



# Prognostic factors influencing implant survival and marginal bone loss in patients with osteoporosis or osteopenia medication

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**Abstract** (J Korean Assoc Oral Maxillofac Surg 2025;51:17-25)

**Objectives:** To evaluate the factors that influence the survival of dental implants and marginal bone loss (MBL) in patients taking osteoporosis or osteopenia medication.

**Materials and Methods:** This study included patients who underwent dental implant treatment after taking medication for osteoporosis or osteopenia. Electronic medical records were used to collect data of patient age, sex, age at osteoporosis or osteopenia diagnosis, types of medications, age at medication initiation, duration of medication before implant surgery, whether the medication was paused before surgery, paused duration of medication, implant survival status, and MBL before and after prosthetic treatment. Firth's logistic regression was used to analyze the relationships between each variable and implant survival as well as between MBL before and after prosthetic treatment.

**Results:** Of the 267 patients, 111 with 209 implants were included in the study. The mean observation period was 57.9 months. The survival rate was 92.8% at the patient level and 96.2% at the implant level. No significant associations were found between implant survival and any of the variables examined. MBL before prosthetic treatment was significantly associated with use of receptor activator of nuclear factor- $\kappa$ B ligand (RANKL) inhibitors ( $P=0.032$ ) and bone formation stimulators ( $P=0.022$ ). Comparing the concurrent and single use of bisphosphonates and RANKL inhibitors, only the use of RANKL inhibitors alone was significantly associated with MBL before prosthetic treatment ( $P=0.039$ ). MBL after prosthetic treatment was significantly associated with injection method among the routes of drug administration ( $P=0.011$ ).

**Conclusion:** The implant survival rate in patients undergoing medical treatment for osteoporosis or osteopenia was comparable to the general implant survival rate. MBL before prosthetic treatment was associated with type of anti-osteoporotic medication, whereas MBL after prosthetic treatment was correlated with drug administration route. Further studies with larger sample sizes are required.

**Key words:** Osteoporosis, Osteopenia, Dental implants, Marginal bone loss, Survival rate

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## I. Introduction

Implant surgery is currently one of the most widely performed treatments for patients with complete or partial edentulism<sup>1</sup>. Previous studies have reported that more than half of individuals aged 70-74 years have three or more systemic

diseases<sup>2</sup>. With increasing life expectancy and demographic changes, the importance of analyzing potential risk factors, such as systemic diseases, for successful implant surgery in older patients is growing. Comprehensive evaluation of patient systemic health and potential factors influencing the success or failure of surgery is essential to anticipate complications and achieve optimal treatment outcomes.

Osteoporosis/osteopenia is a musculoskeletal disorder characterized by decreased bone mass and deterioration of the microarchitectural structure, leading to an increased risk of fracture<sup>3</sup>. Currently, 21.7% of adults aged >50 years have osteoporosis, with a prevalence of 35.3% in female and 12.5% in male<sup>4</sup>. In the United States, the prevalence of osteoporosis among female increased from 14.0% in 2007-2008 to 19.6% in 2017-2018<sup>5</sup>. Osteoporosis is known to cause changes in the

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mineral content of alveolar bone<sup>6</sup>, reduce the volume of the residual alveolar ridge<sup>7</sup>, and delay bone recovery and healing<sup>8</sup>. The prevalence of osteoporosis increases with age<sup>9</sup>, resulting in an increasing number of patients with osteoporosis or osteopenia seeking implant placement.

Osteoporosis can lead to a reduction in the range of bone-implant contact because of impaired bone regeneration and general decrease in bone quality and quantity in the maxillofacial region, potentially resulting in decreased implant stability. This effect is particularly pronounced in edentulous areas<sup>10,11</sup>. Systemic bone density is closely related to mandibular bone density, and studies have shown that patients with osteoporosis exhibit lower bone mass and bone density and thinner cortical plates compared with those without osteoporosis<sup>12-14</sup>. However, numerous studies investigating the relationship between osteoporosis, osteopenia, and implant survival rates have reported that systemic conditions do not directly cause implant failure<sup>15</sup>.

With adequate healing time and appropriate prosthetic design to prevent peri-implantitis and stress concentration from overloading, stable osseointegration can be achieved even under conditions of low bone volume and poor bone quality. One study found no clinically significant differences in the changes in mineral content of peri-implant bone subjected to 5 years of functional loading between patients with osteoporosis/osteopenia and those with normal bone density<sup>15</sup>. Similarly, another study reported that the 5-year survival rate of implants placed in women aged >50 years was unaffected by osteoporosis<sup>16</sup>.

Previous dental studies related to osteoporosis have primarily focused on the development of medication-related osteonecrosis of the jaw (MRONJ)<sup>17,18</sup>. However, there is a lack of long-term studies examining the differences in implant survival and marginal bone loss (MBL) based on type of osteoporosis treatment, administration method, and patient-specific factors.

Therefore, this study aimed to investigate the prognosis of implants in patients diagnosed with osteoporosis or osteopenia by focusing on the type of medication, route of medication, and patient characteristics.

## II. Materials and Methods

This study was approved by the Institutional Review Board of Seoul National University Bundang Hospital (No. B-2407-913-104) and was conducted in accordance with the Declaration of Helsinki and International Conference on Harmoniza-

tion Guidelines for Good Clinical Practice. Written informed consent was waived due to the retrospective nature of the study.

The study initially included 267 patients who underwent dental implant placement and prosthetic treatment at the Department of Dentistry, Seoul National University Bundang Hospital, from January 1, 2004, to September 1, 2024, and who were treated with medications for osteoporosis or osteopenia. Specifically, osteoporosis was defined as a T-score of -2.5 or lower, while osteopenia was classified as a T-score between -1.0 and -2.5. These diagnostic criteria were applied based on bone mineral density (BMD) measurements at clinically relevant sites such as the lumbar spine, hip, or femoral neck<sup>19</sup>.

Electronic medical records (EMRs) were reviewed to collect data on patients' diagnoses, age, sex, location of implant (maxilla or mandible), age at osteoporosis or osteopenia diagnosis, age at initiation of medication, type of medication, active ingredients, duration of medication use before implant surgery, route of medication, whether medication was discontinued before implant surgery, duration of pause, implant survival status and MBL before and after prosthetic treatment. During data collection, patients who were diagnosed with osteoporosis or osteopenia after implant placement or who started medication afterward were excluded. Additionally, patients were excluded if their treatment medications could not be accurately verified in the EMRs due to prescription at another hospital or if they were deceased or could not be followed.

Medications were categorized by active ingredients into bisphosphonates (BPs), receptor activator of nuclear factor- $\kappa$ B ligand (RANKL) inhibitors, selective estrogen receptor modulators (SERMs), and bone formation stimulators (BFSs). (Table 1) The route of medication was classified as oral, subcutaneous, or intravenous. For patients who discontinued medication before implant surgery, pause duration and overall duration of medication were recorded in 1-month increments. For patients taking multiple medications for osteoporosis or osteopenia, data on pause duration and overall duration of treatment were collected based on the medication most closely associated with the timing of implant placement. Implant survival was evaluated according to the criteria established by Buser et al.<sup>20</sup> and Cochran et al.<sup>21</sup>, defining a surviving implant as one that met the following criteria: (1) no clinically detectable mobility, (2) absence of sensory disturbances, (3) no peri-implant infections, and (4) no continuous radiolucency around the implant on radiographs.

**Table 1.** Summary of osteoporosis medications used in the study

Osteoporosis medication	Type	Class	Drug	Route
Anti-resorptive agents	Bisphosphonate	2nd generation	Alendronate	Oral
		3rd generation	Ibandronate	Injection
			Risedronate	Oral
	RANKL SERMs	Zoledronate	Injection	
		Denosumab	Injection	
		Raloxifene	Oral	
Bone formation stimulator		Bazedoxifene	Oral	
		Teriparatide	Injection	

(RANKL: receptor activator of nuclear factor- $\kappa$ B ligand, SERMs: selective estrogen receptor modulators)

Sun-A Lee et al: Prognostic factors influencing implant survival and marginal bone loss in patients taking medication for osteoporosis or osteopenia. *J Korean Assoc Oral Maxillofac Surg* 2025

Patients visited the clinic for follow-up every 6 months or annually before and after prosthetic treatment. During these visits, periapical radiographs (Heliodent Plus; Sirona Dental) were obtained to investigate the occurrence of MBL before and after prosthetic treatment.

Descriptive statistics were calculated as frequencies with percentages for categorical variables and as medians with interquartile ranges for continuous variables. Firth's logistic regression, a bias reduction method based on penalized maximum likelihood estimation (PMLE), was used to examine the associations between each variable and implant survival and between MBL before and after prosthetic treatment. Statistical analyses were performed using R software (ver. 4.2.2 for Microsoft Windows; R Foundation), with a two-sided  $P$ -value  $<0.05$  considered statistically significant.

### III. Results

Of the 267 patients, 111 (8 male and 103 female) met the study criteria and were selected for analysis. Demographic and baseline characteristics of patients are presented in Table 2. A total of 209 implants was placed in these patients (106 in the maxilla and 103 in the mandible). The average observation period was 57.9 (range: 3.0-243.0) months. A total of 8 implants failed, each in a different patient.

No significant associations were observed between implant survival and factors of age, sex, location of implant, age at osteoporosis or osteopenia diagnosis, age at the start of medication, type of medication, duration of medication use before implant surgery, route of medication, or medication pause before surgery, including the pause duration.(Table 3)

MBL before prosthetic treatment was not significantly associated with age, sex, location of implant, age at diagnosis of osteoporosis or osteopenia, age at the start of medication, duration of medication before implant surgery, route of medication, or pause of medication before surgery, including the

**Table 2.** Demographic and baseline characteristics of patients

	Value
No. of patients	111 (100.0)
Age (yr)	
Implant surgery	74.8 $\pm$ 9.8
Diagnosis of osteoporosis or osteopenia	65.5 $\pm$ 10.2
Treatment of osteoporosis or osteopenia	66.0 $\pm$ 10.4
Sex, female	103 (92.8)
Type of bone disease	
Osteoporosis	109 (98.2)
Medication for osteoporosis or osteopenia	
Bisphosphonate	38 (34.2)
SERMs	26 (23.4)
RANKL	31 (27.9)
Bone formation stimulator	7 (6.3)
Duration of medication until surgery (mo)	40.1 $\pm$ 34.6
Pause of medication before surgery (mo)	36 (32.4)
Paused period of medication before surgery (mo)	3.4 $\pm$ 7.9
Route of medication, injection	49 (44.1)

(SERMs: selective estrogen receptor modulators, RANKL: receptor activator of nuclear factor- $\kappa$ B ligand)

Values are presented as number (%) or mean $\pm$ standard deviation.

Sun-A Lee et al: Prognostic factors influencing implant survival and marginal bone loss in patients taking medication for osteoporosis or osteopenia. *J Korean Assoc Oral Maxillofac Surg* 2025

pause duration. MBL was not significantly related to second- or third-generation BPs. However, significant associations were observed with RANKL inhibitors ( $P=0.032$ ) and BFSs ( $P=0.022$ ). Comparing the concurrent and single use of BPs and RANKL inhibitors, only the use of RANKL inhibitors alone was significantly associated with MBL before prosthetic treatment ( $P=0.039$ ).(Table 4) MBL after prosthetic treatment was significantly associated with the injection method among the routes of drug administration ( $P=0.011$ ).(Table 5)

### IV. Discussion

This study investigated implant survival and the occurrence of MBL before and after prosthetic treatment in patients diagnosed with osteoporosis or osteopenia who were taking anti-osteoporotic medications and received dental implants in edentulous areas.

Among the 209 implants placed in 111 patients taking

**Table 3.** Firth's bias-reduced logistic regression for each implant (implant failure)

	Odds ratio	95% Confidence interval		P-value
		Min	Max	
Age	1.057	0.976	1.159	0.181
Diagnosis of osteoporosis or osteopenia	1.029	0.956	1.109	0.445
Treatment of osteoporosis or osteopenia	1.040	0.968	1.121	0.289
Sex (female)	0.565	0.115	5.544	0.559
Location of implant (mandible)	1.030	0.259	4.093	0.965
Duration of the medication	0.987	0.955	1.008	0.257
Paused duration of medication	1.008	0.865	1.071	0.851
Route of medication (injection)	2.842	0.707	15.760	0.145
Generation of bisphosphonate				
Amount, 2nd generation	1.411	0.318	5.487	0.628
Amount, 3rd generation	0.662	0.005	6.269	0.772
SERM (medication)	1.487	0.266	6.074	0.613
RANKL (medication)	2.070	0.465	8.076	0.317
Bone formation simulator (medication)	4.553	0.445	24.832	0.168
Medication of bisphosphonate and RANKL				
Bisphosphonate only	1.892	0.358	11.636	0.446
RANKL only	2.848	0.534	17.650	0.214
Both	3.218	0.022	46.794	0.518
Medication pauses status (pause)	1.240	0.280	4.801	0.760

(SERM: selective estrogen receptor modulator, RANKL: receptor activator of nuclear factor-κB ligand)

Sun-A Lee et al: Prognostic factors influencing implant survival and marginal bone loss in patients taking medication for osteoporosis or osteopenia. J Korean Assoc Oral Maxillofac Surg 2025

**Table 4.** Firth's bias-reduced logistic regression for each implant (marginal bone loss before prosthetics)

	Odds ratio	95% Confidence interval		P-value
		Min	Max	
Age	0.952	0.891	1.020	0.159
Diagnosis of osteoporosis or osteopenia	0.971	0.906	1.040	0.399
Treatment of osteoporosis or osteopenia	0.966	0.903	1.034	0.317
Sex (female)	0.644	0.134	6.260	0.646
Location of implant (mandible)	0.835	0.219	3.028	0.781
Duration of the medication	0.984	0.951	1.005	0.153
Paused duration of medication	1.025	0.937	1.078	0.473
Route of medication (injection)	3.314	0.860	18.075	0.083
Generation of bisphosphonate				
2nd generation	0.715	0.130	2.779	0.646
3rd generation	0.478	0.004	4.232	0.582
SERM (medication)	0.191	0.001	1.554	0.146
RANKL (medication)	4.177	1.138	16.143	0.032*
Bone formation simulator (medication)	8.600	1.424	40.075	0.022*
Medication of bisphosphonate and RANKL				
Bisphosphonate only	1.331	0.201	8.820	0.754
RANKL only	4.692	1.080	26.987	0.039*
Both	3.218	0.022	46.794	0.518
Medication paused status (pause)	1.618	0.422	5.892	0.466

(SERM: selective estrogen receptor modulator, RANKL: receptor activator of nuclear factor-κB ligand)

\*P<0.05.

Sun-A Lee et al: Prognostic factors influencing implant survival and marginal bone loss in patients taking medication for osteoporosis or osteopenia. J Korean Assoc Oral Maxillofac Surg 2025

osteoporosis medications, the mean observation period was 57.9 months. The patient survival rate was 92.8%, and the implant survival rate was 96.2%. A previous study analyzing the survival rates of implants placed in women over the age of 50 with osteoporosis reported a 5-year implant survival rate of 93.8%<sup>22</sup>. In a study observing implants in patients with osteopenia and osteoporosis, a 12-year cumulative survival

rate of 95.1% was reported<sup>23</sup>. A systematic review of general implant survival studies published between 1997 and 2018 reported a 10-year average implant survival rate of 94.0%-96.8%, indicating that the implant survival rates in patients taking anti-resorptive agents are comparable to those in the general population<sup>24</sup>. The implant survival rate observed in the present study is consistent with these findings.

**Table 5.** Firth's bias-reduced logistic regression for each implant (marginal bone loss after prosthetics)

	Odds ratio	95% Confidence interval		P-value
		Min	Max	
Age	0.989	0.945	1.037	0.647
Diagnosis of osteoporosis or osteopenia	0.986	0.942	1.032	0.545
Treatment of osteoporosis or osteopenia	0.984	0.942	1.029	0.482
Sex (female)	6.106	0.793	785.370	0.094
Location of implant (mandible)	2.030	0.855	5.126	0.109
Duration of the medication	0.992	0.977	1.004	0.198
Paused duration of medication	0.909	0.771	1.008	0.080
Route of medication (injection)	3.196	1.296	8.843	0.011*
Generation of bisphosphonate				
2nd generation	1.227	0.481	2.956	0.657
3rd generation	0.217	0.002	1.748	0.186
SERM (medication)	1.147	0.379	3.000	0.794
RANKL (medication)	1.499	0.563	3.687	0.401
Bone formation simulator (medication)	0.398	0.003	3.317	0.472
Medication of Bisphosphonate and RANKL				
Bisphosphonate only	1.364	0.491	3.791	0.547
RANKL only	1.843	0.628	5.324	0.259
Both	0.882	0.007	8.988	0.933
Medication pauses status (pause)	0.539	0.181	1.379	0.205

(SERM: selective estrogen receptor modulator, RANKL: receptor activator of nuclear factor- $\kappa$ B ligand)

\* $P < 0.05$ .

Sun-A Lee et al: Prognostic factors influencing implant survival and marginal bone loss in patients taking medication for osteoporosis or osteopenia. *J Korean Assoc Oral Maxillofac Surg* 2025

A systematic review of the failure rates of implants in patients taking anti-resorptive medications versus those not taking these medications found that, in 8 studies, the failure rate was 4.2% in the medicated group and 3.0% in the non-medicated group, with only one study reporting a significant difference<sup>25</sup>. The risk of implant failure in patients receiving anti-resorptive medications appears conflicting and limited<sup>25</sup>. Therefore, with careful management, including the monitoring of medication use in patients receiving treatment for osteoporosis or osteopenia, successful implant surgery outcomes comparable to those in the general population can be expected.

In this study, implant survival was not significantly associated with location of implants, age at medication initiation, duration of medication use, pause duration of medication, type of medication, or route of medication. This study also revealed differences in implant survival rates based on sex and age among patients prescribed osteoporosis/osteopenia treatments, although no significant associations were observed.

Osteoporosis and osteopenia are more frequently observed in women than in men because of the sharp decline in estrogen levels following menopause<sup>26</sup>. Consequently, the incidence of osteoporosis and osteopenia in men is lower, and only 8 male patients were included in this study. The limited sample size of male participants indicates that even a single implant failure can result in a substantial difference in sur-

vival rates according to sex. This limitation was reflected in this study, where the survival rates were 87.5% in men and 93.2% in women. Research on male patients undergoing anti-resorptive treatment is scarce, and there may be a research bias favoring studies on women<sup>25</sup>. However, the observed differences in survival rates cannot be solely attributed to sampling bias. Many female patients in this study underwent concurrent hormone therapy. Furthermore, previous research has suggested that osteoporosis in men tends to manifest as more extensive bone resorption<sup>27</sup>. Although osteoporosis is less common in men, they have greater potential for more severe disease progression.

MBL before and after prosthetic treatment showed no significant correlation with sex, age, location of implant, age at medication initiation, duration of medication use, or medication pause. Although some studies have indicated that MBL tends to increase with age<sup>28</sup>, this trend was not significant in this study. A previous study showed that MBL is most pronounced in the 50 to 60 age group in women, with the rate of resorption stabilizing thereafter<sup>29</sup>. The present study could reflect the influence of the relatively high average age of the participants (79.5 years). In this study, treatments administered to patients with osteoporosis or osteopenia were classified into four categories based on mechanism of action and potential for combination therapy. BPs mimic pyrophosphate, which is an inhibitor of bone resorption. Approximately 30%

70% of the drug in the bloodstream binds to the bone and integrates into hydroxyapatite in areas of active bone remodeling. BPs remain in the bone for years and are released during resorption, where they inhibit osteoclast differentiation and function<sup>30</sup>. In the present study further categorized BPs by generation for a detailed analysis. SERMs bind to estrogen receptors and mimic estrogenic effects to improve bone quality and reduce the risk of fracture<sup>31</sup>. RANKL inhibitors are monoclonal human antibodies that inhibit RANKL activity, reduce osteoclast function, decrease bone resorption, and improve bone strength<sup>32</sup>. BFSs are the anabolic agents that directly affect osteoblasts and are recombinant parathyroid hormones that promote bone formation<sup>33</sup>. The classification and detailed evaluation of these medications provide insights into their distinct mechanisms and impacts on bone metabolism, aiding in a better understanding of their effects on peri-implant bone resorption and implant outcomes.

Bone resorption before prosthetic treatment exhibited varying trends depending on the medication category. While no significant correlation was observed between MBL and BPs or SERMs, a significant association was identified between RANKL inhibitors and BFSs.

Extensive research in dentistry has focused on potential healing abnormalities in the jaw caused by BP therapy. Studies have shown that patients taking BPs have a 65.3% higher implant failure rate than non-users<sup>20</sup>. Additionally, a case-control study reported a 2.69-fold higher implant failure rate in female BP users<sup>21</sup>. However, a systematic review of BPs and implants concluded the need for long-term studies regarding the direct impact of anti-resorptive medications, such as BPs, on implant-related outcomes such as peri-implant bone regeneration and MBL<sup>28</sup>. Notably, studies investigating the effects of low-dose BPs on implant survival and MBL have suggested that low doses of BPs do not worsen MBL. Similarly, hormone replacement therapy has been linked to reduced implant survival rates; however, these findings are often limited by small sample sizes and short study durations. Furthermore, few studies have addressed high-dose BP impacts<sup>29</sup>. In the present study, all BP users were treated with second- or third-generation BPs, which may have influenced the observed outcomes.

RANKL inhibitors, such as denosumab, are increasingly being used in the management of osteoporosis. Denosumab, designed to modulate the RANKL/osteoprotegerin ratio, is a critical regulator of bone healing and remodeling and has a long half-life, enabling less frequent dosing<sup>29,34</sup>. Unlike BPs, which act intracellularly, denosumab inhibits RANKL in the

extracellular space, resulting in a more rapid reduction in bone resorption<sup>35</sup>. Denosumab is known to be associated with problems such as osteonecrosis of the jaw, similar to BPs, but there are few studies on its association with implant-related bone resorption<sup>36,37</sup>.

This study found a significant association between MBL before prosthetic treatment and the use of RANKL inhibitors and BFSs. However, additional research is needed to elucidate the underlying mechanisms. Teriparatide, a BFS and recombinant parathyroid hormone, is effective in treating postmenopausal osteoporosis. Its intermittent low-dose administration not only benefits patients with osteoporosis, but has also shown promise in managing MRONJ<sup>33,38,39</sup>. In this study, only 9 implants in 7 patients were treated with BFSs, highlighting the need for larger-scale studies to confirm these findings.

The analysis of MBL after prosthetic treatment indicated that patients receiving injectable medications had significantly higher MBL occurrences compared to those receiving oral medications. The medications studied in this research included second- and third-generation BPs, which were administered in both oral and injectable forms, as well as RANKL inhibitors and BFSs, which were exclusively administered via injection. Previous studies have shown that injectable BPs may delay bone healing and increase the risk of MRONJ compared with oral BPs<sup>40</sup>. The findings of the present study align with previous reports, indicating that injectable BPs may have more significant effects on MBL after prosthetic treatment. A study examining bone turnover markers, such as C-telopeptide of collagen (CTX), which serves as an indicator of osteoclast activity, found that patients who received BP injections had lower CTX levels (134 pg/mL) than those who received oral BPs (219 pg/mL). This suggests that osteoclast activity and bone remodeling are notably suppressed in patients receiving injectable BPs<sup>16</sup>. Additionally, the injectable BP group showed a higher accumulation of tartrate-resistant acid phosphatase, a marker of osteoclastic activity, indicating that osteoclastic resorption was inhibited in these patients<sup>41</sup>. The reduced osteoclastic activity and bone turnover may contribute to the increased bone resorption observed after prosthetic restoration.

The association between MBL before prosthetic treatment and medications such as RANKL inhibitors and BFSs may be influenced by the injection route. However, it remains unclear whether this effect is because of the drug mechanism or administration method. Further research is needed to compare the effects of the same drug administered orally versus by

injection alone. Larger sample studies would help determine whether the route of administration or the mechanism of action of the drug plays a more significant role in bone resorption.

This study applied Firth's logistic regression to analyze a small number of failure cases (8 of 209 implants), where the rarity of events could lead to estimation instability and the issue of complete separation. Firth's method, based on PMLE, enhances the stability of estimates and provides reliable results even when the frequency of events is very low<sup>42,43</sup>. This approach is particularly regarded as an effective analytical tool in studies dealing with implant failure.

Many previous studies on implant outcomes in patients with osteoporosis have primarily focused on patients using BPs alone<sup>28,29</sup>. However, this study design reflects the reality that many patients are using a combination of medications, including BPs, RANKL inhibitors, SERMs, and BFSs. This is a significant aspect of this study. Additionally, while many studies have linked osteoporosis and osteopenia with implant survival rates, the present study focuses on long-term research analyzing survival rates and MBL differences according to medication type and administration method<sup>16,41,44</sup>. However, owing to the subdivision of medication categories such as BP generations, SERM usage, and the combination of BPs and RANKL therapy, small sample sizes in specific groups might have resulted in a statistical bias. Therefore, further research with larger sample sizes is needed to clarify the effects of various medication regimens on implant survival.

Patients with osteoporosis have a higher likelihood of graft resorption, fusion failure, and delayed healing compared to individuals without osteoporosis<sup>45</sup>. Therefore, the decision to proceed with bone grafting may affect the outcome and should be considered in future studies. In addition, factors such as hypertension, smoking, and diabetes, which can affect osseointegration, should be considered in future prospective studies to ensure more comprehensive results<sup>46</sup>.

## V. Conclusion

This retrospective study observed the clinical outcomes of 209 implants in 111 patients who were taking various medications for treatment of osteoporosis or osteopenia over an average period of 57.9 months. The implant survival rate was 96.2%. No significant differences in implant survival rates were found with respect to age, sex, location of implant, type of medication, administration method, treatment duration, or drug pause before prosthetic treatment. MBL was signifi-

cantly correlated with RANKL and BFSs medication use, whereas MBL after prosthetic treatment was correlated with injectable medication routes. However, further studies with larger sample sizes are required to obtain more conclusive results.

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## Authors' Contributions

Y.J.Y. and J.H.K. participated in conceptualization and study design. S.A.L. and N.H.C. participated in data collection. S.A.L. and J.H.K. participated in original draft preparation. J.H.K. and S.W. participated in statistical analysis. J.H.K. participated in review and editing. 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 of Seoul National University Bundang Hospital (No. B-2407-913-104) and was conducted in accordance with the Declaration of Helsinki and the International Conference on Harmonization Guidelines for Good Clinical Practice. Written 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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