Analysis of factors affecting the long−term status of adjacent and antagonistic teeth in relation to dental implants

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The aim of this study is to investigate factors that affect the prognosis of adjacent and antagonistic teeth after an implant restoration. In total, 102 implant placement sites of 91 patients who underwent implant placement in Kyungpook National University Dental Hospital were included in this study. The average follow-up period was 68.27 months, whereas the maximum was 136 months. The cause of the previous extraction and implant-related factors were investigated. Radiographic evaluations were performed after the surgery and prosthetic treatment. Extraction and other treatments, including restorative or endodontic treatment of the antagonistic and adjacent teeth, were analyzed during the follow-up period. The chi-square test and Fisher exact test were used to analyze which factors could affect the implant prognosis. Of the studied antagonistic teeth, a total of 4.9% were treated and 12.7% were extracted. Furthermore, of the studied adjacent teeth, a total of 2.9% underwent treatment and 3.9% were extracted. The causes of previous extractions and types of restoration materials showed a significant difference in the treatment rate of adjacent teeth (p=0.05). Furthermore, implant surface types showed a significant difference in the extraction rate of antagonistic teeth (p=0.05). In conclusion, it can be suggested that the cause of the previous extraction and the material of the implant restoration may affect the prognosis of the teeth adjacent to the implant. Moreover, a specific type of implant surface may be a risk factor for antagonistic teeth.

Key Words: Dental implants; Dental occlusion; Survival rate; Tooth extraction; Tooth injuries

Introduction

Introduced in the 1950s by Branemark et al. dental implants have now become a universal treatment option for restoring missing teeth [1]. In the early days, dental implants were limited to completely edentulous patients. Since then, implant treatment has come to be used in partially edentulous patients, and the range of implant treatment has been greatly expanded due to development of implant design, technique, and treatment plan [2]. Over the past decades, a lot of patients have replaced their teeth with implants. Currently, the long-term success rate of implants used to replace one or more missing teeth in partially edentulous patients is very high [3].

In partially edentulous patients, the implant is placed anteriorly or posteriorly to the natural teeth (adjacent teeth) or is occluded (antagonistic teeth). Although many studies on restoration of implants have been made, reports on the

prognosis of adjacent teeth or opposing teeth of such implants were very few.

In a study on adjacent teeth of a single implant, Duqum et al. [4] reported that the teeth adjacent to implants showed a higher restoration rate than that of natural teeth. There was no significant difference in the survival rate or the rate of root canal treatment. On the other hand, according to a study by Priest [5], only 2 teeth out of 196 implant adjacent teeth for 10 years were restored. It was reported that only 3% of the implant adjacent teeth required restoration, and none of the teeth were extracted or received root canal treatment [6]. The teeth adjacent to implants seem to show a generally better prognosis compared to natural teeth adjacent to edentulous area. This can be explained by that a consequence of not preparing the adjacent teeth for crowns included decreased risk for caries and endodontic treatment in abutment teeth, improved ability to clean the proximal surfaces of the adjacent teeth and decreased risk for abutment tooth loss from endodontic failure or caries [7].

Urdaneta et al. [8] reported an increase in the amount of bone loss of natural teeth with the presence of implant-supported restoration in the antagonistic teeth. Furthermore, in a study comparing the amount of bone loss between an implant and a natural tooth, Urdaneta et al. [9] reported that the amount of bone loss between the implant and the antagonist was higher. When the implant acts as an antagonist of a natural tooth, it may be more vulnerable than when the natural tooth is an antagonist.

However, these studies are related to comparison with natural teeth, and investigations on factors affecting the prognosis of implant adjacent or antagonist teeth are very few. In a previous study, Park et al. [10] reported on the effects of patient-related factors, adjacent teeth, and antagonists on the prognosis. Smoking, osteoporosis history, and absence of supportive periodontal therapy (SPT) may be the risk factors for the treatment of the adjacent and antagonistic teeth.

In this study, implant-related factors—design, surface modification, connection type, prosthesis retention type, and restoration materials—were evaluated to investigate the effects on the prognosis of adjacent teeth and antagonistic teeth. In addition, the relationship with the cause of tooth extraction prior to implant restoration was examined.

Materials and Methods

Study population

This study included 91 patients who visited Kyungpook National University Dental Hospital between October 2006 and March 2015 and received implants placement and prosthetic restorations. Teeth with apical lesion adjacent and antagonistic to implant were excluded. Patients who did not visit the clinic for more than 1 year after prosthetic restoration were excluded. The research protocol of this study was approved by the Research Ethics Commitee, Kyungpook National University (KNUD-2021-06-06-00).

Collection of patients and implant information

Panoramic radiographs were taken for radiographic evaluation before surgery, after surgery, and after prosthetic restoration. Panoramic radiographs were used as the basis for analyzing the prognosis of implant adjacent and antagonist teeth. Based on radiographs and chart records before implant placement and on the last day of visit, we investigated whether natural teeth were extracted, received root canal treatments or restorations. If the implant was removed during the follow-up period, it was considered as the date of the last visit.

Factors associated with implant were recorded at each placement site. The length, width, surface treatment method of the implant fixture, the implant abutment connection (external and internal connection), prosthesis retention type (screw/screw and cement retained prosthesis or cement type), and the materials of the prosthesis restorations were recorded. In addition, causes of previous tooth extraction prior to implant placement were included, and these were classified into periodontal causes, tooth fractures, caries, complex reason, and unknown.

Statistical analysis

Chi-square test and Fisher's exact test were performed to determine the relationship between the characteristics of each patient and the prognosis of adjacent and antagonist teeth to the implant. All analyzes were performed using the

SPSS version 23.0 (IBM Corp., Armonk, NY, USA).

Results

102 implant sites were analyzed in a total of 91 patients. If two or more sites were included in one patient, the sites where the implants were antagonistic was excluded.

Data on patients' sex (male: 37.4%, female: 62.6%), age (mean 51.19 years), follow-up period, and cause of previous tooth extraction are shown in Table 1. The mean follow-up period after the final prosthetic restoration was 68.27 months (minimum: 12 months, maximum: 136 months). The most common cause of tooth extraction was periodontal cause, accounting for 63.7% of the total, followed by fracture of the crown or root (14.7%), caries (13.7%), complex causes (3.9%), and unknown reason (3.9%).

A total of 130 implants were placed at 102 sites. The location, distribution, fixture and prosthetic characteristics of the implants are shown in Table 2. In the cases of two missing teeth restorations, each implant had same characteristics of implant abutment connection, prosthesis type, and restoration material. When the diameter of the implant fixture was more than 5mm, it was classified as wide, and when below than 5mm, as regular implant. The number of implants placed in both diameter groups was similar. The length of the fixture was classified into three groups; less than 10 mm, between 10 and 13 mm, and exceeding 13 mm. Implant fixtures between 10 and 13 mm length were most frequently placed.

Changes in the status of the teeth antagonistic and adjacent to implants were evaluated in terms of extraction and treatment (crown restoration, direct or indirect filling, endodontic treatment, etc.) (Fig. 1). Overall, extraction was performed in 12.7% of antagonist teeth and treatment was performed in 4.9%. In adjacent teeth, extraction was performed in 3.9% and treatment was performed in 2.9%. The extraction rate of the antagonist teeth was much higher than that of the adjacent teeth, and there was no significant difference in the treatment ratio.

There were no significant differences according to sex and age in both the antagonistic and adjacent teeth. In the area where the tooth was extracted due to caries (14.3%), more adjacent teeth underwent treatment than in the area where the tooth was extracted due to periodontal causes (0%) or fracture (6.7%) (p=0.047). The restoration material

Table 1. Characteristic of subjects

Variable	Value
Sex	
Male	34 (37.4)
Female	57 (62.6)
Age (y)	51.19±9.69
Follow-up period (mo)	68.27±28.75
Cause of extraction	
Periodontal	65 (63.7)
Crown and/or root fracture	15 (14.7)
Caries	14 (13.7)
Complex	4 (3.9)
Unknown	4 (3.9)

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

Table 2. Location, distribution and prosthetic features of implants

Variable	Value
Sites	
Maxillary premolar	9 (6.9)
Maxillary molar	75 (57.7)
Mandibular premolar	43 (33.1)
Mandibular molar	3 (2.3)
Surface	
RBM	88 (67.7)
Ti-Unite	29 (22.3)
SLA	9 (6.9)
TiO$_2$-blasted fluoride-modified	4 (3.1)
Restoration material	
Cast metal	93 (71.5)
PFM	21 (16.2)
Zirconia	16 (12.3)
Connection type	
External	104 (80.0)
Internal	26 (20.0)
Prosthesis type	
Screw-retained	121 (93.1)
Cement-retained	9 (6.9)
Fixture diameter	
Regular	66 (50.8)
Wide	64 (49.2)
Fixture length(mm)	
< 10	10 (7.7)
10–13	116 (89.2)
≥ 15	4 (3.1)

Values are presented as number (%).
RBM, resorbable blasting media; SLA, sand-blasted and acid-etched; PFM, porcelain-fused-to-metal; Ti, titanium; TiO$_2$, titanium dioxide.
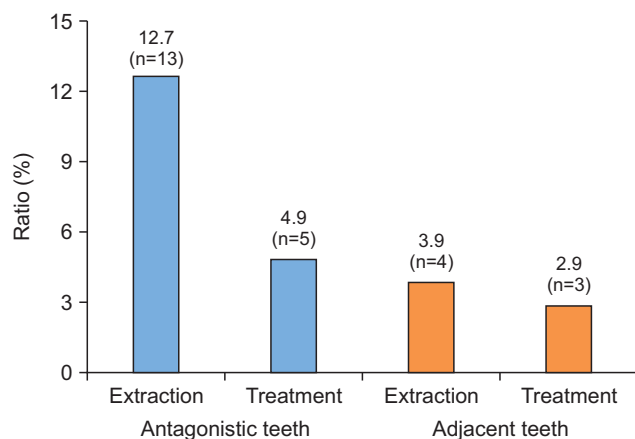
Fig. 1. The proportions of intervention and extraction of antagonistic and adjacent teeth.

also had statistically significant correlation with the treatment of adjacent teeth ($p=0.019$). For cast metal restorations, there was no case of treatment of adjacent teeth (0%), whereas in porcelain-fused-to-metal (PFM) or zirconia restorations, the treatment rates were 11.1% and 10.0%, respectively. Implants with SLA type surface treatment had higher rate (50.0%) of antagonistic teeth extraction compared to that of other surface treatment methods ($p=0.037$). Other than the connection type, diameter, length, and prosthesis retention types, there were no statistically significant differences (Table 3).

Discussion

In this study, only 4 adjacent teeth of 102 implant sites were extracted, and the shortest period until extraction was 47 months. In the case of antagonistic teeth, 13 teeth were extracted. The antagonistic teeth showed a higher extraction rate than adjacent teeth. In the study by Yamazaki et al. [11] that compared the complication rate of abutments of local denture (FPD) and adjacent teeth of implant-supported fixed partial denture (IFD) for 8 years, teeth adjacent to IFD showed a significantly lower complication rate compared to FPD abutments. In the study of Krennmair et al. [6], none of the adjacent teeth was extracted among 78 single implants during the follow-up period of 3 years, and treatment was also required in only 3% of the total teeth.

In this study, the ratio of implant-adjacent teeth receiving treatment during the follow-up period was lower than

in other studies. In the study of Duqum et al. [4], the extraction rate of adjacent teeth was 3.78%, which is similar to the value in this study of 3.9%. In contrast, the treatment rate was 2.9%, much lower than 14.07%. The patients included in this study visited our clinic regularly after implant placement, but many of them also received treatment from other dentists. Therefore, there may be treatments that cannot be found in our dental records or radiographs, which, unlike extractions, may be difficult to detect.

The cause of previous extraction showed a significant relationship with treatment of adjacent teeth. The rate of treatment of adjacent teeth was highest in the case of tooth extraction due to caries, followed by the highest in the case of tooth extraction due to fracture. In the case of tooth loss due to periodontal disease, there was no treatment of adjacent teeth. Subjects included in this study had a history of visitation for more than 1 year after implant prosthesis, and had regular visits after implant placement and received SPT. According to a study by Park et al. [10], poor adherence to SPT can be a risk factor in the treatment of adjacent teeth and antagonist teeth, which can be the basis for supporting the results of this study.

The implant fixture has a smaller diameter than the root of the natural tooth, and its shape is also different from the natural tooth and has a relatively large interdental space [12]. Due to these reasons, the implant adjacent teeth show high proximal, cervical and root caries rates [13]. Smith et al. [14] conducted a retrospective study on the relationship between the distance between the implant and the natural tooth and caries, and concluded that the incidence of caries increases when the distance is greater than 4 mm. Although this study did not evaluate the distance between implants and natural teeth, it is presumed that it acted as a contributing factor to caries of adjacent teeth.

The material of the implant prosthesis showed a significant difference in whether or not the adjacent teeth were treated. Although the proportion of cast metal in the entire implant site was very high, no adjacent teeth were treated, but with the restoration with PFM and zirconia, adjacent teeth were treated in about 10% of cases. This may be related to the roughness of the restoration material. However, in this study, the function period of the restoration, glazing, and the type of gold alloy cannot be traced, so more in-

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

Variable	Antagonistic teeth				Adjacent teeth			
	Extraction	*p*-value	Treatment	*p*-value	Extraction	*p*-value	Treatment	*p*-value
Sex		1.000		0.378		0.153		1.000
Male	5 (12.5)		3 (7.5)		0 (0)		1 (2.5)	
Female	8 (12.9)		2 (3.2)		4 (6.5)		2 (3.2)	
Age (y)		0.765		0.579		0.912		0.364
<40	2 (20.0)		0 (0)		0 (0)		1 (10.0)	
40–49	5 (13.5)		1 (2.7)		2 (5.4)		1 (2.7)	
50–59	3 (9.1)		2 (6.1)		2 (6.1)		0 (0)	
60–69	2 (11.8)		2 (11.8)		0 (0)		1 (5.9)	
70–79	1 (20.0)		0 (0)		0 (0)		0 (0)	
Cause of previous extraction		0.123		0.316		0.344		0.047*
Periodontal	9 (13.8)		3 (4.6)		3 (4.6)		0 (0)	
Fracture	0 (0)		1 (6.7)		0 (0)		1 (6.7)	
Caries	2 (14.3)		0 (0)		0(0)		2 (14.3)	
Unknown	2 (50.0)		0 (0)		1 (25.0)		0 (0)	
Complex	0 (0)		1 (25.0)		0 (0)		0 (0)	
Connection type		0.278		0.580		1.000		1.000
External	9 (12.3)		5 (6.1)		3 (3.7)		3 (3.8)	
Internal	4 (20.0)		0 (0)		1 (5.0)		0 (0)	
Surface		0.037*		0.743		1.000		0.667
RBM	6 (8.5)		3 (4.2)		3 (4.2)		2 (2.8)	
Ti-Unite	4 (18.2)		2 (9.1)		1 (4.6)		1 (4.5)	
SLA	3 (50.0)		0 (0)		0 (0)		0 (0)	
TiO$_2$-blasted fluoride modified	0 (0)		0 (0)		0 (0)		0 (0)	
Diameter		1.000		0.367		1.000		1.000
Regular	7 (13.0)		4 (7.4)		2 (3.7)		2 (3.7)	
Wide	6 (12.5)		1 (2.1)		2 (4.2)		1 (2.1)	
Length		0.491		1.000		1.000		1.000
<10	2 (22.2)		0 (0)		0 (0)		0 (0)	
10–13	11 (12.1)		5 (5.5)		4 (4.4)		3 (3.3)	
≥15	0 (0)		0 (0)		0 (0)		0 (0)	
Prosthesis retention type		1.000		1.000		0.282		0.219
Screw	12 (14.6)		5 (5.3)		3 (3.2)		2 (2.1)	
Cement	1 (12.5)		0 (0)		1 (12.5)		1 (12.5)	
Restoration materials		0.786		1.000		0.302		0.019†
Cast metal	9 (13.8)		4 (5.4)		2 (2.7)		0 (0)	
PFM	2 (11.1)		1 (5.6)		1 (5.6)		2 (11.1)	
Zirconia	2 (20.0)		0 (0)		1 (10.0)		1 (10.0)	

Values are presented as number (%).
RBM, resorbable blasting media; SLA, sand-blasted and acid-etched; PFM, porcelain-fused-to-metal; Ti, titanium; TiO$_2$, titanium dioxide.
*χ^2 test. †Fisher exact test.

depth studies are needed.

Unlike the adjacent teeth, the material of the implant prosthesis did not show a significant relationship with the prognosis of the antagonistic teeth. There were many studies on the effect of restoration materials on the wear of the antagonistic teeth [15-17]. It was known that alloy restorations cause relatively less enamel wear of the antagonist teeth compared to porcelain metal restorations [18,19]. Kwon et al. [20] reported that zirconia restorations also induced much wear on the antagonistic teeth compared to alloy restorations in vitro. On the other hand, Mundhe et al. [21] reported that zirconia crowns were larger than natural teeth, however less wear on the antagonistic teeth compared to metal-ceramic crowns.

In this study, the surface treatment of the implant fixture showed a significant difference in the extraction of the antagonistic teeth. Many studies have been conducted on the relationship between implant surface treatment and implant prognosis. However, there are few studies on the effects of implant adjacent teeth or antagonistic teeth, and it seems that follow-up studies on these are needed.

As this study is a retrospective study, the status of adjacent or antagonistic teeth had to depend on radiographs and chart records. There was a limitation in that the actual condition of the adjacent and antagonistic teeth in the oral cavity had to be indirectly estimated because there was no measurement of the clinical index. Except for the factors included in this study, other factors including the axial relationship between the implant and the opposing tooth, the cusp inclination of the implant prosthesis, and the placement position may affect the prognosis of the antagonistic teeth or adjacent teeth [22]. Based on the results of this study, there is a need to conduct a prospective or controlled study on related factors. In addition, the investigation of factors not covered in this study should also be conducted.

Within the several limitations of this study, it can be suggested that the cause of previous extraction, the material of the implant restoration and the type of implant surface may affect the prognosis of the implant adjacent teeth or antagonistic teeth.

Conflicts of Interest

The authors declare that they have no competing interests.

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