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Original Article

Investigation of peri-implant diseases prevalence and related risk indicators in patients with treated severe periodontitis over 4 years after restoration

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Abstract *Background/purpose:* History of periodontitis is a well-documented risk indicator of peri-implantitis. However, the influence of severity of periodontitis is still unclear, especially for severe periodontitis. This study was aimed to investigate the prevalence of peri-implant disease and analyze the risk indicators in patients with treated severe periodontitis.
Materials and methods: A total of 182 implants from 88 patients (44 males and 44 females) with severe periodontitis with a mean fellow-up period of 76.5 months were enrolled in this study. Patient and implant information, and periodontal and peri-implant conditions were collected to evaluate the prevalence of peri-implant disease and risk indicators.
Results: The prevalence of peri-implantitis was 9.1% and 6.6% at the patient-level and implant-level. The prevalence of peri-implant mucositis was 76.1% and 51.1% at the patient-level and implant-level. Risk indicators of peri-implantitis included older age (OR: 1.132), poor proximal cleaning habits (OR: 14.218), implants in anterior area (OR: 10.36), poor periodontal disease control (OR: 12.76), high peri-implant plaque index (OR: 4.27), and keratinized tissue width (KTW) < 2 mm (OR: 19.203).
Conclusion: Implants in patients with severe periodontitis after periodontal treatment and maintenance show a low prevalence (9.1%) of peri-implantitis and a relatively high prevalence (76.2%) of peri-implant mucositis. Patient age, peri-implant proximal cleaning habits, implant position, periodontal disease control, peri-implant plaque index, and KTW are associated with prevalence of peri-implantitis.

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Introduction

Dental implants have become a common method of replacing missing teeth, with a relatively high success rates.[1] However, many studies reported that the patient with periodontitis history showed lower survival rate of implantation compared with periodontal healthy opeople.[2—4] Biological complications, including peri-implant mucositis and peri-implantitis played an important role. Peri-implantitis may result in loss of peri-implant supporting bone,[5] which is also one of the main reasons for late implant failure.[6]

Periodontal disease is a chronic inflammatory disease characterized by gingival inflammation as well as connective tissue and alveolar bone destruction.[7] Periodontitis is the most common dental disease globally and one of the major threats for tooth loss worldwide.[8] When lost teeth were replaced by implants in patients with periodontitis, the periodontal pathogens would spread from periodontal pockets to the peri-implant soft tissue. These pathogens might induce the inflammation in peri-implant tissue. The peri-implant disease would develop, and finally result in implant failure.[9] Implant surgery should start only after periodontal treatment with periodontal inflammation controlled. Besides, it was reported that even after periodontal therapy, the prevalence of peri-implant disease in patients with periodontitis history was higher than that in periodontal health patients.[10,11] It is important to control periodontal inflammation for the maintenance of peri-implant health.[12—14]

Stage III and IV periodontitis in 2018 new classification means that serious destruction of periodontium have occurred and represents severe periodontitis,[15] which have serious destruction of periodontium. Usually, patients with stage III and IV periodontitis may still have residual periodontal pockets even after periodontal treatment.[16] Studies about the prevalence of peri-implant disease in patients with severe periodontitis are limited, and the relationship between periodontal disease control and peri-implant disease is still unclear.

Therefore, the purpose of this retrospective study is to observe the prevalence of peri-implant disease in patients with treated severe periodontitis during the long-term follow-up after implant restoration, and analyze the related risk indicators of peri-implantitis.

Materials and methods

Patient selection

Subjects were screened from patients with severe periodontitis, who received implant therapy from 2008 to 2018 in the department of periodontology at Peking University School and Hospital of Stomatology. According to the previous records and clinical data (full-mouth periodontal chartings and radiographic examination) before implants were inserted, diagnosis was re-made by the new classification in 2018. Two implant systems, Straumann (Institute Straumann AG, Basel, Switzerland) and Bicon (Bicon LLC, Boston, MA, USA) were used in these patients. Totally 88 patients with 182 implants were involved in this study, and followed up at least 4 years since the final restoration finished. The ethical committee of the Peking University Hospital of Stomatology gave the study approval with the approval code PKUSSIRB-202283178.

Inclusion criteria were: 1) patients were diagnosed as stage III or IV periodontitis by the new classification in 2018, with at least 15 natural teeth; 2) patients received implant therapy from 2008 to 2018 in the department of periodontology at Peking University School and Hospital of Stomatology; 3) single implant supported or 3—4 units implant-supported fixed partial denture; 4) standardized professional periodontal treatments were undertaken before the implants were inserted; 5) preoperative and postoperative clinical data were complete.

Exclusion criteria were: 1) patients with severe systemic diseases, such as uncontrolled diabetes, and mental or psychological diseases influencing daily oral maintenance; 2) patients experienced pregnancy or lactation during follow-up.

Patient and implant information were collected. Clinical and radiologic examination were done to obtain periodontal and peri-implant data.

Patient information

Patient information of gender, age and patients self-administered oral hygiene habits was collected. For oral hygiene habits, brushing and peri-implant proximal cleaning habits were enquired and recorded. If brushing teeth were done at least 2 times per day and at least 3 min each time, brushing habit was fair, otherwise was poor. If peri-implant proximal cleaning was done by daily frequency, the proximal cleaning habit was fair, otherwise was poor.

Implant information

Information of implant system, type (bone level or tissue level), position (anterior or posterior), implant diameter and length were collected.

Periodontal examination

Probing depth (PD) and bleeding on probing (BOP) were recorded at six sites each tooth throughout the entire mouth using a Williams probe. Patients were classified into

two groups. Patients who presented with >10% sites with PD ≥ 5 mm and >40% sites with BOP (+) were classified into group A; others were classified into group B.

Peri-implant examination

Peri-implant clinical examination included peri-implant probing depth (iPD), peri-implant bleeding index (iBI, according to Mazza's Bleeding Index), peri-implant plaque index (iPlI), and keratinized tissue width (KTW). Marginal bone level (MBL) change was calculated from peri-implant radiologic examination. Mesial and distal bone level was measured by The Geometer's Sketchpad (version 5.06; Key Curriculum Press, Emeryville, CA, USA) on the radiographs of baseline (immediately after loading) and last follow-up, and the difference was calculated to represent the MBL change. Mean value of mesial and distal change was used for statistical analysis. Peri-implant conditions were diagnosed as healthy, peri-implant mucositis and peri-implantitis according to the 2018 new classification.[5]

Patients self-administered oral hygiene habits

Brushing and peri-implant proximal cleaning habits were enquired and recorded. If brushing teeth were done at least 2 times per day and at least 3 min each time, brushing habit was fair, otherwise was poor. If peri-implant proximal cleaning was done by daily frequency, the proximal cleaning habit was fair, otherwise was poor.

Statistical analysis

The characteristics for patient, implant, periodontal and peri-implant status were compared between groups with and without peri-implantitis. Variables were presented as mean ± SD/N (%). Student t test (normal distribution) and Mann—Whitney (non-normal distribution) were performed for continuous variables and χ^2 tests were used for categorical variables. If proven to be statistically significant, the Bonferroni test was used to perform multiple comparison. Patient gender, age, brushing and peri-implant proximal cleaning habits, implant length, diameter, type, position, periodontal disease control, and peri-implant related parameters were analyzed to identify the potential risk factor for peri-implantitis by univariate analysis. The variables with $P < 0.05$, as well as age and gender, were entered to multivariate binary logistic regression. The final model selection for the multivariate logistic regression analysis was performed by a backward step-down selection process using a threshold of $P < 0.05$. All the statistical analyses were performed with SPSS software (version 27.0; IBM Corp., Armonk, NY, USA).

Results

A total of 182 implants from 88 patients (44 males and 44 females) were enrolled. The age of patients ranged from 35 to 77 years, with an average age of 53.3 ± 9.8 years. There were 12 (13.6%) current smoking patients. Of 88 patients, 32 (36.4%) patients have poor brushing habits, and 26 (29.5%) for poor peri-implant proximal cleaning habits. Of the 182 implants, 158 (86.8%) were Straumann and 24 (13.2%) were Bicon; 86 (47.3%) were tissue level implants, 96 (52.7%) were bone level implants; 26 (14.3%) implants were used in anterior area, 156 (85.7%) for posterior area.

All implants functioned 54—146 months (average 76.5months) after restoration in stage III or IV periodontitis patients. The prevalence of peri-implantitis was 9.1% at the patient-level and 6.6% at the implant-level. The prevalence of peri-implant mucositis was 76.1% at the patient-level and 51.1% at implant-level respectively (Table 1).

Relationships between peri-implant conditions and periodontal status

According to the periodontal status of residual natural teeth, patients were classified into two groups, group A for patients with >10% sites with PD ≥ 5 mm and >40% sites with BOP (+); others for group B. There were 21 patients with 41 implants in Group A, and 67 patients with 141 implants in Group B.

As shown in Table 2, the subjects in Group A had significantly deeper peri-implant PD, higher peri-implant bleeding index and plaque index, compared with Group B ($P < 0.001$). The peri-implant marginal bone level was lower in Group A than Group B, but no statistical significance was observed (MBL change: −0.52 ± 1.39 mm vs. −0.08 ± 0.35 mm, $P > 0.05$).

The prevalence of peri-implant mucositis and peri-implantitis in Group A was significantly higher than Group B (73.2% vs. 44.7%, $P < 0.05$; 17.1% vs. 3.5%, $P < 0.05$) and the percentage of peri-implant health were significantly lower in Group A (9.8% vs. 51.8%, $P < 0.05$) (Table 3).

Risk indicators for peri-implantitis

The univariate analysis was done to investigate the relationship between peri-implantitis and patient-related, implant-related, periodontal-related factors and peri-implant-related factors. The results including gender, age and the significant factors were listed in Table 4. For the patient-related factor, poor peri-implant proximal cleaning habits was found to be associated with prevalence of peri-implantitis (OR = 4.267). For the implant-related factor, bone level implant and anterior position were found to be associated with prevalence of peri-implantitis (OR = 4.884 and 7.5, respectively). For the periodontal-related factors, poor periodontal disease control (Group A represented poor control) was found to be associated with prevalence of peri-implantitis (OR = 5.6). For the peri-implant-related

Table 1 Peri-implant conditions after at least 4 years function in stage III or IV periodontitis patients.

Peri-implant conditions	Patient-level (N = 88)	Implant-level (n = 182)
Healthy	20 (22.7%)	77 (42.3%)
Mucositis	67 (76.2%)	93 (51.1%)
Peri-implantitis	8 (9.1%)	12 (6.6%)

Table 2 Comparison of peri-implant parameters in different periodontal status.

	Group A (N = 21, n = 41)	Group B (N = 67, n = 141)	*P*
iPD	4.10 ± 1.63 mm	3.05 ± 0.74 mm	< 0.001***
iBI	2.11 ± 1.10	1.06 ± 0.90	< 0.001***
iPII	1.05 ± 0.7	0.62 ± 0.52	< 0.001***
MBL change	−0.52 ± 1.39 mm	−0.08 ± 0.35 mm	0.259

iPD: peri-implant probing depth; iBI: peri-implant bleeding index; iPII: peri-implant plaque index; MBL: marginal bone level; ***: $P < 0.001$.

Table 3 Prevalence of peri-implant disease in different periodontal status.

	Group A (n = 41)	Group B (n = 141)	*P*
Healthy (N = 77)	4 (9.8%)	73 (51.8%)#	< 0.001***
Mucositis (N = 93)	30 (73.2%)	63 (44.7%)#	
Peri-implantitis (N = 12)	7 (17.1%)	5 (3.5%)#	

Group A: patients who presented with >10% sites with PD ≥ 5 mm and >40% sites with BOP (+); Group B: patients who weren't classified into Group A; ***: $P < 0.001$; #: significant differences compare with group A.

factors, KTW<2 mm and iPII were found to be associated with prevalence of peri-implantitis (OR = 6.037, and 5.749, respectively).

The factors demonstrated significance in the univariate analysis were selected for further multivariate analysis. The result of the multivariate analysis showed peri-implantitis associated with patients with older age (OR: 1.132, 95%CI: 1.02,1.257), poor proximal cleaning habits (OR: 14.218, 95% CI: 1.898,106.479), poor periodontal disease control (OR: 12.76, 95%CI: 1.746,93.252), implants in anterior area (OR: 10.36, 95%CI: 1.379,77.81), high peri-implant plaque index (OR: 4.27, 95%CI: 1.147,15.899), keratinized tissue width < 2 mm (OR: 19.203, 95%CI: 2.659,138.699) after adjustment for age and gender (Table 5). Implant type (bone level or tissue level) without significance were excluded from the full model.

Table 4 Univariate and binary logistic regression analysis of factors associated with peri-implantitis.

Variables	Non-peri-implantitis (n = 170)	Peri-implantitis (n = 12)	OR (95%CI)	*P*
Gender			0.714 (0.218,2.339)	0.578
Male	85 (50%)	7 (58.30%)		
Female	85 (50%)	5 (41.7%)		
Age (years)	53.74 ± 9.63	57.42 ± 6.14	1.034 (0.972,1.100)	0.291
Proximal cleaning			4.267 (1.286–14.157)	0.018*
Fair	129 (70.9%)	5 (33.3%)		
Poor	41 (29.1%)	7 (66.7%)		
Implant type			4.884 (1.039–22.956)	0.045*
Tissue level	84 (49.4%)	2 (16.7%)		
Bone level	86 (50.6%)	10 (83.3%)		
Implant position			7.5 (2.205–25.506)	0.001**
Anterior	20 (11.8%)	6 (50%)		
Posterior	150 (88.2%)	6 (50%)		
Periodontal disease control			5.6 (1.674–18.735)	0.005**
Poor (Group A)	136 (80%)	5 (41.7%)		
Fair (Group B)	34 (20%)	7 (58.3%)		
KTW			6.037 (1.8–20.254)	<0.001***
≥2 mm	138 (81.2%)	5 (41.7%)		
<2 mm	32 (18.8%)	7 (58.3%)		
iPII	0.66 ± 0.55	1.49 ± 0.66	5.749 (2.388–13.842)	<0.001***

OR: odds ratio; CI: confidence interval; Group A: patients who presented with >10% sites with PD ≥ 5 mm and >40% sites with BOP (+); Group B: patients who weren't classified into Group A; KTW: keratinized tissue width; iPII: peri-implant plaque index; *: $P < 0.05$, **: $P < 0.01$, ***: $P < 0.001$.

Table 5 Multivariate and binary logistic regression analysis of factors associated with peri-implantitis.

Variable	OR (95%CI)	*P*
Age	1.132 (1.02—1.257)	0.02*
Poor proximal cleaning	14.218 (1.898—106.479)	0.01*
Anterior position	10.36 (1.379—77.81)	0.023*
Poor periodontal disease control	12.76 (1.746—93.252)	0.012*
KTW<2 mm	19.203 (2.659—138.699)	0.003**
iPlI	4.27 (1.147—15.899)	0.03*

OR : odds ratio; CI : confidence interval; KTW: keratinized tissue width; iPlI: peri-implant plaque index; *: $P < 0.05$, **: $P < 0.01$.

Discussion

In this study, peri-implant condition was investigated in patients with severe periodontitis (stage III or IV periodontitis according to the 2018 new classification). After at least 4 years (average over 6 years) loading, all implants survived and functioned. The prevalence of peri-implantitis at patient level and implant level were 9.1% and 6.6%, respectively, which was relatively low when compared with that of 10.2% within 6.8 years and 26% within 3—16 years in previous study among patient with periodontitis history.[2,17] High success rate is related to the standardized professional periodontal treatments before the implant surgery, deliberate treatment plan and operation, meticulous maintenance therapy.

High prevalence of mucositis, 76.2% at patient level and 51.1% at implant level, was also observed in these severe periodontitis patients. Inflammation played an important role in periodontitis and peri-implant diseases, and they shared many common pathogenic factors, such as smoking, diabetes, poor oral hygiene, etc.[18—20] So long-term careful follow-up was required to control the inflammation level of tissues around both natural teeth and implant-supported denture.

In the logistic regression analysis of indicators associated with peri-implantitis, peri-implant proximal cleaning habits, implant type and position, periodontal disease control, KTW and peri-implant PlI were identified.

Plaque is the initiating factor of periodontitis and peri-implant diseases.[21] A wide range of studies have shown that microorganisms associated with periodontitis can cause implant related biological complications, such as: *Porphyromorts gingivalis*, *Treponema denticola*, etc.[22—24] Periodontitis involved teeth could be regarded as carriers of peri-implant related pathogens.[25] In this study, two plaque-related factors, patients self-administered peri-implant proximal cleaning and peri-implant plaque index were both shown to be associated with the prevalence of peri-implantitis. Home and professional plaque control needs to be emphasized throughout the maintenance.

In our study, patients were classified into 2 groups. Group A represented for poor periodontal disease control patients (>10% sites with PD $\geq$ 5 mm and >40% sites with BOP); group B for fair control patients. Worse clinical parameters (PD, BI, PlI and MBL) around implants and higher prevalence of peri-implant diseases (both peri-implant mucositis and peri-implantitis) were found in Group A. Although grouping criteria were different in previous studies, all the results consistently indicated the association between periodontal status and peri-implant diseases. Wang et al. classified the patient's periodontal status as poor ($\geq$5% sites with PD $\geq$ 4 mm and $\geq$30% sites with BOP) and fair periodontal status (<5% sites with PD $\geq$ 4 mm and <30% sites with BOP).12 Peri-implant PD and BI in the poor group were significantly higher than fair group.12 Heitz-Mayfield et al. proposed the "Implant Disease Risk Assessment "(IDRA).[11] The diagram of IDRA include number of residual periodontal pocket ($\geq$PD 5 mm), BOP (+) %, history of periodontitis, bone loss/age, perio susceptibility, supportive periodontal therapy, restorative margin to bone, prosthesis. When patient with the number of residual periodontal pocket $\geq$6 sites and/or $\geq$25% sites with BOP, she or he were considered as high risk for peri-implant diseases.[11] Zhang et al. also found that periodontal status had an impact on the prevalence of peri-implantitis. Their results showed that $\geq$10% of sites with PD $\geq$ 6 mm and $\geq$30% of sites with BI $\geq$ 3 significantly influence on the prevalence of peri-implantitis.[26]

Two implant systems were involved in this study and tooth level implants seemed to have less peri-implantitis. Further studies with more implant systems could be needed to explain the role of different implant design in prevalence of peri-implant disease.

In conclusion, in our study, implants in patients with severe periodontitis after periodontal treatment and in maintenance showed low prevalence (9.1%) of peri-implantitis and relatively high prevalence (76.2%) of peri-implant mucositis. Peri-implant proximal cleaning habits, implant type and position, periodontal disease control, KTW and peri-implant PlI were associated with prevalence of peri-implantitis.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

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References

1. Su M, Shi B, Zhu Y, et al. Comparison of implant success rates with different loading protocols: a meta-analysis. *Int J Oral Maxillofac Implants* 2014;29:344—52.
2. Swierkot K, Lottholz P, Flores-De-Jacoby L, Mengel R. Mucositis, peri-implantitis, implant success, and survival of implants in patients with treated generalized aggressive periodontitis: 3- to 16-year results of a prospective long-term cohort study. *J Periodontol* 2012;83:1213—25.
3. Karoussis IK, Brägger U, Salvi GE, Bürgin W, Lang NP. Effect of implant design on survival and success rates of titanium oral implants: a 10-year prospective cohort study of the ITI Dental Implant System. *Clin Oral Implants Res* 2004;15:8—17.
4. Mengel R, Behle M, Flores-De-Jacoby L. Osseointegrated implants in subjects treated for generalized aggressive periodontitis: 10-year results of a prospective, long-term cohort study. *J Periodontol* 2007;78:2229—37.
5. Berglundh T, Armitage G, Araujo MG, et al. Peri-implant diseases and conditions: consensus report of workgroup 4 of the 2017 world workshop on the classification of periodontal and peri-implant diseases and conditions. *J Periodontol* 2018; 89(Suppl 1):S313—8.
6. Guarnieri R, Di Nardo D, Di Giorgio G, Miccoli G, Testarelli L. Longevity of teeth and dental implants in patients treated for chronic periodontitis following periodontal maintenance therapy in a private specialist practice: a retrospective study with a 10-year follow-up. *Int J Periodontics Restor Dent* 2021;41: 89—98.
7. Lang NP, Bartold PM. Periodontal health. *J Clin Periodontol* 2018;45(Suppl 20):S9—16.
8. Acharya A, Vanwormer JJ, Waring SC, Miller AW, Fuehrer JT, Nycz GR. Regional epidemiologic assessment of prevalent periodontitis using an electronic health record system. *Am J Epidemiol* 2013;177:700—7.
9. Mombelli A, Van Oosten MA, Schurch Jr E, Land NP. The microbiota associated with successful or failing osseointegrated titanium implants. *Oral Microbiol Immunol* 1987;2: 145—51.
10. Alhakeem M, Kanounisabet N, Nowzari H, Aslroosta H, Moslemi N. Risk indicators of long-term outcome of implant therapy in patients with a history of severe periodontitis or no history of periodontitis: a retrospective cohort study. *Int J Dent Hyg* 2023;21:227—37.
11. Heitz-Mayfield LJA, Heitz F, Lang NP. Implant Disease Risk Assessment IDRA-a tool for preventing peri-implant disease. *Clin Oral Implants Res* 2020;31:397—403.
12. Wang R, Zhao W, Tang ZH, Jin LJ, Cao CF. Peri-implant conditions and their relationship with periodontal conditions in Chinese patients: a cross-sectional study. *Clin Oral Implants Res* 2014;25:372—7.
13. Cho-Yan Lee J, Mattheos N, Nixon KC, Ivanovski S. Residual periodontal pockets are a risk indicator for peri-implantitis in patients treated for periodontitis. *Clin Oral Implants Res* 2012; 23:325—33.
14. Sung CE, Chiang CY, Chiu HC, Shieh YS, Lin FG, Fu E. Periodontal status of tooth adjacent to implant with peri-implantitis. *J Dent* 2018;70:104—9.
15. Tonetti MS, Greenwell H, Kornman KS. Staging and grading of periodontitis: framework and proposal of a new classification and case definition. *J Clin Periodontol* 2018;45(Suppl 20): S149—61.
16. Graziani F, Karapetsa D, Mardas N, Leow N, Donos N. Surgical treatment of the residual periodontal pocket. *Periodontol* 2000 2018;76:150—63.
17. Hu C, Lang NP, Ong MM, Lim LP, Tan WC. Influence of periodontal maintenance and periodontitis susceptibility on implant success: a 5-year retrospective cohort on moderately rough surfaced implants. *Clin Oral Implants Res* 2020;31: 727—36.
18. Darby I. Risk factors for periodontitis & peri-implantitis. *Periodontol* 2000 2022;90:9—12.
19. Nibali L, Gkranias N, Mainas G, Di Pino A. Periodontitis and implant complications in diabetes. *Periodontol* 2000 2022;90: 88—105.
20. Romandini M, Lima C, Pedrinaci I, Araoz A, Soldini MC, Sanz M. Prevalence and risk/protective indicators of peri-implant diseases: a university-representative cross-sectional study. *Clin Oral Implants Res* 2021;32:112—22.
21. Hanisch O, Cortella CA, Boskovic MM, James RA, Slots J, Wikesjö UM. Experimental peri-implant tissue breakdown around hydroxyapatite-coated implants. *J Periodontol* 1997; 68:59—66.
22. Socransky SS, Haffajee AD, Cugini MA, Smith C, Kent Jr RL. Microbial complexes in subgingival plaque. *J Clin Periodontol* 1998;25:134—44.
23. Pontoriero R, Tonelli MP, Carnevale G, Mombelli A, Nyman SR, Lang NP. Experimentally induced peri-implant mucositis. A clinical study in humans. *Clin Oral Implants Res* 1994;5:254—9.
24. Eke PI, Braswell LD, Fritz ME. Microbiota associated with experimental peri-implantitis and periodontitis in adult Macaca mulatta monkeys. *J Periodontol* 1998;69:190—4.
25. Sumida S, Ishihara K, Kishi M, Okuda K. Transmission of periodontal disease-associated bacteria from teeth to osseointegrated implant regions. *Int J Oral Maxillofac Implants* 2002;17: 696—702.
26. Zhang H, Li W, Zhang L, Yan X, Shi D, Meng H. A nomogram prediction of peri-implantitis in treated severe periodontitis patients: a 1-5-year prospective cohort study. *Clin Implant Dent Relat Res* 2018;20:962—8.