

Table 3. The odds ratio (OR) and 95 per cent confidence intervals (95 % CIs) of implant location risk variables for peri-implantitis by univariate and multivariate general estimating equations (GEEs) analysis.

| Variables | Univariate GEE | | | Multivariate GEE* | | |
|---|---|---|---|---|---|---|
| | OR | 95 % CI | P value | OR | 95 % CI | P value |
| Jaw position | | | | | | |
| Mandible | 1 | | | 1 | | |
| Maxilla | 1.979 | 1.062-3.686 | 0.032 | 1.892 | 1.025-3.492 | 0.041 |
| Tooth type | | | | | | |
| Molar | 1 | | | 1 | | |
| Non-molar | 1.056 | 0.613-1.819 | 0.844 | 1.180 | 0.642-2.168 | 0.594 |
| Tooth position | | | | | | |
| Middle | 1 | | | - | - | - |
| Anterior | 1.659 | 0.801-3.439 | 0.173 | - | - | - |
| Posterior | 1.160 | 0.677-1.989 | 0.589 | - | - | - |
| Tooth adjacent to implant | | | | | | |
| Presence | 1 | | | 1 | | |
| Absence | 1.959 | 1.261-3.044 | 0.003 | 2.000 | 1.211-3.304 | 0.007 |

* $P$=0.005

peri-implantitis than those in the mandibular anterior position when jaw and position variables were combined (Table 4).

Regarding the number of tooth-facing surfaces, the positive effect of tooth presence for peri-implantitis was only significantly different between implants having no tooth facing surface and those having one tooth-facing surface. The positive effect appeared to increase when an implant had more tooth facing surfaces, but it did not reach a statistical significance ($P$=0.33) (Table 5).

## DISCUSSION

The prevalence rate of peri-implantitis in the maxillary jaw was twice higher than that in the mandibular jaw ($P < 0.05$), consistent with findings of other studies[15~18]. Poor bone quality of maxillary jaw that is more vulnerable to peri-implant inflammation is responsible for the higher prevalence of peri-implantitis than the mandibular jaw[15,16]. In fact, all clinical parameters related to soft tissue condition were worse in maxillary implants than mandibular implants in the present study. However, some studies have found no difference in the prevalence of peri-implantitis between maxillary and mandibular jaws[19~22]. Some studies have even

Table 4. The odds ratio (OR) and 95 per cent confidence intervals (95 % CIs) of risk factors for peri-implantitis in subgroup analysis of jaw and position variables by univariate general estimating equations (GEEs) analysis.

| Variables | OR | 95 % CI | P value |
|---|---|---|---|
| Maxillary jaw | | | |
| Anterior position | 1.656 | 0.657-4.167 | 0.285 |
| Posterior position | 1 | | |
| Mandibular jaw | | | |
| Anterior position | 1 | | |
| Posterior position | 1.628 | 0.347-7.636 | 0.536 |
| Anterior and posterior position in the jaw | | | |
| Mandibular anterior | 1 | | |
| Mandibular posterior | 1.628 | 0.347-7.635 | 0.536 |
| Maxillary posterior | 2.765 | 0.884-8.648 | 0.081 |
| Maxillary anterior | 6.571 | 1.000-43.159 | 0.050 |

Table 5. The odds ratio (OR) and 95 per cent confidence intervals (95 % CIs) for the influence of tooth presence on the occurrence of peri-implantitis in relation to the numbers of tooth-facing surfaces at the implant by univariate general estimating equations (GEEs) analysis.

| Numbers of tooth-facing surfaces | OR | 95 % CI | P value |
|---|---|---|---|
| No | 1 | | |
| One | 0.466 | 0.293-0.742 | 0.001 |
| Two | 0.659 | 0.285-1.525 | 0.330 |
| | | | |
| One | 1 | | |
| Two | 1.285 | 0.621-2.661 | 0.498 |

found opposite results[10,23]. Differences in statistical analysis, inclusion/exclusion criteria, and case definitions for peri-implantitis between studies might have contributed to such contradictory outcomes[8].

It was assumed that implants in the posterior position would be more difficult to perform proper oral hygiene than those in the anterior position, resulting in more plaque induced inflammation for implants in the posterior position. Along with the presence of inflammation, high occlusal force and poor bone quality in the posterior region might have contributed to increased bone loss and the eventual incidence of peri-implantitis. Hence, peri-implantitis and implant failure are expected to oc-

cur more frequently in the posterior position than in the anterior position[8,18]. Since tooth type variable (non-molar/molar) in relation to different occlusal force was overlapped with tooth position variable, we divided tooth position variable into three positions (i.e., anterior, middle, and posterior positions) and mainly compared the position variable between anterior and posterior. In the present study, the prevalence rate of peri-implantitis was not significantly different between implants in anterior and posterior positions regardless whether maxillary and mandibular jaws were assessed together or separately. Besides, clinical parameters such as probing pocket depth and bleeding on probing were not different between anterior and posterior positions, in agreement with other studies that assessed both jaws together[9,20]. In contrast, the highest prevalence rate of peri-implantitis was found in the anterior position[1,10] or posterior position in the mandibular jaw when implant position variable was assessed in combination with jaw position[23]. In a similar way, we also analyzed the prevalence rate of peri-implantitis combining jaw and position variables and found that implants in the maxillary anterior position showed significantly higher prevalence rate of peri-implantitis than implants in the mandibular anterior position. This finding was almost similar to a study that included patients with peri-implantitis in which the highest prevalence of peri-implantitis was found in the incisor area of the maxillary jaw while the lowest prevalence was found in the canine area of the mandibular jaw[16]. According to authors of that study, implants in the maxillary anterior position are often installed with a buccolingual inclination due to bone resorption. Thus, they might be subjected to lateral occlusal force to the neck of the implant, which in turn might increase bone loss at the implant, especially in the presence of inflammation. However, the role of overloading on peri-implantitis remains inconclusive[7]. We could not see difference in peri-implantitis either between implants in non-molar and molar positions in relation to occlusal forces.

When there was no adjacent tooth to an implant, the likelihood of having peri-implantitis was twice higher than implant having a tooth in the adjacent unit ($P < 0.05$). In other words, the presence of an adjacent tooth showed 50% positive effect for peri-implantitis in comparison with an implant with absence of an adjacent tooth. It has been shown that marginal bone loss at the proximal crest in tooth/implant units is lower than that in inter-implant units[24,25]. Furthermore, less bone resorption has been observed around single implant-supported restorations than for implants in edentulous patients, suggesting that the presence of a tooth adjacent to a single implant might contribute to maintenance of bone height at the implant[26,27]. Hence, the presence of a tooth adjacent to an implant appears to be favorable for maintaining marginal bone level or healthy condition of the implant. With respect to peri-implantitis, peri-implant tissue condition of implants having adjacent tooth or implant in partially edentulous patients was better than those in edentulous patients[9,10,19]. Higher prevalence of peri-implantitis was associated with implants supporting

fixed dental prosthesis (FDP) than single implants, especially in totally edentulous patients[10]. Hence, an adjacent tooth or an implant in partially edentulous patients with more uniform distribution of occlusal force than implants in edentulous patients seemed to have protective effect against peri-implantitis[9,19]. However, the role of overloading on peri-implantitis remains inconclusive[7]. Other than the protective effect of the adjacent tooth on occlusal force, the presence of adjacent tooth may better protect plaque associated inflammation than an implant with absence of adjacent tooth considering that peri-implant tissue destruction at peri-implantitis sites is faster and more extensive in comparison to that at periodontitis sites[28]. However, one should know that peri-implant tissue health is related to periodontal health of the tooth adjacent to the implant. Hence, tooth affected by periodontitis could negatively affect peri-implant tissue of the adjacent implant[29,30]. Although the presence of tooth seems to protect the adjacent implant from peri-implantitis in the present study, how the presence of a tooth contributes to maintaining marginal bone level or healthy condition of the adjacent implant is not fully understood yet.

The prevalence rate of peri-implantitis was 26.3 % at implant level, which was a relatively high percentage compared to 6.7 % in previous study conducted on the same ethnic population with the similar case definition for peri-implantitis[31]. The present study included patients who had at least one peri-implantitis affected implant as a "case" and one healthy implant as a "control", meaning that all patients were affected by peri-implantitis at patient level. In fact, most patients had a history of periodontal treatment. They were not under regular IMT. These are well-known patient-related risk factors for peri-implantitis[7]. The prevalence of peri-implantitis at patient level varies widely from 1% to 47.1% depending on criteria for peri-implantitis[32]. Hence, the prevalence of other studies that included mostly healthy patients without peri-implantitis could not be compared with that in the present study, in which all patients were affected by peri-implantitis and highly susceptible to peri-implantitis. However, the present within-subjects study design that compared peri-implantitis affected implants and healthy implants in patients with peri-implantitis enabled us to analyze implant-related risk variables for peri-implantitis without being influenced by patient-related risk variables.

The present study has some limitations. First, it was only focused on implant location variables that could be confirmed in all included implants and serve as risk factors since some data obtainable at implant surgery were unavailable for the implants that were not placed at a university hospital. However, other implant-related risk variables not considered in the present study such as periodontal conditions of adjacent tooth might have influenced data analysis of implant location variables. Furthermore, small numbers of implants placed in the anterior position in comparison with the posterior position at both maxillary and mandibular jaws hampered us to draw a statistically meaningful conclusion for the comparison between implants in anterior and

posterior positions.

Within limitations of the present study, it can be concluded that patients showed significant increase in the prevalence rate of peri-implantitis when the implant was placed in the maxillary jaw or when tooth adjacent to the implant was absent. In addition, the presence of a tooth seemed to provide positive effect on the occurrence of peri-implantitis at the adjacent implant.

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