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CLINICAL RESEARCH

Risk assessment of interproximal contact loss between implant-supported fixed prostheses and adjacent teeth: A retrospective radiographic study

Jui-Ying Yen, DDS,[a] Lei Kang, DDS,[b] I-Chiang Chou, DDS, PhD,[c] Yu-Lin Lai, DDS, MS,[d] and Shyh-Yuan Lee, DDS, DScD[e]

ABSTRACT

Statement of problem. Studies of interproximal contact loss (ICL) associated with implant-supported fixed prostheses (ISFPs) have typically used dental floss or metal strips to determine ICL and have shown a high prevalence of 34% to 66%, which does not match the authors' experience. Moreover, the implant prosthetic factors contributing to ICL have seldom been reported.

Purpose. The purpose of this clinical study was to examine follow-up radiographs of ISFPs to determine the prevalence of open contacts between the ISFP and adjacent teeth and to assess the risk factors associated with ICL at patient, implant prosthesis, and adjacent tooth levels.

Material and methods. Patients treated with ISFPs at a single clinical center were included. Digital radiographs obtained at the time of ISFP delivery and subsequent follow-up were assessed, and a total of 180 ISFPs with 296 interproximal contacts in 147 patients were screened for analyses. The prevalence and risk factors of ICL at the levels of patient (age, sex, diabetes, smoking, and bruxism), implant prosthesis (follow-up period, arch location, splinting, ceramic or metal materials, screw or cement-retained, and abutment-fixture connection), and adjacent tooth (mesial or distal side, contact with unrestored tooth, composite resin restoration, or fixed prosthesis, vitality, bone height, and contralateral spacing) were analyzed with logistic regressions and generalized estimating equation (GEE) analyses (α=.05).

Results. The onset of ICL was from 6 to 96 months after ISFP delivery. The prevalence of ICL at the patient level was 15.0%, at the implant prosthesis level 13.3%, and at the adjacent tooth levels 8.8%. Twenty-six of the participants had 2 or more ISFPs. The multivariable GEE analysis reported that sex at patient level; longer follow-up period and implant prostheses with external hexagonal and internal octagonal connections at implant prosthesis level; and contralateral spacing, contact with composite resin filling and mesial side of ISFP at adjacent tooth level were significant risk factors of ICL, where contralateral spacing had the highest adjusted odds ratio of 20.88 (*P*=.002).

Conclusions. Most of the ICL were found at the mesial side of ISFPs, and the odds of ICL was significant in participants with longer follow-up periods. Internal hexagonal connections reported relatively lower risk than others. Factors relevant to the anterior component of occlusal force, such as male sex, contralateral spacing at adjacent tooth, and proximal contact of ISFP with resin filling, seem to be high risk factors for ICL. (J Prosthet Dent 2022;127:86-92)

Stable occlusion is a fundamental prerequisite for ensuring a long-term predictable outcome of implant therapy.[1] However, interproximal contact loss (ICL) between implant-supported fixed prostheses (ISFPs) and adjacent teeth has been reported.[2-10] Recent systematic reviews have reported that ICL developed 34% to 66% of the time after an ISFP was inserted next to a natural tooth.[11-13] The high prevalence is beyond common experience,[11] and the wide prevalence range of ICL suggests a multifactorial association and reflects the diversity of the study designs reviewed.

Most previous studies used dental floss or metal strips of different thicknesses to determine contact tightness. However, proximal contact tightness could vary with time of day,[14] the results from the examiners were relatively

[a]Attending Doctor, Department of Dentistry, Yangming branch of Taipei City Hospital, Taipei, Taiwan, Republic of China; and Graduate student, Department of Dentistry, National Yang-Ming University, Taipei, Taiwan, Republic of China.
[b]Attending Doctor, Department of Dentistry, National Yang-Ming University Hospital, Yilan City, Taiwan, Republic of China.
[c]Chairperson, Department of Dentistry, Yangming branch of Taipei City Hospital, Taipei, Taiwan, Republic of China.
[d]Chairperson, Department of Stomatology, Taipei Veterans General Hospital, Taipei, Taiwan, Republic of China.
[e]Professor, Department of Dentistry, National Yang-Ming University, Taipei, Taiwan, Republic of China; and Attending Doctor, Department of Stomatology, Taipei Veterans General Hospital, Taipei, Taiwan, Republic of China; and Researcher, Department of Dentistry, Taipei City Hospital, Taipei, Taiwan, Republic of China.

Clinical Implications

This study revealed that the adjusted odds of ICL were significant, especially at adjacent tooth levels, indicating that durable proximal contacts of the adjacent teeth to maintain arch integrity are highly recommended. Further, internal hexagonal connections, having a relatively small odds ratio, seem to help reduce the risk of ICL in fixed implant restorations. Because ICL with fixed implant restorations is still a common, unpredictable event, clinicians should inform patients of the risk and possible need for further intervention.

subjective, and measurements were influenced by saliva.[15,16] Further, the independent factors contributing to different observation levels have not been well organized,[2,9] and cluster correlated data in the same patient or ISFP have not been controlled. Thus, it is difficult to assess the risk factors effectively and to explore methods of reducing ICL. In spite of these shortcomings, most ICL has been associated with the mesial aspect of the ISFP.[2-9] Factors proposed included that proximal wear or tooth movement was induced by the anterior component of occlusal force and that the proximal contact was stable during function.[3,8,17-24] Unlike a natural tooth, dental implants are considered ankylosed without mesial drifting because of the absence of adaptation and remodeling of a periodontal ligament, which might lead to ICL between the ISFP and adjacent teeth over time.[25] As the proper proximal contacts play an important role in maintaining the arch integrity,[26,27] the ICL of ISFPs warrants more in-depth investigations, especially the possible factors counteracting the anterior component of occlusal force on the ICL.[12,28,29]

Therefore, the purpose of this clinical study was to examine ICL associated with ISFPs at patient, implant prosthesis, and adjacent tooth levels and to provide tactics for the prevention and treatment of this complication. The null hypothesis was that patient, implant prosthetic design, or adjacent tooth condition would not affect the prevalence of ICL.

MATERIAL AND METHODS

This retrospective study was approved (IRB-TPEVGH 2017-11-006CC) by the Institutional Review Board of the Taipei Veterans General Hospital, Taiwan. The participants were rehabilitated with ISFPs at the Department of Stomatology, and all implant placements and prosthesis fabrication were completed between January 2007 and December 2016. The patients' records were examined in detail, and the study records were selected based on the following criteria: endosseous root form implants; ISFP had at least 1 proximal contact with a tooth; received routine maintenance, including intraoral photographs and digital radiographs immediately after ISFP delivery and at recall examinations at 1-week, 1-, 3-, 6-month, and annual intervals; digital radiographs (VistaScan Perio Plus, Dürr Dental) were made with the standardized long cone paralleling technique and a film-holding system (Rinn-XCP Kit; Dentsply Sirona) to align the beam with the long axis of the implants. Exclusion criteria included orthodontic or occlusal splint therapy after ISFP delivery and the adjacent tooth receiving a new restoration or being removed. A total of 147 partially edentulous participants were recruited, and 284 patients were excluded.

The study variables were grouped into 3 levels. The patient data consisted of age, sex, diabetes history, smoking, and bruxism habits. The implant prosthesis data consisted of follow-up period, arch location, single crown or splinted prosthesis, restoration material with ceramic or metal, screw-retained or cement-retained, and design of abutment connection (internal hexagon, external hexagon, or internal octagon). The adjacent tooth data consisted of contact side (mesial or distal), contact structure (unrestored tooth, composite resin restoration, or fixed prosthesis), tooth vitality (vital or nonvital), bone loss (greater or less than 50%), and adjacent tooth contralateral contact (contact or spacing) (Fig. 1).

The digital periapical radiographs were enlarged on a monitor for measuring bone height of the implant and tooth and the minimal distance between the ISFP and adjacent tooth at the contact area according to the method of Jeong and Chang.[30] All measurements were obtained with an imaging software program (ImageJ, v1.50; NIH) by a calibrated examiner (L.K.). The known implant length was used to calibrate the images in the software program. Intrarater reliability was tested by calculating the intraclass correlation coefficient (ICC) between measurements on 10 additional sets of radiographs 2 weeks apart and revealed high reliability (ICC=0.978). The proximal contact was considered open if the measured space at the contact area was greater than 50 μm.[4] The radiograph made at the time of definitive prosthesis delivery served as the baseline.

The prevalence of ICL at 3 levels was calculated. Factors related to ICL at patient level were analyzed with logistic regression, whereas factors related to ICL at implant prosthesis and adjacent tooth levels were analyzed with univariate generalized estimating equation (GEE) analyses because the data were cluster correlated. Further, to examine the impact of the confounding factors and to adjust the within factors (the patient and the implant prosthesis) on ICL, a multivariate GEE analysis was conducted on the model, including participant age

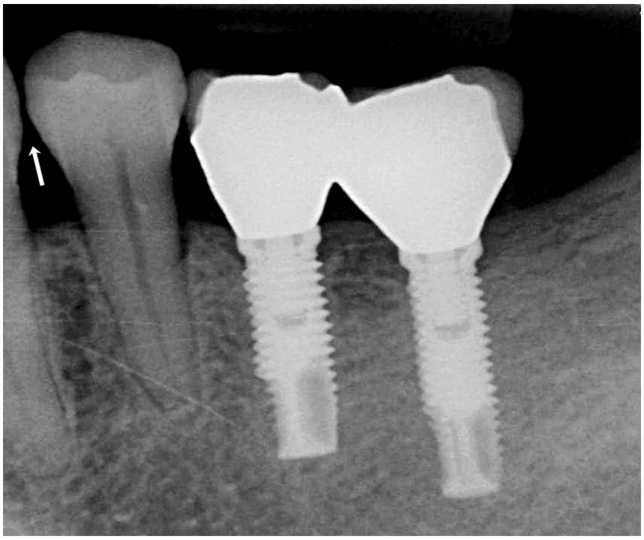

Figure 1. Contralateral spacing defined as existing gap (*white arrow*) at contralateral side of adjacent tooth to implant-supported fixed prosthesis.

Table 1. Descriptive data of participants and prevalence of contact loss at patient, implant prosthesis, and proximal contact levels

Factor	No.	Contact Lost (n)	Prevalence (%)
No. of Participants	147	22	15.0
Patient has 1 prosthesis	121	–	–
Patient has 2 prostheses	20	–	–
Patient has 3 prostheses	5	–	–
Patient has 4 prostheses	1	–	–
Sex ratio (Man/Woman)	77/70	–	–
Mean follow-up months	37 ±25 (3～98)	–	–
No. of implant prosthesis	180	24	13.3
Supported by 1 implant	90	–	–
Supported by 2 implants	62	–	–
Supported by 3 implants	20	–	–
Supported by 4 implants	8	–	–
No. of proximal contacts	296	26	8.8
Mesial	168	–	–
Distal	128	–	–

and sex, and the explanatory variables that had a *P* value <.2 in univariate GEE analyses.[2] All the statistics were analyzed with a statistical software program (IBM SPSS Statistics, v20.0; IBM Corp) (α=.05).

RESULTS

A total of 180 ISFPs supported by 306 implants with 296 interproximal contacts in 147 participants were assessed. Of these, 26 participants had more than 1 ISFP; 116 ISFPs had both mesial and distal contacts, 6 anterior fixed partial dentures had 2 distal contacts, and 52 ISFPs only had a mesial contact. The prevalence of ICL at the patient level was 15.0%, at the implant prosthesis level 13.3%, and at the adjacent tooth levels 8.8% (Table 1).

The risk assessment of patient-related variables reported that male sex, diabetes, and smoking had higher odds ratios (ORs), but differences were not statistically significant (Table 2). In the univariate GEE analyses of implant prosthesis-related variables, a longer follow-up reported that a higher incidence of ICL and ISFP with internal hexagonal connection had less frequency of ICL than those with internal octagonal and external hexagonal connections (*P*<.05). Implants placed in the maxilla or mandible with a single or splinted crown restoration, with a metal or metal-ceramic restoration, and with a screw-retained or cement-retained restoration were statistically similar (Table 3). In adjacent tooth-related variables, mesial contact side (OR=6.61), contact with composite resin restoration (OR=5.55), and spacing on the contralateral side (Fig. 1) (OR=8.95) were found to have higher ICL risks (*P*<.05), whereas tooth vitality and the bone height of the adjacent tooth did not have a statistically significant influence on ICL (Table 4).

Participant age and sex and the explanatory variables which had *P*<.2 in univariate analyses were included in a multivariate GEE analysis (Table 5). Men had more ICL than women. Contralateral spacing (OR=20.88) and mesial contact side (OR=13.10) were the most significant factors associated with ICL. Proximal contact with composite resin restorations (OR=9.67) reported an increase in ICL. Furthermore, compared with internal hexagonal, external hexagonal and internal octagonal connections were statistically associated with ICL (*P*<.05). The follow-up period also reported a significant influence on ICL (*P*<.05).

DISCUSSION

ICL has been suggested as a common multifactorial implant complication. However, previous studies typically used implant prosthesis as the unit of analysis but failed to consider the need to control the confounding and within factors. Therefore, in this study, GEE analyses were performed. The results revealed that the prevalence was significantly different at patient, implant prosthesis, and adjacent tooth levels, and thus, the null hypothesis was rejected. The finding of 13.3% ICL at implant prosthesis level was lower than those of other studies,[2-9] in which a review[13] reported a pooled prevalence of 46.3%. Previously, the contact tightness rather than contact loss was measured with different thicknesses of dental floss[2,6,10] or metal strips[3,9] under unreliable inserting forces.[14,15] In this study, measuring the gap with standardized radiographs[30,31] avoided altering the contact relations. However, the prevalence could be underestimated because the radiographs were made for assessment of the implant itself, not the interproximal gap, and only a gap greater than 50 μm was defined as an ICL.[4]

Table 2. Risk assessment of contact lost at patient level (n=147): odds ratio and 95% confidence interval (CI) from logistic regression analysis

Patient	Contact Lost (n)	Contact (n)	Odds Ratio (95% CI)	*P*
Age (y)	–	–	–	–
N [25 ≤ N ≤ 85]	–	–	Referent	–
N+1	–	–	0.98 (0.94-1.02)	.225
Sex	–	–	–	–
Woman	8	62	Referent	–
Man	14	63	1.72 (0.68-4.40)	.255
Diabetes history	–	–	–	–
No	21	123	Referent	–
Yes	1	2	2.93 (0.25-33.76)	.389
Smoking	–	–	–	–
Nonsmoker	17	112	Referent	–
Smoker	5	13	2.53 (0.80-8.01)	.113
Bruxism	–	–	–	–
No	17	81	Referent	–
Yes	5	44	0.54 (0.19-1.57)	.258

Table 3. Risk assessment of contact lost at implant prosthesis level (n=180): odds ratio and 95% confidence interval (CI) from univariate GEE analysis

Implant Prosthesis	Contact Lost (n)	Contact (n)	Odds Ratio (95% CI)	*P*
Follow-up (mo)	–	–	–	–
N [3 ≤ N ≤ 98]	–	–	Referent	–
N+1	–	–	1.03 (1.01-1.04)	.004*
Arch	–	–	–	–
Maxilla	15	91	Referent	–
Mandible	9	65	1.19 (0.48-2. 97)	.708
Restoration type	–	–	–	–
Single crown	16	77	Referent	–
Splinted	8	79	0.49 (0.17-1.37)	.171
Restoration material	–	–	–	–
Metal	7	38	Referent	–
Metal-ceramic	17	118	0.78 (0.27-2.24)	.646
Retention type	–	–	–	–
Cement-retained	6	70	Referent	–
Screw-retained	18	86	2.44 (0.94-6.35)	.067
Connection type	–	–	–	–
Internal hexagonal	6	110	Referent	–
External hexagonal	14	34	7.55 (2.53-22.55)	<.001*
Internal octagonal	4	12	6.11 (1.62-23.02)	.007*

GEE, generalized estimating equation. *$P<.05$.

Table 4. Risk assessment of contact lost at adjacent tooth level (n=296): odds ratio and 95% confidence interval (CI) from univariate GEE analysis

Adjacent Tooth	Contact Lost (n)	Contact (n)	Odds Ratio (95% CI)	*P*
Proximal side	–	–	–	–
Distal	3	125	Referent	–
Mesial	23	145	6.61 (2.07-21.13)	.001*
Contact structure	–	–	–	–
Unrestored tooth	13	173	Referent	–
Composite filling	5	12	5.55 (1.43-21.49)	.013*
Artificial crown	8	85	1.25 (0.49-3.23)	.642
Vitality	–	–	–	–
Vital	22	227	Referent	–
Nonvital	4	43	0.96 (0.31-2.94)	.943
Bone loss	–	–	–	–
<50%	18	192	Referent	–
≥50%	8	78	0.91 (0.35-2.42)	.856
Contralateral side	–	–	–	–
No spacing	21	263	Referent	–
Spacing	5	7	8.95 (1.93-41.53)	.005*

GEE, generalized estimating equation. *$P<.05$.

At the patient level, many factors may account for the maintenance of physiological tooth position. Continuous growth of the jaw bones and eruptive movement of the teeth could change tooth position adjacent to ISFP.[23] Further, occlusal parafunction and heavy mastication can have a detrimental effect on natural teeth and implants,[24] which may enhance the mesial migration of the adjacent tooth and thus increase ICL.[8] However, this study did not show significant impact of patient-related factors on ICL (Table 2). Because ICL is a multifactorial problem, it would be difficult to identify the causative factors without controlling the confounding variables. Further, some proposed risk factors might be diminished, as most patients with bruxism received an occlusal splint and were excluded from the study.

At the implant prosthesis level, only follow-up period and abutment connection types reported significant impact on ICL (Table 3). A longer follow-up period was expected to be associated with a higher prevalence of ICL.[2,3,8,10] The earliest ICL was found at 6 months after definitive restoration delivery, whereas the latest ICL was found at 90 months follow-up (Fig. 2). Some studies reported that ICL could happen as early as 3 months after ISFP delivery,[4,5,8] and Ren et al[5] also reported that intentionally increasing the proximal contact tightness was not stable and that rapid change would occur. The early onset of ICL could therefore be related to the residual stress generated by the insertion of the ISFP, as the strength of the proximal contacts is difficult to balance evenly on mesial and distal surfaces. Unbalanced contact strength may increase adjacent tooth movement and subsequent occlusal interference, which could partly explain the early onset of ICL, because the periodontal tissue could respond to orthodontic force within weeks. In this study, 8 of 26 (30.8%) ICL were first found in the prostheses delivered more than 5 years earlier, which suggests that these ICLs were not an instant response of the adjacent tooth but could be related to long-term associated factors.[3,4,21]

ISFPs with external hexagonal and internal octagonal connections were associated with significantly higher ICL than those with internal hexagonal connections ($P<.01$), which suggests that the contact stability of ISFP with different connections, both at the time and after

Table 5. Risk assessment of contact lost at adjacent tooth level (n=296): adjusted odds ratio and 95% confidence interval (CI) from multivariate GEE analysis

Adjacent Tooth	Group	Adjusted Odds Ratio (95% CI)	*P*
Age (y)	N [25 ≦ N ≦ 85]	Referent	—
	N+1	0.96 (0.92-1.01)	.088
Sex	Woman	Referent	—
	Man	4.58 (1.40-15.05)	.012*
Smoking	Nonsmoker	Referent	—
	Smoker	0.51 (0.09-3.00)	.455
Proximal side	Distal	Referent	—
	Mesial	13.10 (3.42-50.26)	<.001*
Contact structure	Unrestored tooth	Referent	—
	Composite filling	9.67 (2.43-38.42)	.001*
	Artificial crown	1.79 (0.50-6.41)	.369
Contralateral side	Nonspacing	Referent	—
	Spacing	20.88 (3.19-136.81)	.002*
Restoration type	Single crown	Referent	—
	Splinted	0.33(0.10-1.08)	.067
Retention type	Cement-retained	Referent	—
	Screw-retained	1.34 (0.45-4.00)	.601
Connection type	Internal hexagonal	Referent	—
	External hexagonal	9.73 (2.11-44.80)	.003*
	Internal octagonal	7.24 (1.56-33.51)	.011*
Follow-up (mo)	N [3 ≦ N ≦ 96]	Referent	—
	N+1	1.02 (1.00-1.04)	.017*

GEE, generalized estimating equation. **P*<.05.

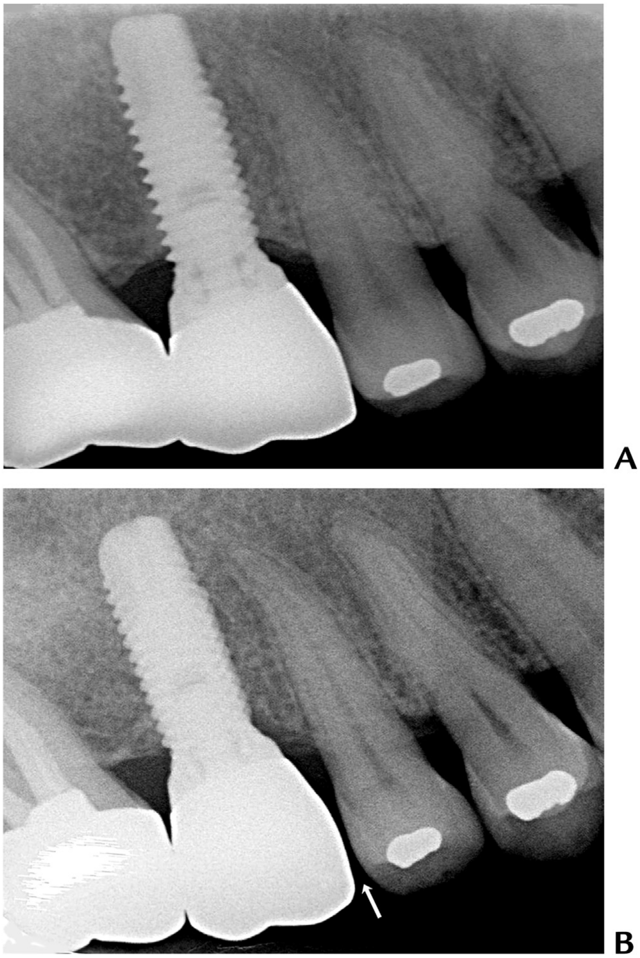

Figure 2. Radiographs showed proximal contacts between implant-supported fixed prosthesis (maxillary right first molar) and adjacent tooth. A, At time of delivery. B, Loss of mesial contact (*white arrow*) at 7.5 years follow-up.

ISFP delivery, were dissimilar. The external hexagonal connection could have more micromotion and mechanical complications,[32,33] whereas internal octagonal connection could have more rotational freedom because of the increasing number of connection edges.[34] The micromotion of the abutment could thus influence the interproximal contact stability. Regarding the retention types of implant prosthesis, screw-retained ISFPs tended to have a higher ICL prevalence (OR=2.44, *P*=.067) than cement-retained ISFPs in the univariate GEE analyses. However, the adjusted OR of retention type was not statistically significant in the multivariate GEE analysis.

At the adjacent tooth level, the odds of ICL at the mesial contact was 6.61 times (*P*=.001) higher than at the distal contact. Most previous studies also reported a similar trend.[2-6,8,12] Mesial drift of teeth occurs naturally because, on mandibular closure, the anterior component of occlusal force will drive the tooth mesially.[18] As the ISFP could be considered as an ankylosed tooth, the tendency of mesial drift of the adjacent tooth is assumed to be a reason for the higher ICL at the mesial aspect.[2,11,27] The assumption can be supported by the findings that if there was a spacing at the contralateral side of the adjacent tooth (Fig. 1) near the ISFP, the OR was high, up to 8.95 (*P*=.005). Further, the interproximal contact of an ISFP with a composite resin restoration also revealed a high prevalence of ICL (OR=5.55, *P*=.013) when compared with the contacts with unrestored teeth, metal restorations, or ceramic restorations. As previous studies have shown, the occlusal force transmitted through the proximal contacts could create friction and cause proximal wear,[26] the composite resin restoration exhibited less wear resistance and thus failed to remain in tight contact over time.[20,22] The periodontal status of the adjacent tooth might have a short-term effect on contact tightness at the time of prosthesis delivery but did not dominate the tooth movement causing ICL in this study.

The multivariable GEE model revealed that an increased risk for ICL was mainly associated with the spacing at the contralateral side of the adjacent tooth (OR=20.88, *P*=.002) and mesial side of the ISFP (OR=13.10, *P*<.001), which might imply that arch integrity to resist the mesial shift from the anterior component of occlusal force could be the major influential factors.[16,18,27,28] In addition, composite resin filling adjacent to an ISFP was also associated with ICL (OR=9.67, *P*=.001) as the proximal contact strength can be influenced by the wear resistance of the material.[14,22] The multivariate GEE analysis, after confounding adjustment, reported a higher ICL in men, which could be related to their more powerful masticatory system and more interproximal tooth wear.[16,19,21,26]

Regarding the consequences of ICL around an ISFP, food impaction[6,9,30] and adverse effects on peri-implant tissue[3,30] were reported. Nevertheless, the results in the present study did not find significant impact on bone height, which was parallel to the findings of previous studies.[2,10] However, ICL could be a sign of unstable occlusion, which may consequently lead to mechanical complications. Given these findings, patients should be informed of the importance of arch integrity in implant therapy. Providing retrievability of an implant prosthesis with a screw connection[11,12] and periodic evaluations of the interproximal contacts between implant restorations and the adjacent teeth are also recommended. Further, an occlusal splint would help serve as a retainer and a night guard to prevent overloading for bruxers.

A major limitation of this study was that the routine follow-up radiographs were to evaluate implant proper but contact area. Therefore, the long cone paralleling technique accompanied by a positioning device specifically customized for monitoring each contact area between ISFP and adjacent tooth is warranted in the future studies.

CONCLUSIONS

Based on the findings of this study, the following conclusions were drawn:

1. In routine follow-up radiographs, 13.3% of ISFP found ICL with high odds for the mesial aspect of ISFP, the male sex, and longer follow-up periods.
2. Internal hexagonal connections between abutments and implants revealed less ICL compared with other implant-abutment connections.
3. The risk factors at the adjacent tooth level seem to be more important than those at the patient and implant prosthesis levels for ICL with implant prostheses according to GEE analyses.

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Corresponding author:
Dr Shyh-Yuan Lee
Department of Dentistry
National Yang-Ming University
No 155, Sec 2, Li-Nong Street, Beitou District
Taipei
TAIWAN, REPUBLIC OF CHINA
Email: sylee@ym.edu.tw

CRediT authorship contribution statement

Jui-Ying Yen: Conceptualization, Methodology, Writing - original draft, Writing - review & editing. **Lei Kang:** Data curation, Investigation, Validation, Writing - review & editing. **I-Chiang Chou:** Investigation, Writing - review & editing, Resources. **Yu-Lin Lai:** Investigation, Writing - review & editing, Resources, Funding acquisition. **Shyh-Yuan Lee:** Conceptualization, Methodology, Validation, Writing - original draft, Writing - review & editing, Supervision.

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Noteworthy Abstracts of the Current Literature

Effect of crown height on the screw stability of titanium screw-retained crowns

Batak B, Johnston W, Lang L, Seghi R, Yilmaz B

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Purpose. The aim of this in vitro study was to evaluate the effect of crown height on the screw stability of screw-retained titanium implant crowns subjected to cyclic loading conditions.

Material and methods. Twenty-one implants with internal hex connections were placed in epoxy resin holders. Mandibular first molar screw-retained titanium implant crowns with UCLA type, crown-abutment connections were CAD-CAM fabricated. Seven crowns of 3 different heights (6 mm, 10 mm, and 14 mm) were made. The crowns were seated onto the implants and screws were tightened to 30 Ncm. The implants were clamped into holders and stepwise cyclic loads were applied to the occlusal surface at 30-degree angles to the long axes of the crowns. The detorque values were measured after each 5 million cycles. Before increasing the applied load, the crowns were secured with new screws and tightened to 30 Ncm. Failure times, survival estimates and detorque values were then analyzed. (alpha=0.05).

Results. Crown height did not significantly affect detorque values. However, five 14-mm crowns failed with varying fractures during the 475 N loading condition. Overall, a significantly lower survival for 14 mm crowns was found compared to 6 mm and 10 mm crowns (P=0.004).

Conclusions. Crown heights of one-piece screw-retained titanium implant crowns did not significantly affect detorque values. Screw fracture, however, was greater for crown height of 14 mm than those of 6 mm and 10 mm.