OUKA
The University of Osaka
Institutional Knowledge Archive

Title	Survival time analysis of remaining teeth following replacement of unilateral free-end missing teeth: A comparison between fixed implant-supported prostheses and removable partial dentures
Author(s)	Tsujioka, Yoshitaka; Mameno, Tomoaki; Akema, Suzuna et al.
Citation	Clinical Oral Implants Research. 2024, 35(5), p. 526-533
Version Type	VoR
URL	https://hdl.handle.net/11094/95277
rights	This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License.
Note	

The University of Osaka Institutional Knowledge Archive : OUKA

https://ir.library.osaka-u.ac.jp/

The University of Osaka

Check for updates

Received: 26 July 2023 | Revised: 8 December 2023 | Accepted: 31 January 2024

DOI: 10.1111/clr.14248

ORIGINAL ARTICLE

CLINICAL ORAL IMPLANTS RESEARCH WILEY

Survival time analysis of remaining teeth following replacement of unilateral free-end missing teeth: A comparison between fixed implant-supported prostheses and removable partial dentures

Yoshitaka Tsujioka[1] | Tomoaki Mameno[1] | Suzuna Akema[1] | Daisuke Hasegawa[1] | Yoshie Okada[1] | Eri Seto[1] | Tomoya Gonda[1] | Tsung-Chieh Yang[2] | Masahiro Wada[1] | Kazunori Ikebe[1]

[1]Department of Removable Prosthodontics and Gerodontology, Osaka University Graduate School of Dentistry, Osaka, Japan

[2]Department of Prosthodontics School of Dentistry, National Taiwan University, Taipei, Taiwan

Correspondence
Tomoaki Mameno, Department of Removable Prosthodontics and Gerodontology, Osaka University Graduate School of Dentistry, 1-8 Yamadaoka, Suita, Osaka 565-0871, Japan.
Email: mameno.tomoaki.dent@osaka-u.ac.jp

Abstract

Objectives: This retrospective study aimed to investigate the differences in tooth loss rate between fixed implant-supported prostheses (FISPs) and removable partial dentures (RPDs) in cases of unilateral free-end missing teeth.

Materials and Methods: The data of 324 patients who underwent treatment with FISPs or RPDs for unilateral free-end missing teeth and satisfied the applicable criteria, were evaluated (47 in the FISPs group and 277 in the RPDs group). After propensity score (PS) matching, which was used to extract patients with similar background factors related to prosthetic selection at baseline, survival time analyses were performed with tooth loss as the endpoint. The adjusted variables were age, sex, number of restored teeth, periodontal status, and the practicing dentist's experience in years. The remaining teeth were classified into subcategories in relation to the missing molars.

Results: Overall, 58 patients (29 in each group) selected by PS matching were evaluated in the final analysis. The total number of lost teeth was 35 (FISPs group: $n=10$; RPDs group: $n=25$). The mean (±SD) period to tooth loss and the 10-year survival rates in the FISPs and RPDs groups were 51.6 (±30.1) months and 42.3 (±29.7) months, 70.5% and 16.4%, respectively. The log-rank test showed that significantly longer survival time in FISPs compared with RPDs.

Conclusions: After adjustments for confounding factors using PS matching, replacing unilateral free-end missing teeth with FISPs may exhibit a lower tooth loss rate in adjacent and contralateral teeth compared to replacing with RPDs.

KEYWORDS
clinical research, fixed implants-supported prostheses, removable partial dentures, tooth loss, unilateral free-end missing teeth

This is an open access article under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs License, which permits use and distribution in any medium, provided the original work is properly cited, the use is non-commercial and no modifications or adaptations are made.
© 2024 The Authors. *Clinical Oral Implants Research* published by John Wiley & Sons Ltd.

1 | INTRODUCTION

In the prosthodontic treatment of free-end missing teeth, fixed implant-supported prostheses (FISPs) and removable partial dentures (RPDs) are primarily used to rehabilitate oral function, reduce the occlusal load on the residual teeth, and prevent further tooth loss. Each treatment has its advantages and disadvantages; however, there is a significant difference between them in terms of stress-bearing capacity.

FISPs may reduce the occlusal load on the remaining teeth in free-end partial edentulous cases because of the stability and support provided by the jawbone. Implant treatment also prevents further tooth loss by improving load-bearing capacity and reducing the occlusal load on the distal-most teeth (Hatta et al., 2021; Yamazaki et al., 2013). Previous studies have focused on the survival rates of the remaining teeth adjacent to the edentulous space in FISPs, and one such study showed that the 10-year survival rate for the adjacent teeth in FISPs is 100% (Misch et al., 2008).

The RPDs for missing posterior free ends lack secure connections to abutment teeth and soft tissues, and each has a different displaceability. Occlusal force loading on RPDs can generate different levels of tissue stress and RPDs mobility; these stress and mobility must remain within physiological limits. Therefore, to reduce the occlusal load applied to the abutment tooth of RPDs, it is important to consider the difference in pressure displacement between the periodontal ligament and the alveolar ridge mucosa. Despite these considerations, increased loading stress leads to a higher risk of loss of abutment teeth (Preshaw et al., 2011).

Additionally, it is considered that RPDs increase the risk of periodontitis, dental caries, and other mucosal diseases of abutment teeth (Preshaw et al., 2011). Gingival inflammation increased periodontal probing depth, and gingival recession are more common in patients wearing RPDs (Zlatarić et al., 2002). As for caries incidence, several studies have reported RPDs as one of the risk factors for root caries (Gati & Vieira, 2011; Preshaw et al., 2011). Regarding tooth loss in partially dentulous patients provided with RPDs, the 5-year survival rate of abutment teeth was significantly lower (86.6%) than that of non-abutment teeth (95.8%) (Tada et al., 2013). Based on these findings, FISPs may reduce the risk of adjacent tooth loss. However, these clinical studies were performed in FISPs or RPDs individually. Information is lacking about the difference between FISPs and RPDs under uniform evaluations.

A retrospective study showed higher hazard ratios for tooth loss when the mandibular first molars had an antagonist with FISPs. This is thought to be chiefly because FISPs do not have a periodontal ligament and are prone to occlusal overloading of the opposing teeth (Park et al., 2021). Moreover, a study reported clear differences in the micro-movement patterns between FISPs and natural teeth (Száva et al., 2022). Thus, the difference in the load-bearing capacity of the two prostheses indicate a different distribution of mechanical forces, which may affect the residual teeth including the adjacent teeth.

However, to the best of our knowledge, few reports have focused on the prognosis of the whole remaining teeth in patients who have undergone prosthodontic treatment for unilateral missing molars. Therefore, this retrospective study aimed to compare the effect of tooth loss between FISPs and RPDs after prosthodontic treatment for unilateral free-end missing teeth.

2 | MATERIALS AND METHODS

2.1 | Study design and participants

This retrospective study was based on the dental records and radiographic images of patients with unilateral free-end partial edentulism who underwent prosthodontic treatment with FISP or RPD between January 2010 and December 2021 at the Department of Removable Prosthodontics Gerodontology, Osaka University Dental Hospital, Osaka, Japan. The study protocol complied with the Declaration of Helsinki and was approved by the Osaka University Graduate School of Dentistry Ethics Committee (approval no. R1-E34). The Strengthening and Reporting of Observational Studies in Epidemiology statement was used as the guideline for this study.

The partially edentulous patients included in this study had unilateral free-end missing molars in maxillary or mandibular arch with occlusal support from the remaining natural teeth or pontics, in the same and/or opposite side, and had either signed or were not opposed to a general consent for participation in the research. Patients who had no panoramic radiographs taken during prosthodontic treatment, who had not visited the hospital for >1 year, or who had jaw defects were excluded.

2.2 | Data collection

2.2.1 | Demographic and clinical characteristics

Patients' demographic information (age at treatment, sex, systemic diseases, status of remaining teeth [such as number of restored teeth, root-filled teeth, and periodontal status]) and details about prosthodontic treatment (type of prosthesis, number of replaced missing teeth, date of prosthesis insertion, attending dentist and years of experience, and RPD design) were collected from the electronic dental record of the hospital. Information on the RPD design included the number and position of the abutment teeth.

2.2.2 | Radiographic evaluation

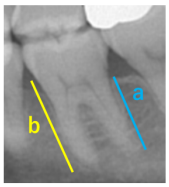
The numbers of restored and root-canal-treated teeth, and periodontal bone loss (PBL) were assessed using pre-treatment panoramic radiographs. The degree of periodontitis was evaluated using a radiography-based PBL method as a screening tool for periodontitis

16000501, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/clr.14248 by Yayoi Yoshida - Osaka University , Wiley Online Library on [14/03/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

(Machado et al., 2020). PBL was assessed by measuring the total bone height (a: distance from the tooth apex to the marginal bone crest) and total root length (b: distance from the tooth apex to the cemento-enamel junction) in each tooth (Figure 1). Teeth with visible cemento-enamel junctions and apices were included. Using the minimum value of b − a/b as the evaluation target, the average value of all remaining teeth was classified as "healthy (PBL ≤ 20%)," "mild to moderate (20 < PBL < 35%)," and "severe (35% ≤ PBL)". All PBL measurements were performed by a trained independent investigator (TY). To test the intra-examiner reliability, 5 radiographs were randomly selected and clinically examined three times, with a one-day interval between each test. The intraclass correlation coefficient value was .98 (95% confidence interval, CI: 0.97–0.99).

2.2.3 | Assessment of tooth loss

The date, position, and reason for the first tooth extraction after treatment were assessed from the dental records. The reasons for tooth extraction were mainly classified into the following three categories: (i) root fracture, (ii) caries, and (iii) periodontitis (Aida et al., 2006; Suzuki et al., 2022). All data collection was performed by a single examiner (TY) in December 2022. The last date of visit was recorded for patients with no history of tooth extraction at the time of the survey.



a: the tooth apex to the marginal bone crest
b: the tooth apex to the cemento-enamel junction

$$\frac{b-a}{b} \times 100\,(\%) = \begin{cases} \text{Healthy (PBL} \leqq 20\%) \\ \text{Mild to moderate (20<PBL<35\%)} \\ \text{Severe (35\%} \leqq \text{PBL)} \end{cases}$$

FIGURE 1 The measuring method for periodontal bone loss on the radiographs. (a) distance from the tooth's apex to the cemento-enamel junction, (b) distance from the tooth's apex to the marginal bone crest.

2.3 | Statistical analysis

Mann–Whitney *U*-tests for continuous variables and chi-square tests for categorical variables were used to compare the characteristics between the FISPs and RPDs groups. To minimize the risk of confounding bias in this cohort, the patients in each group were matched using propensity score (PS) (Austin, 2011; Kim et al., 2016); hence, we could perform covariate adjustment using the information on the covariates and confounding factors. PS was estimated using logistic regression, with the prosthesis type as the dependent variable and the demographic and confounding factors, such as age, sex, history of diabetes, history of osteoporosis, number of filled teeth, degree of periodontitis, and the attending dentist and years of experience, as independent variables. One-to-one matching was performed according to the "nearest-neighbor matching" method using calipers with a width equal to 0.2 of the standard deviation of the logit of PS. Patient characteristics after PS matching were assessed using the Mann–Whitney *U* and chi-square tests. The Kaplan–Meier method and log-rank test were performed to evaluate the effects of FISPs and RPDs on tooth loss in the PS-matched cohort. To assess the region of tooth loss based on the relationship between the missing zone and the position of the remaining teeth, separate survival time analyses were conducted in five sub-zones: (I) adjacent zone to the missing molars; (II) contralateral to the missing molars in the same jaw; (III) ipsilateral to the missing molars in the opposite jaw; (IV) contralateral to the missing molars in the opposite jaw; and (V) anterior teeth zone (Figure 2). All statistical analyses were performed using SPSS version 27 (IBM Corp, Armonk, NY, USA). Statistical significance was set at $p < .05$.

3 | RESULTS

A total of 1276 patients were treated with FISPs or RPDs for unilateral free-end missing teeth between January 2010 and December 2021 at Osaka University Dental Hospital. Thereafter, 952 were excluded based on the exclusion criteria. Finally, we included 324 patients (47 for FISPs and 277 for RPDs; Figure 3). Table 1 shows an overview of the patients

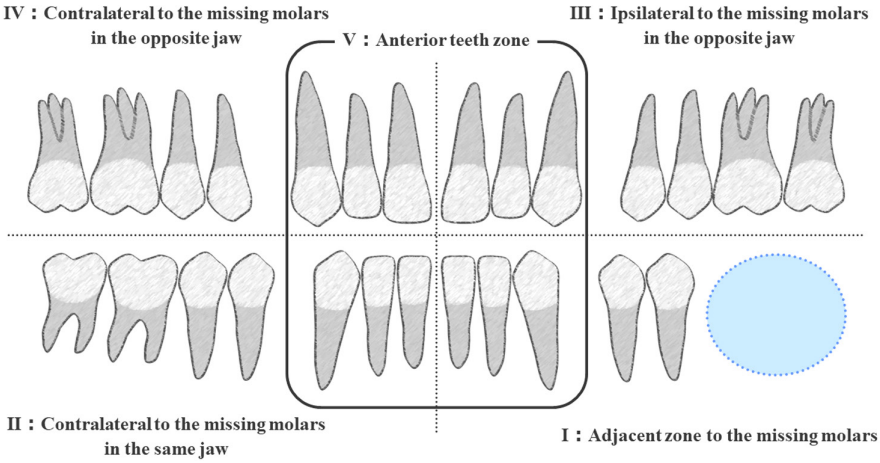


FIGURE 2 Five sub-zones of dentition classified according to their relationship to the unilateral free-end missing teeth. (I) adjacent zone to the missing molars; (II) contralateral to the missing molars in the same jaw; (III) ipsilateral to the missing molars in the opposite jaw; (IV) contralateral to the missing molars in the opposite jaw; and (V) anterior teeth zone.

16000501, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/clr.14248 by Yayoi Yoshida - Osaka University , Wiley Online Library on [14/03/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

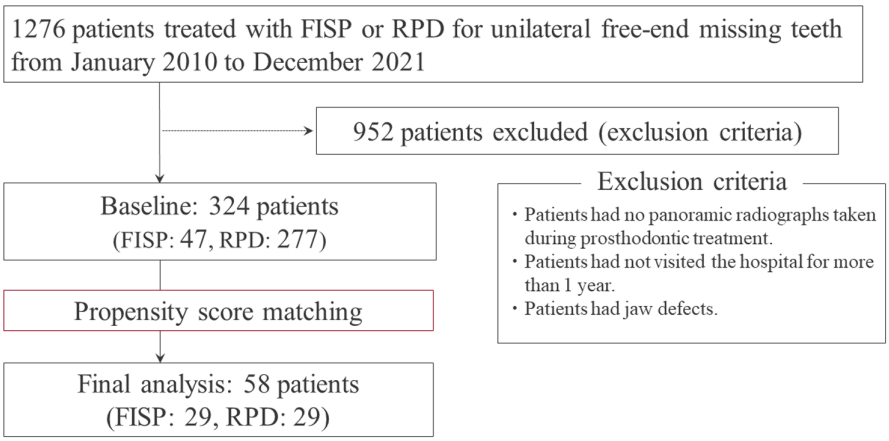


FIGURE 3 Flow diagram and study design. FISP, fixed implant-supported prosthesis; RPD, removable partial denture.

and the comparative results between the groups. In total, 128 patients (12 in the FISPs group and 116 in the RPDs group) had lost their teeth after prosthodontic treatment. Table 2 shows an overview of the patients and the results of comparisons between the groups after using the PS matching method. Fifty-eight patients (29 each in the FISPs and RPDs groups) were included in the final analysis. The total number of lost teeth was 35 (10 in the FISPs group and 25 in the RPDs group, all of which were single-tooth extractions); 28 were root-canal-treated teeth (7 in the FISPs group and 21 in the RPDs group). In the FISPs group, the reasons for tooth loss were root fracture ($n=4$), caries ($n=4$), and periodontitis ($n=2$). In contrast, the reasons for tooth loss in the RPDs group were root fractures ($n=14$), caries ($n=3$), and periodontitis ($n=8$). The two groups had significant differences in the incidence of root fractures ($p=.005$) and periodontitis ($p=.037$).

The teeth positions affected by tooth loss in the FISPs group were the anterior teeth ($n=1$), premolars ($n=0$), and molars ($n=9$), whereas those in the RPDs group were the anterior teeth ($n=0$), premolars ($n=12$), and molars ($n=13$). The mean survival times (±standard deviation [SD]) of the lost tooth were 51.6 ± 30.1 months in the FISPs group and 42.3 ± 29.7 months in the RPDs group.

Table 3 shows the survival analysis results of the entire study zone and each zone individually after PS matching. Significant differences were observed in the entire study zone and in zones I and II. The period to tooth loss (mean ± SD) was the shortest in zone II: 36.3 ± 38.2 months in the FISPs group and 28.9 ± 31.5 months in the RPDs group.

In the analysis of the remaining teeth, the 5- and 10-year survival rates in the FISPs group were 92% and 70.5%, respectively, and 77.8% and 16.4%, respectively, in the RPDs group (Figure 4W). In zone I, six teeth (including four abutments) were lost in the RPDs group, whereas no teeth were lost in the FISPs group (Figure 4I). In zone II, four teeth were lost in the FISPs group, whereas 10 teeth (including six abutments) were lost in the RPDs group (Figure 4II). No significant differences were observed among zones III, IV, and V.

4 | DISCUSSION

In this study, we compared the effects of FISPs and RPDs on tooth loss in patients with unilateral free-end partial edentulous arches. To the best of our knowledge, this study is the first to compare the survival rates of the whole remaining teeth in patients treated with FISPs or RPDs for their unilateral free-end edentulous spaces using PS matching analysis. PS matching analysis was performed to balance the covariates in the two groups, thus reducing this bias. The survival time analysis revealed a significant difference between the FISPs and RPDs groups in terms of the "adjacent zone to the missing molars" and "contralateral to the missing molars in the same jaw," suggesting that the FISPs group had a lower risk of tooth loss in unilateral free-end missing teeth cases.

The 10-year survival rate for missing adjacent teeth in FISPs is 100% (Misch et al., 2008). Priest (1999) reported a 10-year survival rate of 98.7% for missing adjacent teeth with FISPs. Aquilino et al. (2001) reported that the 5-year survival rates of teeth adjacent to a distal free-end edentulous space were 97% in the FISPs group and 77% in the RPDs group. All these cases are FISP treatments for single missing tooth in the molar region. The possibility that FISPs prevent the loss of adjacent teeth to a greater extent than RPDs has also been reported. A previous retrospective study reported that 9.5% of patients with FISPs (2/21 patients) and 12.2% of patients with RPDs (10/82 patients) lost teeth adjacent to a missing distal free-end, with no significant difference between the two groups (Yamazaki et al., 2013). Based on the significantly higher complication rate in RPDs than in FISPs, the authors suggested that the stable occlusal support obtained with FISPs reduced the adverse mechanical stress on the remaining teeth. However, these studies did not consider baseline dental conditions, such as existing periodontitis or restoration status, which have a significant impact on tooth loss. In addition to these factors, we collected data on confounding factors, such as history of diabetes mellitus and osteoporosis, and years of experience as a prosthodontist, which may affect the decision to place implants. Furthermore, the strength of this study was the matching of patients with the background factors associated with the dentist's decision to select prosthodontic treatment. In observational studies, PS matching offers advantages, including intuitive analysis, transparent presentation of covariate balance, effective removal of covariate imbalance with less bias compared to other methods, and no requirement for specifying the PS-outcome association (Kim et al., 2016). While PS methods have limitations, such

16000501, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/clr.14248 by Yayoi Yoshida - Osaka University , Wiley Online Library on [14/03/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

TABLE 1 Comparison of the baseline characteristics of the participants in the FISP and RPD groups before propensity score matching ($n = 324$).

	FISP group ($n = 47$)	RPD group ($n = 277$)	
Categorical variables	***n* (%)**	***n* (%)**	***P*-value**
Sex			
Male	21 (44.7)	85 (31.8)	.06[a]
Female	26 (55.3)	192 (69.3)	
Missing part			
Upper jaw	10 (21.3)	88 (31.8)	.07[a]
Lower jaw	37 (78.7)	189 (68.2)	
Number of teeth in the edentulous area			
1	4 (8.5)	1 (0.4)	<.01[a]
2	39 (83.0)	178 (64.3)	
3	4 (8.5)	72 (26.0)	
4	–	24 (8.7)	
5	–	2 (0.6)	
Periodontal status			
Healthy	22 (46.8)	48 (17.3)	<.01[a]
Mild–moderate	25 (53.2)	188 (67.9)	
Severe	–	41 (14.8)	
Number of lost teeth	12 (9.4)	116 (90.6)	.17[a]
Cause of tooth loss			
Root fracture	5 (41.7)	45 (39.2)	.33[a]
Caries	5 (41.7)	26 (21.6)	.79[a]
Periodontitis	2 (16.6)	45 (39.2)	.03[a]
Site of tooth loss			
Premolar	–	35 (29.8)	.02[a]
Molar	9 (72.7)	72 (62.3)	
Anterior	3 (27.3)	9 (7.9)	
Medical history			
Diabetes mellitus	0 (0)	22 (100)	.05[a]
Osteoporosis	3 (10.0)	27 (90.0)	.46[a]
Continuous variables	**Mean ± SD**	**Mean ± SD**	***p*-Value**
Age	59.3 ± 9.5	66.0 ± 9.6	<.01[b]
Number of restored teeth	14.2 ± 4.5	15.6 ± 4.2	.75[b]
Number of root-filled teeth	6.7 ± 3.4	6.8 ± 3.7	.85[b]
Years of experience of the dentist	8.7 ± 7.7	6.0 ± 7.1	<.01[b]
Follow-up period to tooth loss (months)	49.0 ± 28.4	39.9 ± 26.8	.54[b]

Note: *p* Values were determined using the [a]chi-square test or [b]Mann–Whitney *U* test for continuous variables.

Abbreviations: FISP, fixed implant-supported prosthesis; RPD, removable partial denture; SD, standard deviation.

TABLE 2 Comparison of the baseline characteristics of the participants in the FISPs and RPDs groups after propensity score matching ($n = 58$).

	FISP group ($n = 29$)	RPD group ($n = 29$)	
Categorical variables	***n* (%)**	***n* (%)**	***p*-Value**
Sex			
Male	11 (37.9)	11 (37.9)	1.0[a]
Female	18 (62.1)	18 (62.1)	
Missing region			
Upper jaw	3 (21.3)	10 (34.5)	.45[a]
Lower jaw	26 (78.7)	19 (65.5)	
Number of teeth in the edentulous area			
1	1 (8.5)	1 (3.4)	.55[a]
2	25 (83.0)	22 (75.9)	
3	3 (8.5)	6 (20.7)	
4	–	–	
5	–	–	
Periodontal status			
Healthy	13 (44.8)	10 (34.5)	.30[a]
Mild–moderate	16 (55.2)	17 (58.6)	
Severe	–	2 (6.9)	
Number of lost teeth	10 (28.6)	25 (71.4)	<.01[a]
Cause of tooth loss			
Root fracture	4 (40.0)	14 (56.0)	<.01[a]
Caries	4 (40.0)	3 (12.0)	.65[a]
Periodontitis	2 (20.0)	8 (32.0)	.04[a]
Site of tooth loss			
Premolar	–	12 (48.0)	<.01[a]
Molar	9 (90.0)	13 (52.0)	
Anterior	1 (10.0)	–	
Medical history			
Diabetes mellitus	0 (–)	1 (25.0)	.31[a]
Osteoporosis	2 (100)	3 (75.0)	.64[a]
Continuous variables	**Mean ± SD**	**Mean ± SD**	***p*-Value**
Age	58.9 ± 10.2	63.2 ± 10.7	.07[b]
Number of restoration teeth	14.0 ± 4.3	14.2 ± 4.9	.29[b]
Number of root canal-ted teeth	6.2 ± 3.4	6.4 ± 4.4	.59[b]
Years of experience of the dentist	9.0 ± 7.8	6.2 ± 5.9	.29[b]
Follow-up period to tooth loss (months)	51.6 ± 30.1	42.3 ± 29.7	.28[b]

Note: *p* Values were determined using the [a]chi-square test or [b]Mann–Whitney *U* test for continuous variables.

Abbreviations: FISP, fixed implant-supported prosthesis; RPD, removable partial denture; SD, standard deviation.

16000501, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/clr.14248 by Yayoi Yoshida - Osaka University , Wiley Online Library on [14/03/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

TABLE 3 Results of the survival analysis for whole and sub-zones after propensity score matching.

	Type of prostheses	Number of lost teeth	Cumulative survival rates		Follow-up period for tooth loss (mean ± SD)	*p*-Value
			5 years	10 years		
Whole zone	FISP	10	92.0%	70.5%	51.6 ± 30.1	<.01
	RPD	25	77.8%	16.4%	42.3 ± 29.7	
Zone I	FISP	0	100%	100%	–	<.01
	RPD	6	91.2%	56.0%	59.3 ± 28.5	
Zone II	FISP	4	96.4%	83.1%	36.3 ± 38.2	.03
	RPD	10	84.6%	49.8%	28.9 ± 31.5	
Zone III	FISP	3	100%	94.1%	63.3 ± 30.9	.58
	RPD	3	100%	75.2%	56.7 ± 10.8	
Zone IV	FISP	2	100%	94.4%	64.0 ± 14.1	.19
	RPD	6	95.2%	78.4%	40.3 ± 27.2	
Zone V	FISP	1	95.5%	–	53.0	.32
	RPD	–	–	–	–	

Abbreviations: FISP, fixed implant-supported prosthesis; RPD, removable partial denture; SD, standard deviation.

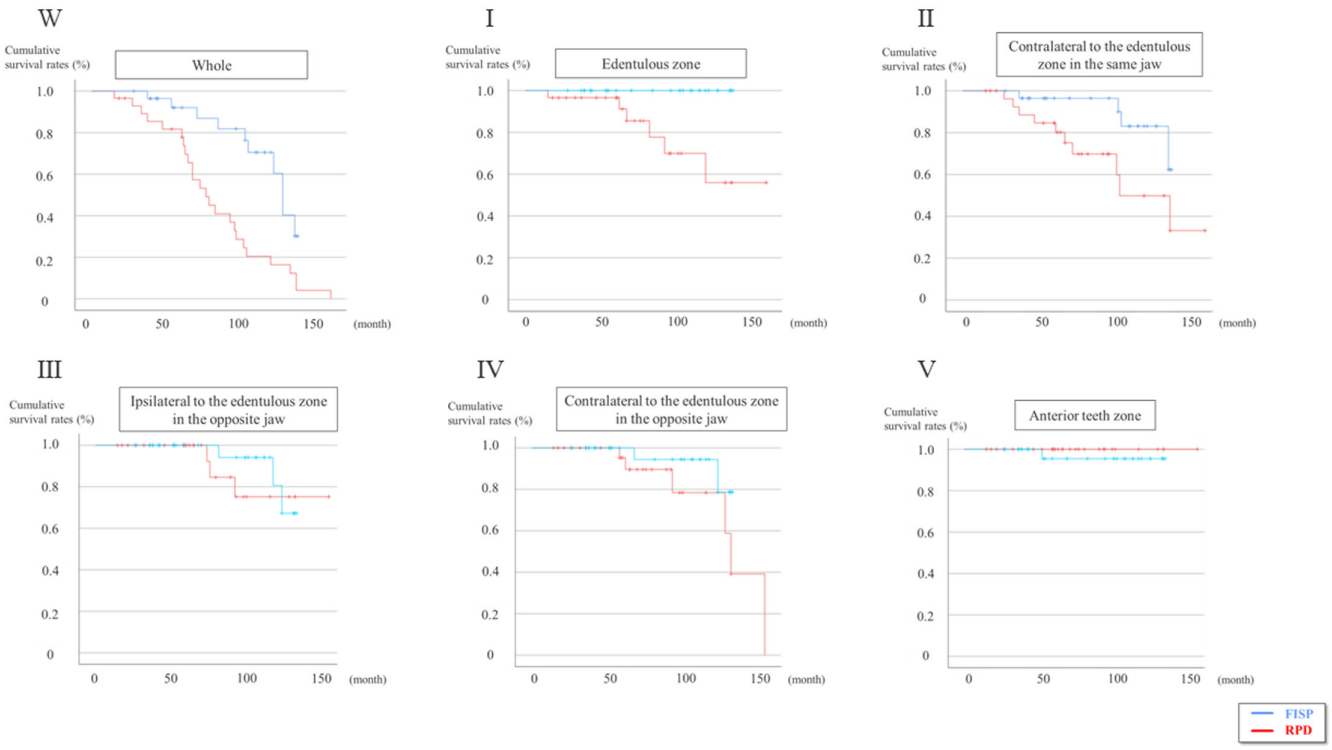


FIGURE 4 Cumulative survival curves in whole and sub-zones after propensity score matching. FISP, fixed implant-supported prosthesis; RPD, removable partial denture.

as limited generalizability and decreased statistical power due to patient exclusions, the increased precision in comparing matched pairs mitigates this loss of power (Kim et al., 2016). This observational study aimed to compare outcomes between prosthodontic treatments using FISPs and RPDs, anticipating significant background differences in non-randomized patients. To carefully adjust for confounding variables and estimate treatment effects, we conducted the analysis using PS matching.

In zone I, among all six lost teeth of the RPDs group, five were adjacent teeth (including four abutment teeth). The teeth adjacent to the missing distal free-end generally serve as removable partial denture abutments. A recent retrospective cohort study reported that RPDs abutment teeth are at high risk of subsequent tooth loss and other problems; they reported that root fractures and periodontitis were significantly associated with abutment teeth in RPDs (Matsuda et al., 2011; Tada et al., 2013). We also observed

16000501, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/clr.14248 by Yayoi Yoshida - Osaka University , Wiley Online Library on [14/03/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

in this study that the RPDs group had a higher risk of losing adjacent teeth. In the missing zone, the increased occlusal load on the abutment teeth in the RPDs group may have affected subsequent tooth loss. Additionally, the results revealed that the risk of tooth loss increased in the RPDs group in the "contralateral to the missing molars in the same jaw." We discovered that the occlusal load increased on the non-edentulous zone in the RPDs group, which is presumed to have influenced tooth loss. Furthermore, in zone II, the time to tooth loss was the shortest in both groups. Here, occlusal support by natural teeth is established, and primary mastication is assumed to occur, potentially resulting in an increased occlusal load on the remaining teeth (Tumrasvin et al., 2005). Notably, a majority of the lost teeth in this zone were molars. In both the FISPs and RPDs groups, over half of the tooth losses were attributed to root fractures, suggesting the possibility of excessive functional load.

In the "ipsilateral to the missing molars in the opposite jaw," there was no significant difference in the survival rate between the FISPs and RPDs groups. FISPs may overload opposing teeth because the absence of a periodontal ligament may result in a lack of proprioceptive function (Kim et al., 2005). In contrast, an observational cohort study of edentulous unilateral posterior regions reported that FISPs were not a risk factor for losing the opposing teeth (Yoshino et al., 2014), which was reinforced by the results of this study. These results indicate that the effect of FISPs on opposing teeth is limited, at least in patients with the adequate occlusal support from their natural teeth.

In the "contralateral to the missing molars in the opposite jaw" and the "anterior teeth zone," there was no significant difference in the survival rate between the FISPs and RPDs groups. These results are consistent with those of a previous report (Yamazaki et al., 2013).

Since this study was a retrospective cohort study based on medical records, data collection had the following limitations. First, the FISPs group, with a total of 47 patients, had a smaller sample size compared to the RPDs group with 277 patients. This difference affected the selection of variables for adjusting confounders such as age, gender, and the condition of remaining teeth associated with the choice of prostheses. To address these differences effectively while preserving the information content of the data, we employed propensity score matching, transforming numerous confounding factors into a limited set of variables. Second, the periodontal examination was not calibrated by each examiner; therefore, the degree of periodontitis was evaluated using an alternative method of interpreting panoramic X-ray images. In addition, factors such as the presence or absence of bruxism and the degree of occlusal force, which may greatly affect tooth loss, have not been investigated. Additionally, the design of RPD might be divergent which might also have an influence on the remaining teeth. Moreover, in this study, medical history was recorded by patient self-report, and the severity of each disease was unknown. Subsequently, the impact of each disease on tooth loss could not be examined in detail. In the future, we intend to investigate the influence of these factors by conducting additional surveys and discussing them in detail further.

In conclusion, after adjusting for confounding factors between the FISPs and RPDs groups, replacing unilateral free-end missing teeth with FISPs may exhibit a lower tooth loss rate in adjacent and contralateral teeth compared to replacing with RPDs. In addition, more teeth were lost in the RPDs group because of root fractures and periodontitis.

AUTHOR CONTRIBUTIONS

Kazunori Ikebe, Masahiro Wada, and Tomoaki Mameno designed the project and developed the overall research plan; Yoshitaka Tsujioka collected data on dental status; Yoshitaka Tsujoka and Tomoaki Mameno performed the statistical analysis; All authors read and approved the final manuscript.

ACKNOWLEDGMENTS

We would like to thank Editage (www.editage.com) for English language editing.

CONFLICT OF INTEREST STATEMENT

The authors confirm that there is no conflict of interest related to this article.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

ETHICS STATEMENT

The study protocol complied with the Declaration of Helsinki and was approved by the Osaka University Graduate School of Dentistry Ethics Committee (approval no. R1-E34). The Strengthening and Reporting of Observational Studies in Epidemiology (STROBE) statement was used as the guideline for this study.

PATIENT CONSENT STATEMENT

Patients had either signed or were not opposed to a general consent for participation in the research.

ORCID

Tomoaki Mameno https://orcid.org/0000-0002-1796-8371
Tomoya Gonda https://orcid.org/0000-0002-5848-7793
Tsung-Chieh Yang https://orcid.org/0000-0002-5642-3382
Masahiro Wada https://orcid.org/0000-0002-0718-8371
Kazunori Ikebe https://orcid.org/0000-0001-5696-6785

REFERENCES

Aida, J., Ando, Y., Akhter, R., Aoyama, H., Masui, M., & Morita, M. (2006). Reasons for permanent tooth extractions in Japan. *Journal of Epidemiology*, *16*(5), 214–219. https://doi.org/10.2188/jea.16.214

16000501, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/clr.14248 by Yayoi Yoshida - Osaka University , Wiley Online Library on [14/03/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Aquilino, S. A., Shugars, D. A., Bader, J. D., & White, B. A. (2001). Ten-year survival rates of teeth adjacent to treated and untreated posterior bounded edentulous spaces. *The Journal of Prosthetic Dentistry*, *85*(5), 455–460. https://doi.org/10.1067/mpr.2001.115248

Austin, P. C. (2011). An introduction to propensity score methods for reducing the effects of confounding in observational studies. *Multivariate Behavioral Research*, *46*(3), 399–424. https://doi.org/10.1080/00273171.2011.568786

Gati, D., & Vieira, A. R. (2011). Elderly at greater risk for root caries: A look at the multifactorial risks with emphasis on genetics susceptibility. *International Journal of Dentistry*, *2011*, 647168. https://doi.org/10.1155/2011/647168

Hatta, K., Takahashi, T., Sato, H., Murakami, S., Maeda, Y., & Ikebe, K. (2021). Will implants with a fixed dental prosthesis in the molar region enhance the longevity of teeth adjacent to distal free-end edentulous spaces? *Clinical Oral Implants Research*, *32*(2), 242–248.

Kim, D. H., Pieper, C. F., Ahmed, A., & Colón-Emeric, C. S. (2016). Use and interpretation of propensity scores in aging research: A guide for clinical researchers. *Journal of the American Geriatrics Society*, *64*(10), 2065–2073. https://doi.org/10.1111/jgs.14253

Kim, Y., Oh, T. J., Misch, C. E., & Wang, H. L. (2005). Occlusal considerations in implant therapy: Clinical guidelines with biomechanical rationale. *Clinical Oral Implants Research*, *16*(1), 26–35. https://doi.org/10.1111/j.1600-0501.2004.01067.x

Machado, V., Proença, L., Morgado, M., Mendes, J. J., & Botelho, J. (2020). Accuracy of panoramic radiograph for diagnosing periodontitis comparing to clinical examination. *Journal of Clinical Medicine*, *9*(7), 2313. https://doi.org/10.3390/jcm9072313

Matsuda, K., Ikebe, K., Enoki, K., Tada, S., Fujiwara, K., & Maeda, Y. (2011). Incidence and association of root fractures after prosthetic treatment. *Journal of Prosthodontic Research*, *55*(3), 137–140. https://doi.org/10.1016/j.jpor.2010.10.003

Misch, C. E., Dietsh, F. M., Silc, J., Barboza, E., & Cianciola, L. J. (2008). Posterior implant single-tooth replacement and status of adjacent teeth during a 10-year period: A retrospective report. *Journal of Periodontology*, *79*(12), 2378–2382. https://doi.org/10.1902/jop.2008.080188

Park, W. B., Kwon, K. H., Hwang, K. G., & Han, J. Y. (2021). Risk indicators affecting the survival of the mandibular first molar adjacent to an implant at the mandibular second molar site: A retrospective study. *Journal of Clinical Medicine*, *10*(12), 2543. https://doi.org/10.3390/jcm10122543

Preshaw, P. M., Walls, A. W., Jakubovics, N. S., Moynihan, P. J., Jepson, N. J., & Loewy, Z. (2011). Association of removable partial denture use with oral and systemic health. *Journal of Dentistry*, *39*(11), 711–719. https://doi.org/10.1016/j.jdent.2011.08.018

Priest, G. (1999). Single-tooth implants and their role in preserving remaining teeth: A 10-year survival study. *The International Journal of Oral & Maxillofacial Implants*, *14*(2), 181–188.

Suzuki, S., Sugihara, N., Kamijo, H., Morita, M., Kawato, T., Tsuneishi, M., Kobayashi, K., Hasuike, Y., & Sato, T. (2022). Reasons for tooth extractions in Japan: The second Nationwide survey. *International Dental Journal*, *72*(3), 366–372. https://doi.org/10.1016/j.identj.2021.05.008

Száva, D. T., Száva, A., Száva, J., Gálfi, B., & Vlase, S. (2022). Dental implant and natural tooth micro-movements during mastication-in vivo study with 3D VIC method. *Journal of Perssonalized Medicine*, *12*(10), 1690. https://doi.org/10.3390/jpm12101690

Tada, S., Ikebe, K., Matsuda, K., & Maeda, Y. (2013). Multifactorial risk assessment for survival of abutments of removable partial dentures based on practice-based longitudinal study. *Journal of Dentistry*, *41*(12), 1175–1180. https://doi.org/10.1016/j.jdent.2013.07.018

Tumrasvin, W., Fueki, K., Yanagawa, M., Asakawa, A., Yoshimura, M., & Ohyama, T. (2005). Masticatory function after unilateral distal extension removable partial denture treatment: Intra-individual comparison with opposite dentulous side. *Journal of Medical and Dental Sciences*, *52*(1), 35–41.

Yamazaki, S., Arakawa, H., Maekawa, K., Noda, K., Hara, E. S., Minakuchi, H., Sonoyama, W., Matsuka, Y., & Kuboki, T. (2013). A retrospective comparative 8-year study of cumulative complications in teeth adjacent to both natural and implant-supported fixed partial dentures. *The International Journal of Prosthodontics*, *26*(3), 260–264. https://doi.org/10.11607/ijp.3120

Yoshino, K., Ito, K., Kuroda, M., & Matsukubo, T. (2014). Loss of teeth opposing implant-supported prostheses in the posterior mandible: A retrospective survey in dental clinics. *The International Journal of Oral & Maxillofacial Implants*, *29*(4), 937–941. https://doi.org/10.11607/jomi.3323

Zlatarić, D. K., et al. (2002). The effect of removable partial dentures on periodontal health of abutment and non-abutment teeth. *Journal of Periodontology*, *73*(2), 137–144. https://doi.org/10.1902/jop.2002.73.2.137

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Tsujioka, Y., Mameno, T., Akema, S., Hasegawa, D., Okada, Y., Seto, E., Gonda, T., Yang, T.-C., Wada, M., & Ikebe, K. (2024). Survival time analysis of remaining teeth following replacement of unilateral free-end missing teeth: A comparison between fixed implant-supported prostheses and removable partial dentures. *Clinical Oral Implants Research*, *00*, 1–8. https://doi.org/10.1111/clr.14248

16000501, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/clr.14248 by Yayoi Yoshida - Osaka University , Wiley Online Library on [14/03/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License