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Long-term clinical study of fixed prosthetic rehabilitation using one-piece narrow-diameter implants: a retrospective study

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Abstract (J Korean Assoc Oral Maxillofac Surg 2024;50:343-349)

Objectives: The objective of this study was to evaluate the long-term clinical outcomes of one-piece narrow-diameter implants (NDIs), with diameters of 2.5 mm and 3.0 mm, and to investigate the factors that affect marginal bone loss (MBL) around these implants.

Materials and Methods: This study analyzed patients who were treated with 2.5 mm and 3.0 mm MS SA narrow ridge implants (Osstem Implant) at the Section of Dentistry in Seoul National University Bundang Hospital from 2007 to 2022 and had more than 6 years of follow-up data. MBL was measured using periapical radiographs. Age, sex, implant location, timing of implant placement and loading, placement depth, guided bone regeneration (GBR), fixture diameter, type of implant prosthesis, and opposing dentition type were investigated in relation to MBL. The implant survival rate was analyzed using Kaplan–Meier survival curves, and univariate and multivariate logistic regression models were used to identify factors associated with MBL. All analyses were conducted using R software (version 4.1.0 for Microsoft Windows; R Foundation).

Results: Twenty-five patients with 40 NDIs were included in this study. The mean observation period after implant function was 10.5 years (range, 6.1 to 14.0 years), and the survival rate of the NDIs was 95.1% at the implant level and 96.0% at the patient level. The average amount of MBL was 0.44±0.57 mm. The only factor that showed a significant association with MBL was the presence of GBR (P=0.046).

Conclusion: Within the limitations of a retrospective evaluation, NDIs have demonstrated optimal clinical outcomes over a long period in areas in which anatomical structures are limited. MBL around the NDI also showed clinically acceptable results, and a correlation with MBL was observed in cases in which a bone graft was performed. Further studies with a larger number of implants over extended periods are needed in the future.

Key words: Dental implants, Narrow-diameter implant, Alveolar bone loss, Survival rate

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I. Introduction

As a treatment method for tooth loss, implant prosthetics have a high success rate, high long-term survival rate, and high patient satisfaction[1,2]. In cases of congenital tooth loss, anatomical limitations to the restoration space, or severe alveolar bone atrophy, the use of standard diameter implants (SDIs) is often restricted. In such cases, the placement of narrow-diameter implants (NDIs) can be advisable in confined areas, such as the anterior region[3-6]. NDIs have the potential to help reduce the costs and timelines associated with guided bone regeneration (GBR) procedures and make minimally invasive surgical approaches more advantageous for elderly patients or those with medical risks[7].

Definitions vary among studies, but typically, implants with a diameter of 3.75-4.0 mm are considered SDIs, and implants with a diameter of 3.5 mm or less are classified as NDIs[8-10]. Recently, there have been proposals to categorize NDIs more specifically to consider their various indications. For example, Klein et al.[7] categorized NDIs into three categories: Category 1, <3.0 mm (mini-implants); Category 2, 3.0 to 3.25 mm (single-tooth indications); and Category 3, 3.30 to 3.50 mm (broader indications). Other researchers who participated in previous studies, including Schiegnitz and Al-Nawas[8], proposed a new categorization in 2018: Category 1,

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<2.5 mm; Category 2, 2.5 mm to 3.3 mm; and Category 3, 3.3 mm to 3.5 mm. The increased categorization seems to arise from the growing use of and need for NDIs and highlights the interest in smaller-diameter NDIs, such as 2.9 mm two-piece implants[8].

Our purpose in this study was to retrospectively evaluate the long-term clinical outcomes of using one-piece NDIs with diameters of 2.5 mm and 3.0 mm to restore tooth loss in both the anterior and posterior regions and to investigate factors affecting bone resorption around NDIs.

II. Materials and Methods

This study was approved by the Institutional Review Board of Seoul National University Bundang Hospital (No. B-2411-938-104) and was conducted in accordance with the Declaration of Helsinki and the International Conference on Harmonization Guidelines for Good Clinical Practice. The written informed consent was waived due to the retrospective nature of the study. This retrospective study evaluated data from patients who underwent treatment for edentulous areas with MS SA narrow ridge implants (Osstem Implant) at the Section of Dentistry, Seoul National University Bundang Hospital, from 2007 to 2022. The implanted fixture lengths varied, measuring 10 mm, 11.5 mm, 13 mm, and 15 mm, and the diameters were 2.5 mm and 3.0 mm. All the implants were one piece and tapered with sandblasted and acid-etched surfaces. Patients were excluded from the study if their observation period was less than 6 years or they were lost to follow-up. Patients who had adjacent natural teeth extracted during the follow-up period were also excluded.

1. Clinical information

The following participant data were collected via electronic medical records: age, sex, jaw position (maxilla/mandible), implant site (anterior/posterior), timing of implant fixture placement after tooth extraction, fixture placement depth, GBR status, fixture diameter, timing of functional loading of the implant prosthesis, prosthesis type, and type of opposing dentition. The final survival of the implants and any prosthetic complications post-treatment were also investigated. The timing of implant fixture placement after tooth extraction was categorized as immediate placement or delayed placement, and the timing for loading the implant prosthesis was categorized as immediate, early, or delayed based on whether provisional restoration or final prosthesis delivery occurred at 1 week or 8 weeks post-surgery. The type of implant prostheses were classified as splinted or non-splinted. The types of opposing dentition was classified into natural teeth including fixed prosthesis, implant prosthesis and removable prosthesis.

2. Radiographic analysis

Based on postoperative panoramic or periapical radiographs, the placement depth at the time of surgery was categorized as subcrestal, equicrestal, or supracrestal. Patients with completed prosthetics underwent recall every 6 months or 1 year, during which periapical radiographs were taken using a Heliodent Plus (Dentsply Sirona) at 7 mA and 60 kV. The exposure times were 0.20 seconds for anterior teeth and 0.35 seconds for posterior teeth. Marginal bone loss (MBL) was measured using periapical radiograph images from an INFINITT PACS (INFINITT Healthcare). MBL was assessed by measuring the difference in bone level between images taken at baseline, immediately after surgery, and the final follow-up after loading. The bone level was determined by measuring the distance between the alveolar bone crest adjacent to the fixture and the top of the fixture platform. The amplification ratio of the radiographic images used to convert the bone loss values was calculated by comparing the implant fixture length from the radiograph and the actual length provided by the manufacturer. Measurements were taken from the mesial and distal sides of the implant fixture to obtain an average value.(Fig. 1)

3. Statistical analysis

The implant survival rate was analyzed using Kaplan–Meier survival curves. To analyze the associations between MBL and sex, age, implant location, timing of implant surgery, placement depth, the presence of GBR, fixture diameter, prosthesis type, and the type of opposing dentition, univariate and multivariate logistic regression models were applied. Data analyses were conducted using R software (version 4.1.0 for Microsoft Windows; R Foundation), and the significance level was set at $P<0.05$.

III. Results

This study analyzed 25 patients (17 males and 8 females) who met the inclusion criteria, with a total of 40 NDIs placed, 5 in the maxilla and 35 in the mandible. Patient demographics are shown in Table 1.

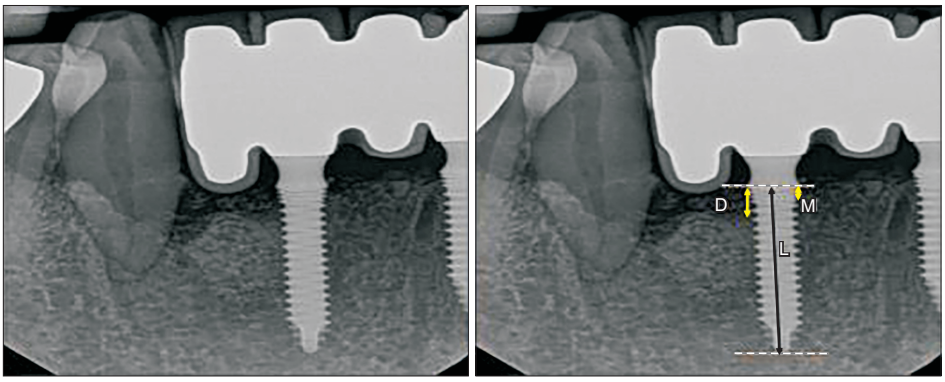

Fig. 1. Measurement of marginal bone loss. The ratio of the fixture length measured on the radiographic image to the implant fixture length provided by the manufacturer is used as the amplification ratio. The distance between the alveolar bone crest and the fixture platform top is measured on the mesial side (M) and distal side (D) to obtain an average value. This average value is then multiplied by the amplification ratio to calculate the actual amount of alveolar bone absorption.
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Table 1. Summary of the Distribution of Variables for Investigated NDIs

Variable	Value
No. of patients	25 (100.0)
Age (yr)	48.96±13.80
Sex	
Male	17 (68.0)
Female	8 (32.0)
Implants	
Jaw position	
Maxilla	5 (12.5)
Mandible	35 (87.5)
Implant position	
Anterior	32 (80.0)
Posterior	8 (20.0)
Implant diameter	
2.5 mm	32 (80.0)
3.0 mm	8 (20.0)
Implant placement depth	
Subcrestal	18 (45.0)
Equicrestal	15 (37.5)
Supracrestal	7 (17.5)
Operation time after extraction	
Immediate	7 (17.5)
Delayed	33 (82.5)
Guided bone regeneration	
GBR	26 (65.0)
No GBR	14 (35.0)
Implant loading time	
Immediate	24 (60.0)
Early	2 (5.0)
Delay	14 (35.0)
Prostheses type	
Splinted	25 (62.5)
Non-splinted	15 (37.5)
Opposing dentition	
Natural tooth	33 (82.5)
Implant	5 (12.5)
Denture	2 (5.0)

(GBR: guided bone regeneration)
Values are presented as number (%) or mean±standard deviation.
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The average functional period after prosthetic placement was 10.5 years (range, 6.1 to 14.0 years). Among the implants, 32 were located in the anterior region, and 8 were in the posterior region. The diameter, length, and placement locations of the NDIs are presented in Table 2. During the observation period, two 2.5 mm NDIs failed, and all the 3.0 mm NDIs survived. The two failed NDIs occurred in the same patient, with one failure happening 3 months after loading and the other occurring 118 months after loading. The Kaplan–Meier survival rates are presented in Fig. 2.

The average MBL during the observation period was 0.44±0.57 mm. Table 3 displays the results of the univariable and multivariable logistic regression analyses of various factors that might influence MBL. Only the presence of GBR at the time of implant placement correlated significantly with MBL (P=0.046).

During the observation period, two prosthetic complications occurred, with one case of decementation and one case of veneer chipping.

IV. Discussion

This study investigated the long-term outcomes of 2.5 mm and 3.0 mm NDIs and factors associated with bone resorption.

The survival rate of the NDIs was 95.1% at the implant level and 96.0% at the patient level, with an average observation period of 10.5 years. Some people have questioned whether the smaller diameters decrease stability. Although animal studies have reported that smaller implant diameters lead to decreased removal torque, other research indicates

that implant diameter does not significantly correlate with survival rates[11-14]. It was previously reported that although the smaller size of NDIs results in reduced resistance to loads, the survival rates did not differ from those of SDIs[5,15,16].

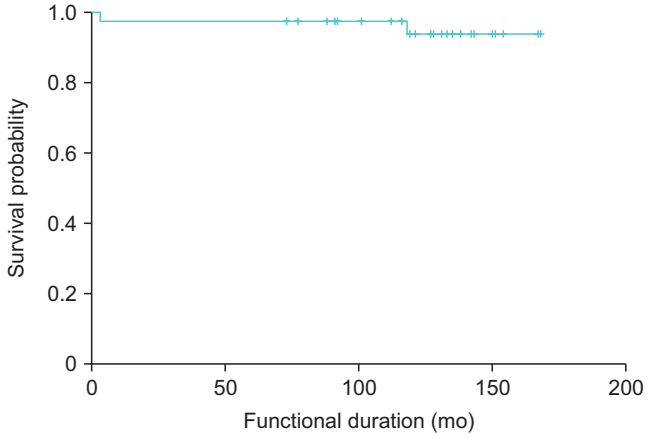

Fig. 2. Kaplan–Meier survival plots of narrow-diameter implants.
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For SDIs, the survival rates for single-tooth restorations range from 94.4% to 97.3%[17-19], and the survival rate in partially edentulous sites was 94.3%[20]. In studies of 2.9 mm NDIs, the 5-year survival rate was 94.2% for single implant restorations, and the 8-year survival rate was 95.3% for single and multiple implant restorations[10,21].

In studies involving 3.0 mm NDIs, a survival rate of 96.7% was reported, and a research paper examining implants with diameters of 2.9 mm and 3.25 mm reported a 7-year survival rate of 95.3%[6,22]. The use of 3.3 mm NDIs for posterior restorations had a success rate of 96.9% over an average period of 10.1 years[23]. The survival rate of NDIs in this study falls within the previously reported ranges.

In this study, two failures of NDIs occurred, both in the same patient. Two 2.5 mm diameter NDIs were placed in the left and right mandibular incisors, and 3 months after immediate loading, the NDI in the right mandibular incisor was removed due to osseointegration failure. The failed site was replaced with a 3.0 mm NDI. After 118 months, the NDI in the left mandibular incisor was removed due to peri-implantitis.

Table 2. The diameter, length, and placement locations of narrow-diameter implants

	Diameter (mm)		Length (mm)				Total	Failed implants
	2.5	3.0	10.0	11.5	13	15		
Maxilla								
1st premolar	1	1			1	1	2	
2nd premolar	1	1			1	1	2	
1st molar		1			1		1	
Mandible								
Incisal	27	5	3	1	23	5	32	2
1st premolar	1		1				1	
2nd premolar	2		2				2	

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Table 3. Risk factors associated with marginal bone loss

	Univariate analysis		Multivariate analysis	
	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value
Sex, male	0.95 (0.26-3.44)	0.935		
Age	0.95 (0.90-1.00)	0.068	0.95 (0.88-1.00)	0.069
Jaw position (maxilla)	4.24 (0.56-87.38)	0.217		
Implant position (anterior)	0.29 (0.04-1.50)	0.169		
Implant diameter (2.5 mm)	0.60 (0.11-2.87)	0.529		
Implant placement depth (subcrestal)				
Equicrestal	0.23 (0.05-0.97)	0.054		
Supracrustal	0.85 (0.14-5.42)	0.856		
Operation time (immediate)	0.30 (0.04-1.56)	0.178		
Guided bone regeneration (no)	3.41 (0.89-15.20)	0.085	5.81 (1.18-42.10)	0.046*
Implant loading time (immediate)				
Early	0.71 (0.03-19.53)	0.819		
Delayed	0.29 (0.06-1.12)	0.083		
Opposing dentition (natural teeth)				
Implant	0.63 (0.08-4.26)	0.633		
Denture	0.00	0.999		
Prosthesis splinting (no)	0.28 (0.07-1.05)	0.065	0.35 (0.07-1.57)	0.200

(OR: odds ratio, CI: confidence interval)
**P*<0.05. (Variables with *P*<0.1 in the univariate analyses were entered into the multivariate analysis model.)
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The patient had uncontrolled diabetes and poor oral hygiene. The replaced NDI at the first failure site demonstrated long-term survival exceeding 10 years; therefore, it was included in calculating the overall survival rates.

Comparing the survival rates of the two NDI sizes used in the study, the 2.5 mm NDIs had a survival rate of 93.8%, and the 3.0 mm NDIs had a survival rate of 100.0%. This finding is consistent with a study that reported that for diameters below 3.0 mm, the survival rate was 94.7%, and for diameters above 3.0 mm, it ranged from 97.3% to 97.5%[8]. NDIs with a diameter of 2.5 mm were used in cases of significant vertical and horizontal bone loss. Such conditions can create environments that can lead to problems such as gingival recession or challenges in maintaining oral hygiene, potentially causing variations in survival rates[24].

Previous studies on MBL around NDIs reported a mean MBL of 0.35-0.41 mm at 1 year, 0.95 mm at 5 years, and 1.19 mm at 10.1 years, with no difference in bone loss from that seen with SDIs[5,15,23,25-28]. According to meta-analytical studies[8], NDIs with diameters below 3.0 mm exhibited MBL values ranging from 0.6 mm to 1.43 mm, and those in the 3.0 mm to 3.25 mm range showed MBL values from 0.09 mm to 1.6 mm. In this study, the average MBL in 10.5 years was 0.44 mm, which is similar to or lower than the levels reported in previous studies. This is likely because our patients underwent regular periodontal check-ups every 6 months or 1 year, including occlusal checks at each visit.

Various factors influence MBL around implants, including fixture shape, surface characteristics, and the relative platform position of the implant and abutment[29,30]. Additionally, MBL can vary based on the condition of the hard and soft tissues at the implant placement site. To minimize MBL, avoiding excessive proximity to adjacent teeth or implants can help maintain the thickness of the surrounding alveolar bone. The distance between adjacent teeth and implants is crucial for forming and maintaining a stable biological width[7]. Therefore, for patients with narrow alveolar bone, performing surgery using NDIs can be advantageous to ensure that an adequate amount of surrounding alveolar bone remains.

In our study, the only factor that showed a significant correlation with MBL was the presence of GBR. Although GBR can be used to supplement insufficient alveolar bone volume, it is known to be invasive and time-consuming. Furthermore, it increases the risk of complications and has often been reported to lead to implant failure[23,31]. It can be inferred that situations requiring GBR often involve lower bone quantity or quality, compared with cases in which GBR is unnecessary, which could explain these outcomes.

Previously, NDI was used in areas with low occlusal loads or was limited to overdentures. This cautious approach is attributed to early studies indicating that stress values increase as the diameter of the implant decreases[18,19]. Furthermore, overloading caused by cantilevers from prosthetic occlusal surfaces exceeding the diameter of the implant has been associated with risks such as biological bone resorption and fatigue fractures of the implant itself[15,18-20,32]. However, this study has demonstrated a high long-term success rate for all fixed prostheses, including both single crowns in the anterior and posterior regions and cantilevers and bridges. It has been reported that careful equilibration is necessary to avoid premature contact during eccentric movements when using NDIs[21]. In this study, the patients were adjusted to maintain an occlusion similar to that of adjacent teeth at maximum intercuspation while ensuring that there was no balanced contact during lateral movements.

In this study, one case of decementation and one case of veneer chipping were observed. Some studies have reported a higher incidence of prosthetic complications associated with NDIs, including decementation, veneer chipping, and screw loosening[25], and long-term studies have indicated that veneer chipping or decementation is the most common prosthetic complication encountered[9,23,25]. Careful design and occlusal adjustments in prosthetics can be necessary to mitigate these issues.

As implant treatments become more common in edentulous areas, there is a growing demand for implants in narrow spaces or areas with limited alveolar bone, which previously posed challenges for clinicians. Concurrently, the aging population increases this demand, leading to greater interest in the clinical outcomes of NDIs and the risk factors associated with bone resorption. This study is significant because it provides long-term insights into the survival rates of NDIs and the factors that influence bone resorption, encompassing a diverse range of fixed prostheses applied in both anterior and posterior areas.

However, this study analyzed only patients with long-term follow-up of more than 6 years, which limited the data available for analysis. Moreover, due to the limitations of a retrospective study design, data regarding the bone quality and quantity at the time of NDI installation were insufficient. Further long-term prospective studies involving a larger number of NDIs, particularly NDIs with a diameter of less than 3.0 mm, are needed.

V. Conclusion

Within the limitations of this retrospective study, 2.5 mm and 3.0 mm one-piece NDIs showed a survival rate of 95.1% during an average long-term observation period of 10.5 years. The average MBL was approximately 0.44 mm, indicating stable maintenance. Among the various factors examined in this study, only GBR showed a significant association with MBL surrounding NDIs. Further studies with a larger number of implants over extended periods are needed in the future.

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Authors' Contributions

Y.J.Y. participated in the study design. J.H.K. participated in writing the manuscript and performed the statistical analysis. J.H.N. and N.H.C. participated in data collection and and coordination. Y.J.Y. and J.H.K. 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 of Seoul National University Bundang Hospital (No. B-2411-938-104) and was conducted in accordance with the Declaration of Helsinki and the International Conference on Harmonization Guidelines for Good Clinical Practice. The 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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