jdhs
Journal of Dental Hygiene Science

J Dent Hyg Sci Vol. 22, No. 2, 2022, pp.99-107
https://doi.org/10.17135/jdhs.2022.22.2.99

RESEARCH ARTICLE

Relationship between Obesity, Gingival Inflammation, and Periodontal Bacteria after 4-Week Weight Control Program in 20's

Min-Seock Seo[1] and Soo-Jeong Hwang[2,†]

[1]Department of Conservative Dentistry, Wonkang University Daejeon Dental Hospital, Daejeon 35233,
[2]Department of Dentistry, Doonsan Health Promotion Center, Daejeon 35230, Korea

Background: Obesity weakens acquired immunity and causes infection. This study aimed to investigate the relationship between the inflammatory markers in the gingival crevicular fluid and serum and *periodontal bacteria* in saliva through obesity control for 4 weeks.

Methods: Forty-six subjects with a body mass index (BMI) of ≥23 kg/m^2 stayed in the camp for 4 weeks, followed by exercise and a low salt-low fat diet. Body size measurements, oral examinations, blood, saliva, and gingival crevicular fluid were collected before and after the program. C-reactive protein (CRP) in serum, matrix metalloproteinase (MMP)-8, MMP-9, and interleukin (IL)-1β in the gingival sulcus fluid were measured. After extracting bacterial genomic DNA from saliva, the presence of periodontal bacteria were detected using Taq probe. The relationship of each index before and after the program was analyzed through paired t-test and partial correlation analysis.

Results: *Campylobacter rectus* (*Cr*) increased after the program, and there was no significant change in other bacteria. Serum CRP and *Fusobacterium nucleatum* (*Fn*), *Aggregatibacter actinomycetemcomitans*, *Cr*, ratio of *Fn*, and ratio of *Cr* had a positive relationship at baseline; however, the relationship was not significant after the program. Ratio of *Prevotella intermedia* had a positive relationship with MMP-9, MMP-8, IL-1β at baseline. Moreover, the ratio of *Treponema denticola* and the ratio of *Tannerella forsythia* showed a positive relationship with MMP-8, MMP-9, and IL-1β. The relationship between the ratio of *Porphyromonas gingivalis* and IL-1β showed a constant positive relationship at baseline and after the program.

Conclusion: Obesity control program in subjects with a BMI of ≥23 kg/m^2 accompanied by diet and exercise did not affect the changes in periodontal bacteria itself, but changes in the relationship between periodontal bacteria and serum CRP, the relationship between the inflammatory index in the gingival crevicular fluid and periodontal bacteria was observed.

Key Words: Bacteria, Inflammation, Obesity, Periodontal diseases

Introduction

Infection may be the cause or the effect of obesity and the two phenomena are in a relationship of mutual interaction[1)]. Obesity reduces the acquired immunity and induces changes in cellular immunity to cause infection[2)]. There are claims that an increase in adipocytes aggravates chronic inflammation and that obesity itself is chronic inflammation[3)]. On the contrary, the term 'infectobesity' was coined based on the observation that obesity could be induced by viral or bacterial infection[4)]. Studies have reported that obesity increased upon the use of antibiotics[5)], or that the gut microbiota could be used in the treatment of obesity[6)].

Periodontal diseases are a form of chronic inflammation, and the relationship between obesity and periodontal diseases has been continuously investigated since the 1970s. Alveolar bone resorption in obese mice was

Received: May 26, 2022, **Revised:** June 2, 2022, **Accepted:** June 8, 2022
eISSN 2233-7679

†Correspondence to: Soo-Jeong Hwang, *https://orcid.org/0000-0003-4725-1512*
Department of Dentistry, Doonsan Health Promotion Center, 60, Daedeok-daero 175beon-gil, Seo-gu, Daejeon 35230, Korea
Tel: +82-42-488-4671, Fax: +82-42-488-4676, E-mail: denthwang@daum.net

reported[7], and the alteration in macrophage function was observed in mice infected with *Porphyromonas gingivalis* (*Pg*) after diet-induced obesity[8]. In a meta-analysis on the prevalence of obesity in patients with periodontal diseases, the odds ratio was significantly high in approximately 1/3 of studies[9]. A 4-week weight control program was shown to decrease the levels of matrix metalloproteinase (MMP)-8, MMP-9, and interleukin (IL)-1β in gingival crevicular fluid (GCF)[10]. In contrast, another meta-analysis claimed that no significant variation in periodontal inflammation indices was found for healthy and obese individuals and the current evidence was insufficient[11].

Periodontal diseases are fundamentally an inflammatory response caused via the infection of periodontal tissues by the Gram negative bacteria. However, only a few studies have reported on the influence or correlation of obesity on or with the oral microbiota. The presence of *Selenomonas noxia* was confirmed in 98.4% of obese females[12] and high levels of *Proteobacteria phylum*, *Campylobacter rectus* (*Cr*) and *Neisseria mucosa* were observed in the sub-gingival plaque in obese children[13]. While a cross-sectional study may be conducted to investigate the influence of obesity on periodontal microbiota, accurate analyses may be difficult regarding the independent relationship between obesity and periodontal bacteria due to the differences in oral health habits and gingival states between obese and healthy subjects. Thus, this study aimed to investigate the change in periodontal bacteria and determine the relationship between obesity and periodontal bacteria. For this, among the subjects in a preceding study[10], those in 20s and with body weight above the overweight criteria of the Asia-Pacific obesity criteria were recruited, and the obesity index was controlled through diet control and exercise training without any intervention of periodontal treatments or oral health behaviors.

Materials and Methods

The participants of this study were the same subjects as those of Park et al.[10]; the individuals in 20s who followed a 4-week program consisting of diet control and exercise training for weight loss. Prior to the program, those with body mass index (BMI) <23 kg/m^2 or a missing value among the analytic indices were excluded to leave a total of 46 participants for analyses. Among the 46 participants, 32 were females (69.6%) and 14 were males (30.4%). Six individuals had BMI ≥ 23 kg/m^2 and <25 kg/m^2 (13.0%) and 40 individuals had BMI ≥ 25 kg/m^2 (87.0%). The participants stayed in a camp for four weeks and performed each day two hours of aerobic exercise, three hours of weight training and a low salt-low fat diet ($\leq$1,300 kcal/day).

The oral examination before and after weight control was performed by one dentist (SJH). Two indices were used; the dental plaque index and the gingival index. The dental plaque index was measured as the dental state after the usual brushing and was thus measured after brushing using the Sum of Turesky modification of the Quigley-Hein Index (STQHI). The gingival index was measures as the level of inflammation using the Sum of Löe-Silness Gingival Index (SLSGI).

Before and after weight control, the physical measurements were taken and after blood collection, the levels of low-density lipoprotein (LDL), high-density lipoprotein (HDL), triglycerides, and C-reactive protein (CRP) were measured. The levels of MMP-8, MMP-9, and IL-1β in the GCF were also measured. The measurements using blood samples were performed at the Dept. of Laboratory Medicine of Konyang University Hospital (Daejeon, Korea) and to estimate the inflammatory indices in the GCF, the Human IL-1β ELISA Kit (Promokine, Heidelberg, Germany), Quantikine human MMP-8 (R&D systems, Minneapolis, MN, USA) and Quantikine human MMP-9 (R&D systems) were used. The blood and GCF samples were analyzed three times and the mean of triplicate was obtained as the representative values.

The saliva samples stored at -20°C were sent to the DocsMedi Laboratory of Appletree Dental Hospital (Ilsan, Korea) for the test of periodontal bacteria. The ExiPrepDx Bacteria Genomic DNA Kit (Bioneer, Daejeon, Korea) was used to extract the bacterial genomic DNA from the saliva. The RT-qPCR (Exicycler^{TM} 96, Bioneer) was used to detect the *Aggregatibacter actinomycetemcomitans* (*Aa*), *Prevotella intermedia* (*Pi*), *Pg*, *Fusobacterium nucleatum* (*Fn*), *Tannerella forsythia* (*Tf*), *Treponema denticola* (*Td*)

and *Cr* using the Taq probe. For the AccuPower® Holobio P Kit (Bioneer), 5 mL of bacterial genomic DNA was mixed with 45 mL of water of molecular grade and the RT-qPCR was run with 5 minutes denaturation at 95°C and subsequently in PCR conditions (5 s at 95°C; 20 s at 56°C). All procedures were performed in compliance with the manufacturer's manual. The total bacterial count in saliva was quantified based on the homologous areas of the 16S rRNA, which served as the denominator in the calculation of the proportion of target bacterial species.

For statistical analyses, the variation before and after weight control was analyzed by paired t-test and the correlation of each index was analyzed by the partial correlation analysis (PCA) after controlling the dental plaque index and the gingival index. The two indices were controlled as they could affect the bacterial indices, while this study mainly aimed to analyze the change in periodontal bacteria based on obesity control. All statistical analyses

Table 1. Change in BMI, Inflammatory Index in Serum, Inflammatory Index in GCF, Plaque Index, and Gingival Index through 4-Week Weight Control Program (n=46)

Index	Baseline	After 4-week weight control	p-value[a]
BMI (kg/m^2)	27.83±2.88	25.54±2.33	<0.001
CRP in serum (mg/dL)	0.21±0.22	0.29±1.28	0.674
LDL in serum (mg/dL)	123.04±24.61	87.87±17.59	<0.001
HDL in serum (mg/dL)	54.30±9.51	54.32±10.19	0.984
Triglyceride (mg/dL)	58.11±13.40	71.94±13.77	<0.001
MMP-9 in GCF (ng/mL)	10.52±5.54	5.80±5.12	<0.001
MMP-8 in GCF (ng/mL)	8.08±6.36	3.31±4.19	<0.001
IL-1β in GCF (pg/mL)	101.59±63.36	39.55±41.39	<0.001
Plaque index	50.65±17.08	72.26±31.47	<0.001
Gingival index	22.63±52.88	20.61±31.39	0.744

BMI: body mass index, GCF: gingival crevicular fluid, CRP: C-reactive protein, LDL: low-density lipoprotein, HDL: high-density lipoprotein, MMP: matrix metalloproteinase, IL: interleukin.
[a]Paired t-test.

Table 2. Change in the Amount of Periodontal Bacteria through 4-Week Weight Control Program (n=46)

Bacteria	Baseline	After 4-week weight control	p-value[a]
Total bacteria	$1.4846\times10^6\pm1.3634\times10^6$	$1.5865\times10^6\pm1.3382\times10^6$	0.369
Fn	2,680.17±4,085.66	4,345.52±10,354.82	0.313
Aa	2,196.24±6,056.90	4,839.61±17,168.15	0.370
Pi	169.52±506.18	315.22±585.34	0.140
Pg	66.39±198.98	64.97±102.57	0.956
Tf	174.50±288.88	138.28±278.88	0.382
Cr	359.04±331.32	959.09±2,005.59	0.044
Td	705.70±1197.96	1,012.76±1,519.37	0.143
Ratio of *Fn* (%)	19.30±23.50	21.76±24.93	0.639
Ratio of *Aa* (%)	11.54±28.98	15.78±47.50	0.295
Ratio of *Pi* (%)	0.85±2.74	2.33±5.38	0.069
Ratio of *Pg* (%)	0.35±0.97	0.33±0.89	0.864
Ratio of *Tf* (%)	0.80±1.56	0.57±1.62	0.414
Ratio of *Cr* (%)	3.00±3.57	5.30±6.59	0.025
Ratio of *Td* (%)	6.61±10.12	7.11±12.18	0.777

Values are presented as mean±standard deviation.
Ratio of each bacteria=amount of each bacteria/amount of total bacteria.
Fn: *Fusobacterium nucleatum, Aa*: *Aggregatibacter actinomycetemcomitans, Pi*: *Prevotella intermedia, Pg*: *Porphyromonas gingivalis, Tf*: *Tannerella forsythia, Cr*: *Campylobacter rectus, Td*: *Treponema denticola*.
[a]Paired t-test.

were performed using the IBM SPSS 20.0 (IBM Corp., Armonk, NY, USA) with the level of significance set to 0.05.

Results

1. The change in body mass index, serum lipid levels, gingival crevicular fluid inflammatory indices and oral indices before and after obesity control

As shown in Table 1, the participants showed a significant fall in BMI through the 4-week program of exercise and diet control. The serum LDL was significantly reduced ($p < 0.001$). The levels of MMP-8, MMP-9, and IL-1β in the GCF were also significantly reduced after the obesity control program ($p < 0.001$). However, the plaque index was increased ($p < 0.001$) and despite weight loss, the serum triglyceride was increased ($p < 0.001$).

2. The change in periodontal bacteria in saliva before and after obesity control

As shown in Table 2, no significant change was found after the obesity control program for the total bacterial count in saliva or for *Fn*, *Aa*, *Pi*, *Pg*, *Tf*, and *Td*, while *Cr* showed a significant increase ($p=0.044$) and the ratio of *Cr* showed a significant increase ($p=0.025$).

3. The correlation of periodontal bacteria in saliva with the serum and gingival crevicular fluid indices before obesity control

As shown in Table 3, no correlation was found between serum lipid indices and GCF inflammatory indices in the PCA controlled for the plaque index and the gingival index based on the pre-intervention data. The BMI was negatively correlated with the total bacterial count and Fn. The plasma CRP showed a weak positive correlation with *Fn* ($r=0.330$), *Aa* ($r=0.447$), *Cr* ($r=0.384$), ratio of *Fn*

Table 3. Relationship between Obesity Index, Inflammation Index in GCF, and Periodontal Bacteria in Saliva at Baseline

	BMI	CRP	LDL	HDL	Triglyceride	MMP-9	MMP-8	IL-1β
CRP	0.202							
LDL	0.101	0.105						
HDL	−0.150	−0.199	0.228					
Triglyceride	0.389*	0.125	0.313	−0.286				
MMP-9	−0.250	−0.211	−0.049	0.063	0.017			
MMP-8	−0.089	−0.110	0.023	0.197	0.127	0.780*		
IL-1β	−0.041	−0.388*	−0.043	0.109	−0.077	0.555*	0.360*	
Fn	−0.301*	0.330*	0.270	0.210	−0.097	0.017	−0.113	0.082
Aa	0.000	0.447*	−0.093	0.128	−0.209	−0.135	−0.171	−0.148
Pi	−0.037	−0.089	0.008	0.145	−0.127	0.247	0.260	0.231
Pg	0.060	−0.091	−0.042	0.113	−0.120	0.141	0.118	0.244
Tf	−0.007	−0.049	−0.085	0.145	−0.1048	0.124	0.161	0.148
Cr	−0.240	0.384*	0.101	0.098	−0.008	0.054	0.053	0.073
Td	0.002	−0.163	0.089	0.209	−0.221	0.116	0.184	0.264
Total bacteria	−0.344*	−0.057	0.086	0.336*	−0.261	0.167	−0.017	0.164
Ratio of *Fn*	−0.147	0.396*	0.261	0.101	−0.065	−0.100	−0.094	−0.027
Ratio of *Aa*	−0.033	0.081	−0.054	0.090	0.134	−0.049	−0.079	−0.042
Ratio of *Pi*	−0.135	−0.222	0.011	0.146	−0.105	0.348*	0.333*	0.304*
Ratio of *Pg*	0.214	−0.172	−0.127	0.265	−0.168	0.075	0.091	0.435*
Ratio of *Tf*	−0.090	−0.143	0.041	0.016	0.118	0.212	0.186	0.148
Ratio of *Cr*	0.000	0.313*	−0.044	−0.163	0.011	0.007	−0.057	0.075
Ratio of *Td*	0.098	−0.107	0.030	0.076	−0.154	0.054	0.092	0.273

GCF: gingival crevicular fluid, BMI: body mass index, CRP: C-reactive protein, LDL: low-density lipoprotein, HDL: high-density lipoprotein, MMP: matrix metalloproteinase, IL: interleukin, *Fn*: *Fusobacterium nucleatum, Aa*: *Aggregatibacter actinomycetemcomitans, Pi*: *Prevotella intermedia, Pg*: *Porphyromonas gingivalis, Tf*: *Tannerella forsythia, Cr*: *Campylobacter rectus, Td*: *Treponema denticola*.
*$p < 0.05$ adjusted by plaque index and gingival index.

(r=0.396), and ratio of *Cr* (r=0.313). The ratio of *Pi* showed a weak positive correlation with MMP-9 (r=0.348), MMP-8 (r=0.333), and IL-1β (r=0.304) in the GCF. The IL-1β in the GCF was also positively correlated with the ratio of *Pg* (r=0.435).

4. The correlation among the periodontal bacteria in saliva before obesity control

As shown in Table 4, the pre-intervention PCA showed significant correlations among 15 out of 28 bacterial strains. A positive correlation was shown by *Pi* with *Pg* (r=0.840), *Tf* (r=0.905), *Cr* (r=0.434), *Td* (r=0.372) and

Table 4. Relationship between Periodontal Bacteria in Saliva at Baseline

	Fn	*Aa*	*Pi*	*Pg*	*Tf*	*Cr*	*Td*
Aa	0.208						
Pi	0.049	0.285					
Pg	0.034	0.215	0.840*				
Tf	0.014	0.362*	0.905*	0.743*			
Cr	0.447*	0.372*	0.434*	0.424*	0.430*		
Td	−0.031	0.078	0.372*	0.203	0.366*	0.214	
Universal	0.617*	0.229	0.308*	0.205	0.353*	0.311*	0.016

Fn: *Fusobacterium nucleatum, Aa*: *Aggregatibacter actinomycetemcomitans, Pi*: *Prevotella intermedia, Pg*: *Porphyromonas gingivalis, Tf*: *Tannerella forsythia, Cr*: *Campylobacter rectus, Td*: *Treponema denticola*.
*p < 0.05 adjusted by plaque index and gingival index.

Table 5. Relationship between Obesity Index, Inflammation Index in GCF, and Periodontal Bacteria in Saliva after 4-Week Weight Control Program

	BMI	CRP	LDL	HDL	Triglyceride	MMP-9	MMP-8	IL-1β
CRP	−0.023							
LDL	−0.204	0.195						
HDL	−0.340*	−0.215	0.006					
Triglyceride	0.187	0.054	0.057	−0.106				
MMP-9	0.111	0.196	−0.197	−0.062	0.022			
MMP-8	0.191	0.259	0.018	0.121	−0.079	0.519*		
IL-1β	0.388*	0.223	−0.133	0.058	−0.185	0.363*	0.801*	
Fn	−0.070	−0.022	0.008	−0.022	−0.081	−0.140	−0.192	−0.164
Aa	0.051	−0.118	0.210	−0.140	−0.020	−0.139	−0.200	−0.085
Pi	−0.108	−0.019	0.062	0.008	−0.194	0.047	0.017	−0.007
Pg	0.032	−0.102	−0.428*	−0.073	−0.338*	0.237	0.110	0.274
Tf	−0.128	−0.011	−0.217	0.060	−0.109	0.130	0.125	0.117
Cr	0.071	0.016	−0.080	−0.144	0.006	−0.026	−0.065	0.017
Td	0.175	−0.033	−0.273	−0.063	−0.140	0.175	0.180	0.248
Total bacteria	−0.042	−0.007	−0.095	−0.055	−0.025	−0.101	−0.271	−0.224
Ratio of *Fn*	0.054	−0.075	−0.034	−0.159	−0.036	−0.115	−0.147	−0.082
Ratio of *Aa*	0.039	−0.116	0.189	−0.149	−0.045	−0.142	−0.189	−0.061
Ratio of *Pi*	−0.001	−0.005	0.115	−0.042	−0.119	0.140	0.098	0.033
Ratio of *Pg*	0.192	−0.060	−0.335*	−0.035	−0.251	0.291	0.269	0.539*
Ratio of *Tf*	0.063	−0.038	−0.329*	0.035	−0.144	0.291	0.327*	0.369*
Ratio of *Cr*	0.040	−0.004	−0.043	−0.243	0.025	0.006	0.044	0.165
Ratio of *Td*	0.327*	−0.068	−0.230	−0.047	−0.106	0.311*	0.345*	0.460*

GCF: gingival crevicular fluid, BMI: body mass index, CRP: C-reactive protein, LDL: low-density lipoprotein, HDL: high-density lipoprotein, MMP: matrix metalloproteinase, IL: interleukin, *Fn*: *Fusobacterium nucleatum, Aa*: *Aggregatibacter actinomycetemcomitans, Pi*: *Prevotella intermedia, Pg*: *Porphyromonas gingivalis, Tf*: *Tannerella forsythia, Cr*: *Campylobacter rectus, Td*: *Treponema denticola*.
*p < 0.05 adjusted by plaque index and gingival index.

total bacterial count (r=0.308), and by *Cr* with *Fn* (r=0.447), *Aa* (r=0.372), *Pi* (r=0.434), *Pg* (r=0.424), *Tf* (r=0.430) and total bacterial count (r=0.311). *Tf* showed a significant positive correlation with all bacterial strains except *Fn*. Total bacterial count was positively correlated with *Fn* (r=0.617), *Pi* (r=0.308), *Tf* (r=0.353), and *Cr* (r=0.311).

5. The correlation of periodontal bacteria in saliva with the serum and gingival crevicular fluid indices after obesity control

As shown in Table 5, no correlation was found between serum lipid indices and GCF inflammatory indices in the PCA controlled for the plaque index and the gingival index based on the post-intervention data. A weak positive correlation was shown by BMI with IL-1β (r=0.388) and ratio of *Td* (r=0.327). In contrast to the pre-intervention data, the serum CRP and periodontal bacteria did not exhibit a significant correlation, while certain lipid indices and bacterial strains displayed a negative correlation: *Pg* and LDL (r=−0.428), *Pg* and triglyceride (r=−0.338), ratio of *Pg* and LDL (r=−0.335), and ratio of *Tf* and LDL (r=−0.329). The inflammatory indices in the GCF were positively correlated with a number of periodontal bacteria: ratio of *Pg* and IL-1β (r=0.539), ratio of *Tf* and MMP-8 (r=0.327), ratio of *Tf* and IL-1β (r=0.369), ratio of *Td* and MMP-9 (r=0.311), ratio of *Td* and MMP-8 (r=0.345), and ratio of *Td* and IL-1β (r=0.460).

6. The correlation among the periodontal bacteria in saliva before obesity control

As shown in Table 6, the post-intervention data varied from the pre-intervention data; the post-intervention PCA showed significant correlations among 13 out of 28 bacterial strains. *Cr* displayed a significant correlation with total bacterial count (r=0.632) and *Td* (r=0.332) but no other strains. *Pi* showed a significant correlation with *Tf* (r=0.505) but no other strains. Compared to the time before obesity control, Fn was found to be correlated with a greater number of bacterial strains; *Aa* (r=0.332), *Tf* (r=0.555), and *Td* (r=0.478), and the positive correlation coefficient with total bacterial count (r=0.634) was also higher.

Discussion

Recently, an increasing number of studies are investigating the relationship between obesity and periodontal bacteria compared to the past. In the study by Tam et al.[14], conducted on Type II diabetes patients, the diversity and composition of oral microbiota significantly varied between the group with BMI ≥ 30 kg/m^2 and the group with BMI < 30 kg/m^2. Thomas et al.[15] conducted microbial analyses on 19 patients with periodontitis and showed that the periodontal state in obese subjects was far more deteriorated with a larger number of missing tooth and a higher score of periodontal-support loss as well as a higher level of the *Capnocytophaga* genus. In de Andrade et al.[16], conducted on 29 healthy, 26 overweight and 22 obese individuals, the level of supra-gingival plaque was

Table 6. Relationship between Periodontal Bacteria in Saliva at Baseline

	Fn	*Aa*	*Pi*	*Pg*	*Tf*	*Cr*	*Td*
Aa	0.332*						
Pi	0.091	0.036					
Pg	0.049	−0.115	0.307				
Tf	0.555*	−0.052	0.505*	0.457*			
Cr	0.278	0.166	0.005	0.008	0.180		
Td	0.478*	−0.046	0.293	0.509*	0.717*	0.332*	
Universal	0.634*	0.334*	0.041	−0.029	0.425*	0.632*	0.332*

Fn: *Fusobacterium nucleatum, Aa*: *Aggregatibacter actinomycetemcomitans, Pi*: *Prevotella intermedia, Pg*: *Porphyromonas gingivalis, Tf*: *Tannerella forsythia, Cr*: *Campylobacter rectus, Td*: *Treponema denticola*.
*p < 0.05 adjusted by plaque index and gingival index.

significantly lower in healthy individuals, while the levels of *Pg* and *Tf* were significantly higher in obese individuals. In addition, the physical indices of obesity were positively correlated with *Prevotella* spp., *Lactobacillus* spp., *Veillonella parvula*, and *Aa*, while they were negatively correlated with *Capnocytophaga* spp.[16]. These studies were cross-sectional studies reporting a deteriorated state of periodontal health in obese individuals; nevertheless, the result may have been due to personal oral health habits or variation in oral states so that it is difficult to clearly identify the correlation between obesity and the increased levels of reported strains.

In a preceding study, the present investigator reported a fall in inflammatory indices of periodontal health achieved through an obesity control program consisting of physical activity and diet control[10]. The study[10] had not applied other interventions such as oral health education or periodontal treatment and thus showed the direct effect of controlling the obesity indices on the other indices examined in the study, compared to previous cross-sectional studies. The results in this study were obtained through additional analyses of the periodontal bacteria in saliva from the same subjects as with the preceding study[10], and the focus of the study was on identifying the correlations among physical obesity indices, serum lipid levels, CRP indices, GCF inflammatory indices and periodontal bacteria. Contradictory to the prediction, however, the bacteria in saliva fluctuated in the mean values of *Fn, Aa, Pi, Pg*, and *Td* as well as total bacterial count before and after the obesity control, with a large standard deviation and hence, no statistical significance. Of note was the significant increase in *Cr* and ratio of *Cr* after the 4-week program, compared to the baseline. In Zeigler et al.[13], six-fold greater levels of *Cr* and *N. mucosa* were detected in the sub-gingival plaque in obese children. Goodson et al.[17] showed significantly high levels of periodontal bacteria including *Cr* in the saliva of overweight group in their cross-sectional study, while the only low level was that of *Eikenella corrodens*. As a cross-sectional study, the study cannot be directly compared with the present study, but it is noteworthy that their result of an increase in *Cr* in obesity was in contrast to the present study. In the Mediterranean diet intervention study[18], the serum CRP as well as periodontal bacteria showed a fall after eight weeks of diet control with a significant change in *Pi*. Regarding the *Capnocytophaga* genus, it is too early to dismiss the result in this study as it contradicts the results in previous studies, because the two studies; Thomas et al.[15] and de Andrade et al.[16] also reported contrasting results. In addition, the significant increase in dental plaque index following the program in this study implied the need to conduct a follow-up study to determine the influence of the respective index.

Correlation analyses were performed on each index in this study at the base line and after the 4-week obesity control program, as it was necessary to investigate the correlation of the periodontal bacteria in saliva and other indices. While no intervention on oral health had been provided, the dental plaque index showed an increase following the program so that the respective index was excluded in the PCA. The periodontal bacteria showed a positive correlation with serum CRP inflammatory indices; *Fn, Aa*, and *Cr*, at the baseline but not after the 4-week program. On the other hand, a steady positive correlation was found for the periodontal bacteria and the GCF inflammatory indices; ratio of *Pg* and IL-1β, both at the baseline and after the 4-week program. A positive correlation was found for the ratio of *Pi* with MMP-9, MMP-8, and IL-1β at the baseline, but after the 4-week program, MMP-8, MMP-9, and IL-1β showed a positive correlation with the ratio of *Td*, while MMP-8 and IL-1β showed a positive correlation with the ratio of *Tf*, to indicate variations in bacterial strains positively correlated with GCF inflammatory indices. The correlations among periodontal bacteria also showed inconsistent results at the baseline and after the 4-week program, while the correlation coefficients with significance after the program decreased compared to the baseline. The results collectively indicated that, although no significant change in the count or proportion of periodontal bacteria was observed after the obesity control program, variations were detected for the correlations of the periodontal bacteria with the serum or saliva inflammatory indices as well as the correlations among periodontal bacteria.

In a study by Maciel et al.[19], normal weight subjects with periodontitis showed a positive correlation between

the WHR and the proportions of *E. nodatum*, *Pi*, and *Streptococcus constellatus*, while obese subjects with a healthy periodontal state had the waist-hip ratio (WHR) and BMI in a positive correlation with the proportion of *Tf* and obese subjects with periodontitis had the BMI in a positive correlation with *Fusobacterium polymorphum* and *Fusobacterium periodonticum*. The study thus showed variations in bacterial strains in a significant correlation with obesity indices in accordance with the level of obesity and periodontal health. In a study on obesity and periodontal bacteria in individuals without a destructive periodontal disease[16], a weak positive correlation was found between *Td* and obesity indices. The study stated that a significant criteria to distinguish between overweight/ obese and normal weight individuals was the *Prevotella* spp. By *Tf*. In de Andrade et al.[16], it was concluded that the oral microbiota did not vary significantly between overweight/obese and normal weight individuals. As can be seen, the reported correlations between obesity indices and periodontal bacteria are inconsistent and further studies should be conducted.

As the subjects of this study were in their 20s with relatively healthy periodontal states and obesity control relied on a short, 4-week intervention without a control group, precise determination of the variations in periodontal bacteria could be difficult. Nevertheless, this study is significant in having conducted an intervention study rather than a cross-sectional study and verified the possibility that obesity control could be used to adjust the relationship between gingival inflammatory indices and periodontal bacteria. Further studies should be conducted by including a control group in the design as well as various additional periodontal states.

Notes

Conflict of interest

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

Ethical approval

This study was approved by the Institutional Review Board of Konyang University Hospital (No. KYUH 13-89).

Author contributions

Conceptualization: Soo-Jeong Hwang. Data acquisition: Soo-Jeong Hwang. Supervision: Soo-Jeong Hwang. Statistics: Min-Seock Seo and Soo-Jeong Hwang. Writing − original draft: Min-Seock Seo and Soo-Jeong Hwang. Writing − review & editing: Min-Seock Seo and Soo-Jeong Hwang.

ORCID

Min-Seock Seo, *https://orcid.org/0000-0001-7203-7775*
Soo-Jeong Hwang, *https://orcid.org/0000-0003-4725-1512*

Acknowledgements

We would like to thank Docsmedi Research Center at Apple Tree Dental Hospital for conducting an experiment to measure periodontal bacteria in saliva, which is the most important experiment for this study. The sequences of primers and probes used for bacterial measurement are not provided in this paper because of the confidentiality of Docsmedi Research Center.

References

1. Lee CJ, Kim MJ, An SJ: Association between obesity and infection. Korean J Health Promot 20: 1-9, 2020. https://doi.org/10.15384/kjhp.2020.20.1.1
2. Dhurandhar NV, Bailey D, Thomas D: Interaction of obesity and infections. Obes Rev 16: 1017-1029, 2015. https://doi.org/10.1111/obr.12320
3. Torres L, Martins VD, Faria AMC, Maioli TU: The intriguing relationship between obesity and infection. J Infectiol 1: 6-10, 2018. https://doi.org/10.29245/2689-9981/2018/1.1104
4. Pasarica M, Dhurandhar NV: Infectobesity: obesity of infectious origin. Adv Food Nutr Res 52: 61-102, 2007. https://doi.org/10.1016/S1043-4526(06)52002-9
5. Del Fiol FS, Balcão VM, Barberato-Fillho S, Lopes LC, Bergamaschi CC: Obesity: a new adverse effect of antibiotics? Front Pharmacol 9: 1408, 2018. https://doi.org/10.3389/fphar.2018.01408
6. Bianchi F, Duque ALRF, Saad SMI, Sivieri K: Gut

microbiome approaches to treat obesity in humans. Appl Microbiol Biotechnol 103: 1081-1094, 2019. https://doi.org/10.1007/s00253-018-9570-8

7. Perlstein MI, Bissada NF: Influence of obesity and hypertension on the severity of periodontitis in rats. Oral Surg Oral Med Oral Pathol 43: 707-719, 1977. https://doi.org/10.1016/0030-4220(77)90055-x
8. Zhou Q, Leeman SE, Amar S: Signaling mechanisms involved in altered function of macrophages from diet-induced obese mice affect immune responses. Proc Natl Acad Sci U S A 106: 10740-10745, 2009. https://doi.org/10.1073/pnas.0904412106
9. Chaffee BW, Weston SJ: Association between chronic periodontal disease and obesity: a systematic review and meta-analysis. J Periodontol 81: 1708-1724, 2010. https://doi.org/10.1902/jop.2010.100321
10. Park HS, Nam HS, Seo HS, Hwang SJ: Change of periodontal inflammatory indicators through a 4-week weight control intervention including caloric restriction and exercise training in young Koreans: a pilot study. BMC Oral Health 15: 109, 2015. https://doi.org/10.1186/s12903-015-0094-7
11. Papageorgiou SN, Reichert C, Jäger A, Deschner J: Effect of overweight/obesity on response to periodontal treatment: systematic review and a meta-analysis. J Clin Periodontol 42: 247-261, 2015. https://doi.org/10.1111/jcpe.12365
12. Sharma M, Tiwari SC, Singh K, Kishor K: Occurrence of bacterial flora in oral infections of diabetic and non-diabetic patients. Life Sci Med Res 2011: LSMR-32, 2011.
13. Zeigler CC, Persson GR, Wondimu B, Marcus C, Sobko T, Modéer T: Microbiota in the oral subgingival biofilm is associated with obesity in adolescence. Obesity (Silver Spring) 20: 157-164, 2012. https://doi.org/10.1038/oby.2011.305
14. Tam J, Hoffmann T, Fischer S, Bornstein S, Gräßler J, Noack B: Obesity alters composition and diversity of the oral microbiota in patients with type 2 diabetes mellitus independently of glycemic control. PLoS One 13: e0204724, 2018. https://doi.org/10.1371/journal.pone.0204724
15. Thomas C, Minty M, Canceill T, et al.: Obesity drives an oral microbiota signature of female patients with periodontitis: a pilot study. Diagnostics (Basel) 11: 745, 2021. https://doi.org/10.3390/diagnostics11050745
16. de Andrade DR, Silva PA, Colombo APV, Silva-Boghossian CM: Subgingival microbiota in overweight and obese young adults with no destructive periodontal disease. J Periodontol 92: 1410-1419, 2021. https://doi.org/10.1002/JPER.20-0187
17. Goodson JM, Groppo D, Halem S, Carpino E: Is obesity an oral bacterial disease? J Dent Res 88: 519-523, 2009. https://doi.org/10.1177/0022034509338353
18. Laiola M, De Filippis F, Vitaglione P, Ercolini D: A mediterranean diet intervention reduces the levels of salivary periodontopathogenic bacteria in overweight and obese subjects. Appl Environ Microbiol 86: e00777-20, 2020. https://doi.org/10.1128/AEM.00777-20
19. Maciel SS, Feres M, Gonçalves TE, et al.: Does obesity influence the subgingival microbiota composition in periodontal health and disease? J Clin Periodontol 43: 1003-1012, 2016. https://doi.org/10.1111/jcpe.12634