Splinting or Nonsplinting Adjacent Implants? A Retrospective Study Up to 15 Years: Part I—Biologic and Mechanical Complication Analysis

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Purpose: To analyze the biologic and mechanical complications of splinted and nonsplinted implant restorations. ***Materials and Methods:*** A total of 423 patients (n = implants: 888) were included in the study. Biologic and mechanical complications that occurred for 15 years were analyzed using the multivariable Cox regression model, and the significant effect of the splinting of prostheses and other risk factors were evaluated. ***Results:*** Biologic complications occurred in 38.7% of implants: 26.4% of nonsplinted implants (NS) and 45.4% of splinted implants (SP). Mechanical complications occurred in 49.2% of implants: 59.3% NS and 43.9% SP. Implants splinted with both mesial and distal adjacent implants (SP-mid) had the highest risk of peri-implant diseases. As the number of implants splinted increased, the risk of mechanical complications decreased. Long crown lengths increased the risk of both biologic and mechanical complications. ***Conclusion:*** Splinted implants had a higher risk of biologic complications and lower risk of mechanical complications. The implant splinted to both adjacent implants (SP-mid) had the highest risk of biologic complications. The greater the number of implants splinted, the lower the risk of mechanical complications. Long crown lengths increased the risk of both biologic and mechanical complications. *Int J Oral Maxillofac Implants 2023;38:435–442. doi: 10.11607/jomi.10053*

Keywords: component fracture, mechanical complication, peri-implant disease, peri-implantitis, splinting

While restoration with implant-supported fixed partial prostheses in partially edentulous patients has been recognized as a successful treatment option, a number of complications have also been reported.[1–3] Peri-implant diseases are defined as biofilm-associated peri-implant diseases.[4] It has been found that poor oral hygiene and history of periodontitis are highly related to biologic complications,[5–7] and mechanical complications have been identified to be associated with overloads caused by inadequate occlusion, cantilevers, and a lack of passive fit.[8,9] Several risk indicators have been mentioned to be associated with the occurrence of complications, one of which is either splinting or nonsplinting of adjacent implants. Several clinical studies have suggested that splinting is more advantageous in preventing mechanical complications[10–13]; however, de Souza Batista et al concluded in their systematic review that there was no significant difference in prosthetic complications between splinted and nonsplinted implant restorations.[14] Studies comparing the biologic complications of splinted and nonsplinted restorations also displayed conflicting conclusions. Vigolo et al,[15] Clelland et al,[10] and Shi et al[11] found that there was no significant difference in marginal bone loss; however, Wagenberg and Froum[16] found significantly higher marginal bone loss in splinted implants than in nonsplinted implants.

Whether to splint should be determined by considering the advantages and disadvantages of each clinical situation. However, conflicting studies have been presented, making it difficult for clinicians to make decisions. Comprehensive research is needed to provide guidance to clinicians.

In a previous study, the need for comparison of biologic and mechanical properties according to the splinted positions was suggested.[17] In this regard, the aim of the present study was to analyze the biologic and mechanical complications of splinted and nonsplinted implant restorations.

MATERIALS AND METHODS

This retrospective study was approved by the Seoul National University Dental Hospital Institutional Review Board (no. ERI20017). STROBE guidelines were followed.

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The data included all patients treated with internal conical connection implants (Oneplant FIT, Warantec) in the posterior area at Seoul National University Dental Hospital from March 2006 to February 2014. Patients and implants with the following criteria were excluded:

- Patients with incomplete clinical records
- Patients who had not received regular maintenance care by 2021
- Patients with a full mouth plaque score ≥ 25%
- Patients who have systemic diseases or conditions
- Patients who smoke ≥ 1 cigarette per day
- Patients who have received treatment for peri-implantitis previously
- Patients who received jaw reconstruction after jaw resection
- Patients who received implant-assisted removable prostheses
- Implant prostheses with cantilevers or pontics
- Implant prostheses that have occlusion with removable prostheses
- Implants re-placed after failure and implants that failed early before loading

The following categories were included in this study: splinted (SP) or nonsplinted (NS); splinted position (NS: nonsplinted, SP-m: the mesial implant splinted to the distally adjacent implant, SP-mid: the middle implant splinted to both mesially and distally adjacent implants, SP-d: the distal implant splinted to the mesially adjacent implant); number of implants splinted for each prosthesis; prosthetic type (C-Ti, cement-retained prosthesis with a titanium abutment; C-Gold, cement-retained prosthesis with a gold-cast abutment; S-MUA, screw-retained prosthesis using a multiunit system, S-UCLA, gold-cast screw-retained prosthesis); location; diameter; length; emergence angle (EA); emergence profile (EP); crown-to-implant (C/I) ratio; crown length (CL); bone augmentation; immediate placement; one- or two-stage protocol; and patient descriptions (sex, age, history of periodontitis).

The radiographic measurement protocol of the EA, EP, C/I ratio, crown length, and marginal bone loss (MBL) were previously reported (Appendix Fig 1; see Appendix in online version of this article at quintpub.com).[17,18] An identical image processing program was used for the present study (ImageJ, National Institutes of Health). Intraoral radiographs were taken using the paralleling technique a year after prosthesis insertion and at follow-up visits. All radiographic files were anonymously numbered, and one blinded examiner performed all measurements (Y.Y.). Intrarater reliability was calculated measuring the consistency of three measurements of 30 specimens selected by simple random selection and showed a high level of reliability (Cronbach's α, intraclass correlation coefficient = 0.98).

Diagnostic Criteria for Complications

The diagnosis of peri-implant disease followed the current guideline defined in the 2017 World Workshop[4]: peri-implant mucositis, defined as presence of bleeding on probing (BOP) and absence of bone loss; peri-implantitis, defined as presence of BOP and/or suppuration, increased probing depth (PD), and presence of detectable bone loss exceeding the measurement error (mean: 0.5 mm).

The following mechanical complications were included: screw loosening, defined as prosthesis mobility in osseointegrated implants without screw fracture; screw or abutment fracture, defined as a fractured screw or abutment being observed; and implant fracture, defined as radiolucency of the implant fracture line or dislocation of the fractured fragment being observed in the radiograph. The time of occurrence was calculated by measuring the time elapsed from the prosthesis delivery to the occurrence of the complication. Data were recorded at the implant and patient level. Multiple events that occurred in an implant or in a patient were recorded once in the complication experience. Repeated events were recorded once and described separately. The time of occurrence in multiple or repeated events was measured from the date of the first event. For the estimation of cumulative hazard rates, data were censored at the date of the last follow-up visit.[18]

Statistical Analysis

Statistical software (IBM SPSS Statistic, version 25.0, IBM) was used for analysis. Kaplan-Meier curves and the multivariable Cox regression model were used to analyze the biologic and mechanical complications of implants. Univariate analysis was performed for each variable to assess its association with the incidence of complications. Covariates that had $P \leq .20$ in univariate analysis were selected for multivariate analysis. The Cox proportional hazard model was conducted considering confounding factors and presented as hazard ratio (HR) and 95% confidence interval (CI).

RESULTS

The distribution of implants and patients is presented in Table 1. The mean follow-up period was 12.7 ± 1.6 years, and 424 patients with 888 implants were included in the study. During the observation period, biologic complications occurred in 38.7% of implants (26.4% of nonsplinted implants, NS; 45.4% of splinted implants, SP) and 41.0% of patients: peri-implant mucositis in 38.7% of implants and 41.0% of patients; peri-implantitis in 23.8% of implants and 30.0% of patients. The prevalence of mechanical complications was 49.2% at the implant level (59.3% of NS; 43.9% of SP), and 59.4%

of patients experienced at least 1 mechanical complication. Screw loosening occurred in 47.2% of implants and 43.3% of patients, and component fractures were observed in 17.0% of implants and 20.2% of patients. Abutments were most frequently fractured among the components (12.7% of implants, 23.6% of patients), followed by implants (4.1% of implants; 5.9% of patients) and screws (2.6% of implants; 4.5% of patients).

In the univariate analysis, splinted implants (SP) showed a higher risk of biologic complications and lower risk of mechanical complications than nonsplinted implants (NS; Figs 1a and 1b). Depending on the splinted position, the SP-mid group had the highest risk of peri-implant disease and the lowest risk of mechanical complications (Figs 1c and 1d). In the multivariate analysis, splinting showed a significant effect on peri-implant disease: The SP-mid group had the highest risk of peri-implant mucositis (HR 3.10; 95% CI [1.36–7.08]) and peri-implantitis (HR 3.69; 95% CI [1.36–10.05]). The crown length had a significant effect on peri-implant mucositis (HR 1.16; 95% CI [1.04–1.29]). Implant prostheses with EA ≥ 30 degrees on both the mesial and distal sides (EA3) and convex EP on at least one side (EP2, EP3) were identified as risk indicators for peri-implant disease. At the patient level, significantly higher risk of peri-implant disease was observed for patients with a history of periodontitis (Table 2). In the mechanical complication analysis, splinted position was not significantly associated, but the number of splinted implants was related to mechanical complications: As the number of splinted implants in a prosthesis increased, the risks of screw loosening, implant component fracture experience, and overall mechanical complications decreased (Table 3). For each implant component, the risk of abutment fracture was higher in the nonsplinted single implant prosthesis (Table 4). The greater the number of splinted implants, the lower the risk of abutment fractures (HR 0.32; 95% CI [0.22–0.47]). Along with splinting of implants, location, crown length, and prosthesis type had a significant effect on mechanical complications; molar implants, long crown length, and S-UCLA–type prostheses had higher risks of mechanical complications (Table 3). Implant diameter was significantly associated with implant fractures; the narrower the diameter, the greater the risk of implant fracture (HR 0.04; 95% CI [0.01–0.18]). Molar implants and male patients had a higher risk of mechanical complications for all component fractures as well as screw loosening (Tables 3 and 4).

Table 1 Distribution of Implants and Patients

		N (%)
Patient level (Total of 424 patients)		
Sex	Male Female	216 50.9%) 208 (49.1%)
Age (y)	Min–Max Mean (SD)	20–80 52.5 (11.3)
History of periodontitis	No Yes	92 (21.7%) 332 (78.3%)
Implant level (Total of 888 implants)		
Splinted or nonsplinted (NS/SP)	Nonsplinted (NS) Splinted (SP)	307 (34.6%) 581 (65.4%)
SP position	NS SP-m SP-mid SP-d	307 (34.6%) 261 (29.4%) 59 (6.6%) 261 (29.4%)
No. of implants splinted (No. SP)	Min–Max Mean (SD)	1–4 1.86 (0.77)
Location	Premolar Molar	221 (24.9%) 667 (75.1%)
Diameter (mm)	Min–Max Mean (SD)	3.6–6.3 4.48 (0.47)
Length (mm)	Min–Max Mean (SD)	7–13 10.54 (1.15)
Crown-implant (C/I) ratio	Min–Max Mean (SD)	0.45–1.77 1.00 (0.22)
Crown length (CL) (mm)	Min–Max Mean (SD)	5.17–18.86 10.45 (2.08)
Emergence angle (EA)†	EA1† EA2† EA3†	349 (39.3%) 246 (27.7%) 293 (33.3%)
Emergence profile (EP)†	EP1† EP2† EP3†	463 (49.1%) 249 (28.0%) 203 (22.9%)
Prosthetic type‡	C-Ti‡ C-Gold‡ S-MUA‡ S-UCLA‡	80 (9.0%) 147 (16.6%) 96 (10.8%) 565 (63.6%)
Bone augmentation	No Yes	468 (52.7%) 420 (47.3%)
Immediate placement	No Yes	797 (89.8%) 91 (10.2%)
1-stage or 2-stage	1-stage 2-stage	381 (42.9%) 507 (57.1%)

†EA and †EP were measured on the mesial and distal aspects, respectively; †EA1 = both < 30 degrees; †EA2 = one < 30 degrees, the other ≥ 30 degrees; †EA3 = both ≥ 30 degrees; †EP1 = both concave or straight profile; †EP2 = one is concave or straight, and the other is convex profile; †EP3 = both convex profile; ‡C-Ti = cement-retained prostheses with a titanium abutment; ‡C-Gold = cement-retained prostheses with a gold-cast abutment; ‡S-MUA = screw-retained prostheses using a multiunit system; ‡S-UCLA = gold-cast screw-retained prostheses.

DISCUSSION

In the present study, the long-term outcomes of implants depending on splinting and other associated features up to 15 years was evaluated by analyzing biologic and mechanical complications. Splinting of implants was identified to affect the occurrence of biologic and mechanical complications. Figure 1 shows that the opposite pattern appears in biologic and mechanical complications depending on whether the implants were splinted as well as the splinted position: The

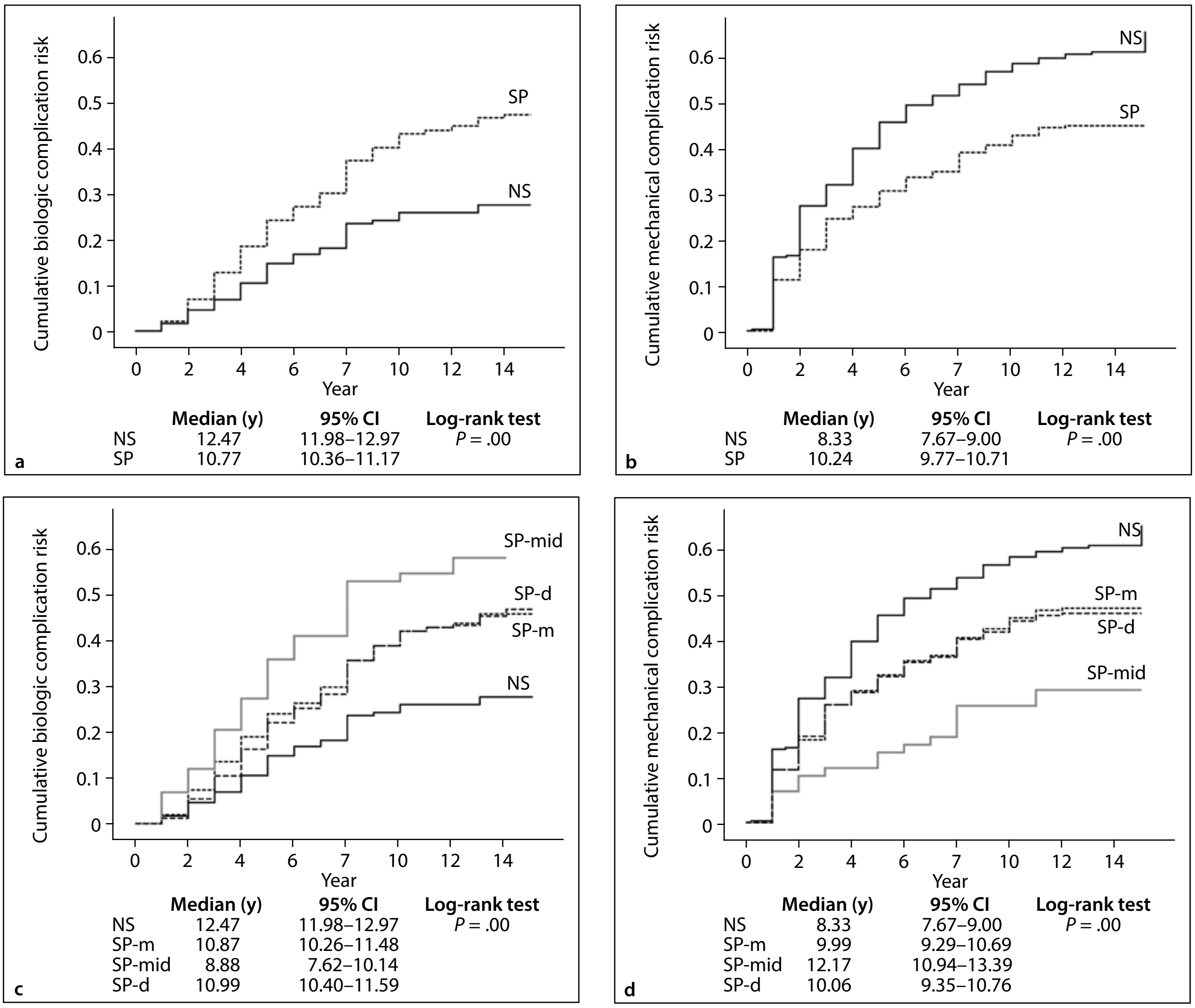

Fig 1 Kaplan-Meier cumulative hazard plots. *(a)* Biologic complications of NS and SP. *(b)* Mechanical complications of NS and SP. *(c)* Biologic complications according to splinted position. *(d)* Mechanical complications according to splinted position. NS = nonsplinted single implant; SP = splinted implant; SP-m = mesial implant splinted to the distal adjacent implant; SP-mid = middle implant splinted to both adjacent implants; SP-d = distal implant splinted to mesial adjacent implant.

SP group had a higher risk of biologic complications and a lower risk of mechanical complications, which is consistent with previous studies.[11,16] SP-mid had the highest risk of biologic complications and the lowest risk of mechanical complications. This result was also found in multivariate analysis for biologic complications. However, in the multivariate analysis for mechanical complications, splinting or the splinted position did not show any significant effects; however, the number of splinted implants in a prosthesis was significantly related. As the number of splinted implants in a prosthesis increased, the risk of screw loosening or component fractures decreased. This is in line with a study by Karlsson et al,[1] which reported that screw loosening only occurred in restorations supported by two implants and was not observed in more extensive restorations. However, Adler et al[3] reported that technical complications occurred more frequently in implants with more than three prosthetic units than in those with fewer than three. There are major issues when performing these types of comparisons due to the lack of consensus on mechanical or technical complications and different diagnostic and research criteria used for each study. The mechanical benefits of splinted prostheses have been revealed through several in vitro studies, which suggested that loads are transferred evenly to implants, resulting in more uniform stress distribution.[19–21] For biologic complications, the number of implants splinted was not related, but the splinted implants and the implants in SP-mid position were identified as risk indicators for peri-implant disease, which is consistent with previous studies.[12,17] Taken together, a higher number of splinted implants supporting a prosthesis reduces

Table 2 Univariate and Multivariate Analysis for Biologic Complications

Features	Univariate analysis (*P*) PM§	PI§
Implant level		
NS/SP	.00*	.00*
SP position	.00*	.00*
No. SP	.00*	.00*
Location	.05*	.09*
Diameter	.00*	.03*
Length	.30	.79
C/I ratio	.08*	.52
CL	.03*	.81
EA	.00*	.00*
EP	.00*	.00*
Prosthetic type	.21	.23
Bone augmentation	.57	.46
Immediate placement	.48	.55
1-stage or 2-stage	.31	.07*
Patient level		
Sex	.02*	.04*
Age	0.42	.61
History of periodontitis	.00*	.00*

Features	Multivariate analysis for peri-implant mucositis (PM) Nª (%)	*P*¶	HR	95% CI	Multivariate analysis for peri-implantitis (PI) Nª (%)	*P*¶	HR	95% CI
Implant level	344 (38.7%)				211 (23.8%)			
NS/SP								
NS	81 (26.4%)		1		52 (16.9%)		1	
SP	264 (45.4%)	.02**	2.68	1.16–6.21	160 (27.5%)	.02**	2.25	1.17–4.32
SP position								
NS	81 (26.4%)		1		52 (16.9%)		1	
SP-m	115 (44.1%)	.06	2.30	0.98–5.40	75 (28.7%)	.01**	2.26	1.23–4.16
SP-mid	34 (57.6%)	.01**	3.10	1.36–7.08	23 (39.0%)	.01**	3.69	1.36–10.05
SP-d	115 (44.1%)	.02**	2.68	1.16–6.21	62 (23.8%)	.08	1.77	0.94–3.35
No. SP		.66	0.70	0.32–1.53		.29	0.80	0.52–1.22
Location								
Premolar	72 (32.7%)		1		44 (19.9%)		1	
Molar	272 (40.8%)	.36	0.86	0.63–1.18	168 (25.2%)	.37	0.83	0.55–1.25
Diameter		.10	0.69	0.52–1.92		.11	0.53	0.25–1.14
C/I ratio		.39	0.64	0.24–1.76				
CL		.01**	1.16	1.04–1.29				
EA								
EA1	78 (22.3%)		1		39 (11.2%)		1	
EA2	99 (40.2%)	.05	1.42	0.99–2.02	60 (24.4%)	.20	1.38	0.85–2.23
EA3	167 (57.0%)	.00**	1.92	1.30–2.82	112 (38.2%)	.05**	1.64	1.00–2.69
EP								
EP1	90 (20.6%)		1		45 (10.3%)		1	
EP2	118 (47.4%)	.00**	2.18	1.58–3.01	68 (27.3%)	.00**	2.35	1.51–3.64
EP3	136(67.0%)	.00**	3.74	2.61–5.36	98 (48.3%)	.00**	4.72	2.96–7.50
1-stage or 2-stage								
1-stage							1	
2-stage						0.19	1.25	0.90–1.73
Patient level	174 (41.0%)				127 (30.0%)			
Sex								
Female	74 (35.6%)		1		53 (25.5%)		1	
Male	100 (46.3%)	.07	1.32	0.98–1.78	74 (34.3%)	.10	1.35	0.95–1.92
History of periodontitis								
No	12 (13.0%)		1		9 (9.8%)		1	
Yes	162 (48.8%)	.00**	4.51	2.51–8.13	118 (35.5%)	.00**	4.01	2.34–7.92

§*P* value calculated from univariate analysis of each covariate; *covariate selected for multivariate analysis ($P < .20$); ¶*P* value calculated from multivariable analysis; **significant influence derived Cox proportional hazard regression analysis ($P < .05$); Nª = cumulative events during study period (15 years).

the risk of mechanical complications but increases the risk of biologic complications with the increase in SP-mid implants. This result makes it difficult for clinicians to decide whether to splint adjacent implants, and other associated factors should be considered to make the appropriate decision.

There was a high risk of peri-implant disease for implant restorations with EA ≥ 30 degrees on both the mesial and distal sides (EA3) and convex EP at least on one side (EP2, EP3) as well as for the SP-mid implants. This is in line with a previous study[17] confirming that an over-contoured prosthesis is a critical risk indicator of biologic

Table 3 Multivariate Analysis of Mechanical Complication Experience, Screw Loosening, and Component Fracture Experience by Each Characteristic Selected from Univariate Analysis ($P < .20$)[b]

	Mechanical complication experience				Screw loosening				Component fracture experience			
Features	N[a] (%)	*P* value	HR	95% CI	N[a] (%)	*P* value	HR	95% CI	N[a] (%)	*P* value	HR	95% CI
Implant level	437 (49.2%)				419 (47.2%)				151 (17.0%)			
NS/SP												
NS	182 (59.3%)		1		176 (57.3%)		1		92 (30.0%)		1	
SP	255 (43.9%)	.59	1.14	0.71–1.84	243 (41.8%)	.14	1.35	0.91–2.02	59 (10.2%)	.61	1.35	0.43–4.20
SP position												
NS	182 (59.3%)		1		176 (57.3%)		1		92 (30.0%)		1	
SP-m	151 (46.4%)	.19	1.35	0.86–2.10	114 (43.7%)	.26	1.30	0.83–2.04	30 (11.5%)	.99	0.99	0.32–3.12
SP-mid	17 (28.8%)	.95	0.97	0.40–2.36	16 (27.1%)	.85	0.92	0.37–2.27	2 (3.4%)	.70	0.61	0.05–7.46
SP-d	118 (45.2%)	.89	1.14	0.71–1.84	114 (43.7%)	.63	1.13	0.69–1.82	27 (10.3%)	.70	0.79	0.24–2.65
No. SP		.02**	0.67	0.47–0.95		.01**	0.65	0.46–0.90		.01**	0.27	0.10–0.72
Location												
Premolar	64 (29.1%)		1		60 (27.3%)		1		13 (5.9%)		1	
Molar	373 (55.8%)	.00**	2.16	1.63–2.88	359 (53.7%)	.00**	2.18	1.62–2.92	138 (20.7%)	.00**	3.19	1.76–5.79
Diameter		.11	1.18	0.96–1.46		.07	1.21	0.98–1.49		.19	0.48	0.16–1.42
Length		.46	1.03	0.95–1.12						.80	0.92	0.50–1.71
C/I ratio		.99	0.98	0.03–28.89		.37	0.69	0.30–1.57		.75	0.37	0.01–148.55
CL		.00**	1.07	1.03–1.12		.02**	1.11	1.02–1.21		.00**	1.13	1.05–1.22
Prosthetic type												
C-Ti	10 (12.5%)		1		9 (11.3%)		1		1 (1.3%)		1	
C-Gold	43 (29.3%)	.00**	3.19	1.60–6.36	41 (27.9%)	.00**	3.32	1.62–6.83	17 (11.6%)	.02**	12.10	1.61–91.20
S-MUA	45 (46.9%)	.00**	5.64	2.83–11.24	45 (46.9%)	.00**	6.09	2.97–12.48	0 (0.0%)	.96	0.00	0.00
S-UCLA	339 (60.0%)	.00**	6.26	3.33–11.80	324 (57.3%)	.00**	6.46	3.32–12.56	133 (23.5%)	.01**	15.49	2.16–111.37
Patient level	252 (59.4%)				237 (55.9%)				121 (28.5%)			
Gender												
Female	96 (46.2%)		1		90 (43.3%)		1		42 (20.2%)		1	
Male	156 (72.2%)	.00**	2.08	1.61–2.69	147 (68.1%)	.00**	2.04	1.56–2.65	79 (36.6%)	.00**	2.06	1.41–2.99

[b]Univariate analysis presented in Appendix Table 1; **significant influence derived from multivariable Cox proportional hazard regression analysis ($P < .05$); N[a] = cumulative events during study period (15 years)

complications. It also emphasizes the importance of accessibility for oral hygiene. This suggests that splinted implants are susceptible to biologic complications, and this vulnerability could be reduced through proper prosthetic design.

Crown length was identified to affect both biologic and mechanical complications. The longer the crown length, the higher the risk of peri-implant mucositis, and the higher the risks of screw loosening and abutment fracture. Clelland et al[10] observed more frequent screw loosening in nonsplinted crowns but concluded that it might be more related to increased crown height than splinting or nonsplinting. Under off-axis loading in internal-connection–type implants, stress is concentrated on the implant-abutment connection area, where all components are involved.[22] Considering this, it could be suggested that as the crown length increases, the mechanical complications of the components involved increase as well. The crown length of the implant prosthesis may depend on the vertical bone height of the residual bone. Implant prostheses restored in areas with severe bone resorption have a longer clinical crown length. The crown-gingival junction of these prostheses is positioned more deeply, making it difficult to access for oral hygiene. Implant placement after vertical bone augmentation might help reduce the crown length; however, a good prognosis is not guaranteed depending on clinical conditions. When it is difficult to reduce the crown length with vertical bone augmentation, alternative methods for reducing the risk of biologic and mechanical complications are required. Considering the results of the present study, it is recommended to splint as many implants

Table 4 Multivariate Analysis of Screw Fracture, Abutment Fracture, and Implant Fracture by Each Characteristic Selected from Univariate Analysis ($P < .20$)[b]

	Screw fracture				Abutment fracture				Implant fracture			
Features	N[a] (%)	*P* value	HR	95% CI	N[a] (%)	*P* value	HR	95% CI	N[a] (%)	*P* value	HR	95% CI
Implant level	23 (2.6%)				113 (12.7%)				36 (4.1%)			
NS/SP												
NS	13 (4.2%)		1		79(25.7%)		1		9 (2.9%)			
SP	10 (1.7%)	.22	0.59	0.26–1.36	34 (5.9%)	.00**	0.30	0.20–0.46	27 (4.6%)			
SP position												
NS	13 (4.2%)		1		79 (25.7%)		1		9 (2.9%)			
SP-m	6 (2.3%)	.94	0.88	0.33–2.33	16 (6.1%)	.74	1.26	0.32–4.90	15 (5.7%)			
SP-mid	1 (1.7%)	.99	0.69	0.09–5.32	1 (1.7%)	.84	1.39	0.06–33.11	1 (1.7%)			
SP-d	3 (1.1%)	.93	0.35	0.10–1.24	17 (6.5%)	.89	1.10	0.29–4.14	11 (4.2%)			
No. SP		.35	2.08	0.45–9.52		.00**	0.32	0.22–0.47		.67	0.90	0.55–1.46
Location												
Premolar	2 (0.9%)		1		7 (3.2%)		1		4 (1.8%)		1	
Molar	21 (3.1%)	.07	4.39	0.90–21.40	106 (15.9%)	.00**	3.91	1.78–8.59	32 (4.8%)	.00**	6.03	1.89–19.21
Diameter										.00**	0.04	0.01–0.18
Length		.98	1.01	0.70–1.45								
C/I ratio						.43	0.53	0.11–2.52		.74	0.61	0.03–11.99
CL						.04**	1.19	1.01–1.41				
Prosthetic type												
C-Ti	0 (0.0%)		1		0 (0.0%)		1		1 (1.3%)		1	
C-Gold	1 (0.7%)	.94	8,004.13	0.00	12 (8.1%)	.77	8,557.21	0.00	5 (3.4%)	0.31	3.07	0.35–26.57
S-MUA	0 (0.0%)	1.00	0.81	0.00	0 (0.0%)	1.00	1.27	0.00	0 (0.0%)	0.98	0.00	0.00
S-UCLA	22 (3.9%)	.93	33,262.96	0.00	101 (17.9%)	.77	9,832.16	0.00	30 (5.3%)	0.11	5.13	0.69–37.92
Patient level	19 (4.5%)				100 (23.6%)				25 (5.9%)			
Gender												
Female	5 (2.4%)		1		36 (17.3%)		1		6 (1.4%)		1	
Male	14 (6.5%)	.04**	2.79	1.01–7.75	64 (29.6%)	.00**	1.91	1.27–2.86	19 (8.8%)	0.01**	3.17	1.27–7.95

[b]Univariate analysis presented in Appendix Table 1; **significant influence derived from multivariable Cox proportional hazard regression analysis ($P < .05$); N[a] = cumulative events during study period (15 years).

as possible and to avoid overcontoured restorations to prevent biologic and mechanical complications.

Screw-retained prostheses (S-MUA and S-UCLA) had a higher risk for screw loosening than cement-retained prostheses (C-Ti and C-Gold). This finding is consistent with Karlsson et al.[1] Abutment fractures occurred only in the prostheses fabricated with gold-cast abutments (C-Gold and S-UCLA), and the S-UCLA group was identified as the risk indicator. Gold alloys were identified to have lower ultimate tensile strengths than titanium alloys.[23,24] Considering that the maximum stress is concentrated on the implant-abutment joint area, the use of gold alloy abutments for internal-connection–type implant prostheses could increase the risk of mechanical complications.

Implant diameter was associated with the risk of implant fracture. The narrower the diameter, the higher the implant fracture risk. Molar implants and male patients were identified as risk indicators for mechanical complications, which is consistent with previous studies.[1,2] Mechanical complications have been identified to be associated with occlusal overload,[8,9] and molar implants and male patients are associated with high occlusal forces.[25–27]

In agreement with previous studies,[5–7] the present study confirmed that history of periodontitis is a risk indicator for peri-implantitis.

As the present study was conducted retrospectively, there were inherent limitations: Information that cannot be identified in patients' clinical charts could not be included, such as attached gingival and soft tissue thickness, buccolingual position or angulation of implants, occlusal forces, and parafunctional habits. Further studies considering these parameters are needed to confirm the present results. Because this study analyzed implants from a single company with a specific design, further research is needed to identify differences depending on the implant manufacturer and design.

CONCLUSIONS

Within the limitations of the study, the results revealed that splinted implants had a higher risk of biologic complications and a lower risk of mechanical complications. The implant splinted to both adjacent implants (SP-mid) had the highest risk of biologic complications. As the number of splinted implants in a prosthesis increased, the risk of mechanical complications decreased. Longer crown lengths increased the risk of both biologic and mechanical complications. Overcontoured prostheses and history of periodontitis were risk indicators for peri-implant diseases. Gold-cast abutments and narrow implants in internal-connection–type implants had higher risks of fracture. Molar implants and male patients were identified as risk indicators for mechanical complications.

ACKNOWLEDGMENTS

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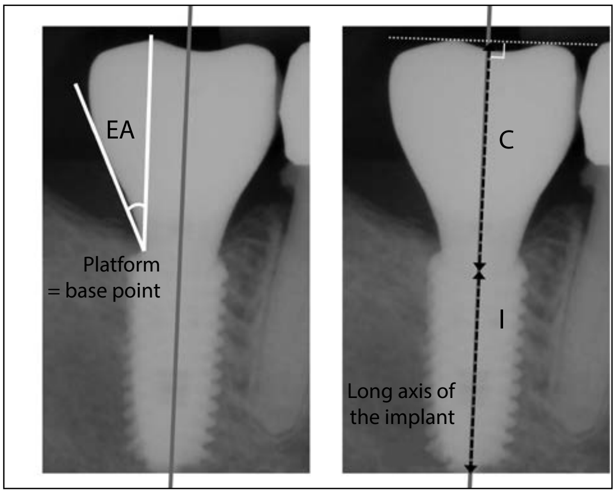
APPENDIX



Appendix Fig 1 Examples of the assessment of emergence angle (EA), emergence profile (EP), crown length (C), crown/implant (C/I) ratio. *(a)* An example of the assessment of emergence angle (EA), crown length and crown/implant (C/I) ratio; *(b)* examples of emergence profile (EP). C = length of the crown includes the entire restoration above the implant platform; I = length of the implant; gray line = long axis of the implant.

Appendix Table 1 Univariate Analysis for Each Covariate of Mechanical Complications

	Mechanical complication experience	Screw loosening	Component fracture	Screw fracture	Abutment fracture	Implant fracture
Implant level						
NS/SP	0.00*	0.00*	0.00*	0.03*	0.00*	0.24
SP position	0.00*	0.00*	0.00*	0.12*	0.00*	0.29
No. SP	0.00*	0.00*	0.00*	0.16*	0.00*	0.06*
Location	0.00*	0.00*	0.00*	0.07*	0.00*	0.05*
Diameter	0.00*	0.00*	0.00*	0.53	0.00*	0.00*
Length	0.13*	0.90	0.06*	0.00*	0.62	0.50
C/I ratio	0.00*	0.00*	0.00*	0.39	0.03*	0.07*
CL	0.01*	0.02*	0.03*	0.65	0.16*	0.03*
Prosthetic type	0.00*	0.00*	0.00*	0.02*	0.02*	0.05*
Patient level						
Sex	0.00*	0.00*	0.00*	0.00*	0.00*	0.01*
Age	0.70	0.51	0.49	0.43	0.63	0.50

*Covariate selected for multivariate analysis ($P < .20$).

Splinting or Nonsplinting Adjacent Implants? A Retrospective Study Up to 15 Years: Part II—Success and Survival Rate Analysis

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Purpose: To analyze the success and survival of splinted and nonsplinted implants. ***Materials and Methods:*** A total of 423 patients (n = implants: 888) were included in the study. The success and survival of implants for 15 years were analyzed using a multivariable Cox regression model, and the significant effect of the splinting of prostheses and other risk factors were evaluated. ***Results:*** The cumulative success rate was 34.2%: 33.2% in nonsplinted (NS) and 34.8% in splinted implants (SP). The cumulative survival rate was 92.9% (94.1%, NS; 92.3%, SP). Whether to splint was not related to the success and survival of implants. The smaller the implant diameter, the lower the survival rate. The crown length and implant length were significantly associated only with NS implants: The longer the crown length and the shorter the implant length, the greater the risk of implant failure. The emergence angle (EA) and the emergence profile (EP) had a significant effect on only the SP implants: EA3 showed a higher risk than EA1, and EP2 and EP3 had a higher risk of implant failure. ***Conclusion:*** Crown length and implant length affected only the nonsplinted implants: The higher the crown length and the shorter the implant length, the greater the risk of implant failure. A significant effect for emergence contour was found only in SP implants: the implants restored with prostheses with EA ≥ 30 degrees on both the mesial and distal sides, and convex EP on at least one side had higher risks of failure. *Int J Oral Maxillofac Implants 2023;38:443–450. doi: 10.11607/jomi.10054*

Keywords: crown length, emergence contour, implant failure, implant success, implant survival splinting

Prosthetic design influences the long-term outcome of implant-supported restorations.[1,2] One of the design elements of implant prostheses is whether to splint adjacent implants. Splinting adjacent implants could further distribute the occlusal load, providing mechanical advantages.[3–5] However, splinting could adversely affect oral hygiene, which is associated with biologic complications.[2,6] With these advantages and disadvantages, it is not clear whether adjacent implants should be splinted. Several studies comparing splinted and nonsplinted restorations have reached conflicting results. Rodrigo et al[7] and Mendonça et al[8] found advantages for splinted restorations; however, Vigolo et al[9] and Clelland et al[3] found that there was no significant difference between splinted and nonsplinted implants. Whether to splint should be determined by considering the advantages and disadvantages of each clinical situation. However, conflicting studies have been presented, making it difficult for clinicians to make decisions.

In the previous study (Part I), complications of splinted and nonsplinted implants were analyzed, and it was revealed that splinting had opposing effects on biologic and mechanical complications. A comprehensive approach is needed to provide guidance to clinicians. In this regard, the aim of the present study was to evaluate the success and survival of splinted and nonsplinted implants.

MATERIALS AND METHODS

This retrospective study was approved by the Seoul National University Dental Hospital Institutional Review Board (no. ERI20017). STROBE guidelines were followed. The data included all patients treated with internal conical connection implants (Oneplant FIT; Warantec) in the posterior area at Seoul National University Dental Hospital from March 2006 to February 2014. Patients and implants with the following criteria were excluded:

- Patients with incomplete clinical records
- Patients who had not received regular maintenance care by 2021
- Patients with a full mouth plaque score ≥ 25%

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- Patients who have systemic diseases or conditions
- Patients who smoke ≥ 1 cigarette per day
- Patients who have received treatment for peri-implantitis previously
- Patients who received jaw reconstruction after jaw resection
- Patients who received implant-assisted removable prostheses
- Implant prostheses with cantilevers or pontics
- Implant prostheses that have occlusion with removable prostheses
- Implants re-placed after failure and implants that failed early before loading

The following categories were included in this study: splinted (SP) or nonsplinted (NS); splinted position (NS, nonsplinted; SP-m, the mesial implant splinted to the distally adjacent implant; SP-mid, the middle implant splinted to both mesially and distally adjacent implants; SP-d, the distal implant splinted to the mesially adjacent implant); number of implants splinted for each prosthesis; prosthetic type (C-Ti, cement-retained prosthesis with a titanium abutment; C-Gold, cement-retained prosthesis with a gold-cast abutment; S-MUA, screw-retained prosthesis using a multiunit system; S-UCLA, gold-cast screw-retained prosthesis); location; diameter; length; emergence angle (EA); emergence profile (EP); crown-to-implant (C/I) ratio; crown length (CL); bone augmentation; immediate placement; one- or two-stage protocol; and patient descriptions (sex, age, history of periodontitis).

The radiographic measurement protocol of the EA, EP, C/I ratio, crown length, and MBL were previously reported.[2,10] The identical image processing program was used for the present study (ImageJ, National Institutes of Health). Intraoral radiographs were taken using the paralleling technique a year after prosthesis insertion and at follow-up visits. All radiographic files were anonymously numbered, and one blinded examiner performed all measurements (Y.Y.). The intrarater reliability was calculated measuring the consistency of three measurements of 30 specimens selected by simple random selection and showed a high level of reliability (Cronbach's α, Intraclass Correlation Coefficient = 0.98).

Diagnostic Criteria for Complications

The diagnosis of peri-implant disease followed the current guideline defined in the 2017 World Workshop[11]: peri-implant mucositis, defined as presence of bleeding on probing (BOP) and absence of bone loss; peri-implantitis, defined as presence of BOP and/or suppuration, increased probing depth (PD), and presence of detectable bone loss exceeding the measurement error (mean 0.5 mm).

The following mechanical complications were included: screw loosening, defined as prosthesis mobility in osseointegrated implants without screw fracture; screw or abutment fracture, defined as a fractured screw or an abutment being observed; and implant fracture, defined as radiolucency of the implant fracture line or dislocation of the fractured fragment being observed in the radiograph. The time of occurrence was calculated by measuring the time elapsed from the prosthesis delivery to the occurrence of the complication. Data were recorded at the implant and patient levels. Multiple events that occurred in an implant or in a patient were recorded once in the complication experience. Repeated events were recorded once and described separately. The time of occurrence in multiple or repeated events was measured from the date of the first event. For the estimation of cumulative hazard ratios, data were censored at the date of the last follow-up visit.[10]

Criteria for Success and Survival of Implants

The criteria for success of implants were classified into two categories: success—biologic and mechanical complication–free implants; and major success—success without major complications, implants without peri-implantitis and implant component fractures requiring reconstruction or replacement of components or prostheses. Survival was defined as the implants present in the oral cavity without loss of osseointegration or implant fracture.

Statistical Analysis

Statistical software (IBM SPSS Statistic, version 25.0, IBM) was used for analysis. Kaplan-Meier curves and the multivariable Cox regression model were used to analyze the success and survival of implants. Univariate analysis was performed for each variable to assess its association with success and survival of implants. Covariates that had $P \leq .20$ in univariate analysis were selected for multivariate analysis. The Cox proportional hazard model was conducted considering confounding factors and presented as hazard ratio (HR) and 95% confidence interval (CI).

RESULTS

The distribution of implants and patients is presented in Table 1. The mean follow-up period was 12.5 ± 1.7 years, and 424 patients with 888 implants were included in the study. During the period, the cumulative success rate was 34.2% at the implant level (33.2% in nonsplinted implants, NS; 34.8% in splinted implants, SP) and 29.0% at the patient level. The major success rate of implants without peri-implantitis and implant component

Table 1 Distribution of Implants and Patients

		N (%)
Patient level (Total of 424 patients)		
Sex	Male Female	216 (50.9%) 208 (49.1%)
Age (y)	Min–Max Mean (SD)	20–80 52.5 (11.3)
History of periodontitis	No Yes	92 (21.7%) 332 (78.3%)
Implant level (Total of 888 implants)		
Splinted or nonsplinted (NS/SP)	Nonsplinted (NS) Splinted (SP)	307 (34.6%) 581 (65.4%)
SP position	NS SP-m SP-mid SP-d	307 (34.6%) 261 (29.4%) 59 (6.6%) 261 (29.4%)
Number of implants splinted (No. SP)	Min–Max Mean (SD)	1–4 1.86 (0.77)
Location	Premolar Molar	221 (24.9%) 667 (75.1%)
Diameter (mm)	Min–Max Mean (SD)	3.6–6.3 4.48 (0.47)
Length (mm)	Min–Max Mean (SD)	7–13 10.54 (1.15)
Crown-implant (C/I) ratio	Min–Max Mean (SD)	0.45–1.77 1.00 (0.22)
Crown length (CL) (mm)	Min–Max Mean (SD)	5.17–18.86 10.45 (2.08)
Emergence angle (EA)†	EA1† EA2† EA3†	349 (39.3%) 246 (27.7%) 293 (33.3%)
Emergence profile (EP)†	EP1† EP2† EP3†	463 (49.1%) 249 (28.0%) 203 (22.9%)
Prosthetic type‡	C-Ti‡ C-Gold‡ S-MUA‡ S-UCLA‡	80 (9.0%) 147 (16.6%) 96 (10.8%) 565 (63.6%)
Bone augmentation	No Yes	468 (52.7%) 420 (47.3%)
Immediate placement	No Yes	797 (89.8%) 91 (10.2%)
1-stage or 2-stage	1-stage 2-stage	381 (42.9%) 507 (57.1%)

†EA and †EP were measured on the mesial and distal aspects, respectively, †EA1: both < 30 degrees; †EA2: one < 30 degrees, the other ≥ 30 degrees; †EA3: both ≥ 30 degrees; †EP1: both concave or straight profile; †EP2: one is concave or straight, and the other is convex profile; †EP3: both convex profile; ‡C-Ti: cement-retained prosthesis with a titanium abutment; ‡C-Gold: cement-retained prostheses with a gold-cast abutment; ‡S-MUA: screw-retained prostheses using a multi-unit system; ‡S-UCLA: gold-cast screw-retained prostheses.

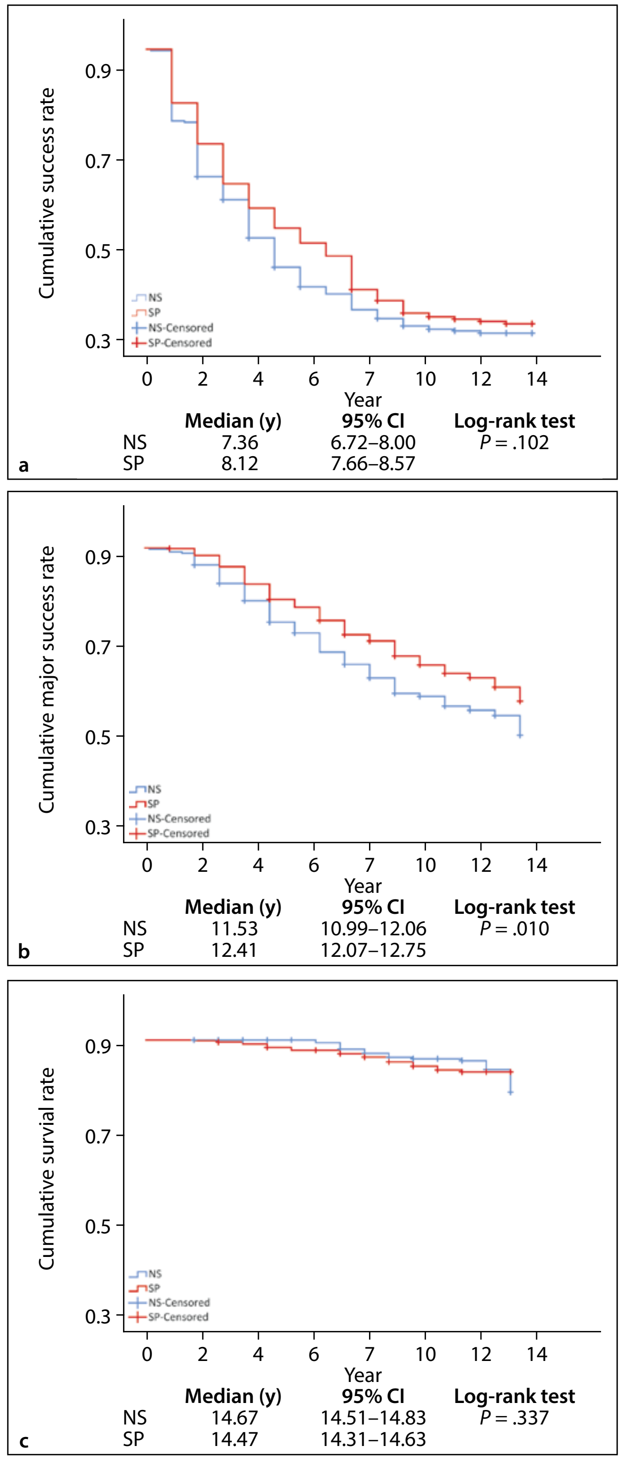

Fig 1 Kaplan-Meier plots for nonsplinted (NS) and splinted (SP) implants: *(a)* cumulative success rate; *(b)* cumulative major success rate (without peri-implantitis and implant component fracture); and *(c)* cumulative survival rate.

fracture was 65.5% at the implant level (60.9% in NS; 68.0% in SP) and 53.2% at the patient level. The cumulative survival rate was 92.9% at the implant level (94.1% in NS; 92.3% in SP) and 90.1% at the patient level. The estimated success and survival rates are presented in Appendix Tables 1, 2, and 3 (see Appendix in online version of this article at quintpub.com).

In the univariate analysis, splinted implants (SP) showed a higher cumulative major success rate than nonsplinted implants (NS); however, there was no significant difference in success and survival rates (Fig 1). In the multivariate analysis, it was revealed that whether to splint was not related to the success and survival of implants: Neither the splinted position nor the number of implants splinted had a significant effect. The

Table 2 Univariate and Multivariate Success Analysis

	Univariate analysis (*P*)		Multivariate analysis of success rate (SR)					Multivariate analysis of major success rate (MSR)			
Features	**SR§**	**MSR§**	**Features**	**N^c (%)**	**$P^{¶}$**	**HR**	**95% CI**	**N^c (%)**	**$P^{¶}$**	**HR**	**95% CI**
Implant level			**Implant level**	304 (34.2%)				582 (65.5%)			
NS/SP	.11*	.01*	**NS/SP**								
SP position	.40	.05*	NS	102 (33.2%)		1		187 (60.9%)		1	
No. SP	.01*	.00*	SP	202 (34.8%)	.81	1.04	0.76–1.43	395 (68.0%)	.48	0.85	0.54–1.34
Location	.00*	.00*	**SP position**								
Diameter	.03*	.00*	NS	102 (33.2%)				187 (60.9%)		1	
Length	.31	.42	SP-m	93 (35.6%)				176 (67.4%)	.89	1.04	0.61–1.78
C/I ratio	.00*	.05*	SP-mid	19 (32.2%)				36 (61.0%)	.39	1.52	0.58–3.96
CL	.00*	.13*	SP-d	90 (34.5%)				183 (70.1%)	.87	0.95	0.54–1.69
EA	.00*	.00*	**No. SP**		.28	0.89	0.72–1.10		.65	0.93	0.68–1.27
EP	.00*	.00*	**Location**								
Prosthetic type	.00*	.00*	Premolar	110 (49.8%)		1		171 (77.4%)		1	
Bone augmentation	.88	.68	Molar	194 (29.1%)	.01**	1.38	1.09–1.76	411 (61.6%)	.49	1.13	0.80–1.60
Immediate placement	.67	.72	**Diameter**		.13	1.16	0.96–1.40		.27	1.16	0.89–1.49
1-stage or 2-stage	.28	.32	**C/I ratio**		.22	0.64	0.31–1.31		.74	0.84	0.31–2.32
Patient level			**CL**		.00**	1.14	1.06–1.23		.00**	1.09	1.03–1.16
Sex	.00*	.01*	**EA**	161 (46.0%)		1		278 (79.4%)		1	
Age	.42	.38	EA1								
History of periodontitis	.05*	.01*	EA2	68 (27.6%)	.06	1.27	0.99–1.71	157 (63.8%)	.09	1.38	0.96–2.01
			EA3	75 (25.7%)	.58	1.08	0.82–1.44	147 (50.3%)	.02**	1.62	1.08–2.44
			EP								
			EP1	210 (48.1%)		1		350 (80.1%)		1	
			EP2	68 (27.3%)	.00**	1.36	1.09–1.71	153 (61.4%)	.00**	1.75	1.25–2.44
			EP3	26 (12.9%)	.00**	2.14	1.66–2.76	79 (39.1%)	.00**	3.02	2.11–4.33
			Prosthetic type								
			C-Ti	47 (58.8%)		1		68 (85.0%)		1	
			C-Gold	52 (35.1%)	.00**	2.07	1.39–3.08	87 (58.8%)	.00**	3.48	1.86–6.50
			S-MUA	37 (38.9%)	.00**	2.67	1.53–3.66	80 (84.2%)	.19	1.69	0.78–3.67
			S-UCLA	168 (29.7%)	.00**	2.30	1.61–3.30	347 (61.4%)	.00**	2.81	1.56–5.56
			Patient level	123 (29.0%)				126 (53.2%)			
			Sex								
			Female	79 (38.0%)		1		123 (59.1%)		1	
			Male	44 (20.4%)	.00**	1.72	1.36–2.16	103 (47.4%)	.01**	1.47	1.10–1.94
			History of periodontitis								
			No	34 (37.0%)		1		61 (66.3%)		1	
			Yes	89 (26.8%)	.09	1.29	0.96–1.71	165 (49.5%)	.02**	1.61	1.01–2.37

§*P* value calculated from univariate analysis of each covariate; *covariate selected for multivariate analysis ($P < .20$); ¶*P* value calculated from multivariable analysis; **significant influence derived from Cox proportional hazard regression analysis ($P < .05$); N^c: cumulative number of failures over the study period (15 years).

crown length (CL) had a significant effect on the success (HR 1.14; 95% CI [1.06–1.23]), the major success (HR 1.09; 95% CI [1.03–1.16]), and the survival (HR 1.87; 95% CI [1.04–1.35]) of implants. The implants restored with prostheses with EA ≥ 30 degrees on both the mesial and distal sides (EA3) and convex EP at least on one side (EP2, EP3) had higher risks of failure to succeed or survive (Tables 2 and 3). The implants with prostheses fabricated with gold-cast abutments (C-Gold; S-UCLA) had lower success and survival rates than the implants with

Table 3 Univariate and Multivariate Survival Analysis

	Univariate analysis		Multivariate analysis			
Features	$P^{\S}$	**Features**	N^{c} (%)	$P^{¶}$	HR	95% CI
Implant level		**Implant level**	825 (92.9%)			
NS/SP	.19*	**NS/SP**				
SP position	.10*	NS	289 (94.1%)		1	
No. SP	.88	SP	536 (92.3%)	.21	1.45	0.81–2.60
Location	.01*	**SP position**				
Diameter	.13*	NS	289 (94.1%)		1	
Length	.46	SP-m	235 (90.0%)	.05	2.62	0.98–6.93
C/I ratio	.05*	SP-mid	57 (96.6%)	.10	1.69	0.9–3.18
CL	.11*	SP-d	244 (93.5%)	.35	0.49	0.11–2.17
EA	.00*	**No. SP**				
EP	.00*	**Location**				
Prosthetic type	.01*	Premolar	215 (97.3%)		1	
Bone augmentation	.46	Molar	610 (91.5%)	.07	2.32	0.94–5.71
Immediate placement	.21	**Diameter**		.03**	0.44	0.21–0.92
1-stage or 2-stage	.38	**C/I ratio**		.57	1.87	0.20–17.17
Patient level		**CL**		.01**	1.18	1.04–1.35
Sex	.06*	**EA**				
Age	.95	EA1	339 (96.9%)		1	
History of periodontitis	.03*	EA2	230 (93.5%)	.31	1.61	0.65–3.98
		EA3	256 (87.7%)	.04**	2.58	1.00–6.65
		EP				
		EP1	422 (96.6%)		1	
		EP2	232 (93.2%)	.73	1.15	0.53–2.49
		EP3	171 (84.7%)	.04**	1.85	1.02–4.29
		Prosthetic type				
		C-Ti	79 (98.8%)		1	
		C-Gold	136 (91.9%)	.06	8.34	0.96–65.38
		S-MUA	95 (100.0%)	.97	0.00	0.00
		S-UCLA	515 (91.2%)	.06	8.68	0.87–69.16
		Patient level	382 (90.1%)			
		Sex				
		Female	193 (92.8%)		1	
		Male	189 (87.5%)	.11	1.69	0.90–3.18
		History of periodontitis				
		No	89 (96.7%)		1	
		Yes	293 (88.3%)	.04**	3.36	1.03–10.81

$^{\S}P$ value calculated from univariate analysis of each covariate; *covariate selected for multivariate analysis (P <.20); $^{¶}P$ value calculated from multivariable analysis; **significant influence derived from Cox proportional hazard regression analysis (P < .05); N^{c}: cumulative number of failures over the study period (15 years).

cement-retained prostheses using titanium abutments (C-Ti). The narrower the implant diameter, the lower the survival rate (HR 0.44; 95% CI [0.21–0.92]). Male patients had lower success and major success rates than female patients; however, there was no significant difference in the survival rate. Patients with a history of periodontitis had a higher risk of failing major success (HR 1.61; 95% CI [1.01–2.37]) and survival (HR 3.36; 95% CI [1.03–10.81]).

In the survival analysis for the NS and SP, respectively, the diameter of the implant was associated with

Table 4 Survival Analysis for Nonsplinted (NS) and Splinted (SP) Implants, Respectively

	Univariate analysis		Multivariate analysis		
Features	$P^§$	Features	$P^¶$	HR	95% CI
NS		**Location**			
Location	.16*	Premolar		1	
Diameter	.06*	Molar	.77	1.27	0.26–6.18
Length	.02*	**Diameter**	.02**	0.04	0.02–0.17
C/I ratio	.04*	**Length**	.03**	0.80	0.68–0.94
CL	.01*	**C/I ratio**	.07	1.46	0.97–2.21
EA	.22	**CL**	.01**	2.11	1.39–3.21
EP	.08*	**EP**			
Prosthetic type	.39	EP1		1	
Bone augmentation	.64	EP2	.16	2.55	0.69–9.42
Immediate placement	.31	EP3	.07	3.23	0.91–11.40
1-stage or 2-stage	.38	**SP position**			
SP		SP-m	.15	1	
SP position	.13*	SP-mid	.17	0.29	0.05–1.66
No. SP	.02*	SP-d	.09	0.57	0.30–1.09
Location	.01*	**No. SP**	.98	1.01	0.38–2.72
Diameter	.15*	**Location**			
Length	.56	Premolar		1	
C/I ratio	.46	Molar	.46	1.86	0.66–9.46
CL	.29	**Diameter**	.02**	0.22	0.06–0.76
EA	.00*	EA			
EP	.00*	EA1		1	
Prosthetic type	.00*	EA2	.69	1.26	0.41–3.88
Bone augmentation	.23	EA3	.04**	2.34	1.77–7.18
Immediate placement	.48	**EP**			
1-stage or 2-stage	.24	EP1		1	
		EP2	.96	0.98	0.38–2.53
		EP3	.01**	2.06	1.76–6.04
		Prosthetic type			
		C-Ti		1	
		C-Gold	.89	2.53×10^4	0.00
		MUA	.99	1.17	0.00
		UCLA	.89	4.19×10^4	0.00

§*P* value calculated from univariate analysis of each covariate; *covariate selected for multivariate analysis ($P < .20$); ¶*P* value calculated from multivariable analysis; **significant influence derived from Cox proportional hazard regression analysis ($P < .05$).

the survival rate of both NS and SP implants. The crown length (CL) and implant length were significantly associated with only NS implants: The longer the crown length (HR 2.21; 95% CI [1.39–3.21]) and the shorter the implant length (HR 0.80, 95% CI [0.68–0.94]), the greater the risk of implant failure. EA and EP had a significant effect only on the SP implants: EA3 showed a higher risk than EA1 (HR 2.34; 95% CI [1.77–7.18]), and EP2 and EP3 had a higher risk of implant failure (Table 4).

DISCUSSION

In the previous study (Part I), the long-term outcomes of implants depending on splinting and other associated features up to 15 years were evaluated by analyzing biologic and mechanical complications.[12] Splinted implants (SP) had a higher risk of biologic complications, and as the number of splinted implants in a prosthesis increased, the risk of mechanical complications decreased. In the present study, splinted and nonsplinted implants were evaluated with comprehensive analysis for the success and survival of implants. There was no significant difference between splinted and nonsplinted implants regarding success and survival rates. This is in line with Vigolo et al[9] and Clelland et al.[3] However, it is not consistent with the results of Rodrigo et al[7] and Mendonça et al,[8] who reported higher survival rates for splinted implants than for nonsplinted implants. Because these studies were limited to short implants, they are different from the present study, which included implants of various lengths.

A fragmentary understanding of the current success and survival analysis cannot provide guidelines for clinicians about whether to splint adjacent implants; comprehensively, it should be considered with other associating factors. Crown length was found to be correlated with the success and survival of implants. The longer the crown length, the greater the risk of implant failure. This is in line with the previous study (Part I), which revealed that the longer the crown length, the higher the risk for both biologic and mechanical complications.[12] However, in the survival analysis for NS and SP, respectively (Table 4), crown length affected only NS implants, not SP implants. Implant length was also significantly related to NS implants only. This suggests that nonsplinted short implants have a risk of failure, whereas splinted short implants have a comparable prognosis to longer implants. This is consistent with the findings of Rodrigo et al[7] and Mendonça et al.[8] A decreased survival rate for implants in association with shorter implants has been reported,[13–15] but the new finding in the present study was that the association between implant length and survival rate was greater in nonsplinted implants.

The implants restored with prostheses with EA ≥ 30 degrees on both the mesial and distal sides (EA3) and convex EP on at least one side (EP2, EP3) had higher risks of failure to succeed and survive. However, a significant effect for emergence contour was found only in SP implants, not in NS implants (Table 4). Overcontoured prostheses were identified as a risk indicator for peri-implant disease.[1,2] Considering that the emergence contour has a greater influence in splinted restorations than in nonsplinted single restorations, a reliable slim contour design is required for fabricating splinted implant restorations.

Implant diameter was found to be associated with success and survival of implants. The smaller the implant diameter, the higher the failure rate, which was the case for both NS and SP implants. Low survival rates associated with narrow implants have been reported in several studies,[15,16] and the present study confirmed these results.

Considering the results of the present research, it could be suggested that with a longer implant crown or with a shorter-length implant, more favorable outcomes can be achieved by splinted restorations. Because splinted implants are highly associated with emergence contour in biologic complications and failures, careful prosthetic design without overcontour is required.

As the present study was conducted retrospectively, there were inherent limitations: Information that cannot be identified in patients' clinical charts could not be included, such as attached gingival and soft tissue thickness, buccolingual position or angulation of implants, occlusal forces, and parafunctional habits. Further studies considering these parameters are needed to confirm the present results. Because this study analyzed implants from a single company with a specific design, further research is needed to identify differences depending on the implant manufacturer and design.

CONCLUSIONS

Within the limitations of the retrospective study design, this study revealed that crown length and implant length affected only the nonsplinted implants: The longer the crown length and the shorter the implant length, the greater the risk of implant failure. A significant effect for emergence contour was found only in SP implants; implants restored with prostheses with EA ≥ 30 degrees on both the mesial and distal sides and convex EP on at least one side had higher risks of failure.

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APPENDIX

Appendix Table 1 Success and Survival of Implants According to Follow-up Years

Follow-up Year		≤ 2	2 to 5	5 to 8	8 to 11	11 to 15
Success						
NS	No. implants	94	160	190	203	205
	Estimated%	69.4%	47.6%	37.3%	32.7%	31.7%
SP	No. implants	132	250	336	373	379
	Estimated%	77.3%	57.0%	42.2%	35.1%	33.9%
NS + SP	No. implants	226	410	526	576	584
	Estimated%	74.5%	53.7%	40.5%	34.6%	33.1%
Major success						
NS	No. implants	13	56	87	110	120
	Estimated%	95.8%	81.6%	71.2%	63.3%	53.6%
SP	No. implants	11	74	124	166	186
	Estimated%	98.1%	87.2%	78.5%	71.0%	62.1%
NS + SP	No. implants	24	130	211	276	306
	Estimated%	97.3%	85.3%	76.0%	68.4%	59.0%
Survival						
NS	No. implants	0	0	7	14	18
	Estimated%	100.0%	100.0%	97.7%	95.2%	86.7%
SP	No. implants	1	11	20	38	45
	Estimated%	99.8%	98.1%	96.5%	93.3%	91.9%
NS+SP	No. implants	1	11	27	52	63
	Estimated%	99.9%	98.8%	96.9%	94.0%	89.7%

No. implants: cumulative number of failures; estimated%: estimated proportion of success or survival.

Appendix Table 2 Life Table Analysis of Success and Major Success of Implants

	Success analysis							Major success analysis					
	NS			SP				NS			SP		
Follow-up (y)	Cumulative events (N)	Cumulative survival (Proportion)	Cumulative survival (Std err)	Cumulative events (N)	Cumulative survival (Proportion)	Cumulative survival (Std err)	Follow-up (y)	Cumulative events (N)	Cumulative survival (Proportion)	Cumulative survival (Std err)	Cumulative events (N)	Cumulative survival (Proportion)	Cumulative survival (Std err)
1	53	0.827	0.022	75	0.871	0.014	1	3	0.990	0.006	1	0.998	0.002
2	94	0.694	0.026	132	0.773	0.017	2	13	0.958	0.011	11	0.981	0.006
3	111	0.638	0.027	188	0.676	0.019	3	27	0.912	0.016	27	0.953	0.009
4	139	0.546	0.028	222	0.618	0.020	4	40	0.869	0.019	52	0.910	0.012
5	160	0.476	0.029	250	0.570	0.021	5	56	0.816	0.022	74	0.872	0.014
6	174	0.428	0.028	271	0.534	0.021	6	64	0.790	0.023	85	0.853	0.015
7	179	0.411	0.028	289	0.503	0.021	7	78	0.742	0.025	104	0.820	0.016
8	190	0.373	0.028	336	0.422	0.020	8	87	0.712	0.026	124	0.785	0.017
9	196	0.352	0.028	351	0.395	0.020	9	97	0.678	0.027	133	0.769	0.018
10	201	0.334	0.027	368	0.365	0.020	10	108	0.640	0.028	154	0.732	0.018
11	203	0.327	0.027	373	0.356	0.020	11	110	0.633	0.028	166	0.710	0.019
12	204	0.322	0.027	376	0.351	0.020	12	116	0.609	0.029	177	0.689	0.019
13	205	0.317	0.027	378	0.345	0.020	13	118	0.598	0.029	181	0.679	0.020
14	205	0.317	0.027	379	0.339	0.020	14	119	0.585	0.031	185	0.655	0.022
15	205	0.317	0.027	379	0.339	0.020	15	120	0.536	0.055	186	0.621	0.040
	Estimated success time		Std err	Lower 95% CI	Upper 95% CI			Estimated major success time		Std err	Lower 95% CI	Upper 95% CI	
NS	7.36		0.328	6.717	8.003		NS	11.527		0.270	10.998	12.057	
SP	8.118		0.232	7.664	8.572		SP	12.409		0.173	12.071	12.748	
Total	7.854		0.19	7.483	8.226		Total	12.106		0.147	11.817	12.394	

Appendix Table 3 Life Table Analysis of Survival of Implants

	NS			SP		
Follow-up (y)	Cumulative events (N)	Cumulative survival (Proportion)	Cumulative survival (Std err)	Cumulative events (N)	Cumulative survival (Proportion)	Cumulative survival (Std err)
1	0	1		0	1	
2	0	1		1	0.998	0.002
3	0	1		3	0.995	0.003
4	0	1		6	0.990	0.004
5	0	1		11	0.981	0.006
6	0	1		15	0.974	0.007
7	2	0.993	0.005	15	0.974	0.007
8	7	0.977	0.009	20	0.965	0.008
9	10	0.966	0.010	25	0.957	0.008
10	13	0.956	0.012	32	0.944	0.010
11	14	0.952	0.012	38	0.933	0.010
12	14	0.952	0.012	43	0.924	0.011
13	15	0.947	0.013	45	0.919	0.012
14	17	0.925	0.020	45	0.919	0.012
15	18	0.867	0.059	45	0.919	0.012
	Estimated survival time		Std err	Lower 95% CI	Upper 95% CI	
NS	14.670		0.083	14.507	14.832	
SP	14.473		0.082	14.312	14.634	
Total	14.540		0.061	14.419	14.660	

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