JPIS
Journal of Periodontal & Implant Science

Research Article
Implant Science

Check for updates

Evaluation of health screening data for factors associated with peri-implant bone loss

Hyunjong Yoo [ID] [1], **Jun-Beom Park** [ID] [1,2], **Youngkyung Ko** [ID] [1,2,*]

[1]Graduate School of Clinical Dental Science, The Catholic University of Korea, Seoul, Korea
[2]Departement of Dentistry, Seoul St. Mary's Hospital, College of Medicine, The Catholic University of Korea, Seoul, Korea

OPEN ACCESS

*Correspondence:
Youngkyung Ko
Departement of Dentistry, Seoul St. Mary's Hospital, College of Medicine, The Catholic University of Korea, 222 Banpo-daero, Seocho-gu, Seoul 06591, Korea.
Email: ko_y@catholic.ac.kr
Tel: +82-2-2258-1784
Fax: +82-2-537-2374

ORCID iDs
Hyunjong Yoo [ID]
https://orcid.org/0000-0003-4429-3987
Jun-Beom Park [ID]
https://orcid.org/0000-0002-8915-1555
Youngkyung Ko [ID]
https://orcid.org/0000-0002-6564-9156

Conflict of Interest
No potential conflict of interest relevant to this article was reported.

Author Contributions
Conceptualization: Youngkyung Ko. Formal analysis: Hyunjong Yoo, Jun-Beom Park, Youngkyung Ko. Investigation: Hyunjong Yoo. Methodology: Hyunjong Yoo, Jun-Beom Park, Youngkyung Ko. Project administration:

ABSTRACT

Purpose: Systemic health has a profound effect on dental treatment. The aim of this study was to evaluate peri-implant bone loss and health screening data to discover factors that may influence peri-implant diseases.

Methods: This study analyzed the panoramic X-rays of patients undergoing health screenings at the Health Promotion Center at Seoul St. Mary's Hospital in 2018, to investigate the relationship between laboratory test results and dental data. The patients' physical data, such as height, weight, blood pressure, hematological and urine analysis data, smoking habits, number of remaining teeth, alveolar bone level, number of implants, and degree of bone loss around the implant, were analyzed for correlations. Their associations with glycated hemoglobin, glucose, blood urea nitrogen (BUN), creatinine, and severity of periodontitis were evaluated using univariate and multivariate regression analysis.

Results: In total, 2,264 patients opted in for dental health examinations, of whom 752 (33.2%) had undergone dental implant treatment. These 752 patients had a total of 2,658 implants, and 129 (17.1%) had 1 or more implants with peri-implant bone loss of 2 mm or more. The number of these implants was 204 (7%). Body mass index and smoking were not correlated with peri-implant bone loss. Stepwise multivariate regression analysis revealed that the severity of periodontal bone loss (moderate bone loss: odds ratio [OR], 3.154; 95% confidence interval [CI], 1.175–8.475 and severe bone loss: OR, 7.751; 95% CI, 3.003–20) and BUN (OR, 1.082; 95% CI, 1.027–1.141) showed statistically significant predictive value. The severity of periodontitis showed greater predictive value than the biochemical parameters of blood glucose, renal function, and liver function.

Conclusions: The results of this study showed that periodontal bone loss was a predictor of peri-implant bone loss, suggesting that periodontal disease should be controlled before dental treatment. Diligent maintenance care is recommended for patients with moderate to severe periodontal bone loss.

Keywords: Blood urea nitrogen; Creatinine; Diabetes mellitus; Peri-implantitis; Periodontitis

Generated by xmlinkpress

Youngkyung Ko. Writing - original draft: Hyunjong Yoo. Writing - review & editing: Hyunjong Yoo, Jun-Beom Park, Youngkyung Ko.

INTRODUCTION

Systemic health has a profound effect on periodontal health [1]. Systemic diseases, ranging from conditions where dental treatment is not possible because of the high risk of complications, such as high bleeding tendency or long-term bisphosphonate-based drug use in cancer patients, to conditions where sufficient treatment is possible with caution, such as mild hypertension and drug-controlled diabetes, can co-exist with oral disease [2]. These systemic diseases not only make periodontal treatment harder or impossible but also can affect the occurrence and severity of periodontal diseases. Overall, these systemic diseases tend to occur with a higher frequency with increasing age, and may show overlap with periodontal disease, which also increases with age. Impaired systemic and oral health can influence an older person's quality of life [3].

Periodontal disease progression may lead to loss of the tooth, and the tooth may be replaced with a screw-type intraosseous implant made of titanium, as designed by Brånemark of Sweden in the 1950s [4], which is now widely used worldwide. Implants have a success rate of over 90%–95% in healthy patients with normal healing ability and good bone quality [5]. The success rate of these implants may vary depending on the type of systemic disease, and in some cases, a systemic disease may be a contraindication to the implant treatment itself [6].

In 2014, the Korean National Health Insurance Service (NHIS) started to cover 50% of the fee of up to 2 dental implants in partially edentulous patients aged 75 years or older. In July 2016, the age of eligibility for this benefit decreased to 65 years, and the NHIS coverage rose to 70% of the total fee in July 2018. According to a press release of the Korean Ministry of Health and Welfare, in July 2014, the number of patients who had implants under insurance increased from 390,320 in 2016 to 582,837 in 2018 [7]. Peri-implant disease is a complication of implant treatment and is divided into peri-implant mucositis and peri-implantitis depending on the presence or absence of bone loss [8]. Peri-implantitis is accompanied by inflammation and bone loss in the peri-implant alveolar bone. The prevalence of the disease is 7.3%–34% at the patient level and 5.5%–21% at the implant level [9-11].

It is well known that smoking induces systemic problems [12]. However, its effects on the oral cavity are still unfamiliar to the public. Smoking affects not only healing after periodontal treatment, but also the progression of periodontal disease and the rate of tooth loss. This rate of tooth loss decreases when a patient quits smoking [13].

The purpose of this study was to analyze the panoramic X-rays of patients who underwent health screenings at the Health Promotion Center at Seoul St. Mary's Hospital in 2018 to discover factors in medical screening data that correlate to the number of residual teeth and implants, peri-implantitis, and periodontitis.

MATERIALS AND METHODS

Study design

Electronic medical records of people who had undergone a health screening examination program that included a dental examination at Seoul St. Mary's Hospital in 2018 were evaluated. The study protocol was approved by the Institutional Review Board (IRB) of the Seoul St. Mary's Hospital (IRB approval number; KC19RESI0392). The patient's physical

examination data such as height, weight, blood pressure, and laboratory test results including blood and urine analysis and t information about smoking status collected at the time of the medical examination and the data obtained by analyzing the panoramic X-rays were evaluated.

Panoramic radiograph evaluation

The authors investigated the number of residual natural teeth, periodontitis, severity of periodontitis, the number of implants placed, the presence of peri-implant bone loss, and the amount of peri-implant bone loss.

The presence or absence of periodontitis was defined as the presence of bone loss at the cementoenamel junction (CEJ) on a panoramic image. The interproximal site with the greatest bone loss was used for classification of severity of periodontitis. No bone loss or slight alveolar bone loss was indicated as 0, alveolar bone loss of up to 30% was indicated as 1 (minor), bone loss of 30%–50% was indicated as 2 (moderate), and bone loss of 50% or more was indicated as 3 (severe) [14]. The percentage of bone loss was measured by dividing the distance between cementoenamel junction to the alveolar crest by the distance from the CEJ to the root apex. The distance was measured perpendicular to an imaginary line connecting the CEJ of the teeth (**Figure 1**). Cases without any residual teeth were excluded from the analysis.

Bone loss of 2 mm or more from the implant platform was taken as peri-implant bone loss, and when different amounts of bone loss were found on the mesial and distal sides, the greater of the 2 values was used [15]. The bone loss of the implant was measured in 1-mm increments.

Physical examination

Height, weight, and blood pressure data were obtained from the physical examination. From height and weight, the body mass index (BMI) was calculated. The BMI is derived from the mass (weight) and height of a person by dividing the body mass by the square of the body height, and is universally expressed in units of kg/m², resulting from mass in kilograms and height in meters. BMI was divided into 3 groups, <23, ≥23 and < 25, and ≥25 kg/m².
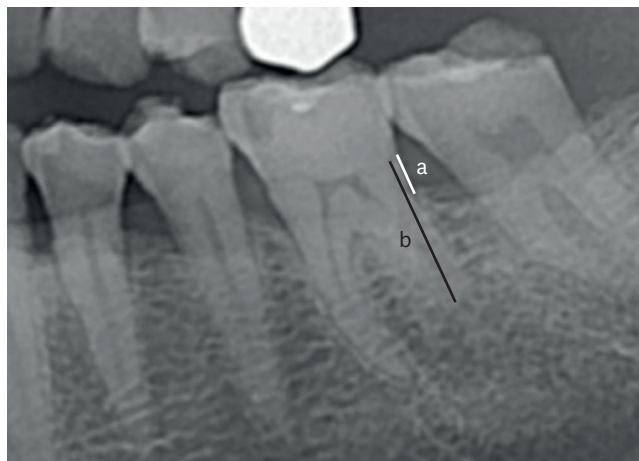

Figure 1. Partial image of a panoramic radiograph. The percentage of the distance between the cementoenamel junction to the alveolar crest (a) was divided by the distance between the cementoenamel junction to the root apex (b).

https://doi.org/10.5051/jpis.2203620181

Laboratory tests

Blood glucose, glycated hemoglobin (HbA1c), blood urea nitrogen (BUN), creatinine, total protein, albumin, sodium, potassium, chloride, total bilirubin, direct bilirubin, aspartate aminotransferase (AST), alanine aminotransferase (ALT), alkaline phosphatase (ALP), γ-glutamyl transpeptidase (γ-GTP), creatine phosphokinase, uric acid, calcium, phosphorus, amylase, total cholesterol, triglyceride, high-density lipoprotein (HDL)-cholesterol, low-density lipoprotein (LDL)-cholesterol, iron, and total iron binding capacity, levels were analyzed. HbA1c levels were used to classify as diabetes mellitus (DM) (≥6.5%), prediabetes (pre-DM) (>5.6% and <6.5%), and normal (no DM) (>4.0% and ≤5.6%).

Smoking

Patients were asked about their smoking habits at the health screening examination visit. Patients are asked to check a box on a question about their smoking habits. The responses were divided into smoking, non-smoking, and former smoking.

Exclusion criteria

Patients without any natural teeth were excluded from the analysis (n=7). Instances where the implant could not be identified due to excessive distortion of the panoramic image were excluded from the final analysis (n=41). In addition, some cases with missing laboratory test values of glucose (n=92) and bilirubin (n=1) were excluded from the final analysis.

Statistical analysis

We decided whether to use parametric or non-parametric tests to compare the differences among 3or more groups by Shapiro-Wilk test. Frequencies (percentages) for categorical variables, means±standard deviations for normally distributed continuous variables, and geometric means (95% confidence intervals, CIs) for non-normal continuous variables, were presented to describe their distributions, respectively.

The χ^2 test was used to compare differences in proportions, and one-way analysis of variance with the Scheffé post hoc test for means and the Kruskal-Wallis test for geometric means among 3 or more groups. Pearson correlation analysis was conducted to detect the relationships between BMI and the number of residual teeth or implant placements.

Finally, stepwise multivariate ordinal logistic regression was performed to identify the factors associated with the amount of bone loss in peri-implantitis after checking the proportional odds assumption. In this multivariate analysis, we considered only 6 variables (DM, glucose, BUN, creatinine, HbA1c, and degree of periodontitis) that were significant at a 10% level in each univariate ordinal logistic regression analysis. All statistical analyses were done with SAS version 9.4 (SAS Institute, Inc., Cary, NC, USA). A P value below 0.05 was considered statistically significant.

RESULTS

Study population

Of a total of 2,264 patients who had opted to undergo a dental examination, 752 (33.2%) had received dental implant treatment (341 women). The mean age was 61.96±9.22 years (men 62.09±9.02 years, women 61.8±9.00 years). In total, 129 (17.1%) had 1 or more implants with

peri-implant bone loss of 2 mm or more. The total number of implants was 2658, and 204 (7%) of these implants had bone loss of 2 mm or more.

BMI

Height and weight data from 442 patients were converted to BMI. Twenty-eight patients met the exclusion criteria, and the BMI of a total of 414 patients (226 men: 63.2±9.46 years old, 188 women: 61.5±9.32 years old) was analyzed. Peri-implant bone loss did not show a statistically significant correlation with BMI (**Supplementary Table 1**), and the number of residual teeth or implants also showed no significant correlations with BMI (**Supplementary Table 2**).

Smoking

The relationship between smoking and periodontal and peri-implant bone loss was analyzed in 192 patients who had answered the questionnaire about smoking (110 men: 65.5±7.33 years old; 82 women: 64.1±8.67 years old) but the presence of peri-implant bone loss or severity of periodontitis did not show a statistically significant relationship with smoking (**Supplementary Table 3**).

DM

HbA1c levels were analyzed in 621 patients (336 men: 61.8±8.61 years old, 285 women: 61.2±8.70 years old). DM showed statistically significant associations with the severity of periodontitis ($P=0.0037$), occurrence of peri-implant bone loss ($P=0.0454$) and degree of peri-implant bone loss ($P=0.0074$), the number of implants placed ($P=0.0012$) and the number of residual teeth ($P=0.0012$) (**Table 1**).

Blood and urine tests

In addition to the above factors, the correlations between blood and urine test results and periodontal and peri-implant bone loss were also analyzed among 621 patients (336 men: 61.8±8.61 years old; 285 women: 61.2±9.70 years old). Periodontal bone loss was correlated with glucose, HbA1c, BUN, creatinine, direct bilirubin, AST, ALT, ALP, γ-GTP, uric acid, and HDL-cholesterol ($P<0.05$) (**Table 2**). Peri-implant bone loss showed slightly different relationships with the laboratory test results compared to periodontal bone loss. In this analysis, glucose, HbA1c, urea nitrogen, and creatinine showed statistically significant

Table 1. DM and oral parameters

Variables	Total	Diabetes mellitus			P value
		No DM	Pre-DM	DM	
Periodontitis	621 (100.00)	305 (49.11)	233 (37.52)	83 (13.37)	
Severity of periodontitis					0.0037[d]
1	140 (22.54)	82 (27.8)	43 (18.4)	15 (18.0)	
2	248 (39.94)	124 (40.6)	100 (42.9)	24 (28.9)	
3	233 (37.52)	99 (32.4)	90 (38.6)	44 (53.0)	
Bone loss in implant (≥2 mm)	87 (14.01)	32 (5.15)	41 (6.6)	14 (2.25)	0.0454[d]
Degree of bone loss in implant					0.0074[d]
No bone loss (<2 mm)	534 (85.99)	273 (89.5)	192 (82.4)	69 (83.1)	
2 and 3 mm	46 (7.41)	20 (6.55)	20 (8.58)	6 (7.22)	
4 and 5 mm	15 (2.42)	4 (1.31)	5 (2.1)	6 (7.22)	
>5 mm	26 (4.19)	8 (2.62)	16 (6.8)	2 (2.4)	
Number of residual teeth	22.98±4.31	23.48±4.09	22.61±4.43	22.16±4.6[b]	0.0116[a),d]
Number of implants	3.13±2.47	2.87±2.2	3.15±2.44[b]	3.99±3.2[b),c]	0.0012[a),d]

Frequencies (%) are shown for categorical variables. Values are presented as means±standard deviations.
DM: diabetes mellitus.
The χ² test or [a)]one-way analysis of variance; [b)]$P<0.05$ vs. no DM by Scheffé post hoc test; [c)]$P<0.05$ vs. pre-DM by the Scheffé post hoc test. [d)]Statistically significant difference ($P<0.05$).

Table 2. Severity of periodontitis and laboratory test results

Laboratory test results	Total	Severity of periodontitis			
		1	2	3	P value
Number of subjects	621	140	248	233	
Glucose	101.54±20.22	98.8±17.62	99.4±16.28	105.46±24.49[a),b)]	0.0008[c)]
HbA1c	5.86±0.79	5.71±0.6	5.79±0.68	6.02±0.96[a),b)]	0.0002[c)]
BUN	15.4±3.97	14.7±3.5	14.88±3.59	16.37±4.41[a),b)]	<0.0001[c)]
Creatinine	0.9±0.43	0.85±0.16	0.87±0.18	0.98±0.66[a),b)]	0.005[c)]
Total bilirubin	0.92 (0.9–0.95)	0.88 (0.83–0.93)	0.93 (0.89–0.98)	0.94 (0.9–0.98)	0.1832
Direct bilirubin	0.25 (0.24–0.25)	0.23 (0.21–0.24)	0.25 (0.23–0.26)	0.26 (0.24–0.27)	0.017[c)]
AST (GOT)	25.89 (25.18–26.62)	24.92 (23.68–26.22)	25.23 (24.29–26.21)	27.22 (25.79–28.72)	0.0213[c)]
ALT (GPT)	24.76 (23.79–25.77)	23.22 (21.43–25.16)	23.53 (22.2–24.95)	27.17 (25.31–29.18)	0.0018[c)]
ALP	52.5±19.49	50.35±13.67	50.96±14.95	55.42±25.53[b)]	0.0141[c)]
γ-GTP	29.15 (27.58–30.81)	26 (23.43–28.85)	27.31 (25.21–29.58)	33.47 (30.23–37.05)	0.0006[c)]
Uric acid	5.49±1.33	5.31±1.33	5.41±1.37	5.67±1.28[a)]	0.0244[c)]
Calcium	9.28±0.42	9.27±0.38	9.28±0.37	9.29±0.48	0.902
Phosphorus	3.56±0.49	3.56±0.46	3.56±0.47	3.56±0.53	0.995
Total cholesterol	198.83±41.6	204.71±38.16	198.4±41.19	195.75±43.75	0.1282
Triglyceride	103.72 (99.26–108.39)	100.02 (91.28–109.59)	103.02 (95.69–110.91)	106.79 (99.71–114.37)	0.5324
HDL-cholesterol	54.47±13.93	56.78±14.7	55.27±14.37	52.24±12.65[a)]	0.0047[c)]
LDL-cholesterol	118.27±36.55	122.35±33.25	116.78±34.79	117.42±40.08	0.3196
Total protein	7.2±0.46	7.19±0.39	7.2±0.46	7.21±0.49	0.8594
Albumin	4.49±0.28	4.51±0.24	4.49±0.29	4.46±0.29	0.2435
Sodium	143.49±2.03	143.79±1.95	143.39±2.05	143.42±2.06	0.1403
Potassium	4.26±0.3	4.25±0.31	4.25±0.29	4.29±0.31	0.2521
Chloride	105.53±2.28	105.62±2.35	105.59±2.17	105.42±2.37	0.6243

Values are presented as means±standard deviations or geometric mean (95% confidence interval).
HbA1c: glycated hemoglobin, AST: aspartate aminotransferase, GOT: glutamic oxaloacetic transaminase, ALT: alanine aminotransferase, GPT: glutamic pyruvic transaminase, ALP: alkaline phosphatase, γ-GTP: γ-glutamyl transpeptidase, CPK: creatine phosphokinase, HDL: high-density lipoprotein, LDL: low-density lipoprotein.
One-way analysis of variance and the Kruskal-Wallis test. [a)]P<0.05 vs. degree 1 by the Scheffé post hoc test; [b)]P<0.05 vs degree 2 by the Scheffé post hoc test. [c)] Statistically significant difference (P<0.05).

correlations, but direct bilirubin, AST, ALT, ALP, γ-GTP, uric acid, and HDL-cholesterol values were not statistically significant (**Table 3**).

Periodontal bone loss and peri-implant bone loss

Periodontal bone loss and peri-implant bone loss were analyzed in 709 patients (382 men: 61.5±8.76 years old, 327 women: 61.3±9.37 years old). Periodontal bone loss showed a statistically significant relationship with peri-implant bone loss (**Table 4**). The severity of periodontitis and existence of peri-implant bone loss had a statistically significant relationship (P<0.0001), and the degree of peri-implant bone loss had a proportional relationship with the severity of periodontitis (P<0.0001).

Factors associated with peri-implant bone loss by univariate and stepwise multivariate analyses

Univariate and stepwise multivariate analyses were performed on the data of 621 participants with no missing variables for any of the factors considered. The factors that were significant at a 10% level in each univariate logistic analysis are shown in **Table 5**. DM, HbA1c, BUN, creatinine, and the severity of periodontitis were significant in the univariate analyses, but when a multivariate analysis was performed, only BUN (P=0.0034) and severity of periodontitis (P<0.0001) were significant. Higher BUN levels were associated with a slight increase in the odds ratio (OR) of 1.082. More severe periodontal bone loss was associated with a higher likelihood of peri-implant bone loss (OR, 3.154 for moderate bone loss and OR, 7.751 for advanced bone loss).

Table 3. Degree of peri-implant bone loss and laboratory test results

Laboratory test results	Total	Bone loss in the implant				
		No bone loss (<2 mm)	2 and 3 mm	4 and 5 mm	>5 mm	P value
Number of subjects	621	534	46	15	26	
Glucose	101.54±20.22	100.91±19.1	102.43±27.8	121.53±32.63[a),b)]	101.35±11.17[c)]	0.0015[d)]
HbA1c	5.86±0.79	5.82±0.77	5.99±0.96	6.5±1.11[a)]	5.95±0.45[a)]	0.0057[d)]
BUN	15.4±3.97	15.16±3.61	16.21±4.95	16.09±3.38	18.49±6.98[a)]	0.0001[d)]
Creatinine	0.9±0.43	0.88±0.18	0.94±0.25	0.94±0.2	1.31±1.91[a),b)]	<0.0001[d)]
Total bilirubin	0.92 (0.9–0.95)	0.93 (0.9–0.96)	0.93 (0.84–1.04)	0.91 (0.72–1.16)	0.8 (0.69–0.92)	0.2036
Direct bilirubin	0.25 (0.24–0.25)	0.25 (0.24–0.26)	0.25 (0.22–0.28)	0.25 (0.2–0.32)	0.2 (0.17–0.23)	0.0759
AST (GOT)	25.89 (25.18–26.62)	25.8 (25.06–26.57)	26.89 (23.62–30.6)	27.99 (22.73–34.46)	24.75 (21.27–28.79)	0.6298
ALT (GPT)	24.76 (23.79–25.77)	24.74 (23.69–25.84)	24.28 (21.07–27.98)	29.79 (22.49–39.44)	23.53 (19.46–28.45)	0.5096
ALP	52.5±19.49	52.42±19.85	52.89±18.68	53.67±15.16	52.81±16.26	0.9932
γ-GTP	29.15 (27.58–30.81)	29.29 (27.56–31.12)	26.34 (21.9–31.68)	39.91 (28.25–56.4)	26.39 (20.68–33.69)	0.2116
Uric acid	5.49±1.33	5.46±1.35	5.53±1.27	6.11±1.1	5.53±1.25	0.3105
Calcium	9.28±0.42	9.27±0.39	9.38±0.67	9.46±0.36	9.22±0.42	0.0956
Phosphorus	3.56±0.49	3.55±0.45	3.58±0.64	3.6±0.8	3.65±0.75	0.7768
Total cholesterol	198.83±41.6	199.46±41.89	186.15±39.69	199.8±35.69	207.77±39.64	0.1324
Triglyceride	103.72 (99.26–108.39)	102.33 (97.69–107.19)	112.27 (93.41–134.93)	119.34 (79.59–178.95)	109.7 (85.84–140.19)	0.4867
HDL-cholesterol	54.47±13.93	54.92±14.26	52.09±11.87	51.27±12.23	51.31±10.19	0.2578
LDL-cholesterol	118.27±36.55	118.94±36.45	105.85±35.44	119.73±37.8	125.73±37.28	0.0855
Total protein	7.2±0.46	7.2±0.46	7.15±0.46	7.27±0.6	7.21±0.48	0.817
Albumin	4.49±0.28	4.49±0.27	4.46±0.28	4.45±0.29	4.39±0.4	0.2817
Sodium	143.49±2.03	143.51±2.06	143.78±1.72	143.53±1.55	142.73±2.05	0.2025
Potassium	4.26±0.3	4.26±0.3	4.23±0.28	4.25±0.4	4.37±0.4	0.2644
Chloride	105.53±2.28	105.54±2.29	105.96±1.95	105.2±1.93	104.77±2.7	0.1849

Values are presented as means±standard deviations or geometric mean (95% confidence interval).
HbA1c: glycated hemoglobin, AST: aspartate aminotransferase, GOT: glutamic oxaloacetic transaminase, ALT: alanine aminotransferase, GPT: glutamic pyruvic transaminase, ALP: alkaline phosphatase, γ-GTP: γ-glutamyl transpeptidase, CPK: creatine phosphokinase, HDL: high-density lipoprotein, LDL: low-density lipoprotein.
Analysis of variance test and Kruskal-Wallis test; [a)]P<0.05 vs. no bone loss by the Scheffé post hoc; [b)]P<0.05 vs. 2 and 3 mm by the Scheffé post hoc test; [c)] P<0.05 vs. 4 and 5 mm by the Scheffé post hoc test. [d)]Statistically significant difference (P<0.05).

Table 4. Severity of periodontitis and peri-implant bone loss

Variables	Total	Severity of periodontitis			
		1	2	3	P value
Number of subjects	709	161	275	273	
Peri-implant bone loss (≥2 mm)	105 (14.81)	9 (5.5)	32 (11.6)	64 (24.5)	<0.0001[a)]
Degree of bone loss					<0.0001[a)]
No bone loss (<2 mm)	611 (86.18)	153 (95.0)	245 (89.0)	213 (78.0)	
2 and 3 mm	51 (7.19)	5 (3.1)	17 (6.1)	29 (10.6)	
4 and 5 mm	18 (2.54)	2 (1.2)	8 (2.9)	8 (2.9)	
>5 mm	29 (4.09)	1 (0.6)	5 (1.8)	23 (8.4)	

Numbers of participants (%) are shown.
The χ² test. [a)]Statistically significant difference (P<0.05).

DISCUSSION

The current investigation explored the correlation between general health data and examination data from panoramic radiographs. Panoramic radiography is usually taken during dental treatment, as a variety of information about the entire maxilla-mandible can be obtained from a single radiograph [16]. Although panoramic radiography is convenient, the errors in the images may be greater than in other radiographic methods such as periapical radiography or computed tomography. These errors include overlapping with other structures and between teeth or different magnifications of the posterior and anterior tooth. Overlapping may make it difficult to evaluate the bone height around the tooth or implant, and due to different magnifications, implants with the same length and width may seem different in panoramic images. However, in health screening examinations, the advantage of

Table 5. Factors associated with peri-implant bone loss by univariate and stepwise multivariate analyses

Variables	Univariate		Stepwise multivariate	
	OR (95% CI)	P value	OR (95% CI)	P value
DM		0.0388[a]		
Normal	1 (Ref.)			
Pre-DM	1.862 (1.133–3.058)	0.014[a]		
DM	1.742 (0.883–3.436)	0.1093[a]		
Glucose	1.009 (0.999–1.019)	0.0687[a]		
HbA1c	1.342 (1.065–1.692)	0.0127[a]		
BUN	1.110 (1.054–1.168)	<0.000[a]	1.082 (1.027–1.141)	0.0034[a]
Creatinine	4.255 (1.394–12.987)	0.0109[a]		
Severity of periodontitis		<0.0001[a]		<0.000[a]
1	1 (Ref.)		1 (Ref.)	
2	3.184 (1.190–8.547)	0.0211[a]	3.154 (1.175–8.475)	0.0225[a]
3	8.772 (3.401–22.727)	<0.0001[a]	7.751 (3.003–20)	<0.0001[a]

OR with 95% CIs are shown. Univariate and stepwise multivariate regression analyses.
OR: odds ratio, CI: confidence interval, HbA1c: glycated hemoglobin, BUN: blood urea nitrogen.
[a]Statistically significant ($P<0.05$).

utilizing panoramic X-rays is that aspects of the overall oral condition, such as the number of teeth and implants and alveolar bone levels, can be perceived quickly.

A 5-year longitudinal study has shown that obese individuals may develop greater marginal bone loss compared to non-obese individuals, but the results of this study did not show a statistically significant correlation (P=0.1732) (**Supplementary Table 1**) [17]. Their mean marginal bone loss was 0.91 mm, while this study defined ≥2 mm of bone loss as peri-implantitis; therefore, an explanation for this discrepancy may be that early changes were not studied in this research. Obesity and tooth loss were not correlated, contrary to our expectations, but BMI and periodontitis showed a correlation as expected [18].

In this study, smoking did not show a correlation with the presence of periodontitis or peri-implantitis. However, the severity of periodontitis, the number of implants in the oral cavity, and the number of residual teeth were statistically significantly related to smoking. This suggests that smoking may not affect the onset of the disease, but may worsen its progression, leading to more tooth loss. However, many studies have also reported no correlation between peri-implantitis and smoking [19]. In Korea, according to the National Statistical Office, 36.7% of adult men and 7.5% of adult women smoked in 2018 [20]. Compared to non-smokers, smoking increases the susceptibility to periodontal disease and increases the severity and progression of periodontitis. The exact mechanism by which smoking affects periodontal disease is unknown, but oxidative stress and changes in immunoinflammatory systems appear to play an important role in the pathogenesis of smoking-associated periodontitis. This change in the immunoinflammatory system and the healing system may explain why the response to periodontal therapy in smokers is poorer than in non-smokers [21]. The intraoral changes caused by smoking tend to be dose-dependent and tend to improve to the same level as in non-smokers when smoking is stopped [22]. There is a risk of underreporting of smoking compared to assessing smoking status by cotinine levels, and this may have affected the study results [23].

DM has been closely linked to periodontal diseases in previous studies [24,25]. This relationship was confirmed by this investigation. DM is known to increase a patient's susceptibility to infection, and it may also affect bacterial pathogens in the periodontal pocket [26]. Periodontitis is a bacterial infection and can be affected by diabetes [25]. DM

is a significant risk factor for periodontitis, and this risk is greater in patients with poorly controlled diabetes, in whom the alveolar bone loss caused by periodontitis is also increased. In addition, controlling one's diabetes reduces the risk of periodontitis, and resolving periodontal inflammation may improve metabolic control [27]. In patients with controlled diabetes, the HbA1c levels decreased by approximately 0.4%p after the resolution of periodontal inflammation.

The BUN test measures the nitrogen portion of urea and is used as a marker for glomerular function; increased levels indicate impaired renal function [28]. An animal study on the effect of chronic kidney disease on osseointegration suggested that chronic kidney disease may impair healing in early stages [29]. Many studies have shown correlation between chronic kidney disease and periodontitis, and animal experiments indicating that periodontitis can have an impact on kidney disease have been reported [30].

Serum creatinine and alkaline phosphatase levels are known to be associated with periodontitis. Patients with severe periodontitis had significantly lower creatinine levels and higher ALP levels than patients without periodontitis [31]. When serum creatinine is lower, the risk of type 2 DM is increased. The biological basis for this change has not yet been elucidated. In this study, serum creatinine was associated with both periodontitis and peri-implantitis, but ALP did not have a statistically significant correlation with peri-implantitis (P=0.9932). ALP is an enzyme that originates from the liver or bone and used as an index of liver and bone disease. High ALP levels occur due to obstruction in the biliary duct, indicative of liver damage, or increased osteoblast activity and deposition of calcium on bone [28]. ALP has been found to be significantly higher in the gingival crevicular fluid (GCF) of periodontitis patients than in that of healthy or gingivitis patients. ALP has been suggested as a periodontal disease marker to distinguish inflammation [32]. However, ALP levels in the GCF around implants have not shown a statistically significant relationship with the bleeding index or plaque index [33]. In this study, serum ALP levels were studied, and the correlation was similar to the results seen in other researches [32,33]. A plausible cause for this difference in the relationship of ALP with periodontitis and peri-implantitis has not been offered, and this is an area that needs further research.

Bilirubin is a breakdown product of heme released from the lysis of aged or abnormal red blood cells. Recent research indicates that mildly elevated levels of bilirubin may be protective [34]. In this study, higher blood bilirubin levels were associated with greater periodontal and peri-implant bone loss. An increase in bilirubin in the blood means increased destruction of red blood cells and may indicate liver damage, such as in hepatitis, liver cirrhosis, or fatty liver. Although the test results were in the normal range (0.0–0.5 mg/dL), these results suggest that a correlation may exist between periodontal and liver diseases. The mechanism underlying the association of bilirubin with peri-implant and periodontal bone loss is unclear.

A meta-analysis has shown that peri-implantitis incidence and implant bone loss are more common in periodontitis patients [27]. Patients with aggressive periodontitis have higher risk of implant loss than patients with chronic periodontitis [35]. We decided to classify periodontal bone loss into 3 levels, as proposed by van der Velden [36,37]. Radiographic bone loss of stages I and II in the new classification would correspond to minor severity in van der Velden's proposal [38]. The OR of severe bone loss (7.751) was more than twice the value of moderate bone loss (3.154), and this was in turn more than 3 times greater than that of minor

bone loss. The severity of periodontal bone loss predicted peri-implant bone loss. The results of the multivariate analysis (**Table 5**) suggest that the correlation seen with DM and creatinine can be explained as reflecting the influence of periodontitis. Only BUN levels had statistical significance, and the OR was low.

Periodontitis and peri-implantitis cannot be said to be identical disease entities. However, their clinical features and treatment methods are quite similar [39]. The incidence of periodontitis and peri-implantitis is related. Periodontitis is a risk factor for peri-implantitis, periodontitis patients have greater implant bone loss, and periodontitis is a risk factor for implant loss [27]. In this study, periodontitis was closely correlated with peri-implantitis. Patients with periodontitis are recommended to receive careful maintenance care after dental implant treatment.

A limitation of this study is that, as a cross-sectional study utilizing health screening tests, it was not possible to acquire information on the time and circumstances of implant placement, and implant factors such as connection type, and prosthesis type were not investigated. In addition, information on the medications taken by patients for pre-existing conditions was not available.

This study showed that BMI and smoking were not correlated with peri-implant bone loss, but it would be prudent to advise weight loss and smoking cessation and more frequent maintenance visits because obesity and smoking impact overall health negatively. BUN, creatinine, glucose, and HbA1c levels showed correlations with both periodontal and peri-implant bone loss. AST, ALT, ALP, and γ-GTP levels showed correlations with periodontitis. Periodontitis has a bidirectional relationship with many diseases, and peri-implantitis may as well [40]. The maintenance of periodontal and peri-implant health will benefit the systemic health of the patient.

Further studies are needed to investigate the correlations between biochemical parameters and peri-implantitis. Patients with severe periodontitis are at greater risk of severe peri-implantitis, and vigilant maintenance care is recommended for dental implant patients with periodontitis.

SUPPLEMENTARY MATERIALS

Supplementary Table 1
BMI and oral parameters

Click here to view

Supplementary Table 2
Linear correlation between body mass index and number of teeth and implants

Click here to view

Supplementary Table 3
Smoking and oral parameters

Click here to view

REFERENCES

1. Albandar JM, Susin C, Hughes FJ. Manifestations of systemic diseases and conditions that affect the periodontal attachment apparatus: case definitions and diagnostic considerations. J Periodontol 2018;89 Suppl 1:S183-203.
   PUBMED | **CROSSREF**

2. Gelazius R, Poskevicius L, Sakavicius D, Grimuta V, Juodzbalys G. Dental implant placement in patients on bisphosphonate therapy: a systematic review. J Oral Maxillofac Res 2018;9:e2.
   PUBMED | **CROSSREF**

3. Ghezzi EM, Ship JA. Systemic diseases and their treatments in the elderly: impact on oral health. J Public Health Dent 2000;60:289-96.
   PUBMED | **CROSSREF**

4. Brånemark PI. Osseointegration and its experimental background. J Prosthet Dent 1983;50:399-410.
   PUBMED | **CROSSREF**

5. Raikar S, Talukdar P, Kumari S, Panda SK, Oommen VM, Prasad A. Factors affecting the survival rate of dental implants: a retrospective study. J Int Soc Prev Community Dent 2017;7:351-5.
   PUBMED | **CROSSREF**

6. Bornstein MM, Cionca N, Mombelli A. Systemic conditions and treatments as risks for implant therapy. Int J Oral Maxillofac Implants 2009;24 Suppl:12-27.
   PUBMED

7. Press release: Dental implants co-pay decreased to 30% for over 65s [Internet]. Sejong: Ministry of Health and Welfare; 2018 [cited 2022 Aug 10]. Available from: https://www.mohw.go.kr/react/al/sal0301vw.jsp?PAR_MENU_ID=04&MENU_ID=0403&SEARCHKEY=&SEARCHVALUE=&page=1&CONT_SEQ=344643.

8. Heitz-Mayfield LJ, Salvi GE. Peri-implant mucositis. J Clin Periodontol 2018;45 Suppl 20:S237-45.
   PUBMED | **CROSSREF**

9. Lee SE, Kim DY, Lee JB, Pang EK. Prevalence and risk factors of peri-implantitis: a retrospective study. J Korean Acad Prosthodont 2019;57:8-17.
   CROSSREF

10. Kordbacheh Changi K, Finkelstein J, Papapanou PN. Peri-implantitis prevalence, incidence rate, and risk factors: a study of electronic health records at a U.S. dental school. Clin Oral Implants Res 2019;30:306-14.
    PUBMED | **CROSSREF**

11. Ahn DH, Kim HJ, Joo JY, Lee JY. Prevalence and risk factors of peri-implant mucositis and peri-implantitis after at least 7 years of loading. J Periodontal Implant Sci 2019;49:397-405.
    PUBMED | **CROSSREF**

12. Yanbaeva DG, Dentener MA, Creutzberg EC, Wesseling G, Wouters EF. Systemic effects of smoking. Chest 2007;131:1557-66.
    PUBMED | **CROSSREF**

13. ALHarthi SS, Natto ZS, Midle JB, Gyurko R, O'Neill R, Steffensen B; SSY AL. Association between time since quitting smoking and periodontitis in former smokers in the National Health and Nutrition Examination Surveys (NHANES) 2009 to 2012. J Periodontol 2019;90:16-25.
    PUBMED | **CROSSREF**

14. Delatola C, Loos BG, Levin E, Laine ML. At least three phenotypes exist among periodontitis patients. J Clin Periodontol 2017;44:1068-76.
    PUBMED | **CROSSREF**

15. Padial-Molina M, Suarez F, Rios HF, Galindo-Moreno P, Wang HL. Guidelines for the diagnosis and treatment of peri-implant diseases. Int J Periodont Restor Dent 2014;34:e102-11.
    PUBMED | **CROSSREF**

16. Choi JW. Assessment of panoramic radiography as a national oral examination tool: review of the literature. Imaging Sci Dent 2011;41:1-6.
    PUBMED | **CROSSREF**

17. Alkhudhairy F, Vohra F, Al-Kheraif AA, Akram Z. Comparison of clinical and radiographic peri-implant parameters among obese and non-obese patients: a 5-year study. Clin Implant Dent Relat Res 2018;20:756-62.
    PUBMED | **CROSSREF**

18. Kim YT, Choi JK, Kim DH, Jeong SN, Lee JH. Association between health status and tooth loss in Korean adults: longitudinal results from the National Health Insurance Service-Health Examinee Cohort, 2002-2015. J Periodontal Implant Sci 2019;49:158-70.
    PUBMED | **CROSSREF**

19. Monje A, Wang HL, Nart J. Association of preventive maintenance therapy compliance and peri-implant diseases: a cross-sectional study. J Periodontol 2017;88:1030-41.
PUBMED | CROSSREF

20. Current smoking rate [Internet]. Daejeon: Korean Statistical Information Service; 2022 [cited 2022 Aug 14]. Available from: https://kosis.kr/statHtml/statHtml.do?orgId=177&tblId=DT_11702_N001&vw_cd=&list_id=&scrId=&seqNo=&lang_mode=ko&obj_var_id=&itm_id=&conn_path=K1.

21. Nociti FH Jr, Casati MZ, Duarte PM. Current perspective of the impact of smoking on the progression and treatment of periodontitis. Periodontol 2000 2015;67:187-210.
PUBMED | CROSSREF

22. Bergström J, Eliasson S, Dock J. A 10-year prospective study of tobacco smoking and periodontal health. J Periodontol 2000;71:1338-47.
PUBMED | CROSSREF

23. Park MB, Kim CB, Nam EW, Hong KS. Does South Korea have hidden female smokers: discrepancies in smoking rates between self-reports and urinary cotinine level. BMC Womens Health 2014;14:156.
PUBMED | CROSSREF

24. Preshaw PM, Alba AL, Herrera D, Jepsen S, Konstantinidis A, Makrilakis K, et al. Periodontitis and diabetes: a two-way relationship. Diabetologia 2012;55:21-31.
PUBMED | CROSSREF

25. Llambés F, Arias-Herrera S, Caffesse R. Relationship between diabetes and periodontal infection. World J Diabetes 2015;6:927-35.
PUBMED | CROSSREF

26. Montevecchi M, Valeriani L, Gatto MR, D'Alessandro G, Piana G. Subgingival pathogens in chronic periodontitis patients affected by type 2 diabetes mellitus: a retrospective case-control study. J Periodontal Implant Sci 2021;51:409-21.
PUBMED | CROSSREF

27. Sgolastra F, Petrucci A, Severino M, Gatto R, Monaco A. Periodontitis, implant loss and peri-implantitis. A meta-analysis. Clin Oral Implants Res 2015;26:e8-16.
PUBMED | CROSSREF

28. Fischbach FT, Margaret A. Fischbach's A manual of laboratory and diagnostic tests. 10th ed. Philadelphia: Wolter Kluwer; 2018.

29. Zou H, Zhao X, Sun N, Zhang S, Sato T, Yu H, et al. Effect of chronic kidney disease on the healing of titanium implants. Bone 2013;56:410-5.
PUBMED | CROSSREF

30. Li L, Zhang YL, Liu XY, Meng X, Zhao RQ, Ou LL, et al. Periodontitis exacerbates and promotes the progression of chronic kidney disease through oral flora, cytokines, and oxidative stress. Front Microbiol 2021;12:656372.
PUBMED | CROSSREF

31. Caúla AL, Lira-Junior R, Tinoco EM, Fischer RG. Serum creatinine and alkaline phosphatase levels are associated with severe chronic periodontitis. J Periodontal Res 2015;50:793-7.
PUBMED | CROSSREF

32. Malhotra R, Grover V, Kapoor A, Kapur R. Alkaline phosphatase as a periodontal disease marker. Indian J Dent Res 2010;21:531-6.
PUBMED | CROSSREF

33. Paknejad M, Emtiaz S, Khoobyari MM, Gharb MT, Yazdi MT. Analysis of aspartate aminotransferase and alkaline phosphatase in crevicular fluid from implants with and without peri-implantitis. Implant Dent 2006;15:62-9.
PUBMED | CROSSREF

34. Creeden JF, Gordon DM, Stec DE, Hinds TD Jr. Bilirubin as a metabolic hormone: the physiological relevance of low levels. Am J Physiol Endocrinol Metab 2021;320:E191-207.
PUBMED | CROSSREF

35. Theodoridis C, Grigoriadis A, Menexes G, Vouros I. Outcomes of implant therapy in patients with a history of aggressive periodontitis. A systematic review and meta-analysis. Clin Oral Investig 2017;21:485-503.
PUBMED | CROSSREF

36. Van der Velden U. Diagnosis of periodontitis. J Clin Periodontol 2000;27:960-1.
PUBMED | CROSSREF

37. van der Velden U. Purpose and problems of periodontal disease classification. Periodontol 2000 2005;39:13-21.
PUBMED | CROSSREF

38. Tonetti MS, Greenwell H, Kornman KS. Staging and grading of periodontitis: Framework and proposal of a new classification and case definition. J Periodontol 2018;89 Suppl 1:S159-72.
PUBMED | CROSSREF

39. Meffert RM. Periodontitis vs. peri-implantitis: the same disease? The same treatment? Crit Rev Oral Biol Med 1996;7:278-91.
PUBMED | CROSSREF

40. Chaushu L, Tal H, Sculean A, Fernández-Tomé B, Chaushu G. Effects of peri-implant infection on serum biochemical analysis. J Periodontol 2021;92:436-45.
PUBMED | CROSSREF