Clinical Outcomes of Posterior Implants with Surveyed Crowns for Implant-Assisted Removable Partial Dentures: A Retrospective Study

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Purpose: To evaluate the clinical outcomes of posterior implants with surveyed crowns in implant-assisted removable partial dentures (IARPDs). ***Materials and Methods:*** Internal-connection implants were inserted and restored with surveyed crowns at the most posterior molar regions of Kennedy class I or II in partially edentulous patients between 2007 and 2018. IARPDs were fabricated and functioned with or without clasps on the surveyed implant crowns. Clinical outcomes of biologic problems, mechanical problems, and marginal bone loss (MBL) through periapical and panoramic views were recorded and measured. The effects of sex, Kennedy classification, opposing dentition, and clasp existence on MBL were analyzed using Mann-Whitney test, and the implant length, crown-to-implant (C/I) ratio, and function period on MBL were analyzed using a multiple regression analysis at α = .05. ***Results:*** A total of 32 posterior implants were restored with a surveyed crown for IARPDs in 16 patients (7 men, 9 women; mean age: 69.3 ± 6.0 years). A total of 15 IARPDs were for the mandible (1 maxilla), and 13 were Kennedy class I (3 class II) before implant insertion. All internal-connection implants (15 bone-level and 17 tissue-level) with 7-mm (n = 12), 8.5-mm (n = 18), and 9-mm (n = 2) lengths were restored for 3 surveyed premolar crowns and 29 molar crowns (15 first molar and 14 second molar). The mean C/I ratio was 1.48. The mean function period of the implants was 60.9 ± 40.2 months (range: 14 to 155), and the mean MBL was 0.11 ± 0.36 mm. Only Kennedy class II showed significantly more MBL (*P* = .002). The implant survival and success rates were 96.9% and 90.6%, respectively. ***Conclusion:*** Within the limitations of this retrospective clinical study, mainly in mandibular IARPDs, implants with surveyed crowns showed high survival and success rates during short- to medium-term functions. Posterior implants with surveyed crowns appear to be a reliable alternative for free-end removable partial denture (RPD) patients.
Int J Oral Maxillofac Implants 2023;38:53–61. doi: 10.11607/jomi.9761

Keywords: dental implant, implant-assisted removable partial denture, marginal bone loss, surveyed crown, survival rate

The application of dental implants to partially edentulous patients with removable prostheses is gradually increasing, and it is reported as a simple and cost-effective successful method for arches with few remaining teeth.[1–4] It is particularly noteworthy that the survival rate of implant-assisted removable partial dentures (IARPDs) has increased through the use of a small number of implants, compared to that of conventional removable partial dentures (RPDs). In a critical review,[3] the IARPDs showed remarkably high survival rates, with eight included studies having rates of 100% and only one study 90%. The authors reported that survival rates of conventional RPDs were 77% after 8 to 9 years and 71.3% after 10 years.

The fundamental disadvantage of distal-extension conventional RPDs is the lack of stability and retention, which results in food retention under the saddle, and eventually, the discontinued use of RPDs due to pain and discomfort. Additionally, the tissueward movement of the flange due to the lack of distal support causes destructive rotational forces that adversely affect the anterior abutment teeth.[5,6] Accordingly, it not only results in a short wearing time for RPDs, but also leads to the requirement of new RPDs.

In contrast, posterior support of implants for IARPDs has many advantages.[6–8] Implants provide retention and support that improves maximum occlusal force and masticatory jaw movement. Generally, patient satisfaction and oral health–related quality of life (OHRQoL) are improved.[8–10] Moreover, it changes RPDs from Kennedy class I or II to class III, which may prevent ridge resorption and reduce stress to the natural abutment.[6,11] In previous crossover studies of conventional RPDs and IARPDs,[10,12] greater occlusal force and greater area of occlusal contact appeared in IARPDs,[12]

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Submitted November 15, 2021; accepted March 13, 2022.

and OHRQoL was improved in IARPD patients.[10] These results were also evident in a meta-analysis. General patient satisfaction was increased, and improved mastication was remarkable. Oral health impact profile (OHIP) scores, physical pain, and psychologic disability were improved. The maximum occlusal force, active occlusal contact area, and mandibular jaw movement also improved with mandibular IARPDs.[8] Above all, it is a highly cost-effective treatment modality, as a small number of implants can provide this effect.[1,4]

This successful clinical outcome of IARPDs presupposes the high survival rate of implants. First, careful case reports on the application of implants to RPDs were dominant.[13–15] Later, various methods of in vitro studies were conducted to analyze stress and to predict the success of implants applied to RPDs including the finite element method (FEM),[16-21] photoelastic model,[11] strain gauge,[19,22] and calculation.[23] Through these studies, stress concentration under various conditions, such as the form of superstructures,[16-18,21] implant position,[18-21,23] implant length,[20] and attachment type,[17,22] have been compared and predicted for proper implant application protocols. Simultaneously, clinical studies in conjunction with in vitro methods have also demonstrated the high success and survival rates of implants used for IARPDs.[1,3,10,24-28]

Most of the clinical reports of IARPDs have applied implants as an overdenture type,[5,9,10,12,24,25,27,29] and occasionally the telescopic double crown type.[3] In contrast, reports of success or survival rates of implants with surveyed crowns of IARPDs are quite limited. The implant abutment with the surveyed crown is familiar to dentists due to the same concept as conventional RPD natural tooth abutments. Additionally, it is a method that uses a small number of implants and is easily accessible at a low cost, as in overdenture-type IARPDs. Therefore, studies on the prognosis of IARPDs using implant-supported surveyed crowns are required with rapidly increasing clinical cases.

There are still some concerns about IARPDs in the form of a surveyed posterior implant-supported crown compared to the overdenture type:

- There are anatomical limitations when placing implants in the posterior region, such as the second molar area of the mandible and posterior region of the maxilla.
- The lateral force of the RPD clasp on the implant with the surveyed crown cannot be excluded.
- It is questionable whether the single posterior implant plays a role in supporting the vertical dimension while enduring the force delivered from the RPD because the structural rotational movement of the distal-extension RPD can produce terminal torquing forces.

In studies of FEM models of implants with surveyed crowns, implants for IARPDs showed high stress concentrations, and the authors concluded that the use of implants with surveyed crowns was not a viable treatment option.[16,17] Although the successful application of implants with surveyed crowns has been reported in a few clinical studies,[28,30] the data are still insufficient, and there are many things to be studied: few comparisons of the results of internal-connection vs external-connection implants, marginal bone loss (MBL) from stress concentration, and success or survival rates with complications. No concerns regarding the evaluation of the crown-to-implant ratio (C/I ratio) have been reported.

This clinical retrospective study aimed to examine the possibility of applying a posterior implant with a surveyed crown as a general IARPD modality by evaluating the clinical outcome, survival, and success rates of implants and IARPDs.

MATERIALS AND METHODS

From 2007 to 2018, patients who received posterior implants in a partially edentulous area and were restored with a surveyed implant-supported crown for IARPDs by a dental prosthodontic specialist (T.W.J.) at a private clinic were enrolled. The inclusion criteria were as follows:

- Patients without systemic disease or osteoporosis affecting bone metabolism
- Patients who were willing to use or already using RPDs, with distal-extension RPDs of Kennedy class I and II
- Patients who wanted to improve the function of conventional RPDs by providing a minimum number of implants
- Bone volume permitting the placement of implants with a minimum length of 7 mm and a minimum diameter of 4 mm without guided bone regeneration (GBR)

To change the Kennedy class I or II RPD to a class III RPD, the primary implant site selected was the second molar region as long as no GBR was possible. In many cases, the old RPD that patients had used was required to continue to function during the healing period; therefore, sufficient bone width without GBR was needed to avoid the interference of bone healing. When the second molar region was not appropriate, the first molar region was selected instead. Short implants (7 mm) were used where the residual ridge height was limited; however, implants of 8.5 mm or more in length were selected as often as feasible.

Table 1 Patients (Implants) and IARPD Information

Variables	No.	No.
Sex	Male, 7 (n = 13)	Female, 9 (n = 19)
Location	Maxilla, 1 (n = 1)	Mandible, 15 (n = 31)
Kennedy classification	Class I, 13 (n = 29)	Class II, 3 (n = 3)
Implant type	Internal bone level, 7 (n = 15)	Internal tissue level, 9 (n = 17)
Implant length	7 mm (n = 12), 8.5 mm (n = 18), 9 mm (n = 2)	
Opposing dentition	Fixed, 7 (n = 14)	Removable, 9 (n = 18)
Presence of clasp	Clasp, 10 (n = 21)	No clasp, 6 (n = 11)
Crown material	PFM, 15 (n = 30)	Gold, 1 (n = 2)
Type of abutment	Ready-made, 15 (n = 30)	CAD/CAM, 1 (n = 2)
Type of crown retention	Screw/cement combination–retained, 10 (n = 23)	Cement-retained, 6 (n = 9)
Cement	Resin-modified glass ionomer, 16 (n = 32)	

PFM = porcelain fused to metal.

The implants used in this study were all internal-connection implants (bone- or tissue-level implants). Efforts were made to prevent horizontal load by placing the implant at the alveolar crest perpendicular to the occlusal plane, as recommended by the manufacturer to avoid inclination. If the primary stability was satisfactory after insertion, the healing abutment was connected to the implant for one-stage surgery. When the old RPD was used during the healing period, the inside of the denture flange was relieved and the tissue conditioner (Co-comfort, GC) was relined to enable immediate loading. The tissue conditioner was changed weekly during the first month and adjusted only to support denture flange the next month. Two months after surgery, the success of the osseointegration was evaluated, and the new prosthesis was made. A full-mouth impression was taken using an individual tray and the pick-up impression coping, and jaw relation was recorded with Aluwax (Aluwax Dental Products) onto the ready-made jig abutment for bite registration (Bite Index, Osstem). Since most of the patients were conventional RPD users, if necessary, anterior natural teeth were restored with surveyed crowns or altered additionally, and along the insertion path of this survey line, posterior implants were restored with surveyed crowns (Table 1). All implant-supported surveyed crowns were adjusted to evenly occlude contact with the opposing dentition. Functional impression for IARPDs was obtained after confirming the occlusal relationship of the surveyed implant-supported crown in the oral cavity. The fit of the RPD framework was adjusted, and the jaw relation was registered using a conventional method. Considering the coronal height, profile, and survey line of the surveyed crown, in some cases, clasps were designed, and in other cases, they were omitted. In the early cases, clasps were often designed for retention and stability (Fig 1), and as one implant failed, a nonclasp design using long rest and rotational path was applied more (Fig 2).

After delivery of IARPDs, hygiene control, occlusion, retention and stability, and clinical symptoms were examined through periodic follow-up, and MBL was evaluated simultaneously using serial panoramic and periapical radiographs. Follow-up was performed every 3 months in the first year and every 6 months to 1 year thereafter. Patients whose IARPDs were in function for over a 1 year and who had follow-up records were included in the study.

Clinical assessments of biologic and/or mechanical complications, such as peri-implant inflammation and screw loosening, were recorded and analyzed. The C/I ratio is the ratio of the length of the restoration to the length of the implant and was calculated based on the fulcrum at the most coronal bone-to-implant contact. MBL was the marginal bone loss that occurred during the function period based on the bone level of the loading time and was calculated by enlargement ratio using a proportional formula considering the implant thread pitch (0.8 mm) in the periapical radiographs.

The statistics of several factors for the MBL were performed. Mann-Whitney nonparametric analysis was performed to check the effect of sex, implant type, Kennedy classification, opposing dentition, and clasp design on MBL after confirming the normal distribution of MBL with Shapiro-Wilk normality test ($\alpha = .05$) using SPSS 25 (SPSS). The relationship between implant length, C/I ratio, and functional months and MBL was determined by multiple regression analysis ($\alpha = .05$).

The success and survival rates of the implants were then calculated. The general criteria for implant success—that is, bone resorption for the first year should be < 1.5 mm and < 0.2 mm annually in subsequent years without mobility, pain, peripheral radiolucency, and pathologic process—was followed.[31,32]

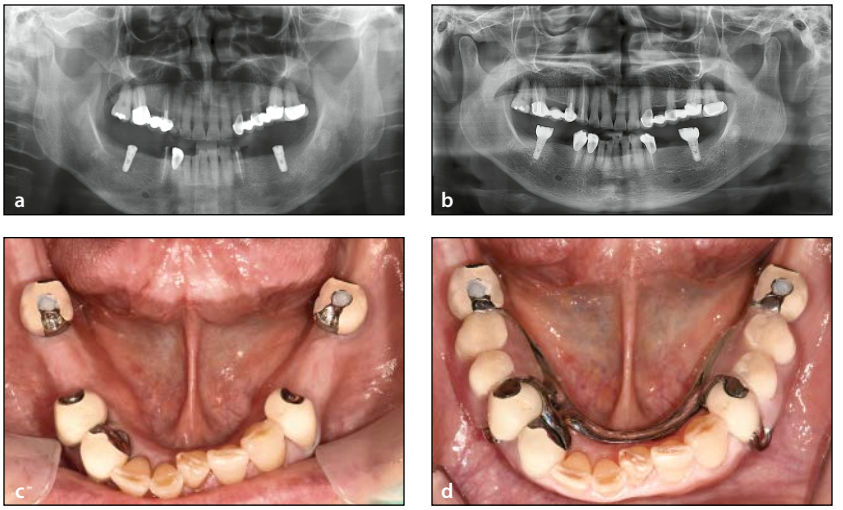

Fig 1 *(a)* Initial panoramic view (July 2016). *(b)* Panoramic view (May 2020). *(c)* Posterior implants with surveyed crowns (September 2016). *(d)* IARPD with posterior implants with surveyed crowns (October 2016).

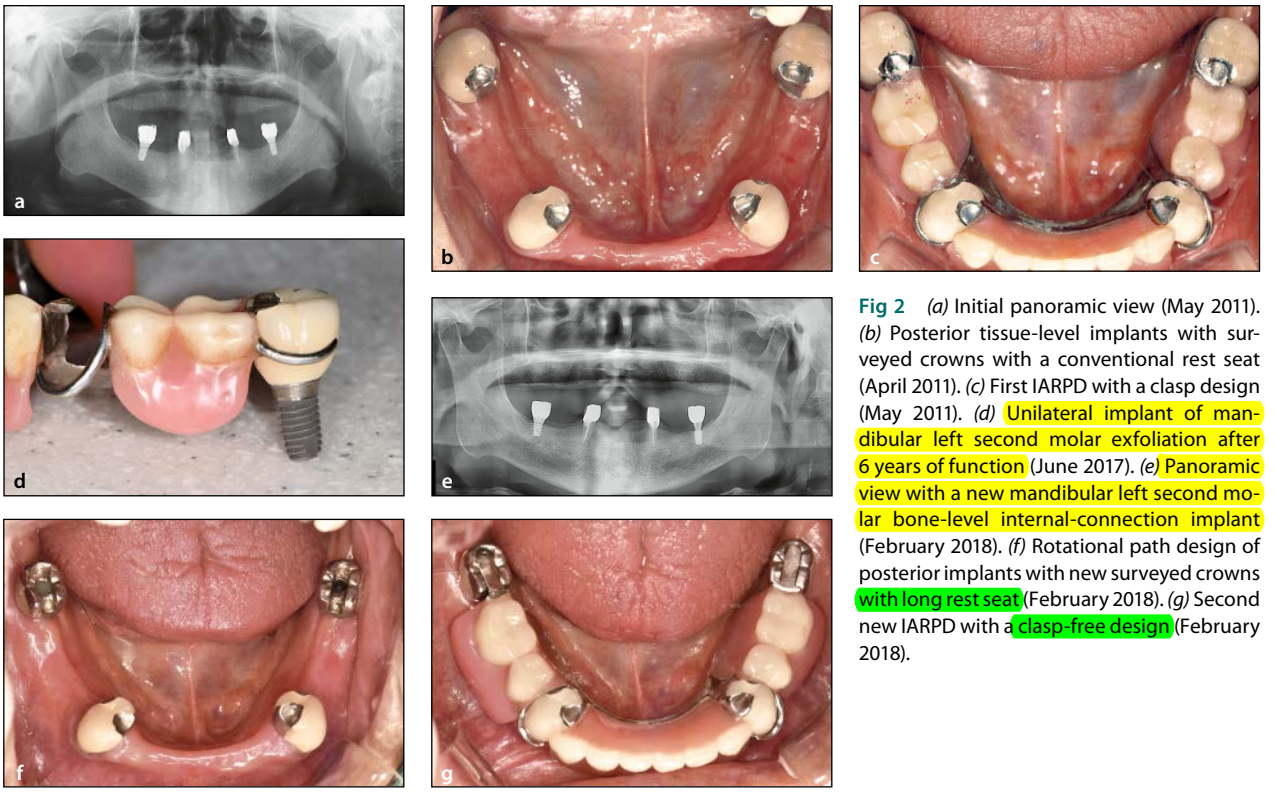

Fig 2 *(a)* Initial panoramic view (May 2011). *(b)* Posterior tissue-level implants with surveyed crowns with a conventional rest seat (April 2011). *(c)* First IARPD with a clasp design (May 2011). *(d)* Unilateral implant of mandibular left second molar exfoliation after 6 years of function (June 2017). *(e)* Panoramic view with a new mandibular left second molar bone-level internal-connection implant (February 2018). *(f)* Rotational path design of posterior implants with new surveyed crowns with long rest seat (February 2018). *(g)* Second new IARPD with a clasp-free design (February 2018).

This study was conducted with the approval of the IRB at Seoul National University Bundang Hospital (B2101-663-105).

RESULTS

The study included 32 implants embedded in 16 patients (7 men, 9 women; mean age 69.3 ± 6.0 years; Table 1). Regardless of the design with or without clasps, IARPDs showed sufficient retention, support, and stability, and the patients did not complain about any discomfort.

A total of 13 patients were Kennedy class I (n = 29; 26 molars and 3 additional auxiliary premolar regions) before implant insertion, and 3 patients were Kennedy class II (n = 3; all molar regions). Only 1 patient had a maxillary RPD (n = 1), and the other 15 had mandibular RPDs (n = 31). For 10 IARPD patients (n = 21), a clasp was designed in the posterior implant with a surveyed crown, and 6 patients (n = 11) received IARPDs with a long rest seat of the crown and rotational path insertion designed without clasps. Of the 10 patients in the clasp-designed IARPDs, in one of the mandibular Kennedy class I categories, the surveyed crown design was changed to

clasp-free after the failure of a unilateral posterior implant; however, this new implant and new IARPD were not included in the statistics. The opposite arch was composed of seven fixed restorations including natural teeth or implants and nine removable restorations.

Of the 32 implants, 15 were internal bone level and 17 were internal tissue level. Except for 2 implants (Osseospeed, Astra Tech), the remaining implants were Osstem bone-level (GS & TS, Osstem) and Osstem tissue-level (SS, Osstem) implants. There were 3 premolars, and the remaining 29 were all molars: 15 first molars and 14 second molars. The implants used mainly consisted of 7 mm (n = 12) and 8.5 mm (n = 18) in length with diameters of 4 mm or more. The 2 Osseospeed implants were 9 mm long. Of the 32 implants, 31 were delayed placements.

The mean function period of implants for IARPDs was 60.9 ± 40.2 months (range: 14 to 155 months). The mean C/I ratio was 1.48. During the function, the mean MBL of the implants was 0.11 ± 0.36 mm.

As a result of analyzing the effects of sex, implant type, Kennedy classification, opposing dentition, and clasp design on MBL, only the Kennedy classification showed significant differences. In Kennedy class II, there was significantly more MBL than in Kennedy class I ($P = .002$). There was no significant difference in bone resorption around the implant according to sex, implant type, opposing dentition, or clasp design ($P > .05$; Table 2). Multiple regression analysis was performed to examine the effect of implant length, C/I ratio, and functional period on MBL; MBL did not show significance according to implant length, C/I ratio, or functional period ($P > .05$; Table 3).

Complications occurred in five patients and six implants (Table 4). Late failure of a 7-mm implant for the surveyed crown in one patient occurred 73 months after function (Fig 2). After the implant was naturally exfoliated, a 7-mm implant was inserted again through a delayed placement procedure. The crowns of both the replaced implant and the contralateral-side implant were changed to a long rest seat design without a clasp. The replaced implant has functioned for 22 months. Peri-implant mucositis occurred in two patients with Kennedy class I: in both the left and right implants in one patient and in the right implant in the other patient. A peri-implantitis sign was observed in one Kennedy class II patient, and 1.4 mm of MBL was observed at 44 months of 51 months in function. Of the 151 months in function in one patient, screw loosening of the right implant-supported surveyed crown was observed at 122 months, and the screw was immediately retightened with 30 Ncm.

The implant survival rate of the posterior surveyed crown was 96.9%, with one out of 32 implants failing to maintain osseointegration. For the success rate calculation of implants, three cases were classified as failures considering the MBL (1.4 mm at 51 months, 0.9 mm at 47 months, and 1 osseointegration failure). Thus, the success rate of implants was 90.6%. IARPDs functioned normally without events in 15 patients, and the survival rate of IARPDs was 93.8%.

Table 2 Mann-Whitney Test of MBL According to Sex, Implant Type, Opposing Dentition, Kennedy Classification, and Clasp Design

Variables		Mean ± SD	*P* value (α = .05)
Sex	Male Female	0.22 ± 0.41 0.06 ± 0.21	.182
Implant type	Internal bone level Internal tissue level	0.12 ± 0.36 0.13 ± 0.27	.823
Opposing dentition	Fixed + implant Removable	0.09 ± 0.25 0.16 ± 0.35	.561
Kennedy classification	Class I Class II	0.05 ± 0.14 0.87 ± 0.55	.002*
Clasp design	Clasp No clasp	0.12 ± 0.25 0.14 ± 0.39	1.000

*Significance (α = .05)

Table 3 Association of MBL with Implant Length, Crown-to-Implant Ratio, and Follow-up Period

Variables	β ± SE	*P* value (α = .05)
Implant length	−0.096 ± 0.071	.19
C/I ratio	0.310 ± 0.253	.23
Follow-up period	0.001 ± 0.001	.62

Table 4 Complications During Follow-up

	Frequency (patient)	Event time (mo)
Peri-implant mucositis	3 (2)	97/36/36
Peri-implantitis	1 (1)	44
Screw loosening	1 (1)	122
Implant fail	1 (1)	73

DISCUSSION

The present study was a clinical and radiographic retrospective study examining the clinical outcomes of posterior internal-connection implants with surveyed crowns used for IARPDs. The survival rate of conventional distal-extension RPDs of Kennedy class I or II, which lack posterior support, is bound to decrease due to the discomfort of the edentulous area and torquing force of the anterior teeth. In contrast, when an implant is positioned in the posterior region and restored with

an IARPD, posterior rotation of the RPD is reduced, and the fundamental weakness disappears. Additionally, by placing implants in the posterior region of the conventional RPD, the burden of the temporomandibular joint (TMJ) could be reduced in the IARPD. In a two-dimensional FEM model of the mandible, posterior support of the implant with the IARPD reduced stress concentration in the glenoid fossa to approximately 20% to 45% of that with conventional RPDs.[33] Ohkubo et al[12] showed that the center of the occlusal force of the IARPD tended to move more distally and was similar to that of an implant-supported fixed prosthesis.

In Korea, with the implementation of the insurance system, each arch of removable dentures can be treated with insurance every 7 years (since 2013), and two implants with abutments of (surveyed) crowns can be covered once in a lifetime (since 2014). The number of cases of insurance-covered IARPDs with implant-supported surveyed crowns is gradually increasing because of easy access to low-cost options.[34–36]

The problem is that there is insufficient evidence to determine the IARPD method: when to apply the surveyed crown and when to apply the attachment type.[37] There have been many comparisons of attachments in overdenture-type IARPDs[12,25,38,39]; however, little information has been reported on the prognosis of IARPDs with implant-supported surveyed crowns. The present study can provide information for indirect comparison of the surveyed-crown IARPDs with overdenture-type IARPDs.

MBL, Implant Type, and Location

Park et al[26] claimed that IARPDs do not impair implant survival rate; however, they affect peri-implant MBL based on the results of clinical studies they reviewed. To date, most of the reports on implant MBLs applied to IARPDs have been the result of overdentures, and the results of Bae et al[30] and Kang et al[28] were based on data from only surveyed crowns to the best of the authors' knowledge. Implant MBLs of earlier clinical studies of IARPDs, including telescopic double crowns, were generally between 1 and 2 mm during the observation period, although some studies showed < 1 mm.[3,26] Surveyed crown-type MBL results showed a similar range of MBLs.[28,30] Kang et al[28] showed overall MBL of 1.3 ± 1.6 mm for implants (1.4 mm for overdenture-type IARPDs and 1.2 mm for surveyed-crown IARPDs) during a mean 47.9 months in 21 patients with 58 implants. A total of 41 implants supporting surveyed crowns were composed of 26 external-connection implants and 15 internal-connection implants. A total of 17 were used in overdenture-type IARPDs. No significant differences in MBL were observed according to the restoration type. Bae et al[30] also compared the MBL of external-connection implants for the overdenture-type and surveyed-crown IARPDs. Of the 53 implants, 28 were used for overdenture support and 25 were used as surveyed crowns. There were significant differences in MBL for implants between overdenture (1.99 ± 0.70 mm for 23.5 months) and surveyed-crown IARPDs (1.44 ± 0.57 mm for 26.7 months).

In the present study, according to the earlier results of fixed restorations,[40–42] internal-connection implants were selected for surveyed-crown IARPDs. In cases of fixed restorations, external-connection implants showed significantly greater linear MBL than internal-connection implants. Vertical MBL of the present study (0.11 ± 0.36 mm) was similar to previous studies of fixed restorations reporting a bone loss of 0.00 ± 0.28 mm[41] and 0.19 ± 0.47 mm,[42] in the internal-connection implant. Recent systematic reviews concluded that crestal bone levels are better when internal types of interfaces are adopted.[43,44]

The MBL of 0.11 ± 0.36 mm in the present study was much smaller than in overdenture-type IARPD studies[3,26] and in previous surveyed-crown IARPD studies.[28,30] It is not clear whether this is the single effect of selecting internal-connection implants or a combined effect with the surveyed crown. In a study of overdenture-type IARPDs, even internal tissue-level implants showed approximately 1 mm of MBL on average 12 months after implant placement around the premolar or molar implants.[5] The only example is the results of a study by Kang et al [28] using 15 internal-connection implants for surveyed crowns, but it is difficult to evaluate accurately because they also used external-connection implants for surveyed crowns. More cases in prospective studies are needed to evaluate the combined effect of internal-connection and surveyed crowns.

In a crossover study that switched the prosthesis implant support position between premolar and molar implants, Jensen et al[5,9] stated that the results of the clinical and radiographic parameters were not different between the two positions in the restoration of overdenture-type IARPDs and that there was no significant difference in masticatory performance. However, the authors stated that the majority of patients preferred the implant support to be in the molar region.[9] Tribst et al[19] showed, in an in vitro FEM study, that a higher stress concentration was observed in the second molar support implant and less stress was observed in the first molar support in the Kennedy class II IARPD model. Alkhodary[45] concluded that the first molar region is a better place for implant support than the second molar region in Kennedy class II with a strain gauge in an in vitro study. In contrast, Kang et al[28] reported no significant difference in MBL according to implant location in their clinical study. Therefore, in this study, the primary location of the posterior implant was the second molar region, but the site with sufficient bone volume that

did not damage the alveolar nerve was selected preferentially.[26] As a result, not only the second molar region but also the first molar region was chosen many times (14 vs 15). The three implants in the premolar region were selected as auxiliary surveyed crowns for better stability in the two Kennedy class I patients. The results of the present study showed that the clinical outcome was not different between the first and second molar regions, indicating that any site can be chosen according to the anatomical condition.

Kennedy Classification, Opposing Dentition, and Clasp Design

In the present study, MBL was investigated according to the Kennedy classification, opposing dentition, and clasp design. The three implants used for Kennedy class II IARPDs showed a significantly large amount of MBL. However, it is difficult to conclude that Kennedy class II is not desirable for surveyed-crown IARPDs because the result was from a limited number of patients. There were no significant differences in opposing dentition. The presence of a clasp was also not related to MBL. Based on these results, it could be that the probability of failure of the posterior single implant with the surveyed crown was low due to the occlusal force of the opposing dentition or the lateral force of the clasp. This indicates that the external occlusal or lateral force on the surveyed crown was insignificant or that the influence of other factors was greater. The clasp-free design with the long rest and the rotational path of the IARPD might not be necessary for low MBL in the surveyed-crown IARPD.

Implant Length, C/I Ratio, Implant Diameter, and Functional Period

Implants of 7 mm and 8.5 mm in length used in this study showed good function. However, the application of short implants to IARPDs was controversial in earlier studies. Gates III et al[10] used 6-mm implants for overdenture-type IARPDs in a prospective study. They reported a 97% survival rate at 2 years of follow-up and concluded that the use of short implants to support IARPDs may be considered. In a 4-year follow-up study of overdenture-type IARPDs, Bellia et al[27] used short wide-diameter implants of 5 or 6 mm in length and reported a 94.3% survival rate. They also concluded that short implants may be considered a viable treatment alternative for patients with reduced mandibular bone. On the contrary, a prospective multicenter study of mandibular IARPDs started seeing late implant failures from 3 years to 10 years predominantly in short implants in the second molar region.[46] The authors reported that all failed implants were short implants of 6 mm in length.

The C/I ratio of the implant for surveyed-crown IARPDs can be an important factor to consider rather than the implant length itself. In the present study, the C/I ratio of the posterior implant with the surveyed crown was a mean of 1.48, which was much lower than that in an earlier study that discussed the clinical threshold of a C/I ratio of 3.4 to avoid excessive bone loss or implant failure.[47] Although a higher C/I ratio could have a negative effect, this ratio was safe for a posterior single implant.

It is also necessary to consider the effect of implant diameter on the failure of IARPDs. Implants with a diameter > 4 mm were used without the GBR procedure in the present study. Although the 6-month follow-up of IARPDs using mini-implants in the premolar region showed a 97.4% survival rate[24] and successful masticatory performance without complication was observed using 3.3-mm–diameter premolar implants during a mean of 7.5 months,[5] use of implants with narrow diameters for IARPDs in the thin horizontal bone is still questionable due to the relatively short follow-up period. Kang et al[28] reported that regular-diameter implants showed a higher survival rate than narrow- or wide-diameter implants.

In general, as the functional period is prolonged, the MBL of the implant increases. In this study, there was no significant difference in the MBL of implants over time during the observation period ranging from 14 to 155 months, indicating high bone stability of a single posterior implant with a surveyed crown.

Survival Rate and Success Rate

In a two-dimensional FEM study, the authors compared different retention systems on a distal-extension RPD with an implant. Of these, implant-supported surveyed crowns showed higher displacement at the implant than in the other models. They concluded that the use of a single fixed implant-supported crown associated with a distal-extension RPD seemed to be a nonviable treatment option.[17] A 3D FEM study also showed similar patterns of von Mises stress on implant abutments in IARPDs. The highest stress was concentrated on the implant.[16]

However, in a retrospective clinical study, survival rates of implants for surveyed crowns were compared to those for overdentures, and there was no significant difference in treatment modality.[28] The authors also reported no significance in the Kennedy classification, opposing dentition, or implant location. The high survival rate of 96.9% in the present study was not different from the results of the overdenture-type IARPD implant.[1–3,10,26–28] In a systematic review of mandibular Kennedy class I or II cases, survival rates of implants for overdenture-type IARPDs ranged from 95% to 100%.[1] In the other review of IARPDs including nine studies, the implant survival rates ranged from 91.7% to 100%.[3] Another systematic review and meta-analysis demonstrated that the weighted mean survival rate of mandibular implants for IARPDs

was 96.60%.[26] In particular, considering that the implant survival rate of Kang et al's IARPD was based on the result that 38 out of 41 implants were splinted crowns,[28] the present study showed a high survival rate even in a much more unfavorable condition of a single posterior implant-supported crown.

Additionally, as in the previous overdenture-type IARPD study, which showed a high rate of 93.75%,[25] the success rate of 90.6% was high in the present study.

Complications

Bassetti et al[3] highlighted that technical complications and maintenance interventions (1,057 events) appeared more frequently than biologic complications (29 events) in IARPDs in their critical review. Kaufmann et al[48] stated that overdenture-type IARPD complications were primarily related to mechanical attachment problems occurring within the first year. In an 8-year retrospective study, the main complication of overdenture-type IARPDs was denture maintenance problems such as denture relining.[25] This tendency appeared to be the same as in other studies.[10]

Complications occurred more frequently in the overdenture group than in the surveyed-crown IARPDs.[30] This was coincident with the complications of Kang et al's study.[28] Complications in overdenture-type IARPDs were 1.8-fold higher than those in the surveyed-crown IARPDs. Dislodgment of the surveyed implant crown (4 out of 16) was the most common complication. In contrast to Kang et al's study, Bae et al[30] stated that the complications of surveyed crowns were not related to implants but general RPD complications, such as resin base relining (4 out of 6) and resin base repair (2 out of 6). In the overdenture-type IARPDs, retention loss (replacement of Locators) occupied an absolute portion, accounting for 14 out of 22 cases. Contrary to expectations, few mechanical complications occurred in the present study. Out of the 6 cases of complications, 4 were biologic complications.

This study has the limitations of a single-sample retrospective study. A comparison between surveyed-crown and overdenture-type IARPDs has to be designed in a future study. More partially edentulous patients of both arches are required to function longer under different conditions, such as different implant connection types, diameters and/or lengths, and Kennedy classifications. Therefore, prospective studies with a large sample size and a long observation period are needed for surveyed-crown IARPDs to establish them as a reliable treatment method for patients with distal-extension RPDs.

CONCLUSIONS

Mainly in the mandible, within the limitations of a retrospective clinical study, IARPDs in the form of implant-supported surveyed crowns showed high survival and success rates during short- to medium-term functions. In particular, a successful clinical outcome with no difference according to the restorative conditions showed that the surveyed-crown IARPD was a stable modality. To improve the function of patients with Kennedy class I and II conventional RPDs, planning posterior implant placement for the surveyed-crown IARPD could be a reliable option.

ACKNOWLEDGMENTS

The authors reported no conflicts of interest related to this study.

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