Radiographic Evaluation of Narrow-Diameter Implants After 5 Years of Clinical Function: A Retrospective Study

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The use of regular-sized dental implants is generally recommended to ensure adequate bone to implant contact. However, when the width of the edentulous crest is insufficient for the placement of a regular-sized implant, the use of a narrow-diameter implant (NDI) should be considered to prevent the need for invasive reconstruction techniques such as grafting procedures. The aim of the present study was to evaluate the survival and marginal bone levels of NDIs 5 years after prosthetic loading. A total of 159 NDIs belonging to 4 brands (Straumann, Astra Tech, Biolok, Xive) were evaluated in 71 patients. Clinical and radiographic evaluations using digital panoramic radiography were carried out. Two implants failed and no progressive bone loss or periapical lesions were detected in the remaining 157 implants, which is an overall success rate of 98.74%. Mean marginal bone loss (MBL) was found 1 mm on the mesial side and 0.98 mm on the distal side of the implants. No statistically significant relationship was detected between patient age, gender, implant location, implant length, type of the prosthesis, and MBL ($P > .05$). Among the 4 brands used, the MBL was highest around the Biolok implants but this was significant only compared with the Astra Tech implants ($P < .05$). The results of the present study indicate that NDIs can be a good solution for specific clinical situations where regular-sized implants are not suitable.

Key Words: narrow-diameter implants, marginal bone loss, dental implants, implant survival, fixed prosthesis, overdenture

INTRODUCTION

The dental implant is a very successful tool in the treatment of partial and complete edentulism, making it a popular treatment modality.[1,2] In particular cases of single or multiple tooth loss, preparation of healthy teeth adjacent to the edentulous areas is avoided, and the alveolar bone is preserved with implant restorations.[3]

The use of a wide or regular-sized implant ($\geq$4.0 mm) is generally recommended to ensure sufficient bone to implant contact.[4–6] However, it should be pointed out that a minimum of 1 mm of bone thickness must surround the entire implant surface.[7] In cases of bone atrophy of the long-term edentulous areas or bone loss due to periodontal diseases, periapical pathologies, and traumatic tooth extractions, bone width is usually not adequate for regular-sized implants.[8–11] This is because the width of the buccal and lingual bone walls will be diminished and, in particular, the height of the buccal socket wall will be reduced.[10,11] Placing a regular-sized implant in such situations may cause large dehiscences, and thus, a risk of complications and failure.[7] Moreover, the use of narrow-diameter implants (NDIs) in alveolar bone with a limited buccolingual or mesiodistal width may prevent the risk of injury to neighboring teeth.[7,12] To overcome the above mentioned and additional problems related to reduced interdental spaces due to migration or drifting of the remaining teeth, replacement of mandibular incisors and maxillary lateral teeth, and narrow denture-bearing

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areas in edentulous patients, almost all implant manufacturers have introduced NDIs (diameter <3.75 mm).[4,13–15] Nevertheless, it has been shown that implants with wider diameters help to reduce maximum stress values in the bone, are mechanically more resistant, and have higher removal torque values than NDIs.[16–19]

Although NDIs have been available for more than 10 years, few studies have analyzed the clinical outcomes.[7,15,16,20,21] These studies mostly showed success rates similar to those of standard-diameter implants. The aim of this retrospective study was to evaluate the survival rate and marginal bone-level changes of NDIs after 5 years of prosthetic loading.

Materials and Methods

The records of patients who had received at least one NDI between January 2004 and 2005 were reviewed, and those who met the following criteria were invited: absence of bruxism and any systemic disease that was likely to compromise implant outcome, sufficient bone volume to receive an NDI without the need for bone grafting at the time of surgery, and presence of a digital panoramic radiograph at the time of loading in the university records. The NDIs had been chosen where space limitations prevented the use of wider ones. A qualified oral and maxillofacial surgeon performed all the original surgical procedures.

A total of 86 patients who met the inclusion criteria were invited to participate in this clinical and radiographic examination. All patients were invited after undergoing exactly 5 years of prosthetic loading of their NDIs. A total of 71 patients (41 women and 30 men ranging in age from 18 to 80 years old; mean age 52 years) attended the clinical and radiographic examinations. The requirements of the Helsinki Declaration were fulfilled, and the patients provided informed consent. The patients had received the following 4 brands of NDIs:

1. Implant A (n = 49): These were 3.3-mm wide standard-neck implants with blasted and acid-etched surfaces and screw threads throughout the bodies (Straumann, Institute Straumann, Waldenburg, Switzerland)
2. Implant B (n = 42): These were 3.5-mm wide standard implants with TiO_2 grit-blasted and fluoride-modified surfaces (Osseospeed, Astra Tech, Mölndal, Sweden)
3. Implant C (n = 37): These were 3.45-mm wide implants with microgrooved surfaces treated with resorbable blast media (Silhouette Laser-Lok, Biolok International Inc, Deerfield Beach, Fla)
4. Implant D (n = 31): These were 3.4-mm wide implants with a shallower thread in the coronal sections and grit-blasted and acid-etched surfaces (Xive, Dentsply-Friadent, Mannheim, Germany)

There were no combined uses of implant brands in any patient.

Follow-up and radiographic examination

Clinical examinations were carried out by a prosthodontist blinded to the study protocol. Assessment of implant survival was based on the following criteria[2]:

- Absence of clinical mobility
- Absence of peri-implant radiolucency
- Absence of painful symptoms or paresthesia
- Absence of progressive marginal bone loss (MBL)

All participants received digital panoramic radiographs using digital imaging equipment (Morita Veraview IC5, J. Morita MFG. Corp, Kyoto, Japan). Measurements were analyzed at ×20 magnification using a software program (CorelDraw 11.0, Corel Corp and Coral Ltd, Ottawa, Canada) by 2 examiners blinded to the study and calibrated before the study. The known diameter of the implant at the collar region, obtained from the manufacturer's dimensions, was used as a reference point for each respective implant. The distance from the widest part of the implant supracrestally to the crestal bone level was measured on the magnified images. To account for variability, the implant dimension (width) was measured and compared with the manufacturer-specified dimensions; ratios were calculated to adjust for distortion. Bone levels were determined by applying a distortion coefficient (true bone height is equal to true implant width multiplied by the bone height measured on the radiograph, which is then divided by the implant diameter measured on the radiograph).

The level at which the marginal bone seemed to be attached was assessed by visual evaluation at the distal and mesial surfaces of all implants. The averages of the received values from the 2

examiners were recorded as one value. Two digital panoramic radiographs were used for each patient: one taken at the time of prosthetic loading, which was one of the inclusion criteria, and one taken at the time of the examination. The difference in MBL around each implant was recorded as the MBL value of that implant.

Statistical analyses

For statistical analysis, the NCSS (Number Cruncher Statistical System) 2007 and PASS 2008 Statistical Software (Number Cruncher Statistical Systems, Version 2000, Kaysville, Utah) were used. Aside from descriptive statistics (means and standard deviations), comparison of quantitative data was accomplished using one-way analysis of variance and Tukey honestly significant difference test. For comparison of 2 groups with parameters of normal distribution, the Student *t* test was used. A Pearson correlation analysis was used to find correlations between responses of nominal variables. Differences were considered statistically significant at $P < .05$.

Results

A total of 159 NDIs in 71 patients were evaluated. Of these, 71 NDIs had been placed in the maxillas, 36 at anterior sites and 35 at posterior sites. The remaining 88 NDIs had been placed in the mandibles, 55 at anterior sites and 33 at posterior sites. Of the 159 NDIs, 32 had been loaded with overdentures whereas the remaining 127 had been loaded with fixed prosthesis.

The mean MBL was 1 mm on the mesial side of the implants and 0.98 mm on the distal side of the implants. No progressive bone loss or periapical lesions were detected in any of the implants.

Although 1 implant B and 1 implant C failed, the others all survived, for an overall success rate of 98.74%. Both of the failed NDIs were in the mandible, one at an anterior and 1 at a posterior site.

No statistically significant relationship was detected between gender and MBL ($P = .341$ for distal and $P = .177$ for mesial MBL). Similarly, there was no significant relationship between bone loss and patient age ($P = .136$ for distal and $P = .103$ for mesial MBL) (Table 1).

The type of prosthesis, whether an overdenture or a fixed prosthesis, did not affect the MBL rates ($P = .075$ for distal and $P = .212$ for mesial MBL). Similarly, no significant relationship was detected between the location of NDIs and MBL (Table 2). No correlation was found between MBL and NDI length ($P = .326$ for distal and $P = .769$ for mesial MBL).

Table 1

Relationship between marginal bone loss (MBL), patient age, and gender

Characteristic	Mean ± SD	*P*
Age[a]		
MBL distal		.136
MBL mesial		.103
Gender[b]		
Women (n = 41)		
MBL distal	0.99 ± 0.19	.341
MBL mesial	0.96 ± 0.18	.177
Men (n = 30)		
MBL distal	1.02 ± 0.24	
MBL mesial	1.01 ± 0.25	

[a] Pearson correlation analyses.
[b] Student *t* test.

The MBL around implant C was significantly higher than around implant B ($P = .019$ for distal and $P = .040$ for mesial MBL). No statistically significant relationship was detected between the MBL of other implant brands (Table 3).

Discussion

This retrospective study analyzed 71 patients with various types of edentulism successfully restored with fixed or removable prostheses supported by 159 NDIs placed by an experienced surgeon at a university clinic. As indicated earlier, all NDIs in this study were placed in alveolar ridges where space limitations prevented the use of wider ones.

It should be pointed out that a clarification on nomenclature may need to be addressed by the field of dental implantology concerning mini, narrow, standard, or wide diameter implants. They seem to be blending together in diameter specifications. Although some authors believe an implant with a diameter <3.75 or 4 mm is narrow or small,[13,21–24] others[4] think these implants require a minimum mesiodistal space of 6 to 6.5 mm to allow adequate implant to tooth distance and call implants with a diameter <3 mm NDIs. However, implant designs with diameters below 3 mm have

Table 2
Relationship between the location of narrow-diameter implants (NDIs) and marginal bone loss (MBL)

	Location (Mean ± SD)[a]				
	Posterior Maxilla	Anterior Maxilla	Posterior Mandible	Anterior Mandible	*P*
MBL distal	1.01 ± 0.26	1.01 ± 0.20	0.99 ± 0.18	1.00 ± 0.19	.956
MBL mesial	0.98 ± 0.26	0.98 ± 0.21	0.99 ± 0.18	0.96 ± 0.17	.925

[a] One-way analysis of variance.

been introduced into the market under the banner of "mini implants."[25,26] In a few published studies, small- or narrow-diameter implants were classified in a specific dimension range.[7,20] Comfort et al[20] regarded implants of 3.0–3.3 mm in diameter as small; whereas implants with a diameter of 3.0 to 3.4 mm were called narrow by Davarpanah et al.[7] In all of these studies, implants with a diameter of 3.75 or 4.0 mm were regarded as regular-sized implants. The implants that we evaluated were 3.3 to 3.5 in diameter and were all below the regular size; thus, calling them narrow was deemed appropriate in the present study. As the smaller-diameter implants known as mini implants[25,26] were not used in this study, the results cannot be applied to these mini implants.

The overall implant success rate after 5 years of loading time (98.74%) indicated that NDIs can be successfully used to support fixed or removable prosthesis. This implant success rate is consistent with previous studies investigating the outcome of NDIs.[16,20–23]

Orthopantomography is a reliable radiographic procedure, and because of its standardized projection in the vertical plane, it is well suited for vertical measurements.[24,27,28] It has been shown that panoramic radiographs provide trustworthy information to assess the point of bone attachment to implant threads.[29] Although the best methods in bone measurements are considered to be dental volumetric tomography or subtraction radiography using standardized periapical radiographs, it should be pointed out that in routine practice these techniques are too impractical and present difficulties for patients.[24,27–30] For standardized periapical radiographs, a custom-made film holder must be developed and mounted on the implant to ensure standardized exposure. Additionally, for the correct performance, the restoration and abutment must be unscrewed from the implant, which is a process patients usually do not prefer. Also, uncomfortable film holders are usually very painful for patients with atrophic mandibles.[30] Panoramic radiographs are a practical alternative to periapical radiographs for evaluating MBL in cases where this type of edentulous mandible makes intraoral periapical radiography difficult or impossible.[27,28,30] Furthermore, computer-aided panoramic radiography, which was used in the present study, has been confirmed to provide accurate and repeatable measurements with the help of calibration using the known implant dimensions in a similar study investigating the clinical and radiographic outcome of NDIs.[21]

Most of the previously published studies dealing with the MBL of implants agree that neither age nor gender of patients seem to be an important factor on peri-implant bone loss, which supports the present findings.[3,29]

Based on previous assumptions, it is widely accepted that MBL of 1 mm during the first year after prosthetic loading, and an annual bone loss not exceeding 0.2 mm thereafter is a natural feature and consistent with successful treatment.[2,29,31,32] The mean MBL found in the present study (1.0 mm at the mesial side and 0.98 mm at the distal side of the implants) satisfies these assumptions. Because this was a retrospective study investigating the MBL of NDIs 5 years after prosthetic loading, it was not possible to monitor the marginal bone level changes 1 year after prosthetic loading, which is a limitation of this study. Nevertheless, it is assumed that the major part of the MBL may have occurred during the first year after prosthetic loading; thereafter, the marginal bone levels stabilized. The survival rate and bone levels found were similar to those found in previous studies of regular-sized implants.[33–40] However, this result is not in accordance with previous experimental findings using finite-element analyses in which reduced stress and strain patterns were observed with wider diameters as a result of increased bone to implant contact

Table 3

Comparison of implant brands in terms of marginal bone loss (MBL)

	Implant Brands (Mean ± SD)[a]				
	Implant A (Straumann; n = 49)	Implant B (Astra Tech; n = 42)	Implant C (Biolok; n = 37)	Implant D (Xive; n = 31)	*P*
MBL distal	0.99 ± 0.23	0.94 ± 0.21	1.09 ± 0.18	1.01 ± 0.19	.019*
MBL mesial	0.96 ± 0.23	0.93 ± 0.20	1.06 ± 0.19	0.99 ± 0.16	.040*

[a] One-way analysis of variance.
* $P < .05$.

area; the researchers concluded that this reduction would in turn result in less MBL around the neck of implants.[6,17,18,41]

The lowest MBL rate, which was also significantly lower than the MBL of implant C, was observed in implant B in the present study. The superiority implant B for MBL was similarly reported in other clinical studies comparing the MBL of different brands.[42–44] It seems that the differences in surface texture and shape of the implant neck between the implant systems result in significant differences in the magnitude of MBL. However, it should be noted that since the present study was retrospective, there was no randomization of implants and there was an unequal distribution of implants among the 4 brands used. Therefore, further randomized controlled clinical trials comparing different brands of NDIs are needed to draw more reliable conclusions.

Reducing the diameter of the implants was shown to increase the risk of fractures due to lower mechanical durability.[45,46] Fatigue fracture may occur in NDIs after a long period of function.[22,46] In 2 long-term studies, the fracture rate of NDIs was reported to be around 0.67% and 0.26%, respectively.[22,23] The NDIs followed for 5 years in the present study showed no signs of fractures. This result could be because the NDIs were splinted with each other or to other regular-sized implants when possible, which was consistent with the results of 2 similar studies.[20,21]

Although a previous study pointed out that compression/tension forces were lower in the overdenture situations than with a fixed prosthesis,[47] the type of prosthesis, whether a fixed or removable denture, did not influence the MBL rates in the present study. As there was an unequal distribution of prosthesis type, it is not possible to make an exact conclusion on this subject.

Survival and MBL of NDIs does not seem to be affected by implant location, according to the results of the present study. However, because of the low number of implant failures observed in the current study, it was not possible to confirm these results.

Previous studies have shown that NDIs of shorter lengths, such as 7 or 8 mm, fail disproportionally in comparison with implants of 10 mm or longer.[33,34] No relationship was found between implant length and MBL in the present study, which is in accordance with previously published studies.[20,21] All the implants used in the present study were 11 mm or longer. Therefore, it was not possible to monitor the marginal bone level changes of shorter NDIs, which can also be regarded as another limitation of this study.

Conclusion

Within the limitations of this study, it can be concluded that survival and MBL rates of NDIs seem to be comparable with those of regular-sized implants and that NDIs can be used confidently when anatomic situations do not permit the use of wider ones.

Abbreviations

MBL: marginal bone loss
NDI: narrow-diameter implant

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