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Clinical performance of implant-assisted removable partial dentures using implant surveyed crowns: a systematic review and meta-analysis

So-Yeun Kim[1], Young-Eun Cho[2], Seoung-Jin Hong[3], Jung-Bo Huh[4], Se-Wook Pyo[5], Yuseung Yi[6], Soo-Yeon Yoo[7]*

[1]Department of Prosthodontics, School of Dentistry, Kyungpook National University, Daegu, Republic of Korea
[2]Department of Prosthodontics, School of Dentistry, Dankook University, Cheonan, Republic of Korea
[3]Department of Prosthodontics, College of Dentistry, Kyung Hee University, Seoul, Republic of Korea
[4]Department of Prosthodontics, School of Dentistry, Pusan National University, Busan, Republic of Korea
[5]Department of Prosthodontics, Gangnam Severance Dental Hospital, Yonsei University, Seoul, Republic of Korea
[6]Department of Prosthodontics, Seoul National University Dental Hospital, School of Dentistry, Seoul National University, Seoul, Republic of Korea
[7]Department of Prosthodontics & Dental Research Institute, Seoul National University Dental Hospital, School of Dentistry, Seoul National University, Seoul, Republic of Korea

ORCID
So-Yeun Kim
https://orcid.org/0000-0001-6714-8315
Young-Eun Cho
https://orcid.org/0000-0003-0341-2150
Seoung-Jin Hong
https://orcid.org/0000-0002-7460-8487
Jung-Bo Huh
https://orcid.org/0000-0001-7578-1989
Se-Wook Pyo
https://orcid.org/0000-0003-1835-8302
Yuseung Yi
https://orcid.org/0000-0001-9116-2328
Soo-Yeon Yoo
https://orcid.org/0000-0002-5171-6426

Corresponding author
Soo-Yeon Yoo
Department of Prosthodontics & Dental Research Institute, Seoul National University Dental Hospital, School of Dentistry, Seoul National University, 101 Daehakro, Chongno-gu, Seoul, 03080, Republic of Korea
Tel +82-2-2072-2153
E-mail sy0502@snu.ac.kr

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PURPOSE. This study aimed to evaluate the clinical performance of implant-assisted removable partial dentures (IARPD) with surveyed crowns, also known as implant-crown-retained removable partial dentures (ICRPDs). **MATERIALS AND METHODS.** Electronic searches of MEDLINE/PubMed, the Cochrane Central Register of Controlled Trials, the Web of Science, and the Korea Citation Index were performed according to the established search terms for ICRPD. A literature search was conducted for studies published in English or Korean until September 2023, using the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines. **RESULTS.** A total of 216 journals were searched, and 31 eligible studies were selected based on the inclusion and exclusion criteria. One systematic review included five case reports of ICRPD. Nine retrospective studies evaluated implant survival/success rate, implant failure cases, marginal bone loss, periodontal status, clinical complications, and patient satisfaction. Twenty-one case reports published in Korea showed good prognoses. **CONCLUSION.** According to the findings of this systematic review, ICRPD has a reasonable survival/success rate, minimal bone loss, and high patient satisfaction. [J Adv Prosthodont 2024;16:255-66]

KEYWORDS
Implant-crown-retained removable partial detnures (ICRPDs); Implant-assisted removable partial dentures (IARPDs); Implant-surveyed-crowns

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INTRODUCTION

The aging population is growing globally because of sophisticated diagnostic techniques and medical advancements. There is an increase in the number of individuals with ages over 65 years. The decade-long development of dental implants has improved the populations' oral health-related quality of life; however, socioeconomic issues, such as financial challenges, limit the ability to obtain costly dental treatment.[1] Furthermore, substantial bone graft or sinus floor elevation surgery is required in case of insufficient alveolar bone for placing implants, which might be a financial and health burden on older individuals.

Under these circumstances, some older individuals choose removable partial dentures (RPDs) over fixed implant prostheses in areas of missing teeth. However, RPDs can cause discomfort owing to rotation or movement, especially if only a few abutments are left. Therefore, strategic implant placement to increase the number of abutments for better support and retention accommodated by RPD can be a useful treatment option to compensate for the problems of fixed implant prostheses and RPD. In 1991, the clinical application of dental implants into RPD treatment was reported[2] and later referred to as implant-retained RPD or implant-supported RPD and is now referred to as implant-assisted RPD (IARPD).[3]

Two types of treatment are available for IARPDs: one uses implants as surveyed crowns or bridges with rest seats and retentive clasps of RPDs, termed implant-crown-retained RPD (ICRPD) in previous studies,[4-6] while others use implants for attachments such as balls, magnets, locators, and bars beneath the RPD (overdenture-type IARPD). Studies on overdenture-type RPDs, including IARPDs using implant attachment, are numerous.[7-9] However, evidence regarding the clinical performance of IARPD with implant-surveyed-crowns, termed ICRPD, is limited. Consequently, clinicians plan treatment for ICRPDs based on their opinions and experiences.

Therefore, this systematic review and meta-analysis aimed to assess current evidence regarding the clinical performance of ICRPDs. The survival/success rate, marginal bone loss (MBL) of implant abutments, prosthetic problems (implant and RPD), patient satisfaction, and oral health-related quality of life were previously investigated, so we collected clinical evidence based on them. This systematic review was conducted to provide a comprehensive overview of ICRPD currently performed in clinical practice, summarize clinical outcomes, and evaluate future potential.

MATERIALS AND METHODS

This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement and its checklist.[10,11] The critical questions of this systematic review were also elaborated according to the Population Intervention, Comparison and Outcome (PICO) as follows[12]: Population, partially or completely edentulous maxilla and/or mandible with an RPD connected with implant-surveyed-crowns and /or bridges in at least one arch; Intervention, implant-surveyed-crowns and/or bridges for RPD; Comparison, conventional RPD using natural tooth abutments and implants used as attachment system underlying RPD/complete denture (CD); Outcome, survival rates and bone loss of implants used as surveyed crowns, prosthetic survival rates and complications of surveyed crowns/bridges and RPD. The resulting PICO question was as follows: Is there a difference in implant survival rates when implants are used as surveyed crowns compared to the attachment system in partially or completely edentulous patients rehabilitated with RPD connected to the implants?

A flowchart of the systematic review is shown in Fig. 1. The entire process was carried out by two authors (SY and SY), who selected and searched a database together. After removing the duplicate papers and confirming the eligibility by screening in the order of title, abstract, and full text, the following four databases were used to identify studies that satisfied the eligibility criteria: the National Library of Medicine (MEDLINE), PubMed, Cochrane Library, Web of Science, and Korea Citation Index. The following criteria were used to include articles in this systematic review: 1) articles published in English or Korean before September 30, 2023; 2) studies using implants as surveyed crowns connected to RPD; 3) studies evaluating dental implants and residual tissues, including bone, soft tissue, remaining

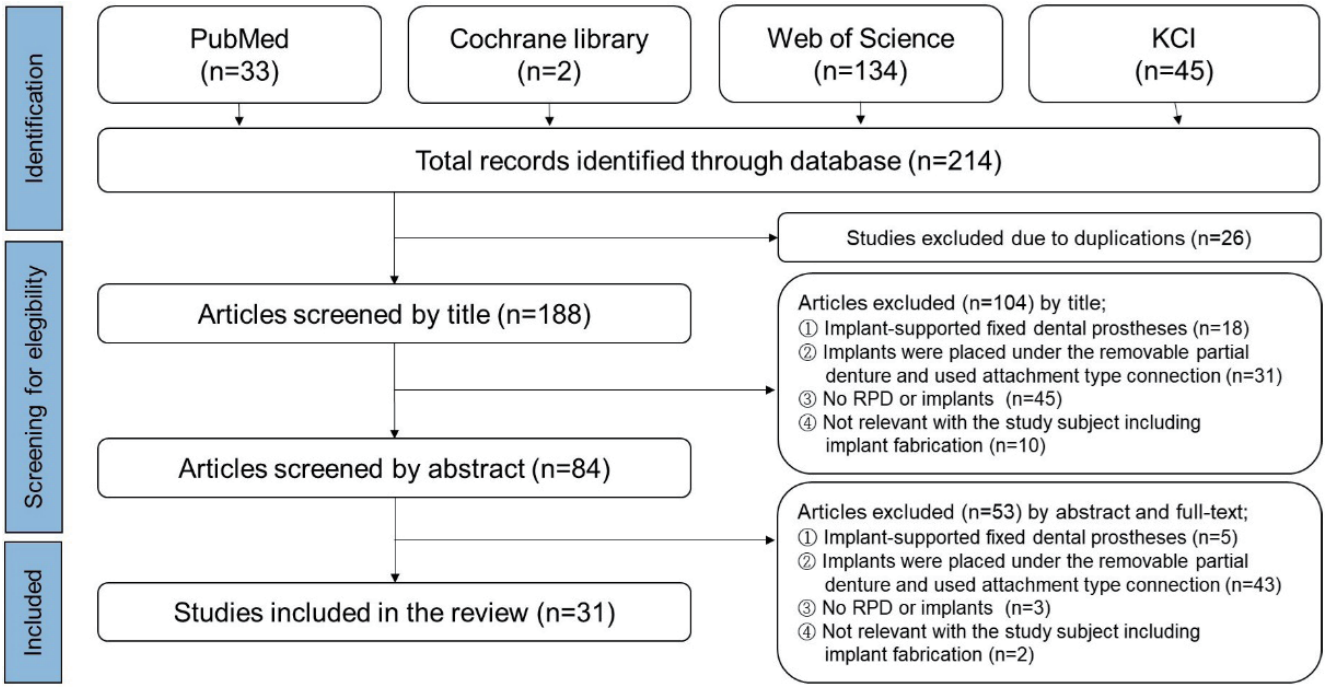

Fig. 1. Flowchart of this study.

teeth, or ICRPDs. The following MeSH and non-MeSH terms were applied using Boolean operators: (((“dental implants” [MeSH Terms] AND (“denture, partial” [MeSH Terms] OR “denture, partial, removable” [MeSH Terms])) OR (“removable” [All Fields] AND “prostheses and implants” [MeSH Terms])) AND (“ICRPD” [All Fields] OR (“ISRPD” [All Fields] OR “implant retained removable partial denture” [All Fields] OR “IARPD” [All Fields]))) OR (“implant assisted removable partial denture” [All Fields] AND (“abutment” [All Fields] OR “abutments” [All Fields] OR “surveyed crown” [All Fields])). The keyword used in the Cochrane library was “implant-assisted removable partial denture.” The keywords used in the KCI were (“Removable partial denture (in Korean)” AND “Implant-surveyed (in Korean)”) OR (“Removable partial denture (in Korean)” AND “Implant fixed prostheses (in Korean)”). In addition to searching these databases, we performed a manual search by checking the references of all identified papers for potentially relevant studies (Table 1).

Table 1. Search strategy for each electronic database

Database	Terms	Search string
National Library of Medicine (MEDLINE) -PubMed, Web of Science (WOS)	MeSH and non-MeSH terms	(((“dental implants” [MeSH Terms] AND (“denture, partial” [MeSH Terms] OR “denture, partial, removable” [MeSH Terms])) OR (“removable” [All Fields] AND “prostheses and implants” [MeSH Terms])) AND (“ICRPD” [All Fields] OR (“ISRPD” [All Fields] OR “implant retained removable partial denture” [All Fields] OR “IARPD” [All Fields]))) OR (“implant assisted removable partial denture” [All Fields] AND (“abutment” [All Fields] OR “abutments” [All Fields] OR “surveyed crown” [All Fields]))
Cochrane library	Keyword	Implant-assisted removable RPD
Korea Citation Index (KCI)	Keywords	(“Removable RPD (in Korean)” AND “Implant-surveyed (in Korean)”) OR (“Removable RPD (in Korean)” AND “Implant fixed prostheses (in Korean)”)

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The data from each study were collected using a spreadsheet. The collected data included author(s)' name(s); publication year; nation; research design; follow-up period; number of patients; design of RPD (rest, clasp, splinting); Kennedy's classification of RPD; presence of natural teeth; implant information (placed numbers, placement position); antagonists of implant crowns; evaluation parameters (dental implants, bone, abutment teeth, and ICRPDs); and occlusal scheme. Scoping reviews do not examine the possibility of bias or heterogeneity of included studies, hence no quality assessments were undertaken.[13,14]

RESULTS

A total of 214 articles were obtained. After checking the titles of the identified studies, 26 papers were excluded owing to duplication. Eighteen studies were removed because they focused on implant-supported fixed dental prostheses, and 31 publications were excluded because all implants in those articles were employed as attachment systems rather than as surveyed crowns. Additionally, 45 articles that did not address RPD or implants and 10 studies irrelevant to the systematic review were excluded. Finally, we evaluated 84 abstracts from the selected publications to determine whether the initially chosen studies fulfilled the inclusion or exclusion criteria. However, five studies were eliminated because they concerned implant-supported fixed dental prostheses, 43 did not discuss implant-surveyed crowns, and three were unrelated to RPD or dental implants. In addition, two studies did not involve implant prostheses. Consequently, 31 studies were considered eligible after extensive discussion and consensus between the two authors (Fig. 1).

The characteristics of the selected studies were as follows: one systematic review (English),[15] including five ICRPD case reports, revealed duplication of data, and only one case report was finally considered valid; 9 retrospective studies (eight English, one Korean; shown in Table 2 and Table 3), 4 - 6,[4,5,16-21] and 21 case reports (all Korean; shown in Table 4 with one case report obtained systematic review article described above).[22-42]

The overall implant survival rates reported in the included studies varied from 95.1% to 100%, whereas the implant success rates ranged from 70.9% to 90.6%. Bae *et al*.[17] and Oh *et al*.[19] reported a 100% cumulative implant survival rate based on the Cochrane criteria for implants in ICRPDs observed for at least one year. In studies by Yoo *et al*.,[4,5] the observed implant survival rates were 98.3% for ICRPDs in the edentulous mandible and 97.3% for the edentulous maxilla. While in Kennedy Class I ICRPDs with the abutment teeth and implant-surveyed-crowns, the survival rate of the implant-surveyed-crowns was 100% for up to 74 months in both the maxilla and mandible.[6]

Kang *et al*.[18] reported an implant survival rate of 95.1% for implant-surveyed-crowns, and this survival rate differed based on implant size; regular-diameter implants showed a higher survival rate than narrow- or wide-diameter implants. Yi *et al*.[20] investigated that ICRPDs with implants adjacent to the abutment tooth in the anterior area had the highest survival rates among the implant-surveyed-crowns. In addition, patients treated in both arches had a higher risk of implant complications than those treated in a single arch. Jung *et al*.[21] reported a 96.9% implant survival rate for implant-surveyed-crowns in the posterior site and an implant success rate of 90.6%.

The reported characteristics of failed implants are as follows: the opposing dentition was fixed dentition[4,16,18] or complete denture (CD),[21] and Kennedy classification included II[16]and III.[21] Tooth locations varied, including canines,[4] pre-molars,[4,5] molars,[16,18,21] embrasure clasps[16,18] and circumferential clasps.[21] Failed implant sizes and lengths also varied, with narrow,[18] regular,[4,5] and wide[18] sizes and lengths of 7,[21] 10,[4,5] and 11.5 mm,[4] respectively.

Kang *et al*.[16] reported the incidence of MBL in implants according to implant location, existence of splinting, clasp type, Kennedy classification, and type of opposing dentition. Bae *et al*.[17] reported that the mean MBL in ICRPD was 1.44 mm, which was significantly lower than that in the comparison group using attachments in IARPD. Oh *et al*.[19] observed a mean MBL of 0.77 ± 0.63 mm in implants for ICRPD after one year of functional loading. Yoo *et al*.[4,5] reported that the MBL of implants of mandibular ICRPD was

Table 2. Main information for research studies

Author	Study design	Year	Nation	Purpose	Implant survival (success) rate	MBL	No. of failed implants	Conclusion
S Kuroshima *et al*.[15]	Systematic review	2023	Japan	To systematically map IARPD research				IARPD treatment may be useful; however, the scientific consensus is limited.
SH Kang *et al*.[16]	Retrospective study	2016	Korea	To identify complications in ICRPD and analyze theirfactors				All ICRPDs functioned successfully during follow-up, yet clinical evidence remains inadequate to ensure long-term prognosis.
EB Bae *et al*.[17]	Retrospective study	2017	Korea	To compare ICRPD and IARPD with attachment	100	1.44 ± 0.57*	0	Well-planned ICRPD was clinically appropriate.
SH Kang *et al*.[18]	Retrospective study	2020	Korea	To investigate survival rates of the implants used in IARPD	95.1	1.2	2	IARPD would be an appropriate treatment option for poor oral conditions and situations.
SY Yoo *et al*.[5]	Retrospective study	2021	Korea	To evaluate ICRPD compared to overdentures in the mandible	98.3	0.93 ± 1.22	1	ICRPD could be considered a viable treatment option for edentulous patients who need few fixed abutments for satisfaction.
SY Yoo *et al*.[4]	Retrospective study	2021	Korea	To evaluate ICRPD compared to overdenture in the maxilla	97.3*	1.12 ± 1.19*	2	ICRPD is a viable treatment for maxillary edentulous patients with anatomical limitations.
YK Oh *et al*.[19]	Retrospective study	2021	Korea	To evaluate complications of ICRPD	100	0.77 ± 0.63	0	Well-planned ICRPDs were clinically successful.
SY Yoo *et al*.[6]	Retrospective study	2022	Korea	To evaluate implants in Kennedy Class I ICRPD	100	0.82 ± 0.93	0	Class I RPD connected to residual teeth and implants as surveyed crowns can be a viable treatment modality.
YS Yi *et al*.[20]	Retrospective study	2023	Korea	To analyze the success of ICRPD according to positions in Kennedy Class I and II arches	(66.7)	-	1	Implant abutments adjacent to the natural tooth had higher success rates than those away from the natural teeth abutments.
TW Jung *et al*.[21]	Retrospective study	2023	Korea	To evaluate posterior implants with ICRPDs	96.9 (90.6)	0.11 ± 0.36	1	Mainly in mandibular free-end RPD case, posterior implants in ICRPD appear to be a reliable alternative.

* indicates a statistically significant difference with respect to the comparison group; N, number; MBL, marginal bone loss; mx and mn, maxilla and mandible; DERPD, distally extended RPD.

Table 3. Detailed characteristics of retrospective clinical studies

Author	Year	No. of RPDs	No. of implants	Implant type (N)	Months (mean)	Arch		Kennedy classification				Implant site (N)	Opposing dentition				Spl (N)	Retainer (N)
						Mx	Mn	I	II	III	IV		Fix	CD	RPD	OD		
SH Kang *et al.*[16]	2016	11	37	Ext (22), Int (15)	9 to 104 (42.1)	7	4	4	5	0	2	Ant (11), pre (15), molar (11)	8	2	1	0	Spl (15) / no (2)	Emb (17), RPA (3), WW (5), Akers (4), No (8)
EB Bae *et al.*[17]	2017	12	25	Ext (25)	12 to 37	4	8	9	3	0	0		5	2	5	0	All spl	-
SH Kang *et al.*[18]	2020	12	41 (n 9, r 24, w 8)	Ext (26), Int (15)	12 to 185 (47.9)	8	4	10	18	3	10	Ant (13), pre (28)	-	-	-	-	Spl (38) / no (3)	-
SY Yoo *et al.*[5]	2021	18	60	Int (60)	Up to 149 (46.6)	0	18	20	0	0	0	Ant (6), ant & pre (51)	-	-	-	-	-	-
SY Yoo *et al.*[4]	2021	20	74	Int (74)	(32.3)	20	0	20	0	0	0	Ant (8), ant & pre (12)	-	-	-	-	-	C-clasp
YK Oh *et al.*[19]	2021	25	80	Ext (80)	Up to 74 (27.6)	12	13	18	3	0	4	Ant (30), pre (36), molar (14)	10	5	9	-	Spl (78)/ no (2)	With (40), without (28)
SY Yoo *et al.*[6]	2022	30	70	Int (70)	Up to 185 (47.9)	13	17	30	0	0	0		29	15	17	9	Spl (50)/ no (20)	Direct (48), Indirect (22)
Y Yi *et al.*[20]	2023	102	223	Ext (86), Int (137)	Up to 104 (58.01)	34	68	65	22	10	5	Adjacent to ant (60), away from ant (107), post (56)	25	29	48	-	-	With (168), without (55)
TW Jung *et al.*[21]	2023	16	32	Bone (15), Tissue (17)	14 to 155 (60.9)	1	15	13	3	0	0	Post (30)	7		9	-	-	With (21), without (11)

N, number; mx and mn, maxilla and mandible; Fix, CD, RPD, OD, fixed dentition, complete denture, removable partial denture, overdenture; Spl, splinting; n, r, and w are narrow, regular, wide; Int and Ext, internal and external; ant, pre-and post, anterior, premolar, and posterior; Emb, embrasure.

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Table 4. Detailed characteristics of reported cases

Author	Year	F/u	K/C	Surveyed crown	Arch	Antagonist	Rest	Clasp	Occlusal scheme
HJ Na *et al*.[22]	2011	12 M	I	#1312=22 23i, #43 42=32 33i	mx & mn	ICRPD	cingul (#13, 23, 33, 43)	Akers (#13, 23, 33, 43)	.
SM Kim *et al*.[23]	2015	6 M	I	#43=41 31=33i (and #47i, 37i healing abutments)	mn	RPD	cingul (#33, 43)	resin (#43, 33)	BBO
SW Yang *et al*.[24]	2017	8 Yr	IV	#16 15=13i, #23=25 26i	mx	Fix	mesial (#14, 24), cingul (#13, 23), distal (#16, 26)	C (#16, 26)	.
YJ Cho *et al*.[25]	2017	7 Yr	I	#44=42=32=34i	mn	Fix	mesial (#34, 44), cingul (#33, 43)	RPA (#34, 44)	.
YJ Cho *et al*.[25]	2017	2 Yr	I	#44=41 31=34i	mn	RPD	mesial (#44), cingul (#33, 42)	RPA (#34, 44)	anterior G/F
KW Roh *et al*.[26]	2018	20 M	I	#44i, 34i	mn	RPD	lingual (#43-32), mesial (#44, 34)	RPA (#34, 44)	BBO
BR Gwon *et al*.[27]	2018	11 M	I	#13=11=23i	mx	RPD	cingul (#13, 23)	RPA (#13, 23)	BBO
JH Park *et al*.[28]	2018	6 M	IV	#34=36i, #47	mn	RPD	mesial (#47), embr (#35-36)	WW (#47), Akers (#34), embr (#35-36)	BBO
GS Gil *et al*.[29]	2018	3 Yr	I	#14 13=11i and #21 22 23 24	mx	Fixed	mesial (#14, 24), cingul (#13, 23)	RPI (#14, 24)	#14 13 G/F, Lt. C/G
JK Park *et al*.[30]	2019		I	#44=42=i and #31 32 33 34	mn	CD	lingual (#31 32 33, 41 42 43), mesial (#34, 44)	combi (#34, 44)	BBO
WJ Kee *et al*.[31]	2019	12 M	I mod. 1	#44 43i and #33 34	mn	CD	mesial (#34, 44)	Akers (#34, 44)	BBO
SL Jin *et al*.[32]	2020	12 M	I	#=43=31=33i, #34 35i (and 47i 36i metal abutments)	mn	CD	mesial (#44), cingul (#43-33)	RPA (#35, 44)	BBO
JH Kim *et al*.[33]	2020	.	I mod. 1	#11 12 and #23 24i	mx	Fix	mesial (#24), cingul (#11, 23)	RPA (#12, 24)	.
YK Oh *et al*.[34]	2020	Over 1 Yr	I	#44 43=33 34 35i	mn	RPD	mesial (#34, 35, 44), cingul (#33-43)	RPA (#35, 44)	BBO
SH Park *et al*.[35]	2021	.	IV	#17 16i, #24=26i	mx	Fix	mesial (#16, 24), distal (#17, 26)	C (#16, 17, 26)	G/F
YN Yun *et al*.[36]	2021	6 M	I mod. 1	#15 14i and #24 25	mx	OD	mesial (#14, 15, 24, 25)	WW (#14, 24), Akers (#15, 25)	BBO
MS Cha *et al*.[37]	2022	16 M	I mod. 1	#44i, 33i	mn	CD	mesial (#44), cingul (#33)	combi (#33, 44)	.
SY Seong *et al*.[38]	2022	12 M	I	#14 13=21=33 34i	mx	Fix	mesial (#14, 24), cingul (#13, 23)	RPA (#14 24)	G/F
HM Kang *et al*.[39]	2022	6 M	I	#14=12=22=24i	mx	Fix	mesial (#14, 24), cingul (#13, 23)	RPA (#14 24)	#14~24 G/F
JR Lee *et al*.[40]	2022	9 Yr	I	#14=12=22=24i	mx	Fix	mesial (#14, 24), lingual (#13-23)	RPA (#14 24)	#14 13 23 24 G/F
JS Back *et al*.[41]	2022	3 M	I mod. 1	#45 44i and #33	mn	CD	lingual (#33), mesial (#44), distal (#45)	RPA (#33 44 45)	BBO
SH Lee *et al*.[42]	2023	6 M	IV	#17i, 14i, 27i and #15	mx	Fix	mesial (#14, 24), distal (#17, 27)	RPA (#14 24), Akers (#17 27)	BBO
S Yeung *et al*.[43]	2014	3 weeks	IV	#18 17=15i, #25 26=28i	mx	Fix	distal (#15, 25), on (#18, 28)	Short C (#17 27)	.

*Statistically significant ($P < .05$). F/u, follow-up months (M) and years (Yr); K/C, Kennedy classification; Underlined surveyed crown sites, natural teeth prosthesis; Fix, CD, RPD, and OD mean fixed dentition, complete denture, removable partial denture and overdenture; cingul, cingulum; C, WW, embr and combi, circumferential, wrought wire, embrasure and combination; G/F and C/G, group function and canine guidance; BBO means bilaterally balanced occlusion.

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0.93 ± 1.22 mm and mandibular overdenture was 2.12 ± 2.09 mm, and the MBL of maxillary ICRPD was 1.12 ± 1.19 mm and maxillary overdenture was 3.31 ± 1.71 mm. The difference in MBL between the ICRPD and overdentures was significant only in the mandible. The MBL of the implant-surveyed crowns in that study showed notable differences based on age and the type of opposing dentition. In Kennedy Class I cases of Yoo *et al*.'s[6], the average MBL was measured at 0.82 ± 0.93 mm. There was a significant difference based on the splinting of the maxillary teeth, and the mean MBL of the implants was significantly higher than that around the abutment teeth in the same ICRPD. The mean MBL of implants in ICRPD reported by Jung *et al*.[21] was 0.11 ± 0.36 mm. They showed that the MBL of implants was significantly different according to the Kennedy classification, with values of 0.05 ± 0.14 mm for Kennedy Class I and 0.87 ± 0.55 mm for Kennedy Class II.

Bae *et al*.[17] reported that the probing depth was 3.19 mm in the ICRPD, which was not significantly different from the value of the IARPD using attachments. Calculi were significantly more frequently observed in the ICRPD group (30.4%) than that in the IARPD group (3.6%). Oh *et al*.[19] reported an overall mean probing depth of 3.4 ± 0.1 mm, meeting the normal range[44] of 3 to 4 mm. However, this value varied according to the arch; in maxillary and mandibular implants in ICRPD, the probing depth was 3.5 ± 0.7 and 3.1 ± 0.6 mm, respectively, indicating a significant difference. There were no reported differences in the bleeding index, peri-implant inflammation, and plaque index based on the material (zirconia vs. metal-ceramic), restored arch, retention design, or opposing dentition.

In a study by Yi *et al*.,[20] the overall prevalence of peri-mucositis was 18.4%, and that of peri-implantitis was 9.4%. The distribution of peri-implant-mucositis differed significantly according to the position of the implants in ICRPDs. In Jung *et al*.'s study,[21] peri-mucositis was observed in two patients with Kennedy class I RPD, and a sign of peri-implantitis was noted in one patient with Kennedy class II RPD at 44 months of function.

Kang *et al*.[16] conducted a clinical evaluation of complications associated with ICRPD, and the dislodgment of temporarily cemented prosthetic crowns was the most common result, with a rate of 10.8%. In another study by Kang *et al*.,[18] 31.2% of the complications were also related to crown issues, with the most prevalent complication being the dislodgement of the implant-surveyed crowns owing to the washout of temporary cement. In addition to that, Yi *et al*.[20] also found that the retention loss of implants was the most common problem, accounting for 11.7% of all implants. However, Yoo *et al*.[4,5] identified clasp loosening as a significant complication of ICRPDs in both the maxilla and the mandible. Clasp loosening was also a serious issue in Kennedy class I ICRPD,[6] with 42.8% of cases occurring in the maxilla and 33.3% in the mandible. Additionally, several other investigations have identified clasp loosening as a major issue.[16,18] Some studies have reported that the most frequent complication in ICRPD was fracture or deformation of the RPD framework, including fracture of rests[18,19] and clasps.[5,19] Other reported complications include screw fracture of implants,[16,18] screw loosening of implants, [16,18,21] opposing tooth fractures,[16,18] veneer porcelain fractures,[16,18,19,20] artificial tooth fractures,[16,18] sore spots,[4-6] and crestal bone resorption.[5,6]

Several studies[4,5,17,18] showed that the incidence rate of complications in overdenture-type IARPD was higher than that in ICRPD. Yi *et al*.[20] identified that Kennedy Class II ICRPD showed a higher failure risk than Class I ICRPD, and the implant survival rate in the mandible exhibited a higher success rate than that in the maxilla in ICRPDs. Additionally, according to that study, the failure rate decreased as the number of abutments increased.

Yoo *et al*.[4,5] compared the esthetic and functional satisfaction of ICRPD and overdentures in mandibular and maxillary patients. Patient satisfaction significantly improved after both ICRPD and overdenture treatment; however, the overdenture seemed to be more fulfilling in the mandible aesthetically, whereas functionally, the ICRPD showed higher satisfaction. While in the maxilla, the overdenture was more satisfactory aesthetically, with no significant difference in functionality between the two prostheses. Another study by Yoo *et al*.[6] demonstrated that functional improvement in ICRPD in the mandible was greater than that in the maxilla in Kennedy class I cases.

DISCUSSION

Patients may find it challenging to adapt to RPD when there is a lack of support and retention, leading to instances of dislodging movements. An alternative treatment modality that uses a limited number of implant-surveyed-crowns placed in strategic positions could be beneficial. In Korea, insurance benefits are attributed to the fabrication of implant-surveyed-crowns in the older population. There are a large number of case reports elaborating on RPD with implant-surveyed-crowns, which was named ICRPD by Yoo *et al*.[4-6] Recently, Kuroshima *et al*.[15] also reported a systematic review including five previous studies on ICRPD. Most case reports in that study demonstrated a good prognosis for ICRPD. Meanwhile, from a biological perspective, Bae *et al*.[17] commented that calculus in ICRPD was significantly more observed than in IARPD using attachments.

However, many other studies reported a good prognosis of ICRPD as a new rehabilitation treatment modality for older individuals.[4-6,16-21] Bae *et al*.[17] demonstrated that overdenture-type IARPD and ICRPD had no significant differences in implants, in probing depth and peri-implant inflammation. Other comparative studies between implant overdenture/IARPD and ICRPD have shown that ICRPD has comparable survival rates and that the MBL of implants is a viable option for partially or fully edentulous patients. Kang *et al*.[18] and Yoo *et al*.[4,5] demonstrated that IARPD and ICRPD showed no significant differences in survival rates and MBL in implants, indicating that ICRPD may have better results in some cases.

Even if the remaining teeth are irregularly distributed, placing a few implants in strategic locations may provide greater support and retention of dentures in cases of ICRPD. This helps patients adapt to their new dentures and improves their overall quality of life. Yoo *et al*.,[4-6] who compared patient-reported outcome measures (PROMs) in patients with ICRPDs to those with implant overdentures, supported this view; patients with ICRPDs showed similar or greater functional and esthetic improvements when ICRPDs were applied than implant overdenture.

The implant position and number of the ICRPD must be carefully planned, considering several factors, including preventing the dislodgement forces generated from the RPD movement, long-term maintenance of the implant, and potential future alternatives for switching to fixed implant prosthesis. Ortiz-Puigpelat *et al*.[45] observed that implant at the first molar site enhanced the biomechanical behavior of the IARPD. However, an inadequate posterior ridge dimension may limit implant placement to a more anterior site: anterior or premolar area.[46] Cunha *et al*.[47] found that as the implant was shifted from the last molar to the premolar area in IARPD, the force distribution of RPD into the remnant tooth and around the edentulous ridge became more favorable.

However, few studies have examined the effects of ICRPD on remnant teeth, ridges, and positioned implants according to their location. Yi *et al*.[20] showed that strategic implant abutments of the ICRPD adjacent to natural teeth exhibited higher success rates of implants than those away from a natural tooth abutment. In addition, most people lose their posterior teeth sooner than anterior teeth;[48] therefore, if implants are placed anteriorly approximating the remnant anterior teeth, ICRPD might show good results. Furthermore, most ICRPD case reports showed a combination of anteriorly placed implant-surveyed crowns and Kennedy Class I RPD.[5,6,22,29,30] Upon reviewing Table 4 summarizing the searched cases, it is evident that only Kennedy's Class I and IV are depicted, and this could indicate a strategic approach to enhance stability through a symmetrical partial denture design. Alternatively, it may result from a deliberate choice to avoid the inclusion of the mandibular molars and maxillary anterior teeth, which are characterized by a compromised alveolar bone condition, and to place the implants in areas with better quality and quantity of bone.

There were some cases of Kennedy Class III ICRPD with posteriorly positioned implant- surveyed-crowns; however, the number is significantly lower than the other Kennedy Class types. Jung *et al*.[21] found that posteriorly positioned implant-surveyed-crowns and Class III RPD were a reliable alternative for conventional RPD; however, they also reported failed implants in the posterior end position of the ICRPD. In that study, failed implants were successfully replaced with other implants, with a long rest

for better support without a retentive arm. Implants are relatively weak against lateral forces, and the retentive arm of the RPD generates force at a distance from the implant up to crown height, generating a greater torque than the attachment directly above the implant.[49,50] Furthermore, implants placed alone in the posterior teeth must withstand more horizontal movement of the denture than implants placed in the anterior teeth, resulting in greater lateral forces. Therefore, it is critical to assess whether the implant-surveyed-crowns can function safely based on their position and number of implants.

While ICRPD research is rare and ongoing, it appears to be important to adhere to basic concepts, such as adopting a rigid major connector design to prevent unnecessary force being transmitted to the implant, and the most successful case reports showed that this was followed. Collectively, the ICRPD is a promising and viable treatment modality for partially or fully edentulous patients, providing a broader support area with rest and improved retention with retentive arm. Additionally, combinations of anterior implants utilized as surveyed crowns and distal extension RPDs may be clinically acceptable options, particularly for individuals with a significant absorptive ridge in a posterior location.

CONCLUSION

Based on case-by-case or retrospective studies, ICRPD is expected to be effective as a long-term treatment strategy because it has a good survival/success rate, minimal bone loss, and great patient satisfaction. Furthermore, strategic implant placement around anterior teeth or premolars, as indicated in the majority of ICRPD studies, can decrease the additional bone grafts or sinus lifts, reducing treatment duration and costs.

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