Received: 8 December 2023 | Revised: 14 March 2024 | Accepted: 18 March 2024

DOI: 10.1002/JPER.23-0739

JOURNAL OF Periodontology

ORIGINAL ARTICLE

Survival rate of teeth adjacent and nonadjacent to dental implants: A retrospective cohort study

Hsuan-Hung Chen[1,2,3] | **Guo-Hao Lin**[3,4] | **Richard T. Kao**[3,5] | **Yu-Ting Yeh**[3]

[1]Division of Periodontology, Department of Stomatology, Taipei Veterans General Hospital, Taipei, Taiwan

[2]Department of Dentistry, School of Dentistry, National Yang Ming Chiao Tung University, Taipei, Taiwan

[3]Division of Periodontology, Department of Orofacial Sciences, School of Dentistry, University of California San Francisco, San Francisco, California, USA

[4]Department of Periodontics & Oral Medicine, School of Dentistry, University of Michigan, Ann Arbor, Michigan, USA

[5]Private Practice, Cupertino, California, USA

Correspondence
Yu-Ting Yeh, Department of Orofacial Sciences, University of California, San Francisco, 707 Parnassus Ave, San Francisco, CA 94143, USA.
Email: Yu-ting.yeh@ucsf.edu

Abstract

Background: The aim of this retrospective study was to investigate the risk of tooth loss for teeth adjacent and nonadjacent to dental implants.

Methods: A total of 787 patients with an average follow-up of 57.1 months were examined to define the tooth loss, cumulative survival rate, and odds ratio (OR) for teeth adjacent versus nonadjacent to implants. A multivariate logistic regression was employed to assess the association between dental history and various recorded etiologies of tooth loss among teeth adjacent to implants.

Results: The incidence of tooth loss for teeth adjacent to implants was 8.1% at the tooth level and 15.1% at the patient level, while 0.7% and 9.5% at the tooth and patientlevel for teeth nonadjacent to implants. The 10-year cumulative survival rate for teeth adjacent to implants was 89.2%, and the primary etiology of tooth loss was root fracture (45.2%). The risk of tooth loss among teeth adjacent versus nonadjacent to implants was significantly higher (OR 13.15). Among teeth adjacent to implants, root canal-treated teeth had a significantly higher risk of tooth loss due to root fracture (OR 7.72), a history of existing restoration significantly increased the risk of tooth loss due to caries (OR 3.05), and a history of periodontitis significantly increased the risk of tooth loss due to periodontitis (OR 38.24).

Conclusion: The present study demonstrated that after patients received dental implant treatment, teeth adjacent to implants showed a 13.2-fold higher risk of tooth loss compared to teeth nonadjacent to implants, with the primary etiology being root fracture.

KEYWORDS
adjacent teeth, caries, complications, dental implants, survival rate, tooth loss, vertical root fracture

1 | INTRODUCTION

Dental implants offer sustainable long-term function and esthetics and have become an increasingly popular choice for replacing missing teeth.[1] A survival rate of 94.6% and a success rate of 89.7% over 10 years have been reported for dental implants.[2] Despite the increased implant survival rates, complications associated with teeth adjacent to dental implants include caries, fractures, and hypermobility.[3–10]

The relationship between dental implants and natural teeth may negatively contribute to the health of the adjacent natural teeth.[6] The lack of proper proximal contact may render the area more susceptible to food impaction,

 © 2024 American Academy of Periodontology.

consequently increasing the risk of caries and periodontal disease in the adjacent teeth versus nonadjacent to dental implants.[5,11] Proximal embrasure morphology and volumes could be influenced by adjacent implant size, and shape and emergency profile of the implant-supported restorations. Though this influences the health and disease status of the dental implant, there has been relatively little information regarding how proximal embrasure anatomy influences the health and disease status of the adjacent teeth. Recent studies suggested further investigation on this topic so the potential risk of this iatrogenic factor can be mitigated/eliminated. Increased caries incidence was reported with increased proximal distance and restorations on the adjacent teeth.[8]

Unlike natural teeth, dental implants are more susceptible to crestal bone loss in the presence of eccentrical occlusal force.[12,13] To manage this occlusal load distribution, reducing occlusal forces on dental implants while increasing force distribution on adjacent natural teeth has been advocated.[14–16] Occlusal loading management strategies for implant-supported fixed prostheses including developing a protective occlusal scheme,[17] reducing cuspal inclination, ensuring centrally oriented contacts within 1–1.5 mm flat area, and narrowing the occlusal table have the potential to overload the adjacent teeth.[18,19] The potential consequences on the adjacent teeth may result in dental cracks or even fractures.[7] Increased risk for caries and tooth fracture along with our limited understanding of periodontal disease progression on the adjacent teeth warrant further investigation.

There is limited evidence investigating the influence of dental implants on the outcomes of the adjacent teeth. The purpose of this retrospective cohort study was to investigate the risk and variables of tooth loss for teeth adjacent to dental implants compared to the teeth nonadjacent to dental implants.

2 | MATERIALS AND METHODS

This retrospective cohort study was approved by the University of California, San Francisco (UCSF) Institutional Review Board (#22-38056) and conducted in accordance with the Helsinki Declaration as revised in 2013. Informed consent requirements were waived due to the retrospective nature of this study. Guidelines for strengthening the reporting of observational studies in epidemiology (STROBE) were followed.[20]

2.1 | Case selection criteria

The subjects were patients who received dental implant placement in the UCSF School of Dentistry between 2000 and 2020. All data of qualified patients were collected from an electronic health record system* used by the UCSF School of Dentistry. All natural teeth in each participant were divided into two groups: adjacent and nonadjacent to dental implants. For the group of teeth adjacent to dental implants, inclusion criteria were as follows: (1) The tooth was mesial or distal to a dental implant, (2) the implant had to be in function for supporting a fixed prosthesis, (3) the implant and its prosthesis had to be completed in the UCSF School of Dentistry and the follow-up period had to be at least 12 months after delivery of the implant-supported restoration, and (4) the opposing dentition of the implant-supported prosthesis was either natural teeth or fixed partial dentures. Exclusion criteria were as follows: (1) The opposing dentition was a removable partial denture, complete denture, or overdenture, and (2) the tooth adjacent to implants had been diagnosed as having a hopeless prognosis, indicating that extraction was necessary,[21] or was planned for extraction before the completion of restorative treatment. For the group of teeth nonadjacent to dental implants, the inclusion criteria were as follows: (1) teeth other than those adjacent to implants in the same patient and (2) the follow-up period had to be at least 12 months after completion of restorative phase treatment. Exclusion criteria were as follows: The tooth nonadjacent to implants was considered hopeless, indicating that extraction was necessary, or was planned for extraction before the completion of restorative treatment.

2.2 | Data extraction

Charts were initially identified by retrieving the corresponding dental codes (Code on Dental Procedures and Nomenclature) for the cases involving natural teeth adjacent to implants. The baseline data were collected from the prosthesis delivery appointment including patients' age, sex, delivery date of the implant-supported restoration, date of failure (tooth extraction or implant removal), if applicable, and date of final follow-up visit. The primary outcome was the survival rate of the adjacent teeth and the nonadjacent teeth at both patient and tooth level. The secondary outcome was to define the etiology assigned for the tooth loss. Furthermore, the following dental history of pre/postimplant treatment of the adjacent teeth was retrieved: (1) Placement of restorations including crowns, inlays, onlays, veneers, and fillings and only restorations in direct contact with the proximal surface of the implant were recorded, (2) root canal treatments, and (3) documented periodontal therapy as

* axiUm; Exan Corporation, Vancouver, Canada.

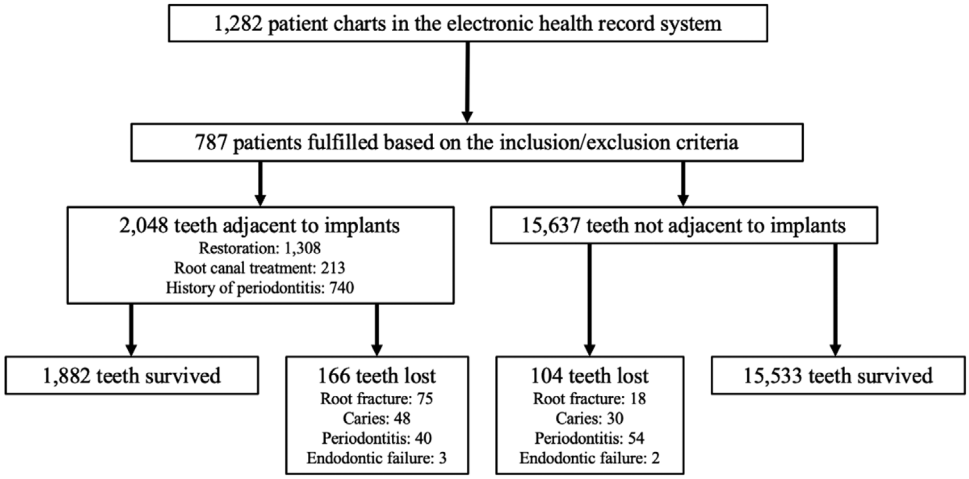


FIGURE 1 Screening strategies and outcomes of tooth survival.

defined by management of periodontitis through scaling and root planing and/or osseous resective/regenerative procedures. Following the completion of the last follow-up visit, outcomes for teeth adjacent and nonadjacent to dental implants were documented to include (1) total numbers of tooth loss and (2) assigned etiology for tooth loss such as root fracture, caries, periodontitis, and endodontic failures. In cases where multiple reasons contributed to tooth extraction, only the primary reason described in the electronic health record was documented for the analysis (Figure 1).

2.3 | Statistical analysis

All analyses were conducted using statistical software.[†] Characteristics of subjects and teeth were presented as mean, standard deviation, and range for continuous data, while frequency counts and percentages were presented for the categorical data. A plot of cumulative survival according to teeth adjacent and nonadjacent to dental implants was constructed using the Kaplan–Meier method. A log-rank test was also conducted to compare the difference in survival of both groups. To compare the risk of tooth loss between the teeth adjacent and nonadjacent to dental implants, numbers of tooth loss and tooth survival were recorded in both groups. Odds ratio (OR) with 95% confidence interval (CI) was also calculated. Multivariate logistic regression was performed for categorical variables to identify their association with the etiologies of tooth loss for the teeth adjacent to dental implants. Statistical differences with a p value < 0.05 were considered significant.

[†] SPSS, version 29.0.1.0; IBM, Chicago, Illinois, USA.

TABLE 1 Demographic characteristics of study participants.

Patients ($N = 787$)	
Age (years)	58.8 ± 13.3 (19–91)
Sex	
Male	389
Female	398
Teeth adjacent to dental implants ($n = 2048$)	
Dental history	
Restoration	1308
Root canal treatment	213
History of periodontitis	740
Follow-up (months)	57.1 ± 44.1 (12–258)

3 | RESULTS

3.1 | Demographics of study

Following a search in the electronic health record, a total of 787 patients fit the inclusion criteria with 2048 teeth adjacent and 15,637 teeth nonadjacent to dental implants (Figure 1). The demography consisted of 389 males and 398 females with an average age of 58.8 ± 13.3 (ranging from 19 to 91) years old. Of the 2048 teeth adjacent to dental implants, 1308 (63.9%) had restoration, 213 (10.4%) had root canal treatment, and 740 (36.1%) had a history of periodontitis during the 20 years examined (individual patient record-reported range of 12–258 months, mean 57.1 ± 44.1 months; Table 1).

3.2 | Incidence and etiologies of tooth loss

During the follow-up period, 166 teeth out of 2048 teeth (8.1%) in 119 of 787 patients (15.1%) were lost for teeth

TABLE 2 Incidence and recorded etiologies of tooth loss.

Incidence	Adjacent to implants	Nonadjacent to implants
Patient level	15.1% (119/787)	9.5% (75/787)
Tooth level	8.1% (166/2,048)	0.7% (104/15,637)
Etiologies of tooth loss		
Root fracture	45.2% (75/166)	17.3% (18/104)
Caries	28.9% (48/166)	28.8% (30/104)
Periodontitis	24.1% (40/166)	51.9% (54/104)
Endodontic failure	1.8% (3/166)	2.0% (2/104)

adjacent to dental implants. The etiologies of tooth loss were attributed to root fracture (45.2%), caries (28.9%), periodontitis (24.1%), and endodontic failure (1.8%). Conversely, 104 out of 15,637 teeth (0.7%) in 75 of 787 patients (9.5%) were lost for teeth nonadjacent to dental implants. The etiologies of tooth loss for this group included periodontitis (51.9%), caries (28.8%), root fracture (17.3%), and endodontic failure (2.0%). The etiologies of tooth loss are summarized in Table 2.

3.3 | Survival rate and tooth loss rate

The survival rate for teeth adjacent to dental implants was 96.7% at 5-year follow-up and 89.2% at 10-year follow-up, with a tooth loss rate of 3.3% at 5-year and 10.8% at 10-year follow-up, respectively. The survival rate for teeth nonadjacent to dental implants was 99.8% at 5-year follow-up and 99.3% at 10-year follow-up with a tooth loss rate of 0.2% at 5-year follow-up and 0.7% at 10-year follow-up, respectively. The difference in survival rates between the teeth adjacent and nonadjacent to dental implants was statistically significant ($p < 0.001$, Figure 2).

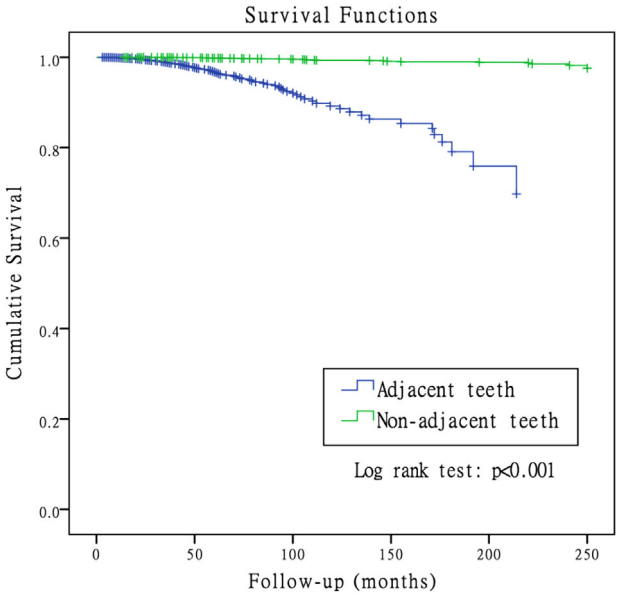


FIGURE 2 Kaplan–Meier survival plot for teeth adjacent and nonadjacent to dental implants.

3.4 | Risk of tooth loss adjacent and nonadjacent to dental implants

Teeth adjacent to implants had 166 tooth losses with 1882 retained, while the nonadjacent ones had 104 tooth losses of 15,533 retained. The OR of tooth loss for the teeth adjacent compared to the teeth nonadjacent to dental implants was statistically significant (OR 13.15, CI [10.25, 16.88], $p < 0.001$).

3.5 | Etiologies of tooth loss for teeth adjacent to dental implants

For teeth adjacent to dental implants, multivariate logistic regression was used to assess the association between the dental history and the etiologies of tooth loss (Table 3). Among these teeth, the risk of tooth loss due to root fracture was associated with a history of root canal treatment (OR 7.72, CI [3.41, 17.47], $p < 0.001$) and periodontitis (OR 0.25, CI [0.12, 0.52], $p < 0.001$). In addition, the risk of tooth loss due to caries was associated with a history of restoration (OR 3.05, CI [1.22, 7.63], $p < 0.05$) and root canal treatment (OR 0.14, CI [0.05, 0.35], $p < 0.001$). The risk of tooth loss attributed to periodontitis was associated with a history of root canal treatment (OR 0.34, CI [0.12, 0.98], $p < 0.05$) and periodontitis (OR 38.24, CI [5.04, 290.32], $p < 0.001$).

4 | DISCUSSION

This report is the first to identify the increased risk of tooth loss for teeth adjacent to dental implants. In the present

TABLE 3 Relationship between dental history and etiologies of tooth loss adjacent to dental implants.

Dental histories for tooth loss adjacent to implants due to root fracture			
	OR	**95% CI**	***p* value**[a]
Restoration	0.59	0.24–1.45	0.247
Root canal treatment	7.72	3.41–17.47	<0.001*
History of periodontitis	0.25	0.12–0.52	<0.001*
Dental histories for tooth loss adjacent to implants due to caries			
	OR	**95% CI**	***p* value**[a]
Restoration	3.05	1.22–7.63	0.017*
Root canal treatment	0.14	0.05–0.35	<0.001*
History of periodontitis	0.65	0.31–1.37	0.257
Dental histories for tooth loss adjacent to implants due to periodontitis			
	OR	**95% CI**	***p* value**[a]
Restoration	0.48	0.19–1.22	0.123
Root canal treatment	0.34	0.12–0.98	0.045*
History of periodontitis	38.24	5.04–290.32	<0.001*

Abbreviations: CI, confidence interval; OR, odds ratio.
[a]Multivariate logistic regression analysis.
*$p < 0.05$.

study, the incidence of tooth loss among teeth adjacent to dental implants was 8.1% at the tooth level and 15.1% at the patient level. The 5-year and 10-year cumulative survival rate of teeth adjacent to implants was 96.7% and 89.2% with a 3.3% and 10.8% tooth loss rate, respectively. Comparative analysis of teeth in natural dentition[22] showed that teeth adjacent to implants exhibited a higher tooth loss rate in comparison to teeth with good periodontal prognosis (1.95%)[21] and teeth with fair to poor periodontal prognosis (7.87%–13.38%).[23] These suggest that teeth adjacent to dental implants may have a worse long-term prognosis as compared to natural teeth. Consequentially, clinical management may necessitate more stringent periodontal surveillance and emphasis on the patients' homecare.

The current study also reported that the risk of tooth loss for teeth adjacent to dental implants was 13.2 times higher than for those nonadjacent to dental implants. Moreover, the primary etiology of tooth loss was different between these two groups. In cases of teeth adjacent to dental implants, the primary etiology was root fracture, accounting for 45.2% of tooth loss. Several studies[7,14,15] confirmed a higher risk of fracture for teeth adjacent to dental implants due to excessive occlusal load on these natural teeth. The suggested rationale was that the lighter occlusal load on dental implants might elevate the occlusal load and the risk of fractures among teeth adjacent to the dental implants.

Caries accounted for the second most common etiology of tooth loss among teeth adjacent to dental implants, representing 28.9% of all lost teeth. Duqum et al.[4] showed in a retrospective study that the incidence for restorative retreatment was 1.75 times higher for teeth adjacent to dental implants as compared to contralateral controls. The primary reasons for restorative retreatments were attributed to the loss of proximal contacts and caries. Another retrospective case–control study[9] compared complication versus noncomplication rate on teeth adjacent to dental implants in the posterior region. The complication rate on teeth adjacent to dental implants was 16.7%, attributed to secondary caries (63.7%), primary caries (16.2%), tooth mobility (8.3%), tooth fracture (6.1%), and tooth cracks (5.6%). In the current study, teeth adjacent to dental implants with a history of restorations exhibited a significantly higher risk of tooth loss due to caries (OR 3.05). Teeth with restoration potentially have a higher risk of developing secondary caries, thus increasing the probability of tooth loss due to caries.[24]

This study confirms that periodontitis is the primary etiology of tooth loss among teeth nonadjacent to dental implants. An analysis of 600 patients with periodontitis after 22 years of supportive maintenance care[25] found that tooth loss (7.1%) due to periodontitis was more frequent as compared to other etiologies (1.2%). A similar study of 100 patients over 19 years had similar findings with tooth loss due to periodontal-related (9.8%) causes being greater than that associated with other etiologies (1.5%).[26] In the present study, for teeth nonadjacent to implants, consistent data were obtained, indicating that more than half (51.9%) of the extracted teeth were attributed to periodontitis.

This study found that teeth adjacent to dental implants with a history of root canal treatment had a higher risk of tooth loss due to root fracture (OR 7.72) as compared to caries (OR 0.14) and periodontitis (OR 0.34). These results confirm a previous study indicating that endodontically treated teeth are more susceptible to root fracture,[27] suggesting that such fractures may be attributed to weakening during endodontic treatment, particularly due to overinstrumentation.[27,28] However, it is unclear if a history of endodontically treatment can decrease the risk of tooth loss secondary to caries or periodontal disease as suggested by our data. Conflicting reports of tooth loss secondary to periodontitis[29] or caries[30] suggest the need for additional studies to further investigate this association.

For teeth adjacent to dental implants, we found that those with a history of periodontitis had a significantly greater risk of tooth loss due to periodontitis (OR 38.24). While the risk of periodontal disease progression is well established for natural dentition, increased susceptibility to disease progression and tooth loss has been associated with certain factors, including high susceptibility to periodontitis,[31] incomplete periodontal treatment with probing pocket depth ≥6 mm and bleeding on probing

≥30%,[32] patients with poor compliance,[33] and individuals under regular maintenance care but with advanced periodontitis.[34] This study also identified that teeth adjacent to dental implants with a history of periodontitis had a lower risk of tooth loss due to root fracture (OR 0.25). This finding could be explained by the possibility that teeth with reduced periodontium might experience more attachment loss or bone loss under occlusal force rather than tooth fracture caused by excessive occlusal load.[35] Future studies should explore this matter further to comprehend the interaction between implant occlusion and the periodontium.

Given the increased risk of complications such as tooth fracture, caries, and periodontal disease progression in teeth adjacent to dental implants, the findings of the present study carry significant clinical implications. They suggest that implants may contribute as an iatrogenic factor leading to future tooth loss. A recent commentary suggests that strategic extraction is a therapeutic option that should be pursued with caution and be deferred until all conservative management of compromised teeth has been explored.[36] The increased risk for tooth loss supports the concept that conservative management of the natural dentition should be a priority. Additionally, there should be increased attention to patient selection for those requiring dental implants, the development of a more effective dental maintenance hygiene program, and an emphasis on appropriate homecare. This report suggests the necessity for a deeper understanding of the implant–tooth intersection, particularly in terms of occlusion and the health and disease patterns in this interproximal area.

There are several limitations to the present study. First, being a retrospective cohort study reliant on data from electronic health records, causal influences cannot be assessed. Second, the study encountered challenges in defining confounding factors such as parafunctional habits and functions due to the retrospective nature. Third, the present study lacks information related to the periodontal prognosis of teeth adjacent to implants and does not assess the impact of implant adjacency on teeth with differing periodontal prognoses. Additionally, the inclusion of the dental histories of nonadjacent teeth was not investigated to determine the potential impact of individual tooth dental histories on tooth loss, comparing teeth adjacent and nonadjacent to dental implants.

The present study reported a 10-year cumulative survival rate of 89.2% for teeth adjacent to dental implants. Furthermore, after patients received dental implant treatment, teeth adjacent to dental implants showed a 13.2-fold higher risk for tooth loss as compared to teeth not adjacent to implants. Though there are multiple etiologies of tooth loss, root fracture was found to be the primary etiology of tooth loss among teeth adjacent to dental implants.

AUTHOR CONTRIBUTIONS

Hsuan-Hung Chen: Concept/design; data collection; data analysis; drafting article. **Guo-Hao Lin and Richard T. Kao**: Data analysis/interpretation; drafting article. **Yu-Ting Yeh**: Drafting article; statistics; critical revision of article.

ACKNOWLEDGMENTS

The authors thank Ms. Hsin-Yi Huang from the Department of Information Management and Big Data Center, Taipei Veterans General Hospital, for her statistical analysis and review.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

FUNDING INFORMATION

The authors do not have any financial interests, either directly or indirectly, in the products or information listed in the paper.

DATA AVAILABILITY STATEMENT

The data sets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

ORCID

Guo-Hao Lin https://orcid.org/0000-0003-1290-9994
Yu-Ting Yeh https://orcid.org/0000-0001-7806-2373

REFERENCES

1. Elani HW, Starr JR, Da Silva JD, Gallucci GO. Trends in dental implant use in the U.S., 1999-2016, and projections to 2026. *J Dent Res*. 2018;97:1424-1430.
2. Moraschini V, Poubel LA, Ferreira VF, Barboza Edos S. Evaluation of survival and success rates of dental implants reported in longitudinal studies with a follow-up period of at least 10 years: a systematic review. *Int J Oral Maxillofac Surg*. 2015;44:377-388.
3. Chopra A, Sivaraman K, Narayan AI, Balakrishnan D. Etiology and classification of food impaction around implants and implant-retained prosthesis. *Clin Implant Dent Relat Res*. 2019;21:391-397.
4. Duqum I, Barker S, Marshall E, Wang R, Preisser JS, Khan A. The effect of single tooth implant restorations on the survival, morbidity, pulpal, and periapical health of adjacent teeth: a chart review. *Clin Implant Dent Relat Res*. 2018;20:479-482.
5. Greenstein G, Carpentieri J, Cavallaro J. Open contacts adjacent to dental implant restorations: etiology, incidence, consequences, and correction. *J Am Dent Assoc*. 2016;147:28-34.
6. Ren S, Lin Y, Hu X, Wang Y. Changes in proximal contact tightness between fixed implant prostheses and adjacent teeth: a 1-year prospective study. *J Prosthet Dent*. 2016;115:437-440.
7. Rosen E, Beitlitum I, Tamse A, Taschieri S, Tsesis I. Implant-associated vertical root fracture in adjacent endodontically treated teeth: a case series and systematic review. *J Endod*. 2016;42:948-952.

8. Smith RB, Rawdin SB, Kagan V. Influence of implant-tooth proximity on incidence of caries in teeth adjacent to implants in molar sites: a retrospective radiographic analysis of 300 consecutive implants. *Compend Contin Educ Dent*. 2020;41:e1-e5.
9. Tagger-Green N, Fridenberg N, Segal S, Levartovsky S, Laviv A. Effect of posterior implant restorations on adjacent teeth and tissues: a case-control study. *Clin Implant Dent Relat Res*. 2023;25:473-480.
10. Yen JY, Kang L, Chou IC, Lai YL, Lee SY. Risk assessment of interproximal contact loss between implant-supported fixed prostheses and adjacent teeth: a retrospective radiographic study. *J Prosthet Dent*. 2022;127:86-92.
11. Jernberg GR, Bakdash MB, Keenan KM. Relationship between proximal tooth open contacts and periodontal disease. *J Periodontol*. 1983;54:529-533.
12. Schulte W. Implants and the periodontium. *Int Dent J*. 1995;45:16-26.
13. Misch CE, Suzuki JB, Misch-Dietsh FM, Bidez MW. A positive correlation between occlusal trauma and peri-implant bone loss: literature support. *Implant Dent*. 2005;14:108-116.
14. 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.
15. Lundgren D, Laurell L. Biomechanical aspects of fixed bridgework supported by natural teeth and endosseous implants. *Periodontol 2000*. 1994;4:23-40.
16. Misch CE. Progressive loading of bone with implant prostheses. *J Dent Symp*. 1993;1:50-53.
17. Sheridan RA, Decker AM, Plonka AB, Wang HL. The role of occlusion in implant therapy: a comprehensive updated review. *Implant Dent*. 2016;25:829-838.
18. Curtis DA, Sharma A, Finzen FC, Kao RT. Occlusal considerations for implant restorations in the partially edentulous patient. *J Calif Dent Assoc*. 2000;28:771-779.
19. Weinberg LA. Reduction of implant loading with therapeutic biomechanics. *Implant Dent*. 1998;7:277-285.
20. von Elm E, Altman DG, Egger M, et al. The strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. *J Clin Epidemiol*. 2008;61:344-349.
21. Kwok V, Caton JG. Commentary: prognosis revisited: a system for assigning periodontal prognosis. *J Periodontol*. 2007;78:2063-2071.
22. Nguyen L, Krish G, Alsaleh A, et al. Analyzing the predictability of the Kwok and Caton periodontal prognosis system: a retrospective study. *J Periodontol*. 2021;92:662-669.
23. McGuire MK. Prognosis versus actual outcome: a long-term survey of 100 treated periodontal patients under maintenance care. *J Periodontol*. 1991;62:51-58.
24. Askar H, Krois J, Gostemeyer G, et al. Secondary caries: what is it, and how it can be controlled, detected, and managed? *Clin Oral Investig*. 2020;24:1869-1876.
25. Hirschfeld L, Wasserman B. A long-term survey of tooth loss in 600 treated periodontal patients. *J Periodontol*. 1978;49:225-237.
26. McFall WT Jr. Tooth loss in 100 treated patients with periodontal disease. A long-term study. *J Periodontol*. 1982;53:539-549.
27. Gher ME Jr, Dunlap RM, Anderson MH, Kuhl LV. Clinical survey of fractured teeth. *J Am Dent Assoc*. 1987;114:174-177.
28. Meister F Jr, Lommel TJ, Gerstein H. Diagnosis and possible causes of vertical root fractures. *Oral Surg Oral Med Oral Pathol*. 1980;49:243-253.
29. Toure B, Faye B, Kane AW, Lo CM, Niang B, Boucher Y. Analysis of reasons for extraction of endodontically treated teeth: a prospective study. *J Endod*. 2011;37:1512-1515.
30. Zadik Y, Sandler V, Bechor R, Salehrabi R. Analysis of factors related to extraction of endodontically treated teeth. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2008;106:e31-35.
31. Rosling B, Serino G, Hellstrom MK, Socransky SS, Lindhe J. Longitudinal periodontal tissue alterations during supportive therapy. Findings from subjects with normal and high susceptibility to periodontal disease. *J Clin Periodontol*. 2001;28:241-249.
32. Matuliene G, Pjetursson BE, Salvi GE, et al. Influence of residual pockets on progression of periodontitis and tooth loss: results after 11 years of maintenance. *J Clin Periodontol*. 2008;35:685-695.
33. Becker W, Becker BE, Berg LE. Periodontal treatment without maintenance. A retrospective study in 44 patients. *J Periodontol*. 1984;55:505-509.
34. Lindhe J, Nyman S. Long-term maintenance of patients treated for advanced periodontal disease. *J Clin Periodontol*. 1984;11:504-514.
35. Fan J, Caton JG. Occlusal trauma and excessive occlusal forces: narrative review, case definitions, and diagnostic considerations. *J Periodontol*. 2018;89(Suppl 1):S214-S222.
36. Kao RT, Lin GH, Kapila Y, Sadowsky S, Curtis DA. A commentary on strategic extraction. *J Periodontol*. 2022;93:11-19.

How to cite this article: Chen H-H, Lin G-H, Kao RT, Yeh Y-T. Survival rate of teeth adjacent and nonadjacent to dental implants: A retrospective cohort study. *J Periodontol*. 2024;95:942–948. https://doi.org/10.1002/JPER.23-0739