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Survival rate of dental implants in the anterior mandible: a retrospective study

Su-Yeon Kim, Yu-Lee Kim, Hyun-Jun Kong

Department of Prosthodontics and Wonkwang Dental Research Institute, College of Dentistry, Wonkwang University, Iksan, Korea

Abstract (J Korean Assoc Oral Maxillofac Surg 2025;51:141-150)

Objectives: The purpose of this study was to analyze the survival rate of implants placed in the anterior mandible to evaluate the impact of various prosthetic restoration parameters, including loading protocols, opposing teeth type, prosthesis type, retention type, and cantilever, on implant survival and to evaluate potential risk factors, including systemic disease, associated with implant failure.

Patients and Methods: Here, 604 implants installed in the anterior lower jaws of 326 patients that had at least one follow-up visit after prosthetic restoration were included. Implant failure was defined as removal of the implant from the oral cavity. For survival rate analysis, the survival period was defined from the date of implantation to the date of failure or last examination. Survival analysis was conducted using Kaplan-Meier survival curves. Cox regression analysis was performed to identify factors affecting implant survival.

Results: Of the 604 implants placed in the mandibular anterior region, 14 failed, a cumulative survival rate of 97.68%. The survival curve varied according to loading method, with immediate loading demonstrating a significantly lower cumulative survival rate compared to early and conventional loading. Survival curves also differed according to retention type, with screw-retained implants having significantly lower cumulative survival than cement-retained and attachment-retained implants. Cantilevered designs also showed significantly reduced cumulative survival compared to non-cantilevered designs. Conventional loading was significantly less likely to fail compared to immediate loading.

Conclusion: The design of implant-supported prostheses affects the survival of implants placed in the mandibular anterior region. Immediate loading is a risk factor associated with failure of implants in the anterior mandible.

Key words: Dental prosthesis design, Mandible, Dental implants, Survival rate, Risk factors

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I. Introduction

Since Brånemark et al.[1,2] and Schroeder et al.[3] first introduced titanium implants, dental implants have evolved into an effective approach for restorations in partially edentulous and fully edentulous patients. Over the past 50+ years, implant-fixed dental prostheses have become the standard of care in dentistry through advancements in surface technology, establishment of surgical techniques, and improvements in the stability of the implant-abutment-prosthesis interface[4].

The mandibular anterior region, which is the area between the mental foramina, is a suitable site for implant placement due to its unique anatomical and structural characteristics[5]. In particular, the mandibular anterior region allows stable implant placement and a variety of prosthetic treatment options due to its favorable bone quality and the ease of sufficient placement depth. Although the narrow cervical width and axial orientation limitations of the mandibular anterior region sometimes necessitate bone grafting, these constraints can be overcome with appropriate treatment planning, enabling successful implant restoration[6,7].

Various types of implant-supported prosthetic restorations are possible in the mandibular anterior region. High long-term survival rates have been reported for implants using both fixed and removable dental prostheses[8-10]. The All-on-four concept, an option for fixed prosthetic restoration in completely edentulous patients[11], consists of a fully acrylic fixed prosthesis supported by four endosseous implants, with

Hyun-Jun Kong
Department of Prosthodontics and Wonkwang Dental Research Institute, College of Dentistry, Wonkwang University, 460 Iksandae-ro, Iksan 54538, Korea
TEL: +82-63-859-2929
E-mail: zsfvzsfv@naver.com
ORCID: https://orcid.org/0000-0001-9331-3572

all implant attachments directed toward the cortical bone anterior to the mental foramina. Implant-retained overdentures utilizing attachments are a predictable removable prosthetic option for completely edentulous mandibular patients due to their high long-term survival rates[12]. Recently, implant-assisted removable dentures have attracted attention as a new treatment option for partially edentulous patients, with reports of high success rates[13].

In a study by Millen et al.[14] on the impact of prosthesis type on implant survival in the edentulous mandible, the authors suggested that prosthesis design can influence implant survival. The choice between screw-retained and cement-retained implant supports affects prosthesis survival and complication rates. Screw-retained full-arch prostheses exhibited a higher frequency of chipping, whereas cement-retained prostheses were associated with more numerous biological and technical complications; however, no significant difference in implant survival was observed[14]. Further research is needed to evaluate the long-term effects of different retention methods.

Several studies on loading protocols demonstrated that immediate loading leads to high survival rates in appropriately selected patient groups. Compared with conventional loading, there were no significant differences in implant failure rates, peri-implant bone resorption, or biological and mechanical complications[15,16]. However, in single-tooth implants or certain occlusal types, the risk of failure tends to be slightly higher[17]. This suggests that the success of immediate loading depends on factors such as patient selection, surgical technique, and prosthetic design.

Risk factors affecting implant survival can be categorized into systemic and local factors[18]. Systemic factors such as smoking, implant length and diameter, immediate placement and loading, osteoporosis, and systemic diseases like Crohn's disease have been reported to be major factors in reduced implant survival rates[18,19]. Local factors including bone quality and quantity, implant position, prosthetic designs involving cantilevers or excessive angulation, and maintenance of aseptic conditions during surgery can also influence survival rates[20].

Although many studies have examined the impact of implant-supported removable and fixed prostheses on implant prognosis[21], they did not consider detailed prosthetic factors such as loading protocol, retention type, cantilever presence, or prosthesis classification. Additionally, systemic conditions in patients were not considered. A recent systematic review of implant survival based on arch position reported a lack of data on patients who are partially edentulous in the mandibular anterior region[22].

This study aims to analyze the survival rates of implants placed in the mandibular anterior region with different prosthetic restorations and to evaluate risk factors associated with implant failure in this area. The null hypotheses are

- Prosthesis design does not affect the survival of implants placed in the mandibular anterior region.
- There are no risk factors associated with implant failure in the mandibular anterior region.

II. Patients and Methods

1. Study population

Information was collected on 631 implants placed in the mandibular anterior region (between the mental foramina) in 343 patients at Wonkwang University Dental Hospital between June 2010 and June 2023. The first implant was installed on June 1, 2010, and the last on June 27, 2023. The implants were placed by skilled oral and maxillofacial surgeons, periodontists, and residents. All implants underwent prosthetic restoration and at least one follow-up visit. Patients were excluded if their medical records were insufficient, if the implants were splinted to another in the posterior region, if they had uncontrolled diabetes, or if they had received radiation therapy to the head and neck region due to malignant tumors. Based on these criteria, the final study population included 326 patients and 604 implants.

2. Ethical approval

This study was approved by the Institutional Review Board (IRB) of Wonkwang University Dental Hospital (WKDIRB202401-01).

3. Data collection

The following information was collected: (1) Patient age at the time of implant placement; (2) Sex; (3) Implant morphological characteristics: diameter, length, and manufacturer; (4) Smoking status; (5) Systemic conditions such as diabetes, osteoporosis, or hypertension; (6) Bone grafting status; (7) Loading protocol; (8) Prosthetic occlusal material; (9) Opposing dentition; (10) Type of prosthesis: single crown, fixed partial denture, hybrid denture, implant overdenture, or implant-assisted removable partial denture; (11) Presence of cantilever; (12) Follow-up period; and (13) Implant failure.

Implant failure was defined as implant loss or removal. The failure criteria were based on those proposed by Cochran et al.[23], which include persistent or irreversible signs such as mobility, pain, or infection. The survival period was the duration from implantation date to the failure date or the last follow-up visit, and survival rates were compared accordingly.

The loading protocol was defined according to the criteria proposed by Weber et al.[24]. Conventional loading was defined as prosthetic loading applied more than 2 months after implant placement. Early loading was defined as loading applied between 1 week and 2 months after implant placement, while immediate loading was defined as prosthetic loading applied within 1 week of implant placement.

Survival analysis was conducted using Kaplan–Meier survival curves. The log-rank test was used to compare survival rates based on prosthesis type. Cox regression analysis was performed to identify factors affecting implant survival. Statistical analysis was conducted using IBM SPSS Statistics ver. 25.0 (IBM), with statistical significance set at 95% (P<0.05).

III. Results

1. General characteristics of the study subjects

The general characteristics of the study subjects and the implants are as follows.(Tables 1, 2)

Table 1. General characteristics of the study participants

Variable	Frequency (%)
Sex	
Male	173 (53.07)
Female	153 (46.93)
Age (yr)	
≤30	25 (7.67)
31-50	48 (14.72)
51-70	154 (47.24)
71≤	99 (30.37)
Smoking	
Non-smoker	275 (84.36)
Smoker	51 (15.64)
Diabetes	
No	272 (83.44)
Yes	54 (16.56)
Osteoporosis	
No	307 (94.17)
Yes	19 (5.83)
Hypertension	
No	214 (65.64)
Yes	112 (34.36)
Total	326 (100.00)

2. Comparison of cumulative survival rate according to prosthesis type

The total number of implants was 604, with an observation period ranging from one day after implantation to 163 months. The average observation period was 44.38 months. A total of 14 implants failed, resulting in an overall cumulative survival rate of 97.68%.

Table 2. Characteristics of the implants

Variable	Frequency (%)
Bone grafting	
None	300 (49.67)
Yes	304 (50.33)
Implant placement	
#31	29 (4.80)
#32	99 (16.39)
#33	120 (19.87)
#34	47 (7.78)
#35	1 (0.17)
#41	40 (6.62)
#42	103 (17.05)
#43	115 (19.04)
#44	50 (8.28)
Diameter (mm)	
≤3.3	82 (13.58)
3.4-4.0	454 (75.17)
≥4.1	68 (11.26)
Length (mm)	
≤10	259 (42.88)
≥11	345 (57.12)
Prosthesis type	
Single crown	110 (18.21)
Fixed partial denture	328 (54.30)
All-on-four	24 (3.97)
Implant overdenture	63 (10.43)
Implant-supported removable partial denture	79 (13.08)
Opposing teeth	
Natural teeth	351 (58.11)
Implant	96 (15.89)
Artificial teeth of dentures	157 (25.99)
Loading protocol	
Immediate	63 (10.43)
Early	7 (1.16)
Conventional	530 (87.75)
Missing	4 (0.66)
Cantilever	
None	561 (90.88)
Yes	43 (7.12)
Prosthetic material	
Metal ceramic crown	457 (75.66)
Zirconia	52 (8.61)
Resin	93 (15.40)
Missing	2 (0.33)
Retention type	
Cement	503 (83.28)
Screw	36 (5.96)
Attachment	61 (10.10)
Missing	4 (0.66)
Event	
Success	590 (97.68)
Failure	14 (2.32)
Total	604 (100.00)

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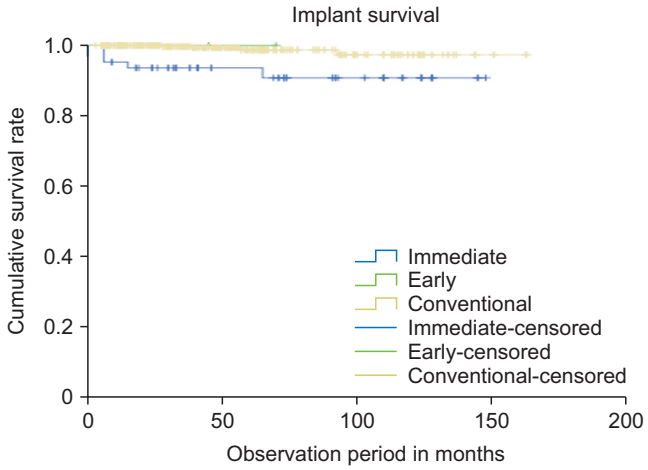

Fig. 1. Impact of loading protocol on implant survival: Kaplan–Meier analysis. The cumulative survival rate was significantly lower for immediate loading compared to conventional and early loading.
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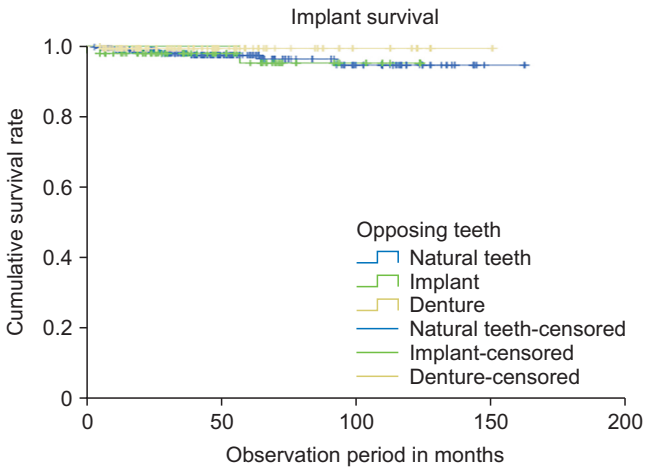

Fig. 2. Impact of opposing teeth type (natural teeth, implants, or dentures) on implant survival: Kaplan–Meier analysis. There was no significant difference in survival among groups based on opposing dentition type.
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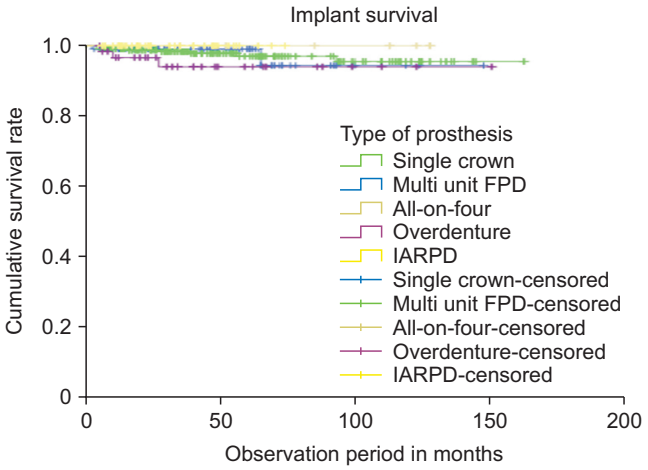

Fig. 3. Impact of prosthesis type on implant survival: Kaplan–Meier analysis. There was no significant difference in survival among groups based on prosthesis type. (FPD: fixed partial denture, IARPD: implant-assisted removable partial denture)
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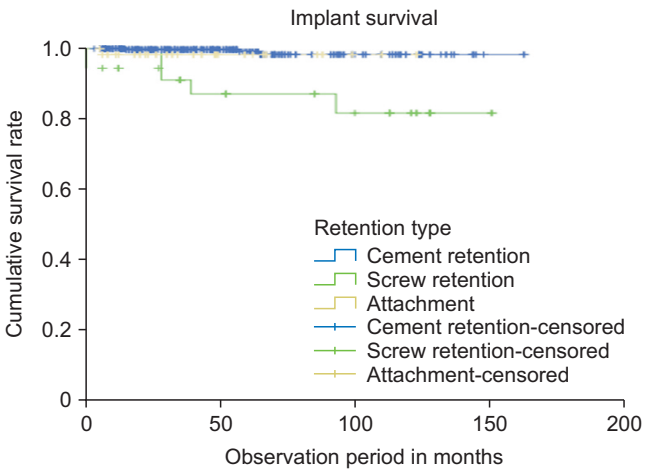

Fig. 4. Impact of retention type on implant survival: Kaplan–Meier analysis. The cumulative survival rate was lower for the screw-retained type compared to the cement-retained and attachment types.
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1) Loading protocol

Survival analysis based on the loading protocol showed that the cumulative survival rate was lower for immediate loading compared to conventional and early loading, and the log-rank test confirmed a significant difference between the survival curves (χ^2=12.71, df=2; P<0.05).(Fig. 1)

2) Opposing dentition type

Survival analysis based on the opposing dentition type showed no significant difference in survival. The log-rank test showed no significant difference in survival curves among groups based on opposing dentition type (χ^2=2.04, df=2; P>0.05).(Fig. 2)

3) Prosthesis type

Survival analysis based on prosthesis type showed no significant difference between groups in survival. The log-rank test showed no significant difference in survival curves among groups based on prosthesis type (χ^2=4.25, df=4; P>0.05).(Fig. 3)

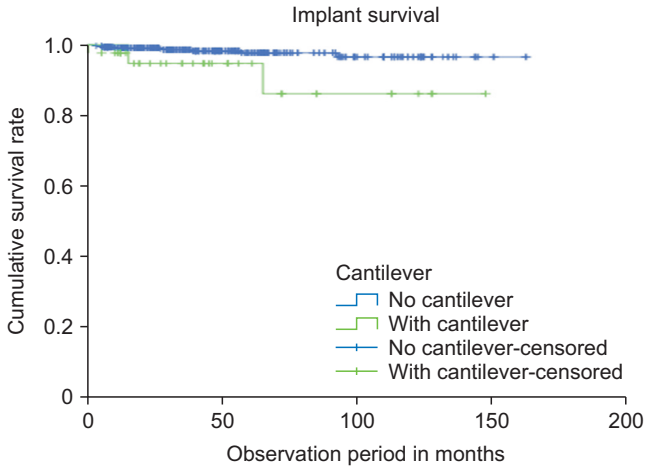

Fig. 5. Impact of cantilever on implant survival: Kaplan–Meier analysis. The cumulative survival rate was significantly lower for prostheses with a cantilever compared to those without a cantilever.
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4) Prosthesis retention type

Survival analysis based on prosthesis retention type showed that the cumulative survival rate was lower for the screw-retained type compared to the cement-retained and attachment types. The log-rank test confirmed a significant difference between the survival curves (χ^2=26.44, df=2; P<0.05).(Fig. 4)

5) Presence of cantilever

Survival analysis based on the presence of a cantilever showed that the cumulative survival rate was significantly lower for prostheses with a cantilever compared to those without a cantilever. The log-rank test confirmed a significant difference between the survival curves (χ^2=5.25, df=1; P<0.05).(Fig. 5)

3. Factors influencing survival rate

Cox regression analysis was used to identify factors affecting survival rate, and the loading protocol was found to have a significant impact on implant failure. In this study, conventional loading was associated with significantly lower risk of implant failure compared with immediate loading (hazard ratio [HR]=0.00, 95% confidence interval [CI]=0.000-0.509; P<0.05).

Table 3 presents the HR for each factor along with its 95% CI. Clinical information on failed implants is provided in Tables 4, 5.

Table 3. Hazard ratio for each risk factor

Category	Hazard ratio	95% Confidence interval	*P*-value
Sex			
Male	1.00	-	-
Female	1.65	0.035-77.401	0.798
Age (yr)			
≤30	1.00	-	-
31-50	0.05	0.000-1.310	0.990
51-70	10645.73	0.000-5.650	0.962
71≤	2758.14	0.000-1.500	0.968
Smoking status			
Non-smoking	1.00	-	-
Smoking	12.11	0.109-1345.890	0.299
Diabetes			
No	1.00	-	-
Yes	0.09	0.000-22.281	0.390
Osteoporosis			
No	1.00	-	-
Yes	0.00	0.000-9.500	0.973
High blood pressure			
No	1.00	-	-
Yes	1.29	0.029-57.221	0.896
Bone graft			
No	1.00	-	-
Yes	0.40	0.014-11.572	0.593
Implant diameter (mm)			
≤3.3	1.00	-	-
3.4-4.0	220556.92	0.000-1.810	0.919
≥4.1	36298.14	0.000-3.210	0.931
Implant length (mm)			
≤10	1	-	-
≥11	0.69	0.022-21.425	0.835
Loading protocol			
Immediate	1.00	-	-
Early	0.00	0.000-0.000	0.992
Conventional	0.00	0.000-0.509	0.027
Prosthetic material			
Metal ceramic	1.00	-	-
Zirconia	0.00	0.000-2.200	0.969
Resin	126.85	0.024-658886.768	0.267
Antagonist			
Natural teeth	1.00	-	-
Implant	5.02	0.061-416.170	0.474
Denture	0.71	0.010-49.171	0.873
Prosthesis type			
Single crown	1.00	-	-
FPD	0.09	0.000-263.870	0.561
All-on-four	0.00	0.000-3.330	0.919
Overdenture	0.01	0.000-9.900	0.987
IARPD	0.00	0.000-6.020	0.977
Retention type			
Cement retained	1.00	-	-
Screw retained	296.25	0.205-428435.954	0.125
Attachment	6.68	0.000-4.730	0.994
Cantilever			
No	1.00	-	-
Yes	13.65	0.503-370.067	0.121

(FPD: fixed partial denture, IARPD: implant-assisted removable partial denture, -: not available)
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Table 4. Patient-related factors associated with failed implants

Patient No.	Case No.	Sex	Age (yr)	Place of implantation	Diameter (mm)	Length (mm)	Smoking status	Systemic disease	Bone graft
43	92	M	62	#43	4.0	11.5	No	No	No
49	104	F	70	#33	4.0	8.5	No	No	No
52	109	M	56	#32	3.8	15.0	No	No	Yes
52	110	M	56	#42	3.8	15.0	No	No	Yes
57	121	F	70	#42	3.5	13.0	No	HBP	Yes
57	122	F	70	#44	5.0	11.5	No	HBP	No
65	139	M	51	#43	4.0	11.5	No	No	Yes
65	140	M	51	#33	4.0	11.5	No	No	Yes
84	171	M	67	#31	4.0	13.0	Yes	No	Yes
118	232	M	86	#41	3.5	8.5	No	Diabetes	No
151	283	M	56	#34	5.0	11.5	No	No	Yes
200	370	F	67	#42	4.0	11.5	No	HBP	Yes
229	420	M	71	#41	3.5	10.0	No	HBP	Yes
319	595	F	65	#41	3.0	10.0	No	No	No

(M: male, F: female, HBP: high blood pressure)
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Table 5. Prosthetic factors associated with failed implants

Patient No.	Case No.	Type of prosthesis	Cantilever	Antagonist	Loading protocol	Prosthetic material	Retention type	Observation period (mo)
43	92	Overdenture	No	Denture	Immediate	Resin	Attachment	6
49	104	FPD	No	Natural teeth	Conventional	Metal ceramic	Screw	93
52	109	FPD	No	Implant	Immediate	Resin	Screw	0
52	110	FPD	Yes	Implant	Immediate	Resin	Screw	0
57	121	FPD	No	Natural teeth	Conventional	Resin	Screw	28
57	122	FPD	No	Natural teeth	Conventional	Resin	Screw	39
65	139	Overdenture	No	Natural teeth	-	Resin	-	27
65	140	Overdenture	No	Natural teeth	-	Resin	-	10
84	171	FPD	Yes	Natural teeth	Immediate	Metal ceramic	Cement	15
118	232	Single	Yes	Natural teeth	Immediate	Metal ceramic	Cement	65
151	283	FPD	No	Natural teeth	-	-	-	4
200	370	FPD	No	Implant	Conventional	Metal ceramic	Cement	57
229	420	Single	Yes	Natural teeth	Conventional	Metal ceramic	Cement	52
319	595	Single	No	Natural teeth	-	-	-	2

(FPD: fixed partial denture, –: not available)
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IV. Discussion

In this study, a comparison of survival curves based on prosthesis type was conducted to evaluate the impacts of various prosthetic restorations on the survival of implants placed in the mandibular anterior region. Additionally, potential risk factors associated with implant failure in this region were assessed. The survival curves of implants placed in the mandibular anterior region differed significantly according to prosthesis type. Therefore, the first null hypothesis was rejected. Risk factor analysis revealed that loading protocol had an impact on implant failure; thus, the second null hypothesis was also rejected.

The survival curve of implants placed in the mandibular anterior region showed a significant difference according to prosthesis type. There was a difference in survival curves based on the loading protocol, with cumulative survival rate being lower for immediate loading compared to early loading and conventional loading. According to a literature review on immediate loading, all studies reported success rates similar to conventional loading, establishing immediate loading as a successful protocol[25]. Another literature review indicated that, while immediate loading showed success rates comparable to those of conventional loading, the clinical success of this technique is highly dependent on patient selection, bone quality and quantity, implant number and design, occlusal load, and surgeon skill. Among these, implant primary stability was the most critical factor[26]. Excessive stress beyond a critical threshold at the implant-bone interface during the initial loading phase can lead to implant or prosthesis failure[27]. In contrast to previous studies, this study found that the cumulative survival rate of implants with immediate loading was lower than that of conventional loading. Of the implants that failed, the proportion that failed during the temporary prosthesis phase was 60% (3 of 5), suggesting that excessive stress had been applied during the initial loading phase.

In this study, there was no significant difference in cumulative survival rate based on opposing dentition type. A study addressing the impact of opposing teeth on implant restorations suggests that, when opposing teeth are not properly aligned or there is abnormal occlusion, there is a higher likelihood of adverse effects such as minor damage, wear, or framework fracture in the prosthesis[28]. Although studies on the impact of opposing teeth on the clinical outcomes of implant restorations are limited, there are indications that the condition and type of opposing teeth may be associated with technical problems in implant prostheses[29]. In this study, the focus was on implant survival rather than these technical problems, and opposing dentition type did not have a significant effect. Additionally, due to the characteristics of the mandibular anterior region, the influence of opposing teeth, such as occlusal forces, might be less pronounced than that in the posterior region.

A systematic review analyzing the impact of implant-supported prosthesis type on implant loss in edentulous patients suggested that the type of restoration affected the estimated implant loss rate[30]. Prosthesis types were divided into fixed and removable prostheses, with significantly lower estimated implant loss rate for fixed prostheses than that for removable prostheses. However, another clinical study reported that prosthesis types such as single crowns, fixed dental prostheses, and removable dental prostheses did not influence the incidence of implant failure[21]. In this study, while the goal was to investigate the effect of prosthesis type on implant failure by subdividing prosthesis types, no difference was found in cumulative implant survival rate. Previous studies controlled clinical conditions such as edentulous range and loading protocol, but in this study, these conditions varied among patients; in addition, the classification of prostheses was more detailed, resulting in smaller sample sizes for each category. The mandibular anterior region also has better initial stability and lower occlusal force, which might have mitigated the effect of prosthesis type on implant prognosis.

In this study, screw-retained prostheses had a lower cumulative survival rate compared to cement-retained prostheses and attachments. A meta-analysis by Lemos et al.[31] showed that cement-retained fixed implant-supported prostheses had less marginal bone loss and higher implant survival rates compared to screw-retained fixed prostheses. However, another systematic review[32] reported no significant difference in 5-year survival rates between cement-retained and screw-retained prostheses (P>0.05). Differences in implant survival rates based on prosthesis retention type have varied across studies, and since the screw-retained prosthesis in this study included a temporary implant restoration cylinder, accurate comparison and interpretation of failure rates can be challenging.

In this study, the cumulative survival rate was higher for prostheses without a cantilever compared to those with a cantilever. A literature review on implant-supported cantilever prostheses[33] indicated that the implant survival rate for cantilever prostheses is very high. However, the rate of mechanical, technical, and biological complications was greater than 25% in partially edentulous patients and greater than 39% in completely edentulous patients. Unlike previous studies, this study was limited to the mandibular anterior region. The mandibular anterior region has a narrow alveolar ridge that requires the use of smaller diameter implants, which is less favorable for distribution of the stresses applied to the implant. This suggests that the use of smaller-diameter implants and longer cantilevers can concentrate the stress[34], increasing the likelihood of implant and prosthesis failure.

In this study, patient-related factors (sex, age, smoking status, diabetes, osteoporosis, hypertension), a surgical factor (bone grafting), implant-related factors (implant diameter, length), and prosthetic factors (loading protocol, prosthesis material, opposing dentition, prosthesis type, prosthesis retention type, presence of a cantilever) were included in risk factor analysis. That analysis demonstrated that only the conventional loading protocol had a significantly lower likelihood of implant failure compared to immediate loading (HR=0.00, 95% CI=0.000-0.509; P<0.05). Table 3 contains some extreme HR values. The primary reason for the abnormally high HR value is the insufficient number of events and the concentration of failures in the 51-70 years age group. Additionally, no failures occurred in the 30 and under and 31-50 years age groups, which can result in extremely low or infinite HR values. Failures were most common in implants with diameters of 3.4-4.0 mm, although the HR values were unstable due to the low number of events relative to the sample size. Therefore, a larger sample size is necessary to obtain more reliable results.

Previous studies have suggested that smoking[20,35,36], immediate implantation[20,36], male[37,38], and short implants[37,38] could influence implant failure; however, these factors were not associated with implant failure in the present research. This study investigated the impact of each risk factor on implant failure as a single variable, and a similar study[19] concluded that the presence of a single risk factor, other than bruxism, does not significantly increase the risk of failure. Addition-

ally, the small sample size for each category might have hindered clear establishment of a relationship between each factor and implant failure.

There are few absolute contraindications to dental implant treatment, though certain conditions can increase the risk of failure or complications[39]. Although hypertension itself does not directly affect implant surgery, complications related to the use of anticoagulants can occur. The use of dental implants in patients with osteoporosis is not contraindicated. However, some case-control studies have reported a weak association between osteoporosis and implant failure[40]. Bisphosphonate-related osteonecrosis of the jaw is a significant concern in patients treated with intravenous bisphosphonates, whereas its occurrence in patients receiving oral bisphosphonates is minimal[41]. The osteoporosis medications used in this study were bisphosphonates, selective estrogen receptor modulators, and calcium supplements for oral administration, while bisphosphonates and RANKL inhibitors were used as injectable treatments. However, no implant failures were observed in patients with a history of osteoporosis. Furthermore, risk factor analysis did not provide evidence that systemic diseases increase the risk of implant failure.

The limitations of this study are as follows. First, among the five failed screw-retained implants included in the study, four failed during the temporary restoration phase, suggesting that other factors, such as impaired initial stability, contributed to failure. Second, the relationships between implant failure and factors other than loading protocol could not be clearly identified. This might be due to the relatively small sample size for each category. Last, due to limitations in the records, factors such as the degree of periodontal disease, oral hygiene status, and bone quality, which have been shown to influence implant failure in previous studies, were not considered in this study.

Future research should exclude the temporary cylinder from screw-retained implants to conduct a more systematic analysis. This will allow clearer identification of the risk factors for failure in each phase. Additionally, future studies should evaluate the relationships between various factors and implant failure with a larger sample size, to increase statistical power. Furthermore, periodontal disease severity and oral hygiene status should be included for a more comprehensive and in-depth analysis of variables that can impact implant failure.

V. Conclusion

This study analyzed the survival rate of implants placed in the mandibular anterior region, providing a clear summary of survival rates based on patient characteristics and implant prosthetic features compared to previous studies. The survival curves were compared based on loading protocol, opposing arch type, prosthetic type, retention form, and cantilever presence, revealing significant differences in survival curves according to loading protocol, retention form, and cantilever presence. Additionally, risk factors were analyzed, including patient characteristics and systemic diseases, highlighting that the loading protocol is a significant factor influencing implant survival.

The following conclusions can be drawn from the evaluation of factors influencing the survival of implants placed in the mandibular anterior region and the potential risk factors associated with implant failure.

1. Among the 604 implants placed in the mandibular anterior region, 14 failed, resulting in an overall cumulative survival rate of 97.68%. The observation period ranged from one day after implantation to a maximum of 163 months, with an average observation period of 44.38 months.

2. No significant difference in cumulative survival rates was observed based on the type of opposing dentition.

3. No significant difference in cumulative survival rates was observed based on the type of prosthesis.

4. The cumulative survival rate of implants subjected to immediate loading was lower compared to those subjected to early and conventional loading.

5. The cumulative survival rate of implants supporting screw-retained prostheses was lower compared to those supporting cement-retained prostheses.

6. The cumulative survival rate of implants supporting prostheses without cantilevers was higher compared to those with cantilevers.

7. Risk factor analysis revealed that conventional loading significantly reduced the likelihood of implant failure compared to immediate loading.

This study has several limitations. Most implant failures occurred during the temporary restoration phase, suggesting impaired initial stability. The relationships between implant failure and factors other than the loading protocol were unclear due to the small sample size. Additionally, factors like periodontal disease, oral hygiene, and bone quality were not considered. Future research should adopt a more systematic approach and include larger sample sizes to better identify

risk factors for implant failure. Nevertheless, this study is expected to provide a foundation for evaluating the prognosis of mandibular anterior implants.

ORCID

Su-Yeon Kim, *https://orcid.org/0009-0008-3358-2656*
Yu-Lee Kim, *https://orcid.org/0000-0003-1350-5895*
Hyun-Jun Kong, *https://orcid.org/0000-0001-9331-3572*

Authors' Contributions

S.Y.K. participated in data collection, performed the statistical analysis and wrote the manuscript. Y.L.K. participated in the study design. H.J.K. participated in the study design and coordination and helped to draft the manuscript. All authors read and approved the final manuscript.

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Ethics Approval and Consent to Participate

This study was approved by the Institutional Review Board (IRB) of Wonkwang University Dental Hospital (WKDIRB202401-01). The requirement for informed consent was waived due to the retrospective nature of the study.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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