Original Article

Clinical evaluation of marginal bone loss of implant-crown-retained removable partial dentures: A retrospective study

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Running title: implant marginal bone loss of implant-crown-retained removable partial dentures

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Abstract

Purpose: *the aim of this study is to evaluate the marginal bone loss of implants in those patients who had implant-crown-retained removable partial denture (IC-RPDs) reconstruction and to confirm the feasibility of IC-RPDs using for partial or complete edentulous patients.*

Materials and methods: *17 IC-RPDs with 72 implant crowns in 16 patients (8 males and 8 females) were enrolled in the study. Marginal bone loss (MBL) of implants was analyzed based on multiple variables including gender, smoking or not, implant location, restored arch, type of opposing arch, splinting implant crown or not, implant as RPD abutment or not, implant diameter, and bone graft or not. To identify the categorical variables significantly associated with MBL, t-test and one-way ANOVA were used to analysis. Significance level $p < .05$ was used for all tests. G power analysis was used as post hoc test. Power ≥ 0.8 defined as clinically meaningful.*

Results: *During mean follow up period of 63.24 month, 1 of 72 implants failed after functional loading for 24 months. When implants were stratified by gender and bone graft, a statistically significant relation could be observed. No significant difference could be observed in the following variables: smoking or not, restored arch, type of opposing arch, splinting implant crown or not, implant as RPD abutment or not, implant diameter.*

Conclusion: *Implant crown used as abutments of RPD is feasible. For the variables above, implants in bone grafted area showed more MBL than in pristine bone and male showed more MBL than female. However, all of the implants marginal bone loss within the normal limits, except the failure one. Original Article: a retrospective study.*

Key words: implant-crown-retained removable partial denture (IC-RPD); marginal bone loss (MBL)

Introduction

According to a survey by Taiwan's Ministry of Health and Welfare in 2016, patients older than 65 years have an average of 18.61 teeth in the mouth, which means that removable partial dentures (RPDs) are an appropriate treatment option for this cohort. However, the condition of the remaining teeth and residual roots is frequently unsuitable for conventional RPDs. For such people, implant-assisted RPDs (IARPDs) may be an alternative choice.

Implant-assisted RPDs include implant overdentures (IODs) and implant-crown-retained removable partial dentures (IC-RPDs). Implants and RPDs have been used in combination for decades.[1,2] This treatment modality is widely accepted and has excellent outcomes. IARPDs improve prostheses retention, stability, occlusal force, and patient satisfaction.[3–5] The long-term survival rates of IARPDs have been assessed in many studies. In their systematic review of 2021, Wigianto et al. found implant survival rates ranging from 91% to 100%.[6] Bassetti et al. in their 2018 critical review of selected literature found implant survival rates of 91.7%–100%.[7] In addition to their highly successful clinical outcomes, IARPDs are a more economical treatment modality, as only a small number of implants is required to achieve these results.[8–10]

While most previous studies on IARPDs discussed IODs, few considered IC-RPDs. In their 2020 study, Kang et al. compared IODs and IC-RPDs and found that the survival rate of IC-RPDs was higher.[11] In Yoo et al.'s 2021 study, IARPDs for the maxilla and mandible were considered. In the maxilla, the implant survival rate of IC-RPDs was 97.3% and that of IODs was 70.4%; in the mandible, it was 98.3% and 83.1%, respectively.[12,13] Since IC-RPDs have been found to have a better clinical prognosis than IODs in recent studies and their design concept is comparable to that of conventional RPDs, it may be easy for dentists to grasp the principles of this therapy.

The International Congress of Oral Implantologists (ICOI) Consensus Conference for Implant Success in Pisa in 2007 classified the dental implant quality of health scale into four categories: success, satisfactory survival, compromised survival, and failure.[14] The diagnosis of the implant's quality of health category is based on clinical indices of pain, mobility, radiographic crestal bone loss, and probing depth. Unfortunately, when pain or implant mobility is present, removal of the implant is usually indicated. Routine probing is not necessary unless there are signs or symptoms. Radiographic crestal bone loss is easy to determine during routine examination. In addition, the importance of maintaining stable bone levels around oral implants is generally accepted. Adell et al. determined that the mean bone loss for Branemark Osseointegrated Implants was 1.5 mm in the first year.[15] Success criteria established as acceptable include an annual bone loss of less than 0.2 mm in subsequent years without clinical signs of peri-implant infection.[16]

Marginal bone loss (MBL) of implants is a key element in the discussion on implant survival or success. Therefore, the aim of this study was to evaluate implant MBL in patients who underwent reconstruction with IC-RPDs and to confirm the feasibility of using IC-RPDs for partially or completely edentulous patients.

Materials and methods

TPatients treated with IC-RPDs at Taipei Chang Gung Memorial Hospital from 2007 to 2021 and had a regular follow-up were enrolled. All participants wore IC-RPDs for at least 12 months. Patients who had a systemic disease which was under control were not excluded. Sixteen patients (8 males and 8 females) with a total of 17 IC-RPDs were enrolled in the study. Nine of the IC-RPDs were in the maxilla and eight were in the mandible. One patient was treated with IARPDs in both arches. The patients' mean age was 73.2 ± 10.3 years, and the follow-up period was 63.24 ± 45.51 months (a maximum of 196 months). All 72 implants were the same system (BIOMET 3i) and internal connection type and the implant crowns were cement type. Each patient's gender, restored arch (maxilla or mandible), Kennedy classification, the number of implants as RPD abutments, implant diameter (narrow, normal, or wide), whether or not the implant crown was splinted, the need for graft or whether pristine bone, the number of failed implants, and opposing dentition were recorded (Table 1).

Nine of the 17 IC-RPDs were Kennedy Class I modification 1 (53%), seven were Kennedy Class IV (41%), and one was Kennedy Class III (6%). Fifty-four of the 72 implant crowns were RPD abutments. The guiding plane, rest, and the placement of the clasp were designed according to implant location. For example, the implants placed in the maxilla were splinted and designed as RPD abutments (Figure 1). The opposing arch was one of three types: fixed dentition (natural teeth and implants), removable denture (complete denture, overdenture, or RPD),or IC-RPD . Implant diameter was classified as narrow type (< 3.75 mm), normal type (≥ 3.75 mm and < 5 mm), and wide type (≥ 5 mm).

Definition of marginal bone loss

All patients were radiographically examined throughout the different clinical phases and at the time of regular follow-up every year. The momentary rate of MBL around the implant was measured as the difference in bone levels at two visits divided by the number of years between the visits.[17] The time of implant functional loading was calculated as the time elapsed from the time of temporary crown delivery. The times of the two visits in the formula were the time of implant functional loading and the time of the last recall visit. To calculate the actual MBL, we took linear measurements of each periapical radiograph from the most distal and mesial side of the implant platform to the crestal bone. The magnification of the radiographs was corrected in accordance with the actual implant length, and the actual bone level was calculated using the proportional equation shown in Figure 2.

Statistical analysis

Data were analyzed using SPSS Statistics 29.0.1 and G power 3.1.9.7. The t-test and one-way ANOVA were used to identify the categorical independent variables with a significant effect on MBL. The independent variables included gender, whether or not smoking, implant location, restored arch, type of opposing arch, whether or not the implant crown was splinted, whether or not the implant was an RPD abutment, implant diameter, and whether or not a bone graft was performed. The null hypothesis was that there was no relationship between MBL and the above independent variables. The significance level of $p < .05$ was used for all tests. If the null hypothesis was rejected in the analysis of variance, G power analysis was used as the post-hoc test. The power level was calculated using the given sample, the effect size, and the desired significance level. A power of ≥ 0.8 was defined as clinically meaningful.

Table 1. Data on participants and implants (M: Male, F: Female, Mx: Maxilla, Mn: Mandible, V: Yes, X: No, CD: complete denture)

Participants	sex	age (y/o)	restored arch	Kennedy classification	Number of RPD implant abutments	implant diameter			splinting or not	Implant side	Number of nature tooth (restored arch)	follow up period (month)	opposing dentition
						Narrow <3.75	regular ≥3.75, <5	wide ≥5					
1	F	61	Mx	class IV	5	5	4	0	V	V	2	61	Nature teeth + implant
2	M	73	Mx	class IV	6	3	8	0	V	X	0	40	Nature teeth + implant
3	M	53	Mx	class IV	5	2	3	2	V	X	3	196	Nature teeth + implant
4	F	72	Mn	class I mod. 1	2	0	2	0	V	X	3	104	CD
5	M	84	Mx	class III mod. 1	2	0	0	2	V	V	8	118	Nature teeth
6	F	68	Mn	class I mod 1	3	2	1	0	V	V	3	37	CD
7	M	62	Mx	class IV	4	0	4	0	V	V	0	15	Nature teeth
8	F	77	Mn	class I mod. 1	2	2	0	0	X	X	0	36	Overdenture (nature teeth)
9	F	77	Mn	class I mod. 1	1	1	0	0	X	X	4	19	CD
10	F	75	Mn	class I mod. 1	2	0	2	0	X	X	0	40	Overdenture (nature teeth)
11	F	67	Mx	class I mod. 1	3	0	5	0	V	V	1	60	ISRPD
			Mn	class I mod. 1	2				V	V	4	60	ISRPD
12	F	93	Mn	class I mod. 1	2	2	0	0	V	V	2	60	CD
13	M	85	Mx	class IV	3	0	5	2	V	V	3	27	Nature teeth + implant
14	M	66	Mx	class IV	4	0	4	0	V	X	0	27	Implant
15	M	74	Mx	class I mod. 1	4	1	3	0	V	X	0	98	Overdenture (implant)
16	M	84	Mn	class IV	4	2	3	2	V	V	0	77	Nature teeth + implant

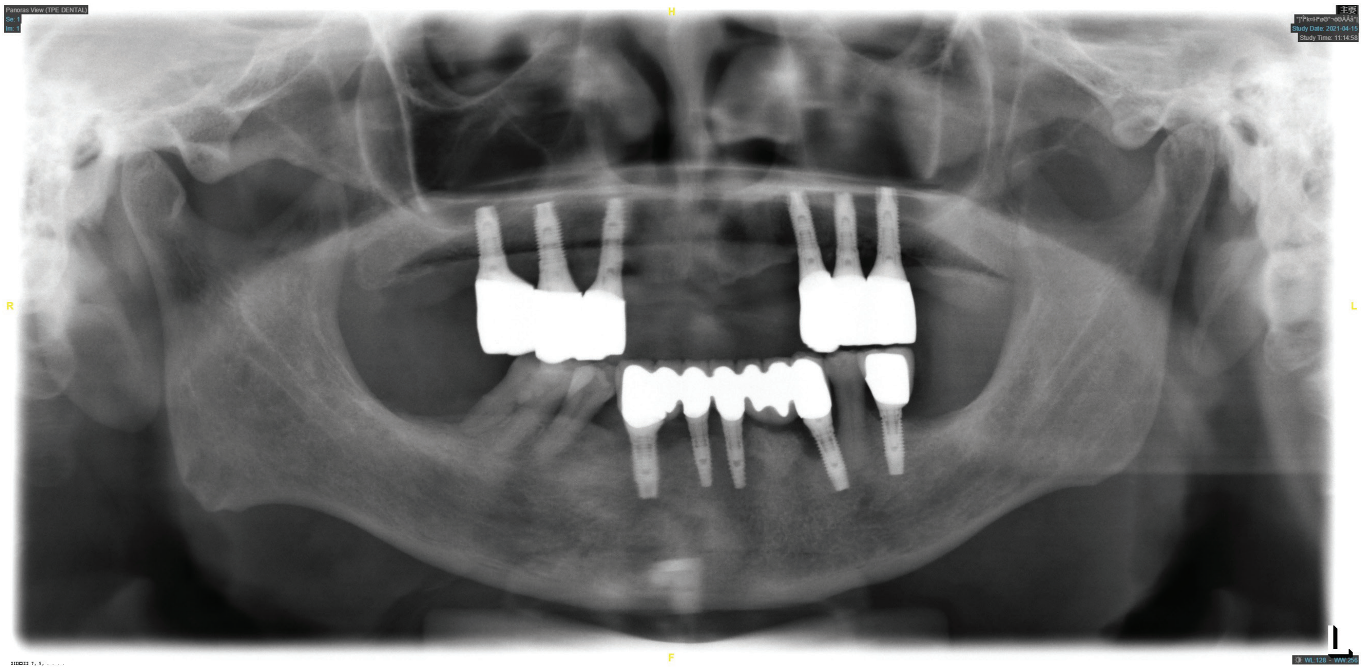

Figure 1. A Case of ICRPD

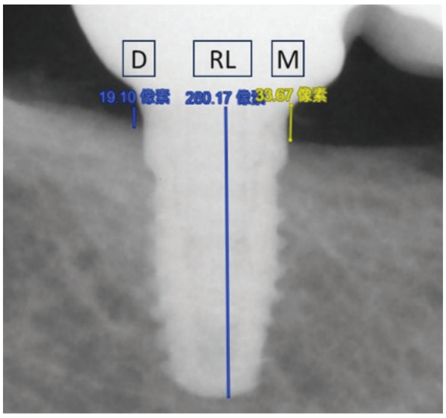

Figure 2.
Definition of MBL (marginal bone loss) around implants

- **M: measure distance from top to marginal bone contact level on radiograph (mesial)**
- **D: measure distance from top to marginal bone contact level on radiograph (distal)**
- **Average bone level (ABL)=** $\frac{M+D}{2} \times \frac{AL}{RL}$
- **AL: Actual length of place implant**
- **RL: Length of implants on radiograph**
- **Momentary rate of marginal bone loss=[(ABL at final visit)-(ABL at implant functional loading)]÷ follow years**

Table 2. Category, number of implants, marginal bone loss, statistical analysis, and power level

	category	number of implants	MBL	statistical	power
(1) Gender	M	45	0.058 ± 0.054	***P= 0.009**	0.5
	F	26	0.037 ± 0.031		
(2) Smoking	Y	11	0.021 ± 0.023	P= 0.022	0.6
	N	60	0.055 ±0.049		
(3) Location	Anterior	15	0.05 ± 0.043	P= 0.959	0.1
	posterior	56	0.05 ± 0.049		
(4) Restored arch	Mx	39	0.042 ± 0.04	P= 0.105	0.4
	Mn	32	0.061 ± 0.054		
(5) Opposing arch	Fixed	32	0.046 ± 0.043	P= 0.561	0.2
	Removable	16	0.046 ± 0.035		
	ISRPD	23	0.059 ± 0.061		
(6) Splinting or not	Y	63	0.049 ± 0.048	P= 0.182	0.2
	N	8	0.068 ± 0.036		
(7) As RPD abutment	Y	53	0.043 ± 0.042	P= 0.064	0.6
	N	18	0.071 ± 0.056		
(8) Implant diameter	Narrow	20	0.05 ± 0.038	P= 0.903	0.1
	Normal	43	0.051 ±0.052		
	wide	8	0.043 ± 0.05		
(9) Graft	Y	20	0.081 ± 0.056	***P< 0.001**	****0.096**
	N	51	0.038 ± 0.038		

* Mean values of MBL showed significant difference based on independent t-test (< 0.05).
** Post hoc power analysis showed clinically meaningful
(M: Male, F: Female, Y: Yes, N: No, Mx: Maxilla, Mn: Mandible, MBL: Marginal bone loss)

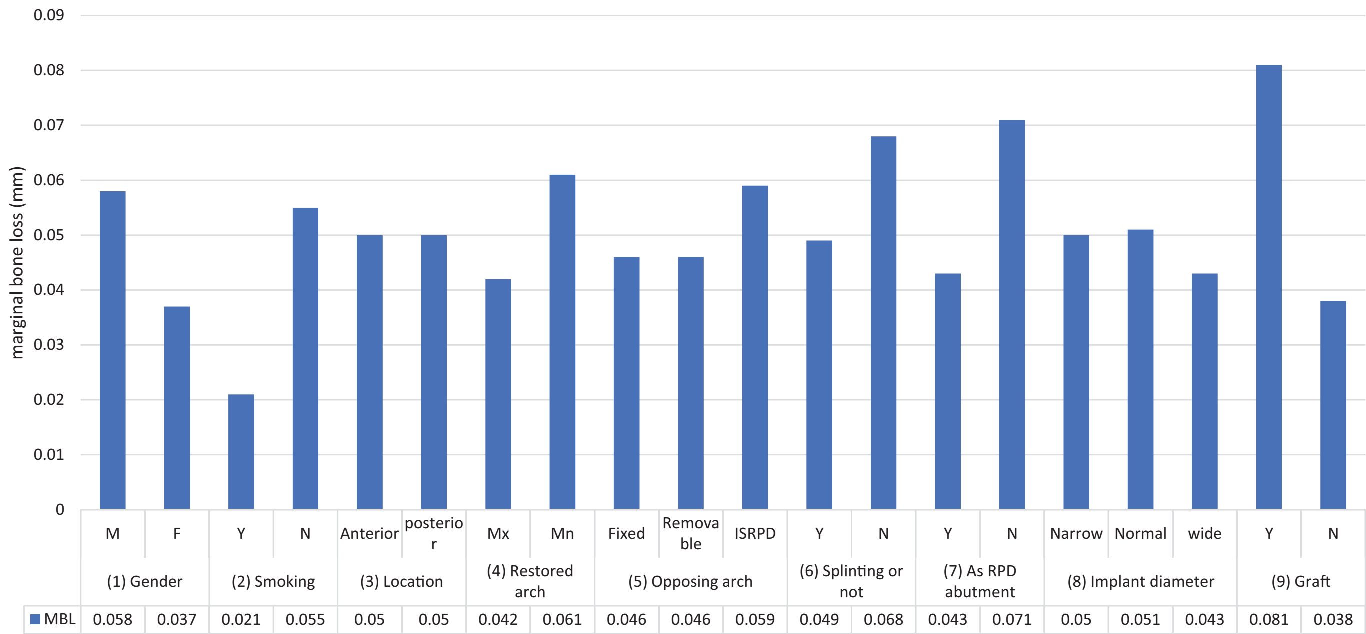

Figure 3. The average level of MBL for each of the main variables (M: male, F: female, Y: Yes, N: No, Mx: Maxilla, Mn: Mandible)

Results

ODuring the observation period, one of the 72 implants failed due to peri-implantitis after functional loading for 24 months. The 71 successful implants were analyzed in this study. The mean values and standard deviations of implant marginal bone resorption associated with different factors are shown in Table 2. Gender and MBL showed a significant association. The MBL of males (0.058 ± 0.054 mm in 45 implants) was significantly higher than that of females (0.037 ± 0.031 mm in 26 implants). No significant differences in MBL were observed for the following factors: whether or not smoking, restored arch, type of opposing arch, whether or not the implant crown was splinted, whether or not the implant was an RPD abutment, and implant diameter.

When implants were stratified by whether or not a bone graft was performed, a statistically significant relationship with MBL was observed. In this study, a bone graft meant guided bone regeneration, sinus lift, or both. A statistically significant result was obtained, which was shown to be clinically meaningful in the power analysis (power = 0.96). The average level of MBL for each category of the main independent variables is shown in Figure 3.

Discussion

Factors influencing marginal bone loss

The purpose of the present study was to evaluate the effects of gender, smoking, insertion side, type of opposing arch, crown splinting, implant as RPD abutment, implant diameter, and bone graft on marginal bone resorption around implants after functional loading. The reasons for MBL are still debated. The main hypotheses are infection and overloading.[18] However, it is clear that MBL is an important parameter of implant success.

Koller at el. classified the factors that influence the MBL of implants into three categories: (a) periodontal condition around implant, including plaque index, sulcus bleeding index, and probing pocket depth; (b) implant–prosthetic evaluation, including location, splinted or single crowns, cemented or screwed type, bone graft, and implant diameter, length, and type; and (c) occlusion design, including the size of occlusal platform, angle of cusps, static and dynamic movements, and region of the implants.[19] In addition to the three categories above, the patient's systemic factors (age, gender, and genetics) and social factors (socioeconomic status, oral hygiene, and stimulant consumption) may play an important role.[20,21]

All patients in the present study underwent reconstruction with IC-RPDs at least on one side. Most of the implant crowns used were RPD abutments. This study focused on implant prosthetic evaluation and the patient's systemic factors to determine effects on MBL. We did not consider the occlusal scheme because all the cases were planned as mutually protective occlusion or balancing occlusion according to the design of conventional removable dentures.

Gender and bone graft as factors affecting MBL

Most previous studies did not show a difference in MBL between males and females.[13,22–24] Some studies showed that the MBL of males was higher than that of females, but this difference was not statistically significant.[22–24] In contrast, other studies found that females had more MBL.[25,26] In this study, the MBL around implants was significantly higher in men than in women. According to Negri al el., MBL progressively increases with age in males, but reaches a peak in the 50–60 year age group in females.[23] The age distribution of females in this study's population was 61–93 years. Age was not included as a factor because most of the population in this study was older. In addition, 16 of the 45 implants in males involved a bone graft compared to only 4 of the 26 implants in females.

Bone graft was another factor in the study with a significant effect on MBL, a result with high power in the post-hoc analysis. MBL was higher in augmented bone not only during the implant functional loading period but also during the submerged implant healing stage.[27] However, most previous studies do not support a relationship between MBL and bone graft.[28–30] A three-year retrospective cohort study concluded that MBL mainly occurred during the first 12 months after functional loading, and was lower in subsequent years.[31] In early MBL, implants in sinus-grafted areas lose significantly less bone than those placed in pristine bone.[32] One of the reasons for this study's result is likely to be bone materials; in the cases of localized defects or insufficient bone height, synthetic substitute material (SinboneHT) and the implant were placed simultaneously. In contrast, in some of the studies discussed above, the xenogenic bone substitute was mixed with autogenous bone.

A cluster effect in marginal bone resorption meant that some patients show a tendency to several implants being affected in the mouth.[18] This effect was also seen in this study. Some patients with a higher number of implants with bone graft showed a higher MBL. This might be another reason for the higher MBL in the graft area.

Opposing arch as a factor affecting MBL

In this study, the opposing arch was classified as fixed, removable, or IC-RPD. These types did not differ significantly in their effect on implant MBL when one arch was restored with an IC-RPD. Some previous studies came to the same conclusion.[24,33] Yoo et al. differentiated dentition into five groups: natural teeth, implants, IODs, RPDs, and complete dentures (CDs). When the maxilla is restored with an IOD and the mandible is restored with implants, the maxilla shows a high level of MBL. In contrast, MBL is relatively low when both arches are reconstructed with implants.[13] Fixed dentures may lead to high occlusal force, resulting in greater MBL in the opposing arch. In eight cases in this study, the opposing dentition consisted of natural teeth or natural teeth combined with implants. Compared to IODs and CDs, IC-RPDs might be able to bear a higher occlusal force, thus resulting in less MBL.

Implant as RPD abutment as a factor affecting MBL

No significant difference in MBL was found between a normally fixed implant and the implant crown used as an RPD abutment. As previous studies tended to focus on implant overdentures, few considered IC-RPDs.[34, 35] In the present study, the use of the implant crown as an RPD abutment was feasible. In this study, most implants used as an RPD abutment were placed in the posterior area for better RPD support and chewing function. Most implants were splinted to resist the horizontal force of the RPD. No implant crown loosening after permanent cementation occurred. The chipping of the porcelain in two implant crowns was noted; there was no discomfort after the chipped area was rounded.

Smoking as a factor affecting MBL

There is evidence that smoking causes higherMBL.[36–38] In light smokers (< 10 cigarette/day), the correlation between the degree of smoking and the degree of MBL is positive.[39] However, the smoking dose was not recorded in this study. In a longitudinal study comparing individuals who had given up smoking for 10 years and those who smoked regularly, the progression in bone loss was significantly slower in the former.[40] The MBL of a patient in our study who had quit smoking for more than 30 years was lower than that of regular smokers.

Other factors affecting MBL

Implant location or restored arch did not have a significant effect on MBL, a result similar to those in previous studies.[13, 26] One study did not find a difference in MBL, but the probing depth was greater in the maxilla,[33] while in another, MBL was greater in the maxilla, but no statistically significant effect of implant crown splinting in the maxilla was found.[41] In this study of only eight solitary implants (two in the maxilla and six in the mandible), the majority of the implants were splinted, which might have resulted in the lower MBL in the maxilla. However, most previous studies found that splinted or solitary implant crowns did not have a significant effect on MBL.[42,43] A proper prosthesis design is crucial. The splinted implant should be designed with a crown emergence angle of < 30° and a concave emergence profile on both the mesial and the distal side.[44] Even with a proper design, the middle implant of multiunit splinted implants has a high risk of peri-implant disease.[45] Therefore, the number of splinted implants should be considered.

In this study, most implants were splinted, of normal diameter, and in the posterior area.The IC-RPDs had a good clinical outcome, with high stability and retention and improved chewing effect compared to conventional RPDs. The limitations of this study include the small number of samples and the short follow-up period of some patients. In addition, not all factors affecting implant MBL were assessed, including bone type, bone quality, implant stability quotient, and the patient's oral hygiene. High disparity between samples might have led to outcome bias. Therefore, future studies on IC-RPDs should involve larger sample sizes and longer follow-up periods.

Conclusion

Based on the findings of this clinical study, the following conclusions may be drawn: (1) the use of implant crowns as RPD abutments is feasible; (2) implants in bone-grafted areas showed higher MBL than implants on pristine bone; and (3) males showed higher MBL than females.

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