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Long-term outcomes of adjacent and antagonistic teeth after implant restoration: a focus on patient-related factors

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

ABSTRACT

Purpose: To investigate factors affecting the antagonistic and adjacent teeth in patients after implant restoration and prosthetic rehabilitation.
Methods: In total, 160 patients who visited Kyungpook National University Dental Hospital for implant surgery, prosthesis placement, and supportive periodontal therapy (SPT) were included in this study. The average follow-up period was 88.06 months, and the maximum was 175 months. Patients' history of smoking, diabetes, hypertension, and osteoporosis was investigated, and panoramic radiographs were taken after surgery and prosthetic treatment. During the follow-up period, extraction and prosthetic/endodontic treatments of the antagonistic and adjacent teeth were analyzed. The statistical analyses were performed using descriptive statistics, the chi-square test, the Fisher exact test, and multiple logistic regression analyses.
Results: Treatment was performed on 29.4% of the studied antagonistic teeth with extraction performed in 20.0% and prosthetic treatment in 10.0%. Furthermore, 19.4% of the studied adjacent teeth underwent treatment, of which extraction was performed in 12.5% and prosthetic treatment in 7.5%. The treatment rate for adjacent teeth was 25.3% in smokers, which was higher than that of non-smokers (12.3%) (P=0.039). Patients who were non-adherent to SPT showed a significantly higher rate (19.6%) of antagonistic prosthetic treatment than did those who were adherent (5.5%) (P=0.006).
Conclusions: Implant restoration can affect the adjacent and antagonistic teeth. Smoking, osteoporosis history, and absence of SPT may be risk factors for the treatment of the adjacent and antagonistic teeth.

Keywords: Dental implants; Dental prosthesis; Follow-up studies; Patient compliance; Survival; Treatment outcome

INTRODUCTION

Economic growth and medical developments have led to improvements in living standards and life expectancy, and aging-related problems have rapidly become more widespread throughout the world [1]. As a consequence, up to 20 million tooth extractions per year [2], followed by 700,000 implants per year to restore the edentulous sites, were reported in the

United States [3]. The importance of functional and aesthetic dental implants that are similar to natural teeth and do not affect adjacent teeth has been emphasized [4].

Osseointegrated implants, unlike natural teeth, react differently against occlusal forces due to the absence of the periodontal ligament [5]. Urdaneta et al. [6] reported increased bone loss of natural teeth when an opposing structure consisting of an implant-supported restoration was present. Furthermore, Urdaneta et al. [7] compared the amount of bone loss between implants and natural teeth as opposing structures and reported that the amount of bone loss was higher when an implant was used as the antagonist. These results imply that natural teeth serving as antagonists to implants may be more vulnerable than those that are antagonists to natural teeth. In terms of the effect of implant treatment on the adjacent teeth, Misch et al. [8] reported that only minimal treatment was performed for natural teeth around a single implant over a 10-year follow-up period, whereas Yoshino et al. [9] reported a high rate of loss of teeth adjacent to implants. Based on these reports, consistent conclusions have not been reported about changes in teeth adjacent to implants, and this issue is therefore worth further study.

Little research has been conducted on the prognosis of natural teeth with implants as antagonistic or adjacent teeth. Furthermore, no long-term studies of natural teeth as implant-antagonistic and/or implant-adjacent teeth have conducted to the authors' best knowledge. The purpose of this study was to investigate changes and patient-related factors affecting the antagonistic and adjacent teeth after implant insertion and prosthetic rehabilitation.

MATERIALS AND METHODS

In total, 160 patients who visited Kyungpook National University Dental Hospital between September 2004 and September 2019 for implant surgery in the posterior area, prosthesis placement, and supportive periodontal therapy (SPT) were included in this study. Patients who did not visit the hospital at least once for SPT after implant surgery and prosthetic treatment were excluded.

Panoramic radiographs were taken after implant placement and prosthesis delivery. All radiographic analyses were based on panoramic radiographs, comparing preoperative radiographs to those from the final recall. The extraction and prosthetic/endodontic treatment of the antagonistic and adjacent teeth were analyzed.

Patient-related factors affecting the natural teeth around implants were recorded. For example, information was recorded on patients' smoking status, diabetes, hypertension, and osteoporosis history. To verify the relationships between the incidence of treatment and SPT adherence, the SPT interval of each patient was examined. The planned appointment interval of the patients included in this study was 6 months. SPT adherence was categorized into 2 groups (adherence: inter-appointment interval <6 months, non-adherence: inter-appointment interval >6 months) [10].

The research protocol of this study was reviewed and approved by the Research Ethics Committee, Kyungpook National University (KNUH 2014-07-050-001).

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Descriptive statistics were calculated for the characteristics of patients, relevant factors for each patient, and the location and number of implants. The chi-square test and Fisher exact test were performed for the association between the characteristics of each patient and all results between the antagonistic and the adjacent teeth of the implant. Multiple logistic regression analyses were performed to calculate odds ratios for risk factors. Data were expressed as mean and standard deviation, and relationships were considered to be statistically significant when the *P*value was below 0.05. All analyses were performed with SPSS version 23.0 (IBM Corp., Armonk, NY, USA).

RESULTS

In total, 269 implants were placed in 160 patients, of which 11 implants failed. The survival rate was 95.91% and the mean follow-up period was 88.06 months. This survival rate is similar to the rates reported in previous studies [11-13].

Data on patients' sex (men: 56.9%, women: 43.1%), age (mean: 60.88 years), follow-up period (mean: 88.06 months), and patient-related factors are shown in Table 1. The location and distribution of implant placement are shown in Table 2. In this study, 88.8% of patients had a follow-up period of more than 5 years, and 55.0% had a follow-up that was longer than 7 years (Table 1).

Table 1. Systemic characteristics of patients

Variables	Values
Sex	
Men	91 (56.9)
Women	69 (43.1)
Age (years)	60.88±9.56
Follow-up period	88.06±27.09
≥ 7 years	88 (55.0)
5–7 years	54 (33.8)
< 5 years	18 (11.3)
Diabetes	
Yes	23 (14.4)
No	137 (85.6)
Hypertension	
Yes	34 (21.3)
No	126 (78.8)
Smoking	
Yes	87 (54.4)
No	73 (45.6)
Supportive periodontal therapy adherence	
Adherence	109 (68.1)
Nonadherence	51 (31.9)

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

Table 2. Location and distribution of implant placement (n=269)

Variables	Values
Maxilla	
Premolar	51 (19.0)
Molar	147 (54.6)
Total	198 (73.6)
Mandible	
Premolar	15 (5.6)
Molar	56 (20.8)
Total	71 (26.4)

Values are presented as number (%).

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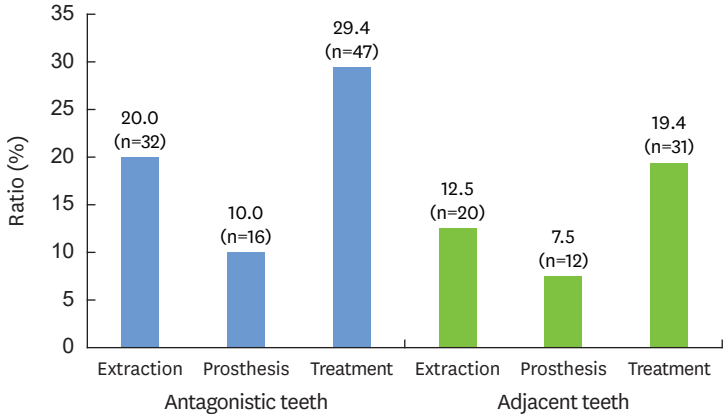

Figure 1. The proportions of extraction, prosthesis placement, and treatment of antagonistic and adjacent teeth.

Status changes in the antagonistic and adjacent teeth were evaluated in terms of extraction, prosthesis (crown, resin filling, amalgam filling, glass ionomer filling, etc.), and total treatment. In total, 29.4% of the antagonistic teeth underwent treatment, with extraction performed in 20.0% of cases and prosthetic treatment in 10.0%. Some of the antagonistic teeth received both extraction and prosthetic treatments, resulting in a greater combined rate than the total treatment rate. Furthermore, 19.4% of the adjacent teeth experienced treatment, which was lower than the proportion for antagonistic teeth by 10%. Extraction and prosthetic treatment were performed in 12.5% and 7.5% of adjacent teeth, respectively. Some of the adjacent teeth also received both extraction and prosthetic treatments. The extraction rate was high in both the antagonistic and the adjacent teeth, and the proportion of teeth that were treated was higher for the antagonistic teeth (Figure 1).

Although a high rate of treatment was found in the 50- to 60-year age group, no statistically significant relationship was found between age and treatment. In the analysis of sex and treatment, 22.0% of antagonistic teeth were extracted in men and 17.4% in women, while the corresponding percentages for adjacent teeth were 7.7% in men and 18.8% in women. Only the ratio of extraction of the adjacent teeth showed a statistically significant difference (P=0.035). A higher percentage of smokers (25.3%) underwent treatment in the adjacent tooth than non-smokers (12.3%), with a statistically significant P value of 0.039. Patients with osteoporosis (40.0%) showed higher rates of prosthetic treatment of the antagonistic teeth compared to those without osteoporosis (9.0%). Patients with low SPT adherence had a higher rate (19.6%) of receiving an antagonist prosthesis than those who were adherent (5.5%), and this was a statistically significant difference. Of 160 patients, 34 patients had hypertension, of whom 10 (29.4%) had their antagonistic teeth extracted. In contrast, only 22 (17.5%) of the 126 patients with no history of hypertension had extraction of their antagonistic teeth. However, the difference in the ratio of antagonist extraction between patients with and without hypertension was not statistically significant. It was notable that patients with diabetes did not have a higher rate of treatment of antagonistic and adjacent teeth than those without diabetes. No other factors that influenced the results were found (Table 3).

Multiple logistic regression analyses were performed to calculate odds ratios for the associations between risk factors and the outcomes (Table 4). For prosthesis placement and any form of treatment of the antagonistic teeth, sex (male), osteoporosis, and SPT nonadherence were risk factors. In addition, sex (female) and smoking were risk factors for the extraction of the adjacent teeth and for any form of treatment of the adjacent teeth, respectively.

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Table 3. The status of antagonistic and adjacent teeth according to implant- and patient-related factors

Variables	Antagonistic teeth						Adjacent teeth					
	Extraction	*P* value	Prosthesis placement	*P* value	Treatment	*P* value	Extraction	*P* value	Prosthesis placement	*P* value	Treatment	*P* value
Sex		0.473		0.123		0.135		0.035[a]		0.187		0.288
Men	20 (22.0)		12 (13.2)		31 (34.1)		7 (7.7)		9 (9.9)		15 (16.5)	
Women	12 (17.4)		4 (5.8)		16 (23.2)		13 (18.8)		3 (4.3)		16 (23.2)	
Age, years		0.368		0.552		0.542		0.352		0.595		0.202
<40	0 (0)		1 (33.3)		1 (33.3)		0 (0)		0 (0)		0 (0)	
40–49	5 (38.5)		0 (0)		5 (38.5)		0 (0)		1 (7.7)		1 (7.7)	
50–59	9 (16.1)		6 (10.7)		14 (25.0)		6 (10.7)		2 (3.6)		8 (14.3)	
60–69	11 (18.6)		6 (10.2)		17 (28.8)		12 (20.3)		7 (11.9)		18 (30.5)	
70–79	7 (28.0)		3 (12.0)		10 (40.0)		2 (8.0)		2 (8.0)		4 (16.0)	
80–89	0 (0)		0 (0)		0 (0)		0 (0)		0 (0)		0 (0)	
Follow-up period (yr)		0.635		0.914		0.746		0.521		0.939		0.580
	20 (22.7)		8 (9.1)		28 (31.8)		13 (14.8)		7 (8.0)		19 (21.6)	
5–7	9 (16.7)		6 (11.1)		14 (25.9)		6 (11.1)		4 (7.4)		10 (18.5)	
<5	3 (16.7)		2 (11.1)		5 (27.8)		1 (5.6)		1 (5.6)		2 (11.1)	
Diabetes		0.257		1.000		0.267		0.741		1.000		0.253
Yes	7 (30.4)		2 (8.7)		9 (39.1)		2 (8.7)		1 (4.3)		2 (8.7)	
No	25 (18.2)		14 (10.2)		38 (27.7)		18 (13.1)		11 (8.0)		29 (21.2)	
Hypertension		0.122		1.000		0.201		1.000		0.284		0.840
Yes	10 (29.4)		3 (8.8)		13 (38.2)		4 (11.8)		4 (11.8)		7 (20.6)	
No	22 (17.5)		13 (10.3)		34 (27.0)		16 (12.7)		8 (6.3)		24 (19.0)	
Smoking		0.068		0.711		0.230		0.134		0.136		0.039[a]
Yes	22 (25.3)		8 (9.2)		29 (33.3)		14 (16.1)		9 (10.3)		22 (25.3)	
No	10 (13.7)		8 (11.0)		18 (24.7)		6 (8.2)		3 (4.1)		9 (12.3)	
Osteoporosis		1.000		0.023[a]		0.127		0.391		0.518		0.265
Yes	1 (20.0)		2 (40.0)		3 (60.0)		0 (0)		0 (0)		0 (0)	
No	31 (20.0)		14 (9.0)		44 (28.4)		20 (12.9)		12 (7.7)		31 (20.0)	
SPT adherence		0.932		0.006[a]		0.062		0.749		0.200		0.363
Adherence	22 (20.2)		6 (5.5)		27 (24.8)		13 (11.9)		6 (5.5)		19 (17.4)	
Nonadherence	10 (19.6)		10 (19.6)		20 (39.2)		7 (13.7)		6 (11.8)		12 (23.5)	

[a]Statistically significant ($P<0.05$).

Table 4. Results of logistic regression for the dependent variable of status of the antagonistic and adjacent teeth

Variables	Extraction			Prosthesis placement			Treatment		
	P value	Odds ratio	95% CI	*P* value	Odds ratio	95% CI	*P* value	Odds ratio	95% CI
Antagonistic teeth									
Sex	-	-	-	0.021[a]	6.460	1.324–31.509	0.045[a]	2.182	1.016–4.679
Osteoporosis	-	-	-	0.004[a]	37.181	3.115–443.808	0.047[a]	7.044	1.030–48.187
SPT compliance	-	-	-	0.002[a]	6.369	1.950–20.803	0.037[a]	2.190	1.050–4.566
Adjacent teeth									
Sex	0.008[a]	4.206	1.460–12.115	-	-	-	-	-	-
Smoking	-	-	-	-	-	-	0.043[a]	2.574	1.029–6.436

CI: confidence interval.
[a]Statistically significant ($P<0.05$).

DISCUSSION

Implant dentistry has developed for over 50 years and has entered the mainstream of modern dentistry; thus, the need for research on the long-term and systemic effects of implant treatment has been growing [14]. The follow-up for the implants included in this study was long-term (more than 7 years in 55% of implants).

Misch et al. [8] published a 10-year retrospective, multicenter study that evaluated posterior single-tooth implants and the condition of the adjacent natural teeth. In their study, patients with hypertension and diabetes were excluded and no information on smoking status was

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recorded. They reported that restoration treatment and endodontic treatment occurred in 15.9% and 5% of adjacent teeth, respectively, after posterior implant rehabilitation. These results appear to be similar to the percentage of total treatment for adjacent teeth (19.4%) in our study. However, the proportion of teeth that received prostheses, including restoration and endodontic treatment, in our study was 7.5%, which differs from the rate reported in their study. In addition, information on adjacent teeth extraction was not provided in their study, whereas the corresponding rate was 12.5% in our study. This discrepancy may have occurred due to the differences in baseline status; in their study, implants were limited to posterior single restoration cases, and patients with underlying diseases were excluded. The period of the study was also different. The previous article was included patients treated from 1996 to 2004, whereas our study analyzed follow-up results after implant placement from 2004 to 2014, with the most recent records dating from 2019. Due to improvements in implant technique during this time interval, teeth with a questionable prognosis may have been more likely to be extracted and receive implant treatment than to be restored or preserved. This trend in dentistry may have influenced the treatment plans.

An implant prosthesis requires the development of occlusal and interproximal contact points, like a prosthesis made for natural dentition. When a contact point with an adjacent tooth is set, the height and tightness would be specifically considered. However, since the bone-implant interface has no capacity to allow movement of the implant, which differs from natural teeth, the occlusal formation of an implant prosthesis in a special environment is especially important. Moreover, many factors need to be considered, including simultaneous bilateral contacts, smooth lateral contacts, equalization of the force of the final contacts, and force distribution [15]. Considering difficulties in the manufacturing process of implant prostheses, it can be cautiously predicted that the overall treatment rate in antagonistic teeth will be higher than that in adjacent teeth.

Akpinar et al. [16] also reported that natural teeth subjected to constant occlusal forces after implant rehabilitation were under high compression, which could lead to tooth intrusion. These results suggest that implant restoration would change the contact points of antagonistic natural teeth, which may affect plaque control in the long term and serve as a factor that increases caries treatment. In addition, the possibility of traumatic force to antagonistic teeth increases due to high compression forces. Nonadherence may delay the early detection of this situation [10,17,18]. This can be shown by the fact that patients with low SPT adherence received more prostheses in antagonistic teeth, with an odds ratio of 6.369 relative to the adherent group in our study. However, several other factors influence the environment of antagonistic natural teeth, such as implant type, fixture angulation, loading force, and prosthetic materials [19-21]. Therefore, further research is needed to explain the related factors.

The effect of systemic osteoporosis on the jaw bones is interesting, and a prior study confirmed that osteoporosis is further enhanced by abnormal occlusal forces in alveolar bone [22]. The results of our study also confirmed that the rate of prostheses in the antagonistic teeth was significantly higher in patients with osteoporosis than in those without osteoporosis. With occlusion after implant restoration, high compression forces may cause alveolar bone changes in osteoporosis patients.

Diabetes and periodontitis are widely known to have a 2-way relationship, and diabetes has been proven to be a risk factor for periodontal diseases [23]. However, no correlations were found between diabetes and any other independent variables in the present study.

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Nobuyoshi et al. [24] reported that systemic blood pressure affected the pulsation of the functioning periodontal tissue, and found that higher loads could cause both tooth compression and circulatory damage [24,25]. This suggests that patients with hypertension may experience damage to the periodontal ligament in functioning teeth. The extraction rate of antagonistic teeth in patients with hypertension in our study was slightly higher than those of the adjacent teeth and the rate of prosthesis placement in the adjacent teeth, but no significant difference was found.

Smokers showed significantly a higher treatment rate in adjacent teeth than non-smokers. Several studies have shown relationships between caries and periodontitis prevalence in natural teeth among smokers; in particular, it was found that caries were the cause of adjacent teeth treatment, and this may also have been the cause of the implant-adjacent teeth treatment in this study [26-31]. In addition, smokers were found to have a low level of dental knowledge and a high proportion of poor oral hygiene. Accordingly, prosthesis placement or extraction would have been performed [32-34].

Sex and smoking were shown to influence the treatment rate of adjacent teeth in this study, while SPT compliance was shown to influence the treatment of antagonistic teeth in a significant way. However, there seems to be more factors that affect antagonistic teeth. For example, the occlusal force may be influential for the treatment of antagonistic teeth after implant rehabilitation [11]. Therefore, factors such as materials, the implantation angle, and the occlusal force of the implant rehabilitation itself should be further studied.

Our study focused on underlying diseases as factors affecting adjacent and antagonistic teeth. The effect of aspects such as the location and distribution of implant placement on the prognosis of adjacent and antagonistic teeth should be analyzed in future research.

In general, in cases of restoration treatment, which range from simple to deep caries, crown restoration and/or root canal treatment can be considered. It is assumed that extraction was performed due to periodontitis or traumatic occlusion that would not be resolved with such forms of restorative treatment. Additionally, the possible presence of endodontic-periodontic lesions and vice versa should not be neglected. For instance, restoration and extraction can be done due to resolve a loose contact point and deep caries, respectively. Therefore, it was challenging to categorize the specific reason for each treatment.

Based on our results, smoking affects the treatment of adjacent teeth, while SPT adherence and osteoporosis history affect the prosthetic treatment of antagonistic teeth. Hypertension may affect the treatment of antagonistic teeth. Patient-related factors should be thoroughly analyzed before implant placement, and SPT should be performed regularly after implant restoration. Furthermore, prevention should be a priority.

REFERENCES

1. Yamaga T, Ogawa H, Miyazaki H. Influence of occlusal deterioration considering prosthetics on subsequent all-cause mortality in a Japanese elderly independent population. Gerodontology 2019;36:163-70.
PUBMED | CROSSREF
2. Marcus SE, Drury TF, Brown LJ, Zion GR. Tooth retention and tooth loss in the permanent dentition of adults: United States, 1988–1991. J Dent Res 1996;75 2_suppl:684-95.
PUBMED | CROSSREF

3. Millennium Research Group. U.S. markets for dental implants 2001: executive summary. Implant Dent 2001;10:234-7.
PUBMED | CROSSREF
4. Pjetursson BE, Karoussis I, Bürgin W, Brägger U, Lang NP. Patients' satisfaction following implant therapy. A 10-year prospective cohort study. Clin Oral Implants Res 2005;16:185-93.
PUBMED | CROSSREF
5. Kim Y, Oh TJ, Misch CE, Wang HL. Occlusal considerations in implant therapy: clinical guidelines with biomechanical rationale. Clin Oral Implants Res 2005;16:26-35.
PUBMED | CROSSREF
6. Urdaneta RA, Daher S, Lery J, Emanuel K, Chuang SK. Factors associated with crestal bone gain on single-tooth locking-taper implants: the effect of nonsteroidal anti-inflammatory drugs. Int J Oral Maxillofac Implants 2011;26:1063-78.
PUBMED
7. Urdaneta RA, Leary J, Panetta KM, Chuang SK. The effect of opposing structures, natural teeth vs. implants on crestal bone levels surrounding single-tooth implants. Clin Oral Implants Res 2014;25:e179-88.
PUBMED | CROSSREF
8. Misch CE, Misch-Dietsh F, Silc J, Barboza E, Cianciola LJ, Kazor C. Posterior implant single-tooth replacement and status of adjacent teeth during a 10-year period: a retrospective report. J Periodontol 2008;79:2378-82.
PUBMED | CROSSREF
9. Yoshino K, Nishibori M, Fujiseki M, Ito K, Kuroda M, Matsukubo T. Loss of teeth in positions mesially adjacent to implant-supported fixed dentures: a retrospective clinical survey. Int J Prosthodont 2015;28:158-60.
PUBMED | CROSSREF
10. Delatola C, Adonogianaki E, Ioannidou E. Non-surgical and supportive periodontal therapy: predictors of compliance. J Clin Periodontol 2014;41:791-6.
PUBMED | CROSSREF
11. Salinas TJ, Eckert SE. In patients requiring single-tooth replacement, what are the outcomes of implant- as compared to tooth-supported restorations? Int J Oral Maxillofac Implants 2007;22 Suppl:71-95.
PUBMED
12. Lindh T, Gunne J, Tillberg A, Molin M. A meta-analysis of implants in partial edentulism. Clin Oral Implants Res 1998;9:80-90.
PUBMED | CROSSREF
13. Busenlechner D, Fürhauser R, Haas R, Watzek G, Mailath G, Pommer B. Long-term implant success at the Academy for Oral Implantology: 8-year follow-up and risk factor analysis. J Periodontal Implant Sci 2014;44:102-8.
PUBMED | CROSSREF
14. Buser D, Sennerby L, De Bruyn H. Modern implant dentistry based on osseointegration: 50 years of progress, current trends and open questions. Periodontol 2000 2017;73:7-21.
PUBMED | CROSSREF
15. Chapman RJ. Principles of occlusion for implant prostheses: guidelines for position, timing, and force of occlusal contacts. Quintessence Int 1989;20:473-80.
PUBMED
16. Akpinar I, Anil N, Parnas L. A natural tooth's stress distribution in occlusion with a dental implant. J Oral Rehabil 2000;27:538-45.
PUBMED | CROSSREF
17. Kim SY, Lee JK, Chang BS, Um HS. Effect of supportive periodontal therapy on the prevention of tooth loss in Korean adults. J Periodontal Implant Sci 2014;44:65-70.
PUBMED | CROSSREF
18. Dockter KM, Williams KB, Bray KS, Cobb CM. Relationship between prereferral periodontal care and periodontal status at time of referral. J Periodontol 2006;77:1708-16.
PUBMED | CROSSREF
19. Machtei EE, Oettinger-Barak O, Horwitz J. Axial relationship between dental implants and teeth/implants: a radiographic study. J Oral Implantol 2014;40:425-31.
PUBMED | CROSSREF
20. Hekimoglu C, Anil N, Cehreli MC. Analysis of strain around endosseous dental implants opposing natural teeth or implants. J Prosthet Dent 2004;92:441-6.
PUBMED | CROSSREF

21. Kasai K, Takayama Y, Yokoyama A. Distribution of occlusal forces during occlusal adjustment of dental implant prostheses: a nonlinear finite element analysis considering the capacity for displacement of opposing teeth and implants. Int J Oral Maxillofac Implants 2012;27:329-35.
PUBMED

22. Kawamoto S, Nagaoka E. The effect of oestrogen deficiency on the alveolar bone resorption caused by traumatic occlusion. J Oral Rehabil 2000;27:587-94.
PUBMED | CROSSREF

23. Grossi SG, Genco RJ. Periodontal disease and diabetes mellitus: a two-way relationship. Ann Periodontol 1998;3:51-61.
PUBMED | CROSSREF

24. Imamura N, Nakata S, Nakasima A. Changes in periodontal pulsation in relation to increasing loads on rat molars and to blood pressure. Arch Oral Biol 2002;47:599-606.
PUBMED | CROSSREF

25. McDonald F, Pitt Ford TR. The effect of blood flow on the material properties of bone. Ann Biomed Eng 1994;22:194-201.
PUBMED | CROSSREF

26. Machuca G, Rosales I, Lacalle JR, Machuca C, Bullón P. Effect of cigarette smoking on periodontal status of healthy young adults. J Periodontol 2000;71:73-8.
PUBMED | CROSSREF

27. de Araújo Nobre M, Maló P. Prevalence of periodontitis, dental caries, and peri-implant pathology and their relation with systemic status and smoking habits: Results of an open-cohort study with 22009 patients in a private rehabilitation center. J Dent 2017;67:36-42.
PUBMED | CROSSREF

28. Genco RJ, Genco FD. Common risk factors in the management of periodontal and associated systemic diseases: the dental setting and interprofessional collaboration. J Evid Based Dent Pract 2014;14 Suppl:4-16.
PUBMED | CROSSREF

29. American Academy of Periodontology. Parameter on plaque-induced gingivitis. J Periodontol 2000;71 Suppl:851-2.
PUBMED | CROSSREF

30. Cao X, Wang D, Zhou J, Yuan H, Chen Z. Relationship between dental caries and metabolic syndrome among 13 998 middle-aged urban Chinese. J Diabetes 2017;9:378-85.
PUBMED | CROSSREF

31. Ritter AV, Preisser JS, Puranik CP, Chung Y, Bader JD, Shugars DA, et al. A predictive model for root caries incidence. Caries Res 2016;50:271-8.
PUBMED | CROSSREF

32. Jiun IL, Siddik SN, Malik SN, Tin-Oo MM, Alam MK, Khan MM. Association between oral hygiene status and halitosis among smokers and nonsmokers. Oral Health Prev Dent 2015;13:395-405.
PUBMED

33. Nishi N, Ogurii S, Onoda T, Nohara M, Inoue H, Okayama A. Knowledge of smoking-related risks and opinions on tobacco control by smoking status and education level in Japan. Nippon Koshu Eisei Zasshi 2005;52:962-70.
PUBMED

34. 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

https://doi.org/10.5051/jpis.2005100255