Title

Comparison of the prognosis of the remaining teeth between implant-supported fixed prostheses and removable partial dentures in partially edentulous patients: A retrospective study

Running Head

Prognosis of the remaining teeth with prostheses

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Conflict of Interest Statement

The authors have no conflict of interest.

Author contribution statement

Ryo Yamada contributed to the design of the trial, acquisition of the data, and analysis and interpretation of the data and drafted the manuscript. Toshifumi Nogawa contributed to the design of the trial, statistical analysis, and analysis and interpretation of the data and drafted the manuscript. Kai Iwata contributed to the acquisition of the data. Yoshiyuki Takayama contributed to the conception and design of the trial and critically revised the manuscript. Masayasu Saito and Atsuro Yokoyama contributed to the design of the trial and analysis and interpretation of the data and critically revised the manuscript. All authors gave final approval and agreed to be accountable for all aspects of the work.

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Summary Box

What is known:

Recent reports suggested that the teeth adjacent to edentulous spaces with implant supported fixed prostheses show good prognosis.

There is no report comparing implant supported fixed prostheses and removable partial dentures with the teeth adjacent to partial edentulous spaces and the other remaining teeth.

What this study adds:

This study is the retrospective study on this topic and suggests that the prognosis of teeth adjacent to or opposing the edentulous space does not depend on the type of prosthesis.

Abstract

Background: There have been several reports about the prognosis of teeth adjacent to edentulous spaces for implant-supported fixed prostheses (ISFPs) and removable partial dentures (RPDs). However, there are few reports about the prognosis of the other remaining teeth comparing ISFPs with RPDs.

Purpose: The aim of this study was to evaluate and compare the prognosis of the remaining teeth for ISFPs and RPDs in terms of survival and complication-free rates.

Methods: Subjects were partially edentulous patients with ISFPs or RPDs inserted in 2003–2016. Teeth adjacent to edentulous spaces (A-teeth), teeth not adjacent to edentulous spaces (R-teeth), and teeth opposing edentulous spaces (O-teeth) were investigated. The endpoints were tooth extraction and complications. A multivariate cox regression model was used to estimate the risk factors for survival of the investigated teeth.

Results: A total of 233 (ISFP: 89, RPD: 144) patients were included in the statistical analyses. An IFSP prosthesis, when compared to an RPD prosthesis did not significantly decrease the tooth loss rate for A-teeth (hazard ratio (HR): 0.76; 95% confidence interval (CI): 0.30-1.92), for R-teeth (HR: 0.54; 95% CI: 0.28-1.05), or for O-teeth (HR: 0.45; 95% CI: 0.10-2.09).

Conclusions: In partially edentulous spaces, the difference between ISFPs and RPDs does not affect the prognosis of teeth adjacent to edentulous spaces, teeth not adjacent to edentulous spaces, and

teeth opposing edentulous spaces. Namely, our findings suggest that it depends largely on the tooth type, jaw, endodontic therapy performed, not on the type of prostheses.

Keywords: implant-supported fixed prostheses, removable partial dentures, survival rates, complication-free rates, adjacent teeth, opposing teeth, retrospective study

1. Introduction

Treatment for partially edentulous spaces aims to restore oral function, esthetics and phonetics; protect the remaining tissues; and prevent diseases subsequently caused by the loss of teeth.[1] Prosthetic treatment methods to achieve these objectives include fixed partial dentures (FPDs), removable partial dentures (RPDs), implant supported fixed prostheses (ISFPs) and implant supported removable partial dentures (ISRPD). In particular, RPDs and ISFPs are frequently used in cases where multiple teeth are missing.

RPDs can be applied to various forms of partial edentulism, and their range of application is wide. They also require minimal invasion to the abutment teeth. However, components such as retainers, major connectors, and bases may cause patient discomfort and poor esthetics. It has also been reported that abutment teeth of RPDs have a higher risk of tooth loss. It is well known that the survival rates of abutment teeth of RPDs are lower than other teeth as a result of mechanical and hygiene factors. Because the occlusal load on the edentulous space is distributed to the abutment retainers, the minor connectors and retainers worsen oral hygiene around the abutment teeth.[2-4]

An ISFP requires some surgical intervention for the patient but is less invasive for the teeth adjacent to the dental implant. Additionally, patients with ISFPs are reported to be highly satisfied with the masticatory function and esthetics of their prostheses, and have a high oral-related quality of life (QoL).[5-10]

A previous study reported that the 5-year survival rate of direct abutment teeth with an RPD was 86.6%.[11] Aquilino et al. reported that the survival rates of the adjacent teeth with one tooth missing with an FPD or RPD was 97% and 77% over 5 years and 92% and 56% over 10 years respectively.[12] It was also reported that the survival rates of teeth adjacent to an ISFP for one lost tooth were 100% over 5 years and 99% over 10 years.[13] There are many reports on the prognosis of teeth adjacent to edentulous spaces with ISFPs and RPDs.[12,14-16] However, there are a few reports about the prognosis of teeth adjacent to partial edentulous spaces and especially the other remaining teeth in ISFPs compared with RPDs.[17]

ISFPs may overload opposing teeth compared to RPD because the absence of a periodontal ligament of them may result in a lack of proprioceptive function[25]. However, there are few studies comparing prognosis of opposing teeth with RPDs and ISFPs.

It is important for patients to know the prognosis of the remaining teeth depending on difference of prostheses when considering prosthodontics treatment.

Therefore, the aim of this retrospective study was to assess and compare the prognosis of the remaining teeth with ISFPs or RPDs in partially edentulous patients in terms of survival and complication-free rates. The null hypothesis is that there is no difference in the prognosis of the remaining teeth between ISFPs and RPDs.

2. Materials and Methods

2. 1. Study population

The subjects were partially edentulous patients who had ISFPs or RPDs inserted at the removable prosthodontic clinic at Hokkaido University Hospital from 2003 to 2016. Patients who had been followed up at least twice a year were selected. Only RPDs with a metal framework were included. Patients with complete dentures, resin dentures, or an observation period of less than 1 year were excluded.

2. 2. Study design

From the clinical data, we obtained the patient's age, sex, number of remaining teeth, Eichner classification, the type of prosthesis, and the state of the remaining teeth at the date of prosthesis insertion.

The teeth investigated were those adjacent to edentulous spaces (A-teeth), teeth not adjacent to edentulous spaces in jaw with edentulous space (R-teeth), and teeth opposing edentulous spaces (O-teeth). Each tooth was also assessed in terms of the type of tooth, endodontic therapy performed, type of prosthesis, type of tooth restoration, tooth splinting, and presence of opposing teeth. The restorations were subdivided into crowns, partial restorations, and no restorations.

The date of prosthesis insertion was defined as the start of the observation period. Patients were followed up to check for any technical or biological complications. The endpoint for survival

was defined as tooth extraction. The endpoint for complications was defined as loss of cementation or fracture of a crown restoration, fracture of a tooth, caries, periapical disease, or periodontal disease. Periodontal disease as an endpoint was defined as tooth mobility or alveolar bone loss that led to extraction or replacement of the root coping. These endpoints defined for a tooth not a patient.

If no complications were found, the end of the observation period was defined as the date of the last visit to the hospital before December 2017.

The number of cases in the Hokkaido University Hospital during the study period determined the sample size.

2. 3. Statistical analysis

In order to examine multicollinearity, Spearman's rank correlation coefficients among independent variables were calculated, and one clinically meaningful variable was selected as a candidate for cox regression model if there were mutually highly correlated variables. A univariate cox regression model was used to estimate the risk factors for survival and complications of the investigated teeth[18]. Multivariate cox regression model was performed with independent variables whose $p < 0.2$ in the univariate analysis[19]. Clustering of multiple teeth in each patient was taken into consideration in univariate and multivariate cox regression models by robust standard errors[18]. Hazard ratios and 95% confidence intervals were estimated using the Wei-Weissfeld method with patient as a clustering variable [18].

Kaplan–Meier analysis was used to evaluate survival rates and complication-free rates for the three types of teeth (A-teeth, R-teeth, and O-teeth) since it has been shown that the usual Kaplan-Meier estimator is consistent for correlated data[20]. P-values from univariate cox regression adjusting clustering were provided along with Kaplan-Meier curves[18].

Statistical analyses were performed using JMP 14.0 (SAS Institute Inc., Cary, NC, USA) and EZR (Saitama Medical Center, Jichi Medical University, Saitama, Japan)[21], which is a graphical user interface for R (The R Foundation for Statistical Computing, Vienna, Austria) with a significance level of 0.05. We used the EZR coxph function with cluster (patient ID) term to obtain robust standard errors[18].

The protocol of this study was approved by the Ethics Committee of Hokkaido University Hospital (017-0213).

3. Results

3. 1 Study population

From the 366 patients who had ISFPs or RPDs inserted at the removable prosthodontic department at Hokkaido University Hospital from 2003 to 2016, 177 patients were excluded based on the exclusion criteria. There was no one in Eichner C group with ISFPs, and Eichner A group had only four patients with RPDs based on the Eichner classification. Therefore, in the statistical analysis, groups A and C in the Eichner classification were excluded. Finally, 233 patients were evaluated. There were 89 patients with ISFPs (male: 24, female: 65), and 144 patients with RPDs (male: 37, female: 107). The mean observation period was 55.6 ± 35.3 months (Table 1).

The number of evaluated teeth in patients with ISFPs was 192 A-teeth, 988 R-teeth, and 210 O-teeth. The number of evaluated teeth in patients with RPDs was 512 A-teeth, 1147 R-teeth, and 698 O-teeth (Table 2).

3.2. Survival rates

In ISFP patients, the survival rates over 5 years and 10 years were 92.8% and 92.8% for A-teeth, 98.4% and 98.1% for R-teeth, and 97.5% and 97.5% for O-teeth respectively. In RPD patients, the survival rates over 5 years and 10 years were 93.0% and 89.7% for A-teeth, 96.1% and 91.6% for R-teeth, and 96.9% and 93.9% for O-teeth respectively (Fig. 1). There was no statistically significant difference between the survival curves for ISFP patients and RPD patients for A-teeth

($p = 0.567$) and O-teeth ($p = 0.311$). In R-teeth, a statistically significant difference was found between the survival curves of ISFP and RPD patients ($p = 0.002$). There was no significant difference in the prognosis of A-teeth, R-teeth, and O-teeth in RPD patients ($p = 0.064$), but there was a significant difference in ISFP patients ($p = 0.033$) (Fig. 2)

The most common cause of extraction in A-teeth, R-teeth and O-teeth in ISFP patients was tooth fracture (3.6%, 0.7% and 1.0% of the total subject teeth, respectively). The number of tooth extractions due to fracture in ISFP patients was six of the seven A-teeth, six of the 11 R-teeth, and two of the three O-teeth. Of the 25 A-teeth in RPD patients, 16 were extracted due to tooth fracture (3.8% of the total subjects). Of the 40 R-teeth in RPD patients, 13 (1.3% of the total subjects) were extracted due to fracture and 13 (1.3% of the total subjects) were extracted due to periapical disease. Of the 22 O-teeth of RPD patients, 7 were extracted due to caries (1.1% of the total subjects).

3. 3. Complication-free rates (Fig. 3)

In ISFP patients, the complication-free rates over 5 years and 10 years were 74.2% and 61.9% for A-teeth, 84.0% and 78.9% for R-teeth, and 78.3% and 68.9% for O-teeth respectively. In RPD patients, the complication-free rates over 5 years and 10 years were 74.9% and 56.8% for A-teeth, 79.7% and 65.2% for R-teeth, and 82.6% and 65.7% for O-teeth respectively. There was no statistically significant difference between ISFPs and RPDs in A-teeth ($p = 0.921$), R-Teeth ($p = 0.086$), or O-teeth ($p = 0.591$).

There was no significant difference in the prognosis of A-teeth, R-teeth, and O-teeth in ISFPs ($p = 0.390$). On the other hands, there was significant differences in the prognosis of them in RPDs ($p = 0.048$) (Fig. 4).

In ISFP patients, caries was observed in 10 A-teeth (6.0% of the total subjects), in 51 R-teeth (6.0% of the total subjects), and in 13 O-teeth (6.6% of the total subjects). In RPD patients, loss of retention was observed in 30 A-teeth (7.0% of the total subjects), and caries were observed in 80 R-teeth (8.1% of the total subjects) and 46 O-teeth (7.3% of the total subjects). In both groups, caries was the most frequently found complication, except for A-teeth in RPD patients, in which loss of retention was most frequently observed.

3.4. Multivariate analysis

Because there were strong correlations between the number of remaining teeth ($\rho = -0.52$, $p < 0.001$), the number of occlusal supports ($\rho = -0.53$, $p < 0.001$), and Eichner classification, and between type of tooth restoration ($\rho = 0.72$, $p < 0.001$) and endodontic therapy, we selected Eichner classification and endodontic therapy, which has been reported to be one of the risk factors for tooth loss, as the representative of these variables.[11]

Therefore, age, sex, Eichner classification, type of prothesis, type of tooth, endodontic therapy performed, presence of opposing teeth and splinting of teeth were used as covariates of the survival and complication-free functions in the Cox regression model.

Risk factors for tooth survival are shown in Table 3-5. Cox proportional hazard analysis indicated that endodontic therapy and jaw (maxilla) were significant prognostic factors in the survival of A-teeth (Table.3). In R-teeth, type of prothesis, endodontic therapy were indicated as significant prognostic factors for survival (Table.4). In O-teeth, there was no significant prognostic factor for survival (Table.5). Risk factors for teeth complications are shown in Table 6-8. There was no statistically significant difference in the complications of A teeth. The jaw (maxilla) were significant prognostic factors for complications in R-teeth. Eichner classification and jaw (mandible) were significant prognostic factors for complications in O-teeth.

4. Discussion

4-1. Study design

In this study, we examined the survival rate and complication-free rate of remaining teeth of patients with ISFPs and RPDs. Inclusion criteria were set to adjust as much as possible for the factors that influence survival and the complication-free rate. Subjects were limited to patients who visited the clinic at least twice a year, as it has been reported that there is a significant difference in the survival rate of teeth between patients who visit regularly and those who do not.[22-25] Because the design of the denture affects the prognosis of the remaining teeth, a denture using a metal framework was selected, and we excluded acrylic resin dentures and temporary dentures.[26]

4-1. Prognosis of abutment teeth

Priest et al. reported that the 10-year survival rate of A-teeth in ISFPs was 98.7%.[13] Krennmair et al. reported that the tooth adjacent to edentulous spaces in implants more than 3 years old had a 100% survival rate and a 97.2% complication-free rate.[14] Misch et al. reported a 100% survival rate and a 94.7% complication-free rate over 10 years.[15] In this study, the 10-year survival rate for A-teeth in ISFP patients was 92.8%, slightly lower than the previous study. However, the complication-free rate over 10 years was 61.9%, which is considerably lower than in the previous reports. In all of the previous reports, the subjects included those with teeth adjacent to edentulous spaces with a single implant, and the number of remaining teeth may have been higher than that in this study. With a single missing tooth, the prognosis is good because strong occlusal force is not applied to the adjacent teeth, and the prognosis of the remaining teeth deteriorates as the number of defects increases.[11] Additionally, our study included multiple missing teeth, which may have caused adjacent teeth to be overloaded while edentulous space was expanding.

Vanzeveren et al. reported that the abutment tooth survival rate of RPDs was 90.2%.[27] Tada et al. reported that the abutment tooth survival rate of RPDs was 86.6% over 5 years.[11] In our study, the 10-year survival rate for A-teeth in RPD patients was 89.7%. This was similar to the results of the study by Vanzeveren et al.[27] and higher than that of Tada et al. [28]. The RPDs in Vanzeveren et al.'s[27] study had a metal framework, but Tada et al. also included RPDs without the

metal framework covered by Japanese medical social insurance, so there may have been differences in the rigidity of the RPDs.

Tada et al.[28] reported that the direct abutment teeth of RPDs are affected by continuous overload and poor oral hygiene from the RPD and have a higher risk of periodontal tissue damage than non-abutment teeth.[11] The denture design in our study had high rigidity and superior hygienic design with a metal framework. This ensured that the disadvantageous effect to the abutment teeth were not high enough to result in overload leading to tooth extraction.

Yamazaki et al. reported that the difference between ISFP and RPD prostheses was not a significant risk factor for the loss of teeth adjacent to edentulous spaces.[17] The subjects selected for their study had edentulous spaces of at least four continuous missing teeth. Our study subjects included a single to multiple missing teeth, and no significant difference was observed, suggesting that a rigid and well-designed RPD could be expected to have a remaining teeth prognosis comparable to that of an ISFP due to suitable distribution of occlusal force to the remaining teeth.

There is little literature on the prognosis of R-teeth. Indirect abutment devices of RPDs have been reported to affect oral hygiene and act as a risk factor for the prognosis of indirect abutment teeth,[11] but there are few reports about long-term outcomes. The effect of indirect abutment retainers on R-teeth can help us predict abutment tooth survival prospects at diagnosis based on individual characteristics. In this study, differences in the prostheses were not significant in terms of

both the survival rate. Tada et al.[28] reported that indirect abutment retainers cause a deterioration in oral hygiene and can be a risk factor for the prognosis of indirect abutment teeth. Our study did not investigate whether R-teeth were indirect abutment teeth, but it is thought that they were included with R-teeth because the RPD had well designed metal connector with high rigidity. Because the oral hygiene around RPDs seems to be similar than that of ISFPs and mechanical stress via connectors is evenly distributed to R-teeth in RPD, a significant difference might not be observed according to different prostheses. It was suggested that prognosis of R-teeth was influenced by state of teeth such as with/without of endodontic therapy and type of teeth but not type of prostheses.

For O-teeth, there was no significant difference in the survival rate or the complication-free rate between ISFPs and RPDs. Yoshino et al. reported that ISFPs were not a risk factor for the loss of opposing teeth.[29] ISFPs may overload opposing teeth because the absence of a periodontal ligament may result in a lack of proprioceptive function.[30] However, because the results were no different from the RPD results in this study, so it is considered that the effect of ISFPs on opposing teeth is not high.

This study provided suggestions for the prognosis of the remaining teeth in the patients with partial prostheses. The long-term prognosis of teeth adjacent and opposing of ISFPs was similar to that of RPDs. The adjacent teeth to ISFPs were considered to be superior to that of RPDs in terms of hygienic and mechanics, because ISFPs did not require direct retainers unlike RPDs. However,

the damage caused by overload might be accumulated to the adjacent teeth due to the expansion of the teeth loss in partially edentulism.

4-2. Limitation of the study

The survival rate of prostheses has been estimated to deteriorate rapidly 100 months after installation.[31] However, our findings may have been affected by missing data such as variations in the skill levels of the dentists, the periodontal condition, the type of post-core, and the type of cement.[32-36] Regarding opposing teeth to prostheses, it was not possible to investigate the strength of occlusal contact and the occlusal scheme. Therefore, prospective studies or randomized clinical trials should be undertaken to take these effects into account.

The null hypothesis of this study was that there was no difference in prognosis of the remaining teeth between ISFPs and RPDs. That was not rejected by all investigated teeth. In this study conditions, this suggested that the remaining teeth with RPD that designed rigidity metal framework have similar prognosis to these of ISFPs.

5.Conclusion

In the partially edentulous space, the prognosis of the remaining teeth to RPDs are similar to these of ISFPs. Our findings suggest that it depends largely on the state of teeth such as with/without of endodontic therapy, jaw, and type of teeth, not on the type of prostheses.

Also, it is suggested in this study that special consideration is required for teeth in jaw edentulous spaces to ISFPs same as these of RPDs and that the teeth opposing to ISFPs might be a good prognosis by giving an appropriate occlusion.

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Table 1 Baseline characteristics of subjects

Variables		**ISFPs**	**RPDs**	**P-value**
Sex	Male	24	37	0.0080*
	Female	65	107	
Age (SD) (year)		58.60(8.81)	66.94(9.01)	< 0.0001**
Eichner classification	B1	37	15	< 0.0001*
	B2	23	34	
	B3	18	47	
	B4	11	48	
Number of remaining teeth (SD)		21.04(3.60)	16.70(3.77)	< 0.0001**
Number of occlusal supports (SD)		8.06(2.68)	5.24(2.59)	< 0.0001**
Jaw	Upper	22	97	< 0.0001*
	Lower	69	49	

*: χ^2-test

**: t-test

ISFPs, implant-supported fixed prostheses; RPDs, removable partial dentures

Table 2 Baseline data of teeth adjacent to partial edentulous spaces

Variables		**A-teeth**	**R-teeth**	**O-teeth**
Prosthesis	ISFP	192	988	210
	RPD	512	1147	698
Endodontic therapy	Without	193	1048	318
	With	398	797	511
Restorations	Without	36	601	88
	Partial restoration	47	324	129
	Crown	508	920	612
Presence of opposing teeth	Absence	192	1323	768
	Presence	399	522	61
Splinting of teeth	Without	484	1590	670
	With	107	255	159

ISFPs, implant-supported fixed prostheses; RPDs, removable partial dentures; A-teeth, teeth adjacent to edentulous spaces; R-teeth, teeth not adjacent to edentulous spaces; O-teeth, teeth opposing edentulous spaces

Table.3 Cox regression models for each independent variable adjusting clustering of multiple teeth in each patient in A-Teeth for survival rate

survival rate		Univariate analysis			Multivariate analysis		
		HR	95%CI	P-value	HR	95%CI	P-value
Age (years)	< 65	1.00					
	≥ 65	1.35	0.64-2.84	0.433			
Sex	Male	1.00			1.00		
	Female	2.14	0.83-5.54	0.116	1.92	0.76-4.84	0.168
Eichner classification	B1,B2,B3	1.00			1.00		
	B4	1.70	0.80-3.63	0.164	1.28	0.61-2.69	0.515
Jaw	Upper	1.00			1.00		
	Lower	0.38	0.17-0.83	0.016	0.39	0.17-0.89	0.026
Prothesis	RPD	1.00					
	ISFP	0.76	0.30-1.92	0.567			
Type of teeth	Anterior	1.00					
	Posterior	1.04	0.53-2.01	0.916			
Endodontic therapy	Without	1.00			1.00		
	With	8.30	2.03-34.05	0.003	6.75	1.57-29.03	0.010
Opposing teeth	With	1.00					
	Without	1.31	0.62-2.80	0.478			
Splinting of teeth	With	1.00					
	Without	0.65	0.29-1.45	0.293			

HR, hazard ratio; ISFPs, implant-supported fixed prostheses; RPDs, removable partial dentures; A-teeth, teeth adjacent to edentulous spaces

Table.4 Cox regression models for each independent variable adjusting clustering of multiple teeth in each patient in R-Teeth for survival rate

survival rate		Univariate analysis			Multivariate analysis		
		HR	95%CI	P-value	HR	95%CI	P-value
Age (years)	< 65	1.00					
	≥ 65	1.19	0.64-2.20	0.587			
Sex	Male	1.00					
	Female	0.87	0.42-1.81	0.713			
Eichner classification	B1,B2,B3	1.00			1.00		
	B4	2.57	1.34-4.92	0.005	2.01	0.998-4.02	0.051
Jaw	Upper	1.00			1.00		
	Lower	0.38	0.20-0.71	0.003	0.80	0.44-1.48	0.479
Prothesis	RPD	1.00			1.00		
	ISFP	0.31	0.15-0.65	0.002	0.54	0.28-1.05	0.068
Type of teeth	Anterior	1.00			1.00		
	Posterior	3.48	1.83-6.63	<0.001	2.46	1.28-4.73	0.007
Endodontic therapy	Without	1.00			1.00		
	With	17.57	6.75-45.72	<0.001	10.48	3.73-29.47	<0.001
Opposing teeth	With	1.00			1.00		
	Without	2.03	1.13-3.66	0.018	0.70	0.37-1.33	0.275
Splinting of teeth	With	1.00					
	Without	1.71	0.59-5.00	0.327			

HR, hazard ratio; ISFPs, implant-supported fixed prostheses; RPDs, removable partial dentures; R-teeth, teeth not adjacent to edentulous spaces

Table.5 Cox regression models for each independent variable adjusting clustering of multiple teeth in each patient in O-Teeth for survival rate

survival rate		Univariate analysis			Multivariate analysis		
		HR	95%CI	P-value	HR	95%CI	P-value
Age (years)	< 65	1.00					
	≥ 65	0.72	0.28-1.84	0.491			
Sex	Male	1.00					
	Female	1.34	0.51-3.51	0.558			
Eichner classification	B1,B2,B3	1.00			1.00		
	B4	2.52	0.97-6.53	0.057	2.54	0.95-6.79	0.063
Jaw	Upper	1.00					
	Lower	1.60	0.66-3.86	0.300			
Prothesis	RPD						
	ISFP	0.45	0.10-2.09	0.311			
Type of teeth	Anterior	1.00			1.00		
	Posterior	3.63	0.82-16.12	0.090	2.71	0.55-13.33	0.220
Endodontic therapy	Without	1.00			1.00		
	With	3.27	1.06-10.04	0.039	1.18	0.34-4.06	0.791
Splinting of teeth	With	1.00					
	Without	1.07	0.27-4.15	0.927			

HR, hazard ratio; ISFPs, implant-supported fixed prostheses; RPDs, removable partial dentures; O-teeth, teeth opposing edentulous spaces

Table.6 Cox regression models for each independent variable adjusting clustering of multiple teeth in each patients in A-Teeth for complication-free rate

complication free rate		Univariate analysis			Multivariate analysis		
		HR	95%CI	P-value	HR	95%CI	P-value
Age (years)	< 65	1.00					
	≥ 65	1.12	0.77-1.62	0.553			
Sex	Male	1.00					
	Female	1.18	0.77-1.80	0.445			
Eichner classification	B1,B2,B3	1.00			1.00		
	B4	1.35	0.93-1.97	0.116	1.42	0.97-2.07	0.072
Jaw	Upper	1.00			1.00		
	Lower	0.70	0.47-1.05	0.086	0.71	0.49-1.05	0.089
Prothesis	RPD	1.00					
	ISFP	1.02	0.65-1.60	0.921			
Type of teeth	Anterior	1.00					
	Posterior	0.91	0.63-1.31	0.606			
Endodontic therapy	Without	1.00					
	With	0.99	0.65-1.50	0.957			
Opposing teeth	With	1.00					
	Without	1.02	0.67-1.53	0.937			
Splinting of teeth	With	1.00			1.00		
	Without	1.46	0.83-2.58	0.186	1.55	0.87-2.75	0.136

HR, hazard ratio; ISFPs, implant-supported fixed prostheses; RPDs, removable partial dentures; A-teeth, teeth adjacent to edentulous spaces

Table.7 Cox regression models for each independent variable adjusting clustering of multiple teeth in each patients in R-Teeth for complication-free rate

complication free rate		Univariate analysis			Multivariate analysis		
		HR	95%CI	P-value	HR	95%CI	P-value
Age (years)	< 65	1.00			1.00		
	≥ 65	1.35	0.94-1.93	0.107	1.09	0.73-1.61	0.674
Sex	Male	1.00					
	Female	0.87	0.60-1.27	0.471			
Eichner classification	B1,B2,B3	1.00			1.00		
	B4	1.58	1.05-2.38	0.030	1.44	0.91-2.30	0.123
Jaw	Upper	1.00			1.00		
	Lower	0.54	0.39-0.76	<0.001	0.63	0.44-0.89	0.010
Prothesis	RPD	1.00			1.00		
	ISFP	0.72	0.50-1.05	0.086	0.96	0.63-1.46	0.849
Type of teeth	Anterior	1.00			1.00		
	Posterior	1.35	0.999-1.83	0.051	1.22	0.91-1.64	0.185
Endodontic therapy	Without	1.00			1.00		
	With	1.60	1.15-2.23	0.006	1.20	0.81-1.77	0.369
Opposing teeth	With	1.00					
	Without	0.90	0.69-1.18	0.456			
Splinting of teeth	With	1.00					
	Without	1.01	0.63-1.59	0.984			

HR, hazard ratio; ISFPs, implant-supported fixed prostheses; RPDs, removable partial dentures; R-teeth, teeth not adjacent to edentulous spaces

Table.8 Cox regression models for each independent variable adjusting clustering of multiple teeth in each patients in O-Teeth for complication-free rate

complication free rate		Univariate analysis			Multivariate analysis		
		HR	95%CI	P-value	HR	95%CI	P-value
Age (years)	< 65	1.00					
	≥ 65	0.83	0.53-1.30	0.405			
Sex	Male	1.00					
	Female	1.02	0.62-1.68	0.947			
Eichner classification	B1,B2,B3	1.00			1.00		
	B4	1.66	1.06-2.61	0.028	1.60	1.01-2.52	0.0445
Jaw	Upper	1.00			1.00		
	Lower	1.73	1.04-2.55	0.319	1.57	1.00-2.45	0.0488
Prothesis	RPD	1.00					
	ISFP	1.14	0.70-1.85	0.591			
Type of teeth	Anterior	1.00					
	Posterior	0.91	0.58-1.44	0.694			
Endodontic therapy	Without	1.00					
	With	0.86	0.60-1.27	0.457			
Splinting of teeth	With	1.00					
	Without	1.17	0.63-2.17	0.621			

HR, hazard ratio; ISFPs, implant-supported fixed prostheses; RPDs, removable partial dentures; O-teeth, teeth opposing edentulous spaces