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Clinical and radiographic evaluations of implants as surveyed crowns for Class I removable partial dentures: A retrospective study

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PURPOSE. The purpose of this study was to evaluate survival rates and marginal bone loss (MBL) of implants in IC-RPDs. **MATERIALS AND METHODS.** Seventy implants were placed and used as surveyed crowns in 30 RPDs. The survival rates and MBL around implants based on multiple variables, e.g., position, sex, age, opposing dentitions, splinting, type of used retainer, and first year bone loss, were analyzed. Patient reported outcome measures (PROMs) regarding functional/esthetic improvement after IC-RPD treatment, and complications were also inspected. **RESULTS.** The 100% implant survival rates were observed, and 60 of those implants showed MBL levels less than 1.5 mm. No significant differences in MBL of implants were observed between implant positions (maxilla vs. mandible; $P = .341$) and type of used retainers ($P = .630$). The implant MBL of greater than 0.5 mm at 1 year showed significantly higher MBL after that ($P < .001$). Splinted implant surveyed crowns showed lower MBL in the maxilla (splinted vs. non-splinted; $P = .037$). There were significant esthetic/functional improvements observed after treatment, but there were no significant differences in esthetic results based on implant position (maxilla vs. mandible). Implants in mandible showed significantly greater improvement in function than implants in the maxilla ($P = .002$). Prosthetic complication of IC-RPD was not observed frequently. However, 2 abutment teeth among 60 were failed. The bone loss of abutment teeth was lower than MBL of implants in IC-RPDs ($P = .001$). **CONCLUSION.** Class I RPD connected to residual teeth and strategically positioned implants as surveyed crowns can be a viable treatment modality. [J Adv Prosthodont 2022;14:108-21]

KEYWORDS
Removable partial dentures with implants used as surveyed crowns (IC-RPDs); Implant surveyed crowns; Survival rates; Marginal bone loss (MBL); Patient reported outcome measures (PROMs); Abutment teeth

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INTRODUCTION

Complaints concerning partially edentulous patients are related to difficulty in adapting to removable prostheses due to reduction of alveolar ridge and decreased soft tissue. Common clinical problems with distal extension removable partial denture (RPD) include lack of stability and retention, as well as discomfort. In recent decades, prosthetic treatment with dental implants for partially edentulous patients have made progressive improvements. Implant-supported fixed prostheses are a common treatment option for partially edentulous patients. However, clinicians often encounter difficult situations placing implants due to the lack of alveolar ridge or financial limitations that prevent placing sufficient numbers of implants to support long-span fixed prostheses. In this regard, implant-assisted removable partial dentures (IARPDs) are an alternative treatment option, allowing additional support and retention with fewer implants.[1-3] By inhibiting removable prosthetic movement, implants provide comfort and improved esthetics, phonetics and masticatory function in patients with RPDs.[3]

There are two different types of treatment modality for IARPDs. One is the IARPD using implants as surveyed crowns or bridges (i.e. IC-RPD) with rest seats and retentive clasps of RPDs, which we defined as IC-RPD in our previous studies,[4,5] and the other is an overdenture (OD) type of IARPD with implant attachments such as balls, magnets and locators. Most previous studies of IARPDs covered only the OD type of IARPDs and focused on implant survival rates without considering multiple variables or related conditions.[6-8]

There are clinical advantages to the use of OD type of IARPDs. Ohkubo *et al*.[8,9] demonstrated that the efficiency of masticatory function was greatly increased by implant supports to the distal extension area in partially edentulous patients. There are also several case reports indicating that RPD with a small number of implants supporting the posterior edentulous area is useful for overcoming difficulties with conventional RPD because they protect the remaining tissue and improve support, retention, and stability.[10-12] IARPDs with implants also provide better mastication function, fit, retention and quality of life.[13]

Recent studies founded that anterior positioning of implants with OD type of IARPDs results in less dislodging of dentures vertically and horizontally. Therefore, placing implants to approximate positions of supporting teeth is being beneficial for stress distribution.[14,15] When force is applied to implant abutments and the location of implants is moved from the last molar area to the premolar area, the force distribution to the implant abutments is more favorable.[14] Furthermore, case reports and long-term clinical studies of implants placed in the anterior part of the edentulous area showed satisfying results.[6,16,17] In short, anterior implant placement adjacent to abutment teeth for distal extension class I RPD is a good treatment modality especially for patients who have severely absorptive ridges in the posterior area to place implants surgically.

Previous studies have suggested that OD type of IARPD can be a predictable treatment modality for partially edentulous patients.[11,18] Bassetti *et al*.[19] reviewed studies of OD type IARPDs and found that the mean implant survival rate was as high as 91.7 - 100%. Recently, Bae *et al*.[20] and Kang *et al*.[21] performed clinical analyses of implant survival rate, marginal bone loss (MBL), and periodontal indices in IC-RPD as well as OD type of IARPDs held in place by stud attachments. Kang *et al*. reported that the survival rate of implants for IC-RPD was 95.1%.[21] Our previous studies demonstrated 98.3% implant survival rates for IC-RPDs in maxillary edentulism and 97.3% implant survival rates for IC-RPD in mandibular edentulism.[4,5] Based on the survival rates of previous studies, both IC-RPDs and OD type of IARPDs could be considered a competent prosthetic solution for patients who are not suitable candidates for extensive fixed implant prostheses.[6,7,22] However, clinical research on IC-RPDs in partially edentulous patients still remain insufficient. Only few case reports or short-term results on implant survival rates have been introduced, and these previous studies did not provide other information or clinical guidelines for dental practitioners.[12,23-25] In the present study, focus was on the IARPDs with implant surveyed crowns (IC-RPDs) with rest, retentive arms and proximal plate of RPDs.

In this study, IC-RPDs were evaluated clinically and radiographically, analyzing the survival rate, the MBL of implants, and patient reported outcome measures (PROMs) describing functional and esthetic improvement after treatment, as well as prosthetic complications. The aim of this study was also to assess which factors, such as implant location (upper or lower dentition), sex, age opposing dentition, splinting, type of used retainer and first year bone loss, influenced our results. The first null hypothesis was that survival rates and MBL of implants in IC-RPD showed no differences between maxilla and mandible and the second null hypothesis was that there were no statistical differences between PROMs and prosthetic complications between the two groups.

MATERIALS AND METHODS

Thirty-four partially edentulous patients who were treated with IC-RPDs between January 2012 and July 2020 at Seoul National University Dental Hospital and S Leader Dental Clinic in South Korea, were inspected. This study was authorized by the Institutional Review Board of Seoul National University Graduate school of Dentistry (No. S-D20200040). Of the 34 patients, 30 (17 men, 13 women) patients and 70 implants were ultimately included (Table 1). All patients were treated by prosthodontic and surgical specialists and visited the clinic for periodical check-ups. Patients with systemic diseases including diabetes and osteoporosis, and patients who had any conditions that contraindicated check-ups were all excluded. The study sample was divided into two groups of partially edentulous patients treated with IC-RPDs based on the location: maxilla and mandible.

According to clinical chart, 70 implants were placed under the following guidelines: 1) adequate bone for placing two to four implants over the arch; 2) no severe systemic problems affecting implant prognosis and no anesthetic complications; 3) smokers obligatorily taking part in a smoking cessation program before dental treatment; and 4) demand of good oral hygiene.

Clinical and radiographic assessments were performed for a total of 70 implants. All implants in IC-RPDs were placed in the anterior (incisor or canine) or premolar area and were therefore Class I IC-RPDs (or Class I with modification 1). Our study included 30 patients who received IC-RPDs.

All 70 implants were observed as regular internal type; 55 were 4 - 4.5 mm in diameter and 10 mm or 11.5 mm in length, and 15 were 4.8 - 6 mm in diameter and 8.5 mm or 10 mm in length (Table 1). The 30 IC-RPDs were assisted by 70 implant-supported porcelain fused metal (PFM) surveyed crowns (Fig. 1). The follow-up period in this study ranged from 13 to 74 months (mean: 30.6 months).

All patients got maintenance instructions at the date of delivery. Follow-up was conducted on all patients from 1 to 7 years. The evaluations for this study including implant survival, MBL of implants, PROMs at 6-month recall check, and prosthetic complications, were performed during follow-up.

The main outcome was cumulative implant survival rate. The implant survival criteria of this study followed the Pisa consensus statement of the International Congress of Oral Implantologists (ICOI) Con-

Table 1. Number of implants in RPDs using implant surveyed crown (IC-RPDs) and related information

Position	Implant connection type	Implant manufacturer	Implant diameter	Total
ISC-RPD in maxilla (n = 13)	Internal type	Osstem	Regular (4, 4.5 mm)	24
			Regular (5 mm)	3
		Dentium	Regular (4.3 mm)	2
			Regular (4.8 mm)	2
ISC-RPD in mandible (n = 17)	Internal type	Osstem	Regular (4, 4.5 mm)	27
			Regular (5 mm)	8
		Dentium	Regular (4.3 mm)	2
			Regular (4.8 mm)	2

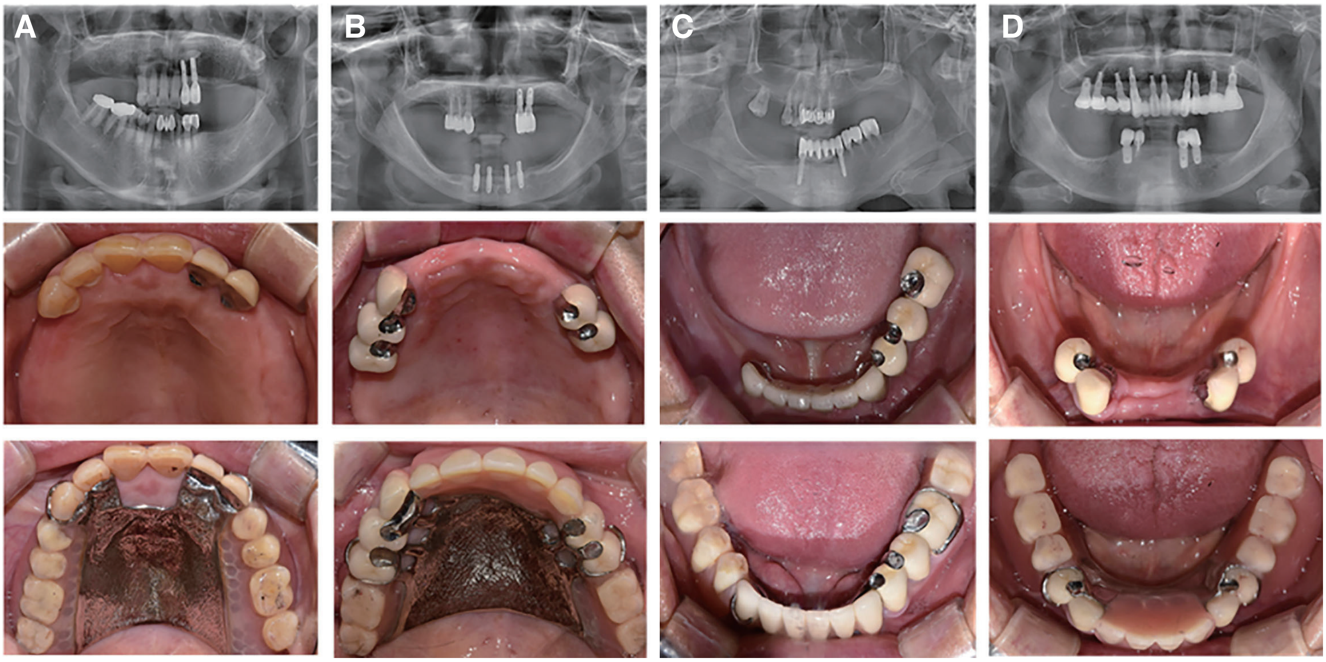

Fig. 1. Representative cases of IC-RPDs in this study: (A) Kennedy Class I in maxilla; implants were placed adjacent to the remaining abutment teeth to restore anterior teeth. 2 natural teeth (#13,12) were used for support and retention for RPD through natural tooth alteration. (B) Kennedy Class I with modification 1 in maxilla; implants were placed symmetric to the remaining abutment teeth (#13,14,15) to improve stability of RPDs. (C) Kennedy Class I in mandible; implants were placed adjacent to the remaining abutment teeth (#34,35,36) to restore anterior teeth for better function and esthetics. (D) Kennedy Class with modification 1 in mandible; implants were placed symmetric to the remaining abutment tooth (#43) to improve stability of RPDs.

ference in 2007.[26] Implants were considered as survived if the implants were functioning normally at the final observation.

Peri-implant bone loss was assessed with intraoral radiographs, using digitized panoramic and periapical radiographs. Radiographs taken during the final recall were evaluated to determine the peri-implant bone level as the distance between the platform of the implant and the level of the adjacent osseous crest on the mesial and distal aspects, respectively. Based on the actual length of the implants noted in charts, the actual bone level was calculated by a proportional equation.[27] The MBL was defined as the variances between mean value of bone loss in the mesial and distal aspects at final check-up and implant delivery.

To exclude bias, all radiographic data were categorized by order of chart number and assessments were randomly performed by a single examiner (SYY) according to the same criteria twice. For checking reliability, the Intra-class Correlation Coefficient (ICC) value was calculated and statistically analyzed.

The MBL of implants based on multiple variables such as position, sex, age, opposing dentition, splinting, type of used retainer and first year bone loss were evaluated. According to guidelines for peri-implantitis defined by the 2017 World Workshop on the Classification of Periodontal and Peri-implant Diseases and Conditions,[28] existence of detectable bone resorption exceeding measurement error (mean 0.5 mm) radiographically observed at the first year was included. Thus, in this study, the first-year bone resorption standard was 0.5 mm apical bone loss. The MBL differences at final check-up, according to the groups categorized by the first year bone loss (MBL $<$ 0.5 mm group at year 1 vs. MBL $\geq$ 0.5 mm group at year 1), were analyzed.

Patient quality of life and contentment are the main considerations when selecting treatment modality.[29] The PROMs after IC-RPD treatment according to visual analog scales (VAS) of 1 to 5 were evaluated, in which 5 was the most favorable. The questionnaires were to: 1) rate before and after esthetic satisfaction with

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the prosthesis procedure; and 2) rate before and after functional satisfaction with the prosthesis procedure. Contentment levels were analyzed after IC-RPD prosthesis delivery (usually at the 6-month recall check).

All chart records were analyzed to inspect complications associated with IC-RPDs. Prosthetic complications were categorized into 4 groups: 1) Denture: fractures or distortions of the denture components followed by repair or fabrication of new dentures; 2) Implant: screw fractures, screw loosening, dislodgement of prostheses and veneer porcelain fracture in PFM; 3) Abutment teeth: loss of tooth and fracture of tooth followed by extraction, PDL space widening (mobility) and apical periodontitis; and 4) Tissue: gingival sore spots or alveolar bone resorption.

Finally, for more inspection of prognosis of abutment teeth, the survival rates and bone loss of abutment teeth in IC-RPDs were all analyzed depending on position (maxilla vs. mandible), splinting, and type of used retainer (abutment teeth with direct retainer vs. abutment teeth with only indirect retainer). Bone loss of abutment teeth was adjusted by the length of the implants in panoramic radiograph and calculated by a proportional equation.

All data were assessed through the statistical package SPSS version 23 (SPSS Inc., Chicago, IL, USA). The time interval standard for implant MBL was set as the time difference between delivery date of the prosthesis and final observation date. For analysis of final bone resorption, we adjusted values over time using mixed analysis due to the variances of observation period. A linear mixed model as well as posterior comparisons of the T-test with significance levels adjusted by Bonferroni's method (P = .0125) were applied. For the reliability of measurement on implant MBL, ICC was also analyzed at 95% confidence interval in this study.

The Kruskal-Wallis test was taken to configure the differences of MBL according to sex, age, occluding dentition, splinting with adjacent implants, type of used retainers and first year bone loss and the Mann-Whitney test was done with the results.

The Wilcoxon signed rank test to detect significant functional or esthetic improvements after treatment was used, and also the Kruskal-Wallis test to determine differences in PROM variables was applied. With the results derived, final comparisons were done through the Mann-Whitney test.

Additionally, for analysis of abutment teeth, the Mann-Whitney test was proceeded according to multiple variables; position (maxilla vs. mandible), splinting (splinting vs. non-splinting) and type of used retainer (abutment for direct retainer vs. abutment for indirect retainer).

RESULTS

A total of 70 implants of 30 patients (13 women, 17 men) with the mean age of 76.6 years (ranged from 66 to 84 years) were examined.

During the observation period (up to 74 months), 70 implants all survived with a 100% survival rate as shown in Table 2. Of the 74 implants, 63 passed the success criteria drawn from the literature: 1) implant without mobility, pain, radiolucency; 2) peri-implant bone loss (< 1.5 mm); and 3) peri-implant soft-tissue level was without suppuration, bleeding, or severe PD.[30]

Table 2. Survival rates of implants based on variables

Condition		No. of implants	Survival rates (%)
Treatment dentition	Implants in Mx	31	100
	Implants in Mn	39	100
Sex	Male	37	100
	Female	33	100
Age	under 75	27	100
	over 75	43	100

Mx: maxilla; Mn: mandible.

The MBL of implants at final recall check ranged from 0.2 to 4.6 mm. No significant relationships were found between implant MBL measurements on the mesial and distal sides of the same implant at final recall check (*P* = .306); therefore, the averages of the mesial and the distal measurements were evaluated as one value for each implant.

The MBLs of all implants in this study are illustrated in Figure 2. The average MBL for all implants was 0.15 ± 0.23 at year 1 and 0.82 ± 0.93 mm at final recall check (Table 3). The implant MBL at final check-up showed no significant difference between maxillary and mandibular implants (*P* = .341).

Table 4 shows the results of MBL around implants based on multiple variables. No statistical differences of MBL were found based on sex, age, opposing dentition and type of used retainer (*P* = .220, .307, .142, 630 respectively). In maxillary implants, splinting significantly affected MBL (*P* = .037). According to the first year bone loss, the MBL around implants at final check-up significantly differed (*P* < .001).

ICC of MBL measurement was 0.99 at year 1 after loading, 0.973 at year 2 after loading and 0.981 at final recall check. All MBL measurements presented an excellent reliability.

In both maxillary and mandibular implant groups, satisfaction of patients was enhanced significantly (*P* < .05) after the delivery of prostheses (Fig. 3). Improvement in function showed significantly higher scores in the mandibular implant group than the maxillary implant group (*P* = .002), while improvement in esthetics was similar in both groups (Fig. 4).

Complications in both maxilla and mandible were categorized into 4 groups and analyzed. Complication occurrence time was variable in both groups. Table 5 shows that the most frequent prosthetic complication is clasp loosening; 42.8% in maxillary IC-RPD and 33.3% in mandibular IC-RPD, which was solved by adjusting the clasps. Denture base relief or relining due to sore spots and bone resorption were also performed frequently and solved technically. However, because of abutment teeth losses, two IC-RPDs have been repaired. About 7.4% of maxillary abutment teeth showed periodontal ligament (PDL) space widening and 3% of mandibular abutment teeth showed apical periodontitis.

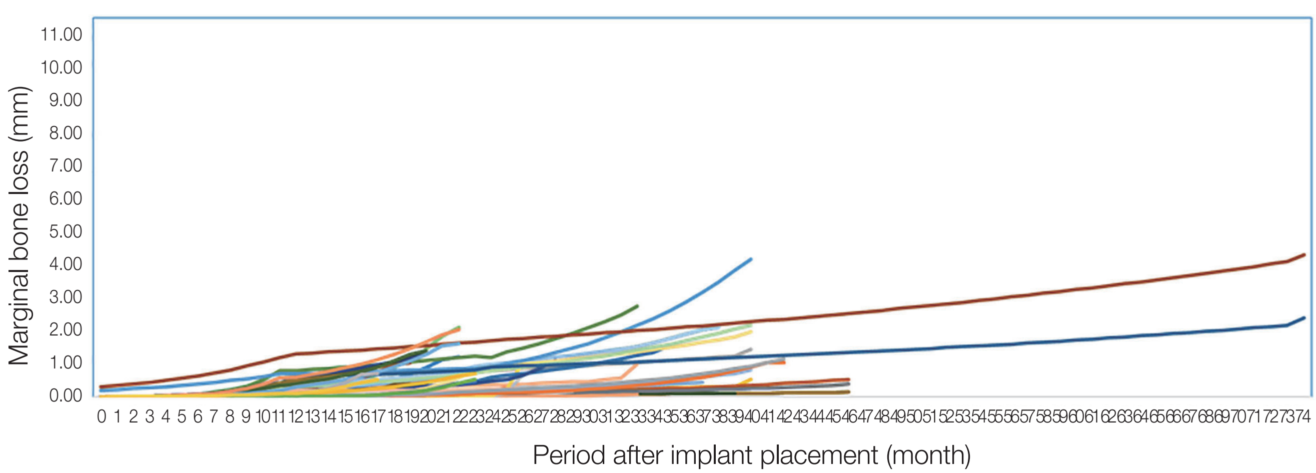

Fig. 2. Marginal bone loss (MBL) of 70 implants in IC-RPDs. The 85% implants showed MBL levels less than 1.5 mm at the final observation.

Table 3. Marginal bone loss (MBL) of implants in IC-RPD at year 1 and at end date of observation

	Implants in Mx (n = 31)	Implants in Mn (n = 39)	Total (n = 70)	*P*-value
at year 1	0.09 ± 0.14 mm	0.20 ± 0.27 mm	0.15 ± 0.23 mm	.871
at end date of observation	0.50 ± 0.64 mm	1.0 ± 1.05 mm	0.82 ± 0.93 mm	.341

Mx: maxilla, Mn: mandible.

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Table 4. MBL of implants in IC-RPDs based on multiple variables

Condition		No. of implants	Bone loss (mm)	*P*-value
Sex	Male	37	0.94 ± 0.98	.220
	Female	33	0.69 ± 0.88	
Age	Under 75	27	0.66 ± 0.70	.307
	Over 75	43	0.92 ± 1.05	
Occluding dentition	Natural teeth	21	0.78 ± 0.71	.142
	Implants	8	1.02 ± 1.67	
	RPD	17	0.99 ± 1.12	
	CD	15	0.44 ± 0.57	
	OD	9	1.04 ± 0.56	
Splinting (Mx)	Splinting	28	1.42 ± 1.25	.037
	Non-splinting (solitary)	3	0.40 ± 0.49	
Splinting (Mn)	Splinting	22	1.09 ± 1.06	.604
	Non-splinting (solitary)	17	1.06 ± 1.09	
Type of used retainer	Abutment with direct retainer	48	0.89 ± 1.02	.630
	Abutment with indirect retainer	22	0.68 ± 0.70	
First year bone loss	MBL ≥ 0.5 mm	7	2.71 ± 1.27	< .001
	MBL < 0.5 mm	63	0.61 ± 0.61	

MBL: marginal bone loss, RPD: removable partial denture, CD: complete denture, OD: overdenture.

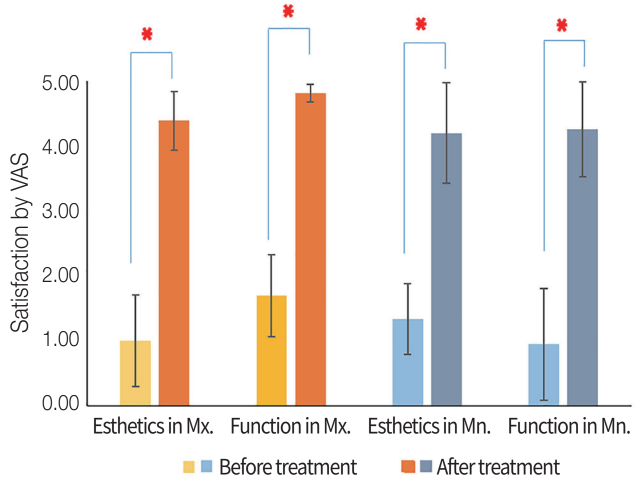

Fig. 3. Comparison of satisfaction in esthetics and function by VAS before and after prosthetic treatment. Significant differences between before and after treatment in both esthetics and function were found according to the Wilcoxon signed-ranks test regardless of the dentition ($P < .05$). Red asterisk means $P < .001$.

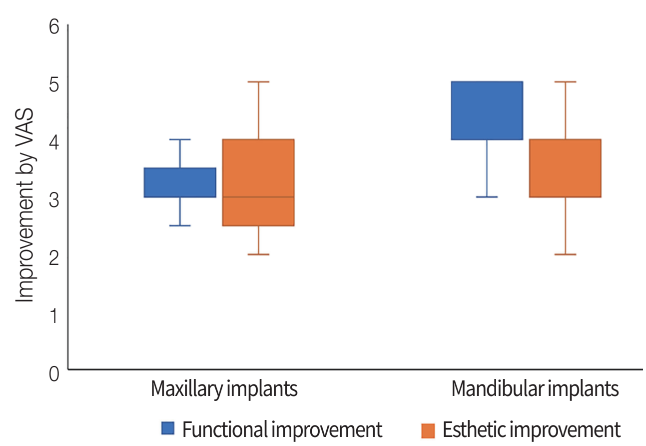

Fig. 4. Esthetic and functional improvement by VAS based on treatment dentition (maxilla vs. mandible). There were no significantly different esthetic results according to implant position ($P > .05$), but the mandibular implant group showed significantly higher improvement in function ($P = .002$).

Table 5. Prosthetic and biological complications in IC-RPDs

	Prosthetic complication	Number of incidences (n / %) - Mx	Average time of complication occurrences /Total follow up time (months) -Mx	Number of incidences (n / %) - Mn	Average time of complication occurrences /Total follow up time (months) -Mn	Remarks
Denture	Fracture of RPD clasp	-		-		-
	Fracture of RPD rest	-		1/8.3	6/19	Refabrication
	Fracture of artificial teeth	-		-		-
	Clasp loosening	3/42.8	21.5/28.6	4/33.3	23/30	Akers' clasp
Implant	Implant screw loosening	-		-		-
	Implant screw fracture	-		-		-
	Dislodgement	1/14.2	36/46	1/8.3	16/36	Cr recementation
	Crown veneer fracture	-		-		-
Abutment teeth	Loss of tooth (periodontitis)	-		1/3.0	19/26	Repair
	Fracture of tooth → extraction	1/3.7	6/21	-		Repair
	PDL space widening (mobility)	2/7.4	32/47			Curettage, occlusal adjustment
	Apical periodontitis			1/3.0	19/36	Endodontic treatment
Tissue	Sore spot around major connector	1/14.2	4/22	-		Relief
	Denture base sore spot	1/14.2	1/22	3/25	14/33	Relief
	Crestal bone resorption	-		2/16.6	29.2/32.5	Relining

Mx: maxilla, Mn: mandible, PDL: periodontal ligament.

The mean bone loss of abutment teeth in IC-RPDs was 0.29 ± 0.25 mm for a mean period of 30.6 months. Abutment teeth in maxilla showed greater bone loss compared to mandible (*P* = .004), while no statistical difference was found according to splinting of abutment teeth (*P* = .456). However, Table 6 showed that according to type of used retainer (abutment teeth with direct retainer vs. abutment teeth with indirect retainer), there was a statistical difference (*P* = .006). Abutment teeth with direct retainers showed greater bone loss than abutment teeth with only indirect retainers.

Table 6. Bone loss of abutment teeth in IC-RPDs based on multiple variables

	Condition	No. of abutment teeth	Bone loss (mm)	*P*-value
Position	Maxilla	27	0.38 ± 0.30	.004
	Mandible	33	0.22 ± 0.16	
Splinting	Splinting	38	0.29 ± 0.27	.456
	Non-splinting	22	0.29 ± 0.20	
Type of used retainer	Abutment teeth with direct retainer	32	0.37 ± 0.29	.006
	Abutment teeth with indirect retainer	28	0.20 ± 0.14	

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DISCUSSION

When a patient cannot be rehabilitated with fixed prostheses or fails adapting to a traditional RPD because of dislodging movement and compromised residual teeth, an alternative solution is the use of a minimum number of implants located in strategic positions with RPD. Few studies have evaluated improvements of RPD connected with teeth and posteriorly positioned implants.[6,16,17] Even when the preserved remaining teeth are unfavorably distributed, placing a limited number of implants in strategic positions could provide more favorable support and retention for dentures. This is helpful for patients to adapt to a new denture and improves quality of life.

In this study, implant survival rates and MBL of implants in IC-RPDs (IARPD with implant surveyed crowns) for partially edentulous patients and identified factors that influenced the results were analyzed. The first null hypothesis was accepted. The implant survival rate in IC-RPD was 100% for both maxillary and mandibular partially edentulous patients during a mean 30.6 months (up to 74 months). In our previous studies, 98.3% implant survival rates were observed for IC-RPDs in maxillary edentulism and 97.3% implant survival rates in mandibular edentulism.[4,5] While the survival rates of the present study showed a higher result of 100%, this was assumed due to the presence of abutment teeth connecting to IC-RPDs. Abutment teeth and few implants in strategic positions as surveyed crowns were used to support and retain RPDs together, resulting in favorable force distribution of implant surveyed crowns with residual abutment teeth. Like previous studies demonstrating that IC-RPDs in complete edentulism were clinically acceptable,[4,5] IC-RPDs using few implants with the help of few abutment teeth could also be an effective and suitable treatment modality in partially edentulous patients with anatomical and socio-economical limitations.

The MBL of both arches (maxilla and mandible) showed no differences (P = .341). The MBL of most implants in this study was less than 1.5 mm, meeting success criteria for implant MBLs[30] and showing consistent behavior within accepted bone loss according to previous studies,[31,32] although longer follow-up will be needed for decisive conclusions. Mandibular implants showed more bone loss than maxillary implants, but no statically significant differences in implant MBL were found at final check-up (up to 74 months) between the maxillary and mandibular implants according to the position, sex, age, type of used retainers and occluding dentition with time variable. In this study, there was a limitation that the mean observation period was different in the two groups (29.3 months for maxilla vs. 31.5 months for mandible). Furthermore, for maxillary implants, buccal bone loss is more profound than palatal side due to axis of loading and density of buccal bone; however, in this study there is no consideration on this. In further studies, controlled prospective study and observation of MBL through computed tomography would be needed.

Isidor,[33,34] Miyata *et al*.,[35] and Chitumalla *et al*. found correlations between overloading and biological changes such as bone loss. Several previous studies recommended splinting crowns in patients with parafunction or when excessive loading is expected because of possible bone loss.[36-38] Grossmann *et al*.[36] suggested that implants should be splinted when they are off-axis or the natural tooth stop is reduced, as well as for canine restoration. In this study, 90% of maxillary implants were splinted while only 60% of mandibular implants were splinted. The MBL of splinted implants showed statistically significant lower values than solitary abutment implants in maxilla (P = .037) but not in mandible (P = .604). However, the splinting might affect MBL of implants at final recall check in mandible; therefore MBL of mandibular implants (1.0 ± 1.05 mm) were observed higher than maxillary implants (0.5 ± 0.64 mm). If clinicians need to place few implants in bone with low density or bad axis of ridge, splinting implants for better force distribution might be recommended.

Additionally, the first-year bone loss above 0.5 mm later resulted in higher MBL. Therefore, when early bone loss in IC-RPDs is observed, clinicians should examine biological changes closely and often via periodic recall checks. The periodontal intervention at the right time to prevent further MBL is needed.

The factors influencing bone loss around implants are various, including prosthetic configuration, OH, and force of occlusion.[39-41] In this study, prosthetic configuration of implant surveyed crowns in IC-RPD usually showed unfavorable convex configurations because most patients already had severe buccal plate bone loss after tooth extraction. Though MBL around most implants in IC-RPDs in this study were observed within the successful range (less than 1.5 mm), clinicians should be careful to plan IC-RPDs for long-term prognosis. Concerning the OH, aged people with lower dexterity may experience aggravated MBL surrounding implants. In other words, patients who cannot maintain good OH have limited capability of maintaining implant OH despite consistent periodic recall checks and instructions as well as periodontal treatment intervention. In those cases, IC-RPD might not be a good treatment option. For better occlusal force distribution in IC-RPDs, periodic recall checks and occlusal adjustments are needed. In addition, retention and stabilization of denture should be checked as well as the fit of the distal extensions to the residual ridges to prevent harm to implant surveyed crowns caused by dislodgement of dentures. Adequate prosthetic treatment planning, consistent OH instructions, careful denture fitting and occlusion adjustments during recall appointments are mandatory for preventing severe MBL in IC-RPDs.

Implant locations should be carefully selected in IC-RPDs, considering dislodging force and possible upcoming options to change to the fixed implant prostheses. The first molar and second premolar positions for ideal implant positions have been demonstrated to increase stability of IARPDs in clinical and *in vitro* studies.[6,8-10] Ortiz-Puigpelat reported that implants in the first molar position offer more favorable force distribution and reduction of stress along residual tissue, while implants in the second premolar area reduce strain forces in the periodontal ligaments of residual teeth.[42] However, anatomic constraints, like the position of the mandibular canal or ridge proximity to the paranasal sinuses, might result in positioning implants anteriorly to the edentulous region. In addition to that, implants placed in anterior positions can aid esthetic improvement in IC-RPDs. Therefore, middle or anterior positions for implant surveyed crowns in IC-RPDs could be recommended considering anatomical limitations and esthetic reasons.

Jensen *et al*.[43] found that Kennedy class I in IARPDs was a good treatment option, with high implant survival rates, and that anteriorly located implants showed better results than posterior implants. Similarly, in this study, implants were placed anteriorly, approximate to natural abutment teeth or symmetrical to residual teeth on the other side of the jaw (Fig. 1). We could thereby shorten or harmonize the length of free end tissue (saddle) for better force distribution. This concept was based on the findings of Aviv *et al*.,[44] who reported that when residual ridges had unequal lengths, the axis of rotation may not be perpendicular to the residual ridges that were unfavorable. Consequently, anteriorly positioned few implant surveyed crowns in class I RPDs, to improve appearances of patients and reduce free end length for balanced physiologic force distribution,[45] can be considered as a viable treatment modality for patients with anatomical and socioeconomic limitations

PROMs after delivery of IC-RPDs and mechanical complications in IC-RPDs were also evaluated and our second null hypothesis was disapproved. Significant functional and esthetic improvements with IC-PRD in both maxilla and mandible were observed, showing greater functional improvement in the mandible (Fig. 4). That might attribute to greater additional support (rest), retention (retentive arm) and stabilization (proximal plate) of RPD owing to implant surveyed crowns in mandible, which has less tissue support compared to the maxilla that already had enough support and retention by a large major connector covering palate.

Although the placement of implants improves the stability of dentures and dissipates stress in residual tissue, it adds stress to implants, the metal framework and resin of the RPD.[42,46] This means that more stresses to implants and increased occluding force in IC-RPDs might incur more frequent prosthetic complications than in conventional RPD. In the present study, 7 prosthetic complications in maxilla and 12 prosthetic complications in mandible were encountered. The most frequent complications were adjustment of the retainers of RPDs in both groups, followed by denture base relief due to sore spots. Denture repair was not frequent and no denture fractures were observed. The maintenance of OD type of IARPDs have been re-

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ported frequently, resulting in the need for high maintenance fee because of frequent change of various attachments or other repairs.[47] In the present study, mechanical complications of IC-RPDs were not frequent and had the advantage that could be resolved by easy chairside manufacturing process. However, two abutment teeth showed mobility due to PDL space widening and one abutment tooth was treated endodontically due to apical periodontitis.

Abutment tooth failure due to crown fracture in maxilla and periodontitis in mandible was noticeable among complications of IC-RPDs in partially edentulism. Therefore, we additionally analyzed the prognosis of abutment teeth in IC-RPDs. Sixty teeth (27 maxillary teeth, 33 mandibular teeth) among residual teeth were used for abutment teeth as surveyed crowns or after natural tooth alteration (NTA). The survival rates of all abutment teeth were 96.6%; 96.2% in maxilla and 96.9% in mandible.

There was greater bone loss of abutment teeth in maxilla compared to mandible (P = .004). One single abutment tooth occluding mandibular natural tooth failed because of post and crown fracture, and two splinted abutment teeth experienced mobility due to PDL space widening in maxilla. Furthermore, one terminal abutment tooth adjacent to residual teeth was also extracted due to periodontitis even though oral hygiene (OH) was adequate, and one isolated single abutment tooth showed apical periodontitis in mandible (Table 5). Those five abutment teeth in IC-RPDs were assumed to experience excessive loading, considering they were all used as occluding stops biting implants or natural dentition.

The mean bone loss of abutment teeth had no statistical difference according to splinting of abutment teeth (P = .456). However, according to type of used retainer (abutment teeth with direct retainer vs. abutment teeth with only indirect retainer), there was a statistical difference (P = .006). In this study, the terminal abutments with direct retainers showed greater bone loss than abutments with indirect retainers which were adjacent to other implants or teeth. This is assumed to be due to flexion and distortion of RPD along the fulcrum line. Lateral force could be produced higher in terminal abutment teeth with direct retainer compared to abutment teeth with only indirect retainer more vertically forced. There are limitations of dfferences in the observation period and inaccuracy of panoramic radiograph used to derive proportional equation for calculation of actual bone loss around abutment teeth compared to actual implant length. Although bone loss of abutment teeth was irrelevant with the observation time period in this study according to Spearmans's correlation analysis (P = .812), the bone loss comparison among abutment teeth for the same period would be needed. The highly qualified study of bone loss comparison between abutmnet teeth with different type retainers would also be needed.

Additionally, the mean MBL of implants (0.82 ± 0.93 mm) were statistically different with the mean bone loss of abutment teeth (0.29 ± 0.25 mm) at the end date of observation (P = .001). Previous study has demonstrated that both stresses and strains were considerably higher in the bone surrounding the implant compared to the bone in the vicinity of the natural tooth due to PDL.[48] The lesser bone loss around abutment teeth can be explained by this but the survival rate of abutment teeth (96.6%) was lower than that of implant surveyed crowns (100%) in present study. This could be also attribute to the existence of PDL around natural teeth. For implants, there is no mobility unless they are ill by severe bone loss apically, so they can be recorded as survival. However, natural teeth with substantial bone loss showing mobility commonly result in pain and cannot act as abutment teeth for RPD. Also, clinicians usually encounter more frequent fracture of endodontically treated natural tooth than implant.

Several clinical benefits of IARPDs claimed in previous studies are increased retention of the denture, limiting lateral and vertical displacement of IARPDs, efficient distribution of masticatory forces along the IARPDs and remaining teeth, and reduction of bone resorption below the distal base saddle.[49] IC-RPDs, which are IARPD with implant surveyed crowns, can be helpful to make stable implant and teeth occlusal stops in crossed occlusion, leading to comfort and stability of temporomandibular jaw. Taken together, the results of previous studies and of the present study indicate that IARPD especially IC-RPD can be a viable treatment modality.

However, we must admit the limitation of this study was associated with the small number of sample size and different observation time periods. Furthermore, several associated variables affecting prognosis of implants and abutment teeth in IC-RPDs were not all identified, including OH, bite force, inclination of implants and abutment teeth. IC-RPDs was still in the preliminary stage of clinical practice. A further controlled study on IC-RPD with a larger sample size and longer period of time is needed.

CONCLUSION

The survival rate of implants in IC-RPDs was 100% for periods up to 74 months. MBL of 85.7% implants in IC-RPDs were at successful levels of less than 1.5 mm throughout the follow-up period. Assessment of PROMs indicated improved functional and esthetic results after IC-RPD treatment ($P < .001$) and prosthetic complications were not observed frequently. The mean MBL of implants was statistically higher than the mean bone loss of abutment teeth in same IC-RPD ($P < .001$). The survival rate of abutment teeth was observed as 96.6%, which was lower than that of implants. Within the limitations of retrospective studies, anteriorly positioned implants used as surveyed crowns with class I RPDs could be an effective treatment modality for patients who had anatomical limitations. Studies with long-term randomized clinical trials focusing on both implants and abutment teeth are needed.

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