

Original Article

Clinical evaluations of implant-assisted removable partial dentures with implant surveyed crowns: A retrospective study

Tzu-Ching Yang, DDS^a

Yu-Chen Lo, DDS^a

Pi-Lun Chen, DDS^b

^aDivision of Prosthodontics, Department of Dentistry, Taipei Chang Gung Memorial Hospital, Taipei, 105, Taiwan

^bDentway International Stomatological Hospital, Taipei, 114, Taiwan Running title: Implant surveyed crowns with IARPDs

*Corresponding author:

Tai-Min Lin, Yu-Hwa Pan

Division of Prosthodontics, Department of Dentistry, Taipei Chang Gung Memorial Hospital, 6F., No. 199, Dunhua N. Rd., Songshan Dist., Taipei City 105406, Taiwan
Tel : +886-2-27135211 ext. 3247

Fax: +886-2-25147247

Email: alan8302018@gmail.com

shalom.dc@msa.hinet.net

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Abstract

Purpose: The aim of this retrospective study was conducted to analyze the implants success rate and complication rate of implant surveyed crown type of implant-assisted removable partial dentures(IARPD) with regard to different clinical factors.

Materials and methods: Patients with IARPDs categorized as surveyed crown type and under routine follow-up visits were included. Patients using attachment or healing cap types of IARPDs and not under routine follow-up visits were otherwise excluded. Overall, 16 patients, 17 dentures, 56 implants, and 35 natural teeth were examined. Implant success rates and complication rates of the subjects (dentures, implants, and natural teeth) were analyzed by multiple different factors, which were gender, age, treated arch, post-treatment Kennedy classification, implant locations, implant diameters and lengths, and crown materials. Kaplan-Meier and Cox regression model were used to analyze the success rates. Chi-square tests were used to analyze the complication rates. A p-value less than 0.05 is considered to be statistically significant.

Results: The mean follow-up period was 59.3 month. Overall success rate of implants was 91.1%. All subgroups showed no significant differences. 38 incidents of complication were recorded. Denture base sore spot was the most common complication (21.1%). Peri-implant mucositis was the most common complication in implant-related complication (10.5%/1 patients). Despite the complications, all the IARPDs were still functioning at the end of observation.

Conclusion: A 91.1% implant success rate was recorded. Different clinical factors did not have significant effects on implant success rates, but were significantly different in success rates of IARPDs and natural teeth, as well as complication rates of IARPDs and implants.

Key words: implant surveyed crown, removable partial denture, implant success rate

Introduction

For patients with partial or complete edentulism, conventional removable dentures are considered the treatment of choice, especially for those with a limited budget.¹ However, removable dentures have several disadvantages, including a high risk of caries¹ and residual ridge resorption. According to Kordatzis et al.,² the estimated average reduction in posterior mandibular ridge height for implant overdentures is almost 1 mm less than that for conventional dentures, and bone levels adjacent to implants can be more favored. In addition, patients wearing Kennedy Class I or II removable partial dentures often complain of lack of stability, limited retention, and discomfort under loading.³ Implant-assisted removable partial dentures (IARPDs), with the help of a limited number of strategically placed dental implants,⁴ may improve the situation by enhancing support, retention, and stability.^{3, 5-8}

IARPDs can be categorized based on implant prostheses into three types: healing cap, attachment, and surveyed crown.⁹ The attachment type of IARPD has been widely used and studied and has an implant survival rate ranging from 91.7% to 100%.¹⁰ According to Putra Wigianto et al.,¹¹ ball attachment is the most widely used. Previous studies have reported heterogeneous complications with ball attachments,¹²⁻¹⁴ with replacement of plastic retentive components being the most frequently mentioned.¹⁴ The surveyed crown type of IARPD was first described by Jang et al. in 1998,¹⁵ who reported a single implant in the mandibular canine area supporting a surveyed crown with a removable partial denture. This implant was successful as it survived for 14 months with no bone loss. Other studies have also shown favorable results, with implant survival rates of 95.1%–100% and marginal bone losses of 0.77–1.2 mm.^{9, 16-19} Complications of the surveyed crown type of IARPD include clasp loosening,^{17, 18, 20} residual ridge resorption requiring resin base relining,¹⁹ and dislodgement of the surveyed crowns.¹⁶

Implant prostheses are important clinical options in daily practice. For patients who can afford only a limited number of implants due to financial or clinical concerns, the surveyed crown type of IARPD is an alternative. Therefore, the aim of this retrospective study was to analyze the implant success rate and complication rate of surveyed crown type of IARPD in relation to different clinical factors. The null hypotheses were

that different clinical factors would not result in significant differences in implant success rate and complication rate.

Materials and methods

Research Subjects

This retrospective study was approved by the Chang Gung Medical Foundation Institutional Review Board (No.202400340B0). The study included patients with partially or totally edentulous ridges who received removable partial dentures with implant-surveyed crowns since 2007 in the department of prosthodontics in Taipei Chung Gung Memorial Hospital. The inclusion criteria were as follows: patients without systemic diseases or personal habits that would affect implant osseointegration; patients with IARPDs categorized as surveyed crown type; and patients who were under follow-up for at least one year and accepted routine denture and implant check-up. The exclusion criteria were as follows: patients with IARPDs categorized as attachment or healing cap type; patients with IARPDs delivered less than a year or not under routine follow-up; and patients with inadequate ridge conditions that contraindicated implant treatment.

Sixteen patients (8 males and 8 females), with a total of 56 implants, were included in the study. Each patient's gender, age, denture experience, treated arch, and follow-up period were recorded. Figure 1 shows a representative case of implant surveyed crown–assisted removable partial denture in this study.

Success rate analysis

The main outcomes of the study were success rates. Implant success, as the optimum condition, was defined according to the ICOI Pisa Implant Quality of Health Scale: no pain or tenderness upon function; 0 mobility; <2 mm radiographic bone loss from initial surgery; and no history of exudates. Implant survival refers to implants being still functional but not in ideal condition. A failed implant is one that should be or has already been removed.²¹

The diagnosis of implant diseases was based on the guideline defined in the 2017 Workshop : peri-implant mucositis, defined as the presence of bleeding and/or suppuration on gentle probing, with or without increased probing depth compared to previous examinations, and the absence of bone

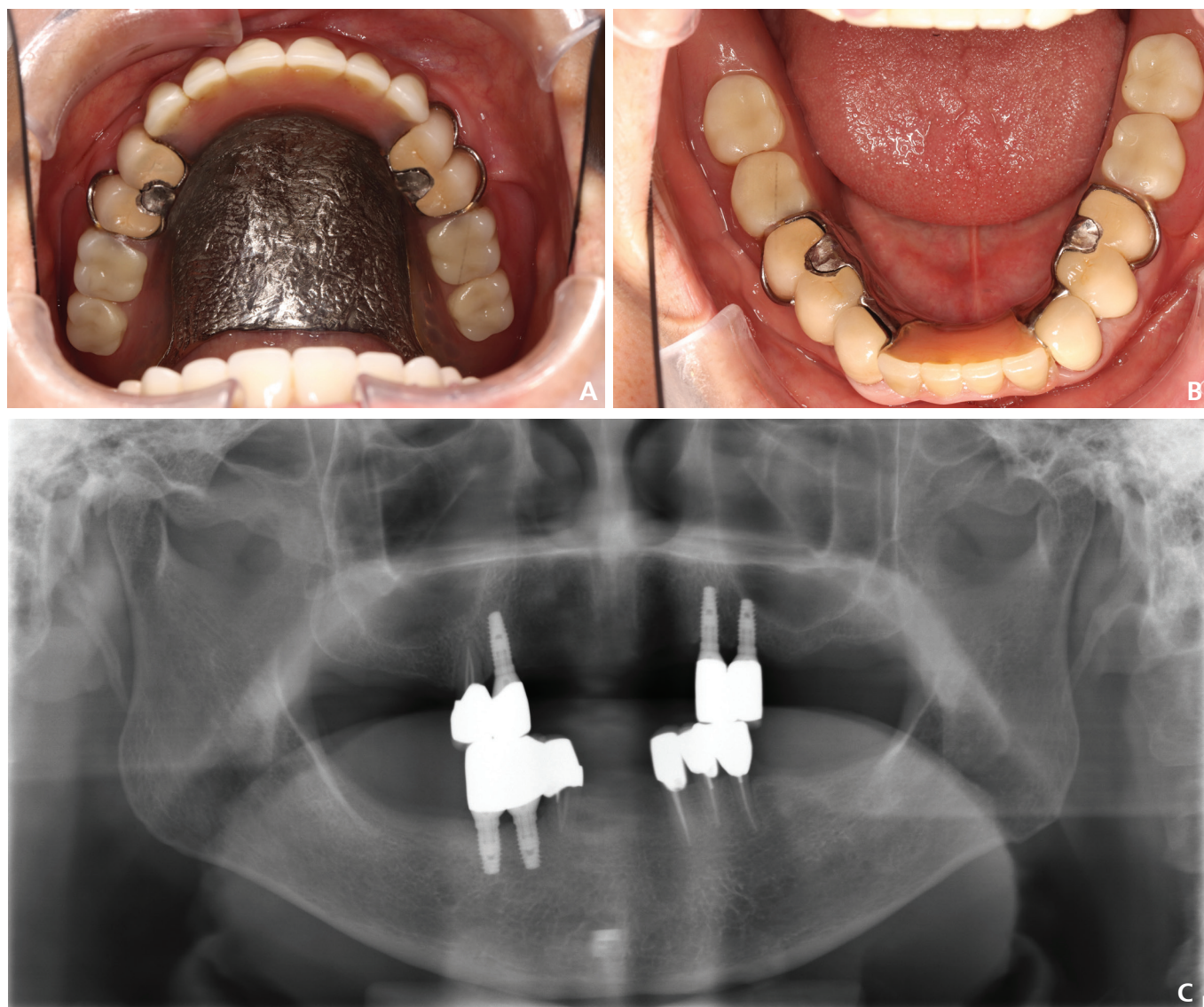


Figure 1. A representative case of implant surveyed crown type of IARPD in the study.
 (A) Maxillary arch treated with #15 nature teeth and #14,24,25 implant surveyed crowns.
 (B) Mandibular arch treated with #33,34,35,43 nature teeth and #44,45 implant surveyed crowns. Implant assisted removable partial dentures were used in both arches.
 (C) Panoramic film of the patient.

loss beyond crestal bone level changes resulting from initial bone remodeling; and peri-implantitis, defined as the presence of bleeding on probing and/or suppuration, increased probing depth, and the presence of detectable bone loss exceeding the measurement error (a mean of 0.5 mm).²²

The success of IARPDs and natural teeth abutments was also evaluated. Successful IARPDs and natural teeth were defined as those with no complications, whereas surviving IARPDs and natural teeth were defined as those having complications but were still functional at the last follow-up appointment.

Modifying factors

The success rates and complication rates of

implants, IARPDs, and natural teeth were calculated and analyzed in relation to multiple factors, including gender, age, treated arch, opposing arch, post-treatment Kennedy classification, implant location, implant diameter and length, and crown material.

Complications

Complications were recorded and divided into four subgroups as follows:^{9, 16-20, 23}

denture-related complications, including fracture of artificial teeth, clasps, rests, or denture base and clasp loosening; implant-related complications, including peri-implant mucositis, peri-implantitis, retention loss, porcelain fracture, and implant loss; complications involving natural

teeth abutments, including pulp or apical involvement indicating endodontic treatment, caries, tooth fracture, periodontitis, and tooth loss; and complications involving soft tissue, such as sore spots under denture base bearing areas.

The time to occurrence of complication was calculated in months as the time from the delivery of prostheses to the occurrence of incident. Multiple complications classified in different subgroups of the same prostheses were calculated separately, whereas repeated complications of the same prostheses were measured once at the time of the first event.²³

Statistical analysis

All data were analyzed using SPSS statistical software (IBM SPSS Statistic, v29.0.1.0; IBM Corp., New York, US). Chi-square tests were performed to analyze complications of the different subgroups—IARPDs, implants, and natural teeth. Fisher's exact test was used when more than 20% of the expected count was less than 5 or the minimum expected count was less than 1. The Kaplan–Meier method and Cox regression were used to analyze the success rates. The time interval in Kaplan–Meier and Cox regression were defined as months from the delivery of prostheses to the first occurrence of complication or the end of observation. Mean estimated months to occurrence of complication were calculated and analyzed using the logrank (Mantel–Cox) test. Cox regression results are presented as hazard ratios and 95% confidence intervals (CIs). A p -value less than 0.05 was considered statistically significant, and G*Power statistical software (Erdfelder, Faul, & Buchner, 1996) was then used to determine the post-hoc statistical power.

Results

A total of 56 implants in 16 patients (8 males and 8 females) with a mean age of 73.25 (ranged 53–93) years were examined. One patient had both arches treated with implant surveyed crown type of IARPD; therefore, 17 arches were included. The mean follow-up period was 59.3 months. Patient and implant data are presented in Table 1. Kennedy Class I was the most common classification before and after treatment (52.9%). Fifty-six implants and 35 natural teeth were used as abutments for the 17 dentures. Of the 56 implants, 36 (64.3%)

were in the maxilla and 20 (35.7%) were in the mandible. Implants were mostly located in the premolar region (58.9%). The majority of the implant prostheses were made of porcelain-fused-to-metal material (89.3%). Of the 35 natural teeth, 16 (45.7%) were in the maxilla and 19 (54.3%) were in the mandible. The remaining natural teeth were mostly premolars (51.4%). The distribution of each subgroup is presented in Table 2.

Success rate analysis

The overall success rate of IARPDs was 47.1%, with nine arches experiencing complications. The results of the Kaplan–Meier and Cox regression analyses of the IARPDs are shown in Table 3. No significant difference was found in post-treatment Kennedy classification, opposing arch, and implant prostheses positions groups. The mean estimated time to complication occurrence was significantly different for treated arches ($p = .008$; G*Power = 83.5%), and mandibular IARPDs had a significantly higher risk of complications (hazard ratio [HR] = 5.999; $p = .029$).

The overall success rate of implants was 91.1%, with four implants having peri-implant mucositis and one having peri-implantitis. Table 4 provides specific information about these five implants. The subgroups did not show significant differences (Table 5). The overall success rate of natural teeth was 74.3%, with nine natural teeth experiencing complications. One premolar was extracted and the other eight teeth were still functioning at the end of observation. Mean estimated time to complication occurrence was significantly different for the opposing arch group ($p = .006$; G*Power = 31.22%). Natural teeth opposing the complete denture or overdenture had a significantly higher risk of complication (HR = 10.285; $p = .034$; Table 6).

Complications

During the observation period, 38 complication incidents were recorded. Sore spot under the denture base was the most common complication (21.1%). Table 7 shows a list of complications, including their incidences, average time to occurrence, and related treatments. Among denture-related complications, fracture of artificial teeth was the most common (7.9% /3 patients). No rest fracture was observed. Peri-implant mucositis was the most common implant-related complication (10.5%/1 patient). One implant

Table 1. Data of patients and implants

				Kennedy classification			RPD implant abutments		RPD natural teeth abutments		Follow-up period (month)
Participant	Gender	Age (y/o)	Treated arch	Pre-treatment	Post-treatment	Opposing dentition	Number	location	Number	location	
1	F	61	Mx	II	IV	Natural dentition and implant FPD	5	#13, 15, 17, 25, 26	2	#27, 28	61
2	M	73	Mx	Edentulous	IV	Natural dentition and implant FPD	6	#13, 15, 17, 24, 25, 26	0	0	40
3	M	53	Mx	II mod. 1	IV	Natural dentition and implant FPD	5	#13, 15, 16, 26, 27	3	#17, 24, 25	158
4	F	72	Mn	I	I mod. 1	CD	2	#34, 35	3	#43, 44, 45	104
5	M	84	Mx	I mod. 1	II mod. 1	Natural dentition and FPD	2	#15, 16	7	#11-14, 21, 23, 24	118
6	F	68	Mn	I	I mod. 1	CD	3	#43, 44, 46	3	#33, 34, 35	37
7	M	62	Mx	Edentulous	IV	Natural dentition	4	#15, 16, 24, 26	0	0	15
8	F	77	Mn	Edentulous	I mod. 1	Overdenture	2	#34, 43	0	0	36
9	F	77	Mn	I mod. 1	I mod. 1	CD	1	#34	4	#33, 43, 44, 45	19
10	F	75	Mn	I	I mod. 1	Overdenture	2	#33, 44	0	#34	40
11	F	67	Mx	I	I mod. 1	IARPD	3	#14, 24, 25	1	#15	60
11	F	67	Mn	I mod. 1	I mod. 1	IARPD	2	#44, 45	4	#33, 34, 35, 43	60
12	F	93	Mn	I	I mod. 1	CD	2	#34, 35	2	#44, 45	60
13	M	85	Mx	II mod. 1	IV	Natural dentition and implant FPD	3	#25, 26, 27	3	#14, 15, 17	27
14	M	66	Mx	Edentulous	IV	Implant FPD	4	#14, 15, 23, 25	0	0	27
15	M	74	Mx	Edentulous	I mod. 1	Implant overdenture	4	#14, 15, 22, 24	0	0	98
16	M	85	Mn	I mod. 1	IV	Natural dentition and implant FPD	4 2	#34, 35, 44, 46 45 47	2	#33, 43	77 (IARPD) 15(#44-x-46) 49(#45-x-47)

Table 2. Distribution of patients, IARPDs, implants and natural teeth

Patients		IARPDs		Implants		Natural teeth	
Overall	16 patients	Overall	17 arches	Overall	56 implants	Overall	35 natural teeth
Gender		Treated arch		Treated arch		Treated arch	
Male	8 (50%)	Maxilla	9 (52.9%)	Maxilla	36 (64.3%)	Maxilla	16 (45.7%)
Female	8 (50%)	Mandible	8 (47.1%)	Mandible	20 (35.7%)	Mandible	19 (54.3%)
Age (y/o)	Mean: 73.25	Pre-treatment Kennedy		Implant location		Natural teeth location	
<65	3 (18.75%)	Edentulous	5 (29.4%)	Anterior	8 (14.3%)	Anterior	13 (37.1%)
>65	13 (81.25%)	I	9 (52.9%)	Premolar	33 (58.9%)	Premolar	18 (51.4%)
		II	3 (17.6%)	Molar	15 (26.8%)	Molar	4 (11.4%)
Denture experience		Opposing arch		Implant diameter		Opposing arch	
Yes	13 (81.25%)	Natural dentition/FPDs	8 (47.1%)	3.25mm	14 (25%)	Natural teeth/FPDs	17 (48.6%)
No	3 (18.75%)	CD/Overdenture	6 (35.3%)	4mm	33 (58.9%)	CD/overdenture	13 (37.1%)
		IARPD	3 (17.6%)	5mm	9 (16.1%)	IARPD	5 (14.3%)
Treated arch		Number of abutments		Implant length		Post-treatment Kennedy	
Maxilla	8 (50%)	Natural teeth	35	6.5mm	2 (3.6%)	I	18 (51.4%)
Mandible	7 (43.75%)	Implants	56	8.5mm	8 (14.3%)	II	7 (20%)
Both	1 (6.25%)			10mm	21 (37.5%)	IV	10 (28.6%)
				11.5mm	25 (44.6%)		
Follow-up period (month)	Mean: 59.3	Post-treatment Kennedy		Post-treatment Kennedy			
12~60	10 (62.5%)	I	9 (52.9%)	I	21 (37.5%)		
60~120	5 (31.25%)	II	1 (5.9%)	II	2 (3.6%)		
>120	1 (6.25%)	IV	7 (41.1%)	IV	33 (58.9%)		
				Material			
				PFM	50 (89.3%)		
				Full zirconia	6 (10.7%)		

Table 3. Success analysis of IARPDs

	Number of IARPDs	Number of IARPDs with complications	Success rate	Kaplan-Meier		Cox regression		
				Mean estimated time of complication occurrence (month)	p-value (log-rank test)	95% CI	Hazard Ratio	p-value
Overall included	17	9	47.1%					
Treated arch								
Maxilla	9	2	77.8%	124	.008*		1	
Mandible	8	7	12.5%	13		1.196-30.099	5.999	.029*
Post-treatment Kennedy								
I	9	6	33.3%	36.2	.105		1	
II	1	1	0	1		.309-25.944	2.829	.358
IV	7	2	71.4%	116.3		.066-1.658	.331	.179
Opposing arch								
Natural dentition/FPDs	8	3	62.5%	101.9	.167		1	
CD/overdenture	6	5	16.7%	14.7		.697-12.626	2.966	.141
IARPD	3	1	66.7%	65.7		.088-8.291	.855	.892

*: p value less than 0.05, statistically significant

Table 4. The specific information of the implants with peri-implant mucositis or peri-implantitis

Patient	A	B
Gender/Age (y/o)	M/74	M/85
Complication/time of occurrence (month)	Peri-implant mucositis/74	Peri-implantitis/15
Location	#14, 15, 22, 24	#46
Post-treatment Kennedy	Class I mod. 1	Class IV
Implant diameter/length(mm)	14 (4x10); 15 (4x10); 22 (3.25x11.5); 24(4x11.5)	4x8.5
Opposing dentition	#34, 44 implant with ERA overdenture	Natural teeth, FPDs, implants
Related treatment	OHI, routine dental follow-up, and SPIT	Separate #44-x-46 implant bridge and #46 implant removal

Table 5. Success analysis of implants

	Number of implants	Number of successful implants	Success rate	Kaplan-Meier		Cox regression		
				Mean estimated time of complication occurrence (month)	p-value (log-rank test)	95% CI	Hazard Ratio	p-value
Overall included	56	51	91.1%					
Treated arch								
Maxilla	36	32	88.9%	127.5	.526		1	
Mandible	20	19	95%	99.6		.059-4.724	.527	.567
Implant location								
Anterior	8	7	87.5%	116.0	.858		1	
Premolar	33	30	90.9%	132.8		.065-6.006	.624	.683
Molar	15	14	93.3%	148.5		.032-8.107	.507	.631
Implant diameter								
3.25mm	14	13	92.9%	130			1	
4mm	33	29	87.9%	123.1	.263	.172-13.772	1.539	.700
5mm	9	9	100%	---		.000	.000	.983
Implant length								
6.5mm	2	2	100%	---	.898	.000	.000	.992
8.5mm	8	7	87.5%	92.9		.137-16.691	1.513	.735
10mm	21	19	90.5%	134		.128-6.510	.914	.928
11.5mm	25	23	92%	130			1	
Post-treatment Kennedy								
I	21	17	81%	84	.096		1	
II	2	2	100%	---		.000	.000	.993
IV	33	32	97%	153.7		.202-1.623	.181	.127
Materials								
PFM	50	45	90%	134.6	.729		1	
Full zirconia	6	6	100%	---		.000-4.895E+10	.042	.823

(#46) experienced peri-implantitis after 15 months of loading and had to be removed. The failed implant was separated from the old implant bridge (#44-x-46), and a new implant bridge (#45-x-47) was fabricated. Among natural-teeth-related complications, periodontitis was the most common (13.2%/2 patients). In the case of tooth failure, one residual natural tooth (#34) was extracted seven months after denture delivery. Despite the complications, all the IARPDs were still functioning at the end of observation.

Tables 8–10 show the results of the chi-square and Fisher's exact tests of the different subgroups. At the denture level, the mandibular arch had a significantly higher complication rate in terms of denture sore spot (75%; $p = .015$; G*Power = 83.67%). At the implant level, the complication rate for retention loss was significantly different for treated arch ($p = .013$; G*Power = 79.39%) and implant length ($p = .011$; G*Power = 82.85%). The complication rate for peri-implant mucositis was significantly different between post-treatment Kennedy classes ($p = .027$; G*Power = 66.71%). At the natural teeth level, no significant differences were observed.

Discussion

The results of this study confirmed the null hypothesis that different clinical factors of surveyed crown type of IARPD would not result in significant differences in implant success rate but rejected the null hypothesis that complication rates would not be significantly different. The success rate of IARPDs in this study was 47.1%. This is lower than a previously reported success rate of 66.7% for IARPDs.²³ The Kaplan–Meier and Cox regression analyses showed that the patients whose mandibular arch was treated had a significantly higher risk of complications (Table 3). This is inconsistent with the results of a previous study that reported that the mandibular arches had a higher success rate.²³

Tissue sore spots were the most common complication (Table 8), a result consistent with those of other studies.^{17,19,20} In the present study, 75% of the mandibular arches had tissue sore spots, a significantly higher incidence than that observed for maxillary arches ($p = .015$; G*Power = 83.67%), which possibly led to the higher risk of complications. In addition, according to Yi et al., Kennedy Class II has the highest risk of complications, and IARPDs in Classes I and II show

lower success rates than those in Classes III and IV.²³ Similar outcomes were found in this study, with a success rate of 33%, 0%, and 71.4% for Class I, II, and IV, respectively, although this was not a significant result. No other factors significantly influenced success rates.

Overall, of the 56 implants in this study, 51 did not show pain or tenderness during functioning or mobility, showed a radiographic bone loss of less than 2 mm, and had no history of exudates. These 51 implants were considered successful according to the ICOI Pisa Implant Quality of Health Scale,²¹ resulting in a 91.1% success rate. This rate is comparable to those reported in other studies: a 90.6% success rate for 32 implants;²⁴ and an 85.1% success rate for 70 implants.²⁰ In the case of implant survival rate, four implants diagnosed with peri-implant mucositis were still functioning at the end of observation, leading to a 98.2% survival rate in this study. This rate is consistent with the 95.1%–100% survival rates reported in other studies.^{9,16–20,24} No significant differences were found in survival rate between the factors analyzed in the Kaplan–Meier and Cox regression analyses (Table 5). In a previous study, the survival rate of regular diameter implants was significantly higher than that of narrow (<3.75 mm) and wide (≥ 5 mm) diameter implants¹⁶, and the study concluded that implants with a wide diameter are not more advantageous than implants with a regular diameter.²⁵ In the present study, implant width did not have a significant effect on the survival rate ($p = .263$). In the case of complications, retention loss was found to be significantly higher for the mandibular arch ($p = .013$; G*Power = 79.39%) and 6.5-mm implant length ($p = .011$; G*Power = 82.85%; Table 9). The four implants suffering from retention loss were in the same patient and supported #34-35 and #44-x-46 temporarily cemented prostheses (TempBond™, Kerr, California, United States). These prostheses were able to be re-cemented.

In addition to implants, we also evaluated the remaining natural teeth in the IARPDs. In a previous study, natural abutments in IARPDs had a survival rate of 96.6%. The five failed teeth were thought to experience excessive loading, being occluding stops to implants or natural dentition. The mean bone loss of abutment teeth in the maxilla and of teeth with direct retainers was significantly higher. Teeth with direct retainers were assumed to withstand higher lateral force

Table 6. Success analysis of natural teeth

				Kaplan-Meier		Cox regression		
	Number of natural teeth	Number of natural teeth with complications	Success rate	Mean estimated time of complication occurrence (month)	p-value (log-rank test)	95% CI	Hazard Ratio	p-value
Overall included	35	9	74.3%					
Treated arch								
Maxilla	16	4	75%	125.6	.155		1	
Mandible	19	5	73.7%	65.8		.578-17.499	3.180	.184
Natural teeth location								
Anterior	13	3	76.9%	97.1	.369		1	
Premolar	18	6	66.7%	87.4		.421-6.841	1.698	.456
Molar	4	0	100%	---		.000	.000	.985
Opposing arch								
Natural dentition/FPDs	17	4	76.5%	127.6	.006*		1	
CD/overdenture	13	5	61.5%	51.8		1.189-88.949	10.285	.034*
IARPD	5	0	100%	---		.000	.000	.984
Post-treatment Kennedy								
I	18	5	72.2%	54.6	.178		1	
II	7	2	71.4%	98.6		.013-1.750	.150	.130
IV	10	2	80%	114.7		.020-1.918	.195	.161

*: p value less than 0.05, statistically significant

Table 7. List of complications

	Complications	Incidences/Patients	Average time of occurrence	Related treatments
Total incidents of complication: 38				
Denture	Fracture of artificial teeth	3 (7.9%)/3	26	Direct acrylic repair/ Pick up impression and repair
	Fracture of RPD clasp	2 (5.3%)/2	24.5	Pick up impression and repair/ Rounding and polishing
	Fracture of RPD rest	---	---	---
	Clasp loosening	2 (5.3%)/2	11.5	Clasp adjustment
	Denture base fracture	1 (2.6%)/1	3	Rounding and polishing
Implant	Peri-implant mucositis	4** (10.5%)/1	74	OHI and SPIT
	Peri-implantitis	1 (2.6%)/1	15	Cut #44-x-46 bridge and #46 implant removal
	Retention loss	2 (5.3%)/1	9	#44-x-46 and #34-35 re-cementation
	Porcelain veneer fracture	2 (5.3%)/1	66.5	Rounding and polishing
	Implant loss	1 (2.6%)/1	15	Cut #44-x-46 bridge and #46 implant removal
Natural teeth abutments	Endodontic treatment	1 (2.6%)/1	147	#25 endodontic treatment
	Fracture	1 (2.6%)/1	64	Direct composite filling
	Caries	4 (10.5%)/3	66.8	Direct composite filling
	Periodontitis	5 (13.2%)/2	71.3	Localized root planing
	Tooth loss	1 (2.6%)/1	7	#34 residual root and extraction
Tissue	Denture base sore spot	8 (21.1%)/7	9	Denture adjustment and relief pressure spots

*: p value less than 0.05, statistically significant

Table 8. Details of complications of IARPDs

Complication rate: 9/17 (52.9%)		Treated arch			Post-treatment Kennedy				Opposing arch			
Complication types	No. of IARPDs	Maxillary (9)	Mandible (8)	p	I (9)	II (1)	IV (7)	p	Natural dentition/ FPDs (8)	CD/ overdenture (6)	IARPD (3)	p
Denture												
Artificial teeth	3 (17.6%)	2 (22.2%)	1 (12.5%)	1.000	1 (11.1%)	1 (100%)	1 (14.3%)	.228	2 (25%)	1 (16.7%)	0	1.000
Clasp fracture	2 (11.8%)	1 (11.1%)	1 (12.5%)	1.000	1 (11.1%)	1 (100%)	0	.118	1 (12.5%)	1 (16.7%)	0	1.000
Clasp loosening	2 (11.8%)	0	2 (25%)	.206	2 (22.2%)	0	0	.537	0	2 (33.3%)	0	.132
Denture base	1 (5.9%)	0	1 (12.5%)	.471	1 (11.1%)	0	0	1.000	0	0	1 (33.3%)	.176
Implant												
Peri-implant mucositis	1 (5.9%)	1 (11.1%)	0	1.000	1 (11.1%)	0	0	1.000	0	0	1 (33.3%)	.176
Peri-implantitis	1 (5.9%)	0	1 (12.5%)	.471	0	0	1 (14.3%)	.471	1 (12.5%)	0	0	1.000
Retention loss	1 (5.9%)	0	1 (12.5%)	.471	0	0	1 (14.3%)	.471	1 (12.5%)	0	0	1.000
Porcelain veneer fracture	1 (5.9%)	1 (11.1%)	0	1.000	0	0	1 (14.3%)	.471	1 (12.5%)	0	0	1.000
Implant loss	1 (5.9%)	0	1 (12.5%)	.471	0	0	1 (14.3%)	.471	1 (12.5%)	0	0	1.000
Natural teeth												
Endo	1 (5.9%)	1 (11.1%)	0	1.000	0	0	1 (14.3%)	.471	1 (12.5%)	0	0	1.000
Fracture	1 (5.9%)	1 (11.1%)	0	1.000	0	1 (100%)	0	.059	1 (12.5%)	0	0	1.000
Caries	3 (17.6%)	2 (22.2%)	1 (12.5%)	1.000	1 (11.1%)	1 (100%)	1 (14.3%)	.228	2 (25%)	1 (16.7%)	0	1.000
Periodontal	2 (11.8%)	1 (11.1%)	1 (12.5%)	1.000	1 (11.1%)	1 (100%)	0	.118	1 (12.5%)	1 (16.7%)	0	1.000
Tooth loss	1 (5.9%)	1 (11.1%)	0	.471	1 (11.1%)	0	0	1.000	0	1 (16.7%)	0	.529
Tissue												
Sore spots	7 (41.2%)	1 (11.1%)	6 (75%)	.015*	5 (55.6%)	1 (100%)	1 (14.3%)	.134	2 (25%)	4 (66.7%)	1 (33.3%)	.377

*: p value less than 0.05, statistically significant

Table 9. Details of complications of implants

	Complication types				
Complication rate: 10/56 (17.9%)	Peri-implant mucositis	Peri-implantitis	Retention loss	Porcelain veneer fracture	Implant loss
Number of implants	4 (7.1%)	1 (1.8%)	4 (7.1%)	2 (3.6%)	1 (1.8%)
Treated arch					
Maxillary (36)	4 (11.1%)	0	0	2 (5.6%)	0
Mandibular (20)	0	1 (5%)	4 (20%)	0	1 (5%)
p	.285	.357	.013*	.532	.357
Implant location					
Anterior (8)	1 (12.5%)	0	0	0	0
Premolar (33)	3 (9.1%)	0	3 (9.1%)	0	0
Molar (15)	0	1 (6.7%)	1 (6.7%)	2 (13.3%)	1 (6.7%)
p	.454	.411	1.000	.086	.411
Materials					
PFM (50)	4 (8%)	1 (2%)	4 (8%)	2 (4%)	1 (2%)
Full zirconia (6)	0	0	0	0	0
p	1.000	1.000	1.000	1.000	1.000
Implant diameter					
3.25mm (14)	1 (7.2%)	0	0	0	0
4mm (33)	3 (9.1%)	1 (3%)	2 (6.1%)	1 (3%)	1 (3%)
5mm (9)	0	0	2 (22.2%)	1 (11.1%)	0
p	1.000	1.000	.161	.357	1.000
Implant length					
6.5mm (2)	0	0	1 (50%)	0	0
8.5mm (8)	0	1 (12.5%)	2 (25%)	0	1 (12.5%)
10mm (21)	2 (9.5%)	0	1 (4.8%)	1 (4.8%)	0
11.5mm (25)	2 (8%)	0	0	1 (4%)	0
p	1.000	.179	.011*	1.000	.179
Post-treatment Kennedy					
I (21)	4 (19%)	0	0	0	0
II (2)	0	0	0	0	0
IV (33)	0	1 (3%)	4 (12%)	2 (6.1%)	1 (3%)
p	.027*	1.000	.267	.550	1.000

*: p value less than 0.05, statistically significant

Table 10. Details of complications of natural teeth

Complication rate 9/35 (25.7%)	Complication types				
	Endodontic	Caries	Fracture	Periodontal	Tooth loss
Number of natural teeth	1 (2.9%)	4 (11.4%)	1 (2.9%)	5 (14.3%)	1 (2.9%)
Treated arch					
Maxillary (16)	1 (6.3%)	3 (18.8%)	1 (6.3%)	2 (12.5%)	0
Mandibular (19)	0	1 (5.3%)	0	3 (15.8%)	1 (5.3%)
<i>p</i>	.457	.312	.457	1.000	1.000
Natural teeth location					
Anterior (13)	0	1 (7.7%)	1 (7.7%)	3 (23.1%)	0
Premolar (18)	1 (5.6%)	3 (16.7%)	0	2 (11.1%)	1 (5.6%)
Molar (4)	0	0	0	0	0
<i>P</i>	1.000	.772	.486	.657	1.000
Opposing arch					
Natural dentition/ FPDs (17)	1 (5.9%)	3 (17.6%)	1 (5.9%)	2 (11.8%)	0
CD/ Overdenture (13)	0	1 (7.7%)	0	3 (23.1%)	1 (7.7%)
IARPD (5)	0	0	0	0	0
<i>P</i>	1.000	.797	1.000	.537	.514
Post-treatment Kennedy					
I (18)	0	1 (5.6%)	0	3 (16.7%)	1 (5.6%)
II (7)	0	1 (14.3%)	1 (14.3%)	2 (28.6%)	0
IV (10)	1 (10%)	2 (20%)	0	0	0
<i>P</i>	.486	.399	.200	.247	1.000

than teeth with indirect retainers.²⁰ A total of 35 teeth were included in the study and a success rate of 74.3% was reported. The success rate was lower than that of another previous study,²⁰ but eight of the nine teeth with complications were still functioning at the end of observation, showing a comparable 97.1% survival rate. Table 6 shows that natural teeth occluding a complete denture or overdenture had significantly higher risks of failure (HR = 10.285; $p = .034$) in this study. One tooth occluding a complete denture was extracted seven months after delivery. This was in order to save the tooth with the poor prognosis to maintain vertical dimension; the tooth was able to be extracted after completion of the final prosthesis.

A limitation of the present study is its small sample size, which might have affected statistical power and caused bias. Post-hoc tests of mean estimated time to occurrence of complications in natural teeth opposing arch groups (G*Power = 31.22%) and of the complication rate of implants with peri-implant mucositis in post-treatment Kennedy classification groups (G*Power = 66.71%) had a power lower than the ideal power of 80%; therefore, these results should be interpreted with caution. In addition, clinical information on implants, such as marginal bone loss, soft tissue condition, and patient-reported outcome measures were not analyzed. Furthermore, five patients were edentulous before treatment. Previous studies showed that in edentulous patients, the implant

survival rates of implant surveyed crown type of IARPD were comparable to those of implant overdentures with attachments.¹⁶⁻¹⁸ These factors should be considered in future studies to confirm the clinical feasibility of surveyed crown type of IARPD.

Conclusion

Within its limitations, this study reports a 91.1% implant success rate. Surveyed crown type of IARPD could be a viable treatment option for totally or partially edentulous patients. Different clinical factors did not have significant effects on the success rate of implants, but had significant impacts on the success rates of IARPDs and natural teeth. In addition, these factors had significant effects on the complication rates of IARPDs and implants. Further clinical studies are necessary to confirm these results.

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