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Clinical and radiographic assessment of narrow-diameter and regular-diameter implants in the anterior and posterior jaw: 2 to 6 years of follow-up

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ABSTRACT

Purpose: The present retrospective clinical study aimed to evaluate and compare the clinical and radiographic parameters, complications, and satisfaction in patients who received fixed prostheses supported by narrow-diameter implants (NDIs) in the anterior and posterior jaw.
Methods: Patients aged ≥30 years who had NDI-supported fixed prostheses in the anterior or posterior region of either jaw for at least 2 years were included. Complications such as chipping of the crown; loosening or fracture of the screw, crown abutment, or implant; and loss of retention were recorded. Clinical peri-implant outcomes and crestal bone loss (CBL) were measured. A questionnaire was used to record responses regarding the aesthetics and function of the fixed restorations. Analysis of variance was used to assess the significance of between-group mean comparisons. The log-rank test was performed to analyze the influence of location and prosthesis type on technical complications.
Results: Seventy-one patients (mean age: 39.6 years) provided informed consent with a mean follow-up duration of 53 months. Only bleeding on probing showed a statistically significant difference between NDIs in the anterior and posterior regions. The complication rate for NDIs in the posterior region was significantly higher than that for NDIs in the anterior region (P=0.041). For NDIs, CBL was significantly higher around splinted crowns than single crowns (P=0.022). Overall mean patient satisfaction was 10.34±3.65 on a visual analogue scale.
Conclusions: NDIs in the anterior and posterior jaws functioned equally well in terms of peri-implant soft and hard tissue health and offered acceptable patient satisfaction and reasonable complication rates.

Keywords: Alveolar bone loss; Dental implants; Patient satisfaction; Questionnaires

INTRODUCTION

Dental implants are devices used to secure artificial teeth and are widely used to restore missing teeth, a practice that has existed worldwide for several decades. In some clinical

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Conflict of Interest

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

scenarios, such as cases of inadequate bone volume, treatment with regular-diameter implants (RDIs) is often hampered, leading to relatively unfavorable clinical outcomes [1]. For this purpose, advanced and complex surgical techniques including bone splitting, guided bone regeneration, and distraction osteogenesis are often required to increase the horizontal bone dimension [2-4]. However, these surgical interventions are unrealistic for some patients, because they may involve extended treatment time, can have unforeseen complications, and can be costly [5].

Extensive research has led to the development of multiple types of dental implants that vary in shape and size according to the patient's needs [6]. Among these dental implants, the short- and long-term survival of artificial narrow-diameter implants (NDIs) has been extensively researched in patients with reduced horizontal bone height in edentulous jaws [7-10]. According to Al-Johany *et al.* [11], NDIs are defined as dental implants with diameters ranging from 3.0 mm to 3.75 mm. NDIs are designed to work well in edentulous areas where there is limited mesiodistal space, such as the maxillary lateral and mandibular lower incisors [12,13]. Using a RDI in such limited spaces may damage the adjacent natural dentition. Furthermore, several reports on the survival rates, aesthetic outcomes, and technical complications of NDIs have been published. Although results regarding clinical and radiographic peri-implant parameters of NDIs in the esthetic zone are widely documented, few clinicians have studied the clinical success rate of NDIs in the posterior jaws [14,15]. In their short-term clinical study, Tolentino *et al.* [16] observed 100% implant survival and success rates for NDIs in the molar region of the mandible. A long-term retrospective study with up to 11 years of follow-up reported an overall survival rate of 95.1% for NDIs in the posterior region [17]. A recent meta-analysis reported a mean implant survival rate of 97.7% for NDIs that was reflective of clinical success in all regions, including posterior single-tooth restorations [18].

Nevertheless, there are still several limitations that should be taken into account when considering the introduction of NDIs in the posterior jaws. These include the risk of fracture of the screw and implant fixture due to the thin fixture wall of the NDI, as well as the risk of overload stemming from the reduced ratio of the diameter of the implant to the occlusal surface area, which can produce cantilever effects [19]. These factors may contribute to the complication rate and thereby reduce the overall clinical success of NDIs placed in the posterior region. Therefore, the present retrospective clinical study aimed to evaluate and compare the clinical and radiographic parameters, complication rates, and patient satisfaction levels of fixed prostheses supported by NDIs placed in the anterior and posterior regions.

MATERIALS AND METHODS

Design and research ethics

Ethical approval was obtained from the Ethics Research Committee of the Center for Specialist Dental Practice and Clinical Research (UDCRC/004-86). The current clinical study was a retrospective study that followed the Strengthening the Reporting of Observational Studies in Epidemiology guidelines [20]. The follow-up duration ranged from 2 to 6 years. Suitable participants were telephoned to invite them to the study and, later, to carry out follow-up assessments. The present clinical study was performed in accordance with the guidelines described in the Declaration of Helsinki. Participants were invited to participate in the clinical study and asked to provide informed consent.

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Subject selection

Patients aged ≥30 years who had NDI- and RDI-supported fixed prostheses in the anterior or posterior region of either jaw for a minimum duration of 2 years were selected for the study. Participants were excluded if they had undergone advanced surgical procedures such as bone augmentation, were former or current smokers [21], had medically compromised status including uncontrolled diabetes mellitus, had severe periodontal or peri-implant disease, had bone disorders or osteoporosis, exhibited complete edentulism, or were missing baseline radiographs.

Assessment of NDIs and RDIs and their fixed prostheses

All details regarding NDIs and RDIs were obtained from the records saved in the database. All NDIs and RDIs were screened to determine the depth of placement, total number of implants, implant loading and duration of implants in service, implant design, and implant length and diameter. The restoration type was also determined at the follow-up assessment. In addition, baseline standardized periapical radiographs were examined for a detailed radiographic analysis.

Technical complications

Complications such as chipping of the crown; loosening or fracture of the screw, crown abutment, or implant; and loss of retention were evaluated and recorded.

Patient satisfaction

A questionnaire sheet was provided to all eligible participants and consisted of questions regarding the aesthetics and function of the fixed restorations. Responses were made on a Likert scale ranging from "exceptionally dissatisfied" to "exceptionally satisfied."

Clinical peri-implant measurements

All clinical peri-implant assessments were conducted by a single and calibrated examiner (Mohammed Alrabiah). Kappa scores were used to estimate probing depth (PD) before detailed clinical measurements were performed. Two parameters—the plaque score (PS) and bleeding on probing (BOP)—were based on dichotomous measurements, for which the responses were "yes – 1" and "no – 0" [22]. The measurement of PD was based on the recommendations described in the consensus report of the 11th European Workshop on Periodontology in 2015 [23]. All clinical measurements were taken at 6 sites of the NDIs and reported as mean percentages per individual. All clinical parameters were measured using a manual periodontal probe (UNC-15, Hu-Friedy, Chicago, IL, USA).

Standardized radiographs

Crestal bone loss (CBL) was assessed by a single and calibrated examiner (Fahim Vohra). Radiographic techniques were performed as explained in our previous reports; these techniques include standardization of a bite registration material and an aluminum step wedge of specific density [24,25]. Digital radiographs were incorporated in a software program (Romexis; images stored at a 1:1 ratio) and studied on an adjusted personal computer screen integrated with an image analyzer (Scion Image Analyzer, Scion Corp., Frederick, MD, USA). The range of pixels for calibration was set at 16 bits in Scion Image and was generated automatically according to a linear density calibration function for original 16-bit pixel values.

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Statistical analysis

Normality testing was conducted using the Shapiro-Wilk test before performing any further statistical tests. For all dependent variables, including clinical peri-implant parameters and CBL, analysis of variance was used to assess the significance of between-group comparisons of mean values. The Dunn test was used for multiple comparisons. The log-rank test was performed to analyze the influence of location and prosthesis type on the rate of technical complications. *P* values <0.05 were considered to indicate statistical significance.

RESULTS

Subjects and implants

Table 1 describes the details of subject selection and implant-related characteristics. Of 194 patients, 71 patients (mean age: 39.6 years) with NDIs and 65 patients (mean age: 41.4 years) with RDIs provided informed consent. The mean follow-up duration was 53 months. A total of 114 NDIs (36 in the maxilla and 78 in the mandible) and 121 RDIs (48 in the maxilla and 73 in the mandible) were examined, of which 61 NDIs and 74 RDIs were implanted in the anterior jaw, while 53 NDIs and 47 RDIs were implanted in the posterior region. All implants were bone-level platform-switched implants with moderately rough surfaces that were either 10 mm or 12 mm in length and that had diameters of 3.3 mm (for the NDIs) or 4.0 mm (for the RDIs). The NDIs and RDIs had mean loading periods of 3.8 and 3.9 months, respectively. The implant-supported fixed restorations included a total of 85 screw-retained and 29 cement-retained restorations for NDIs and 72 screw-retained and 49 cement-retained restorations for RDIs, while 46 NDIs and 52 RDIs supported single crowns and 68 NDIs and 69 RDIs supported splinted restorations.

Clinical parameters

The follow-up peri-implant conditions are reported in Table 2. Around anterior NDIs, the mean percentages of sites for which "yes" was recorded in the assessments of PS and BOP were 18.2% and 23.8%, respectively, while these values around posterior NDIs were 26.5% and 35.1%, respectively. At follow-up, the overall mean PD values around anterior and posterior NDIs were 3.1 mm and 3.3 mm, respectively. The overall mean CBL was found to be 1.3 mm around anterior NDIs and 1.4 mm around posterior NDIs. None of the

Table 1. Descriptions of patients and implants

Description	Narrow-diameter implants	Regular-diameter implants
Implant diameter (mm)	3.3	4.0
No. of patients	71	65
Mean age of patients	39.6 (31–49)	41.4 (34–48)
Male:female	48:23	39:26
Mean follow-up duration (mon)	53 (35–69)	52 (34–70)
Total No. of implants	114	121
Anterior region	61	74
Posterior region	53	47
Maxilla:mandible	36:78	48:73
Implant length (10 mm:12 mm)	73:41	82:39
Depth of placement	Bone level	Bone level
Implant design	Platform-switched with moderately rough surfaces	Platform-switched with moderately rough surfaces
Implant loading after placement (mon)	3.8±0.2	3.9±0.4
Type of restoration (screw:cement)	85:29	72:49
Single crown:splinted crown	46:68	52:69

Values are presented as median (interquartile range) or mean±standard deviation.

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Table 2. Clinical and radiographic peri-implant status

Peri-implant parameters	Narrow-diameter implants		Regular-diameter implants	
	Anterior	Posterior	Anterior	Posterior
Plaque index (% of sites)	18.2±6.9	26.5±9.2	21.7±5.4	26.4±6.3
Bleeding on probing (% of sites)	23.8±7.7	35.1±6.4[a]	28.4±7.5	31.6±8.8
Probing depth (mm)	3.1±0.4	3.3±0.6	3.0±0.8	3.2±1.8
Mean crestal bone loss (mm)	1.3±0.1	1.4±0.2	1.6±0.3	1.7±0.5
Mesial	1.1±0.1	1.2±0.1	1.3±0.2	1.5±0.1
Distal	1.4±0.2	1.5±0.3	1.7±0.3	1.7±0.2

Data are shown as mean±standard deviation.
[a]Statistically significant difference compared to the anterior group at $P<0.05$.

clinical parameters displayed statistically significant differences between NDIs and RDIs or between the anterior and posterior regions ($P>0.05$), with the exception of BOP, for which a statistically significant difference was observed between the anterior and posterior regions for NDIs.

Influence of implant location and type of prosthesis on technical complications and CBL

The rate of technical complications for NDIs in the posterior region was statistically significantly higher than that for NDIs in the anterior region ($P=0.041$). In general, NDIs were associated with a significantly higher number of technical complications than RDIs ($P=0.001$). In addition, splinted crowns were also associated with a higher rate of technical complications than single crowns ($P=0.039$), with increased risk for NDIs compared to RDIs ($P=0.01$). The log-rank test showed that the CBL of NDIs was statistically significantly higher around splinted crowns than around single crowns ($P=0.022$) (Table 3).

Complication rates and patient satisfaction

Common complications described by the patients were chipping and loosening of crowns. Of 71 patients with NDIs and 65 patients with RDIs, 65 (91.5%) and 63 (96.9%) patients, respectively, were extremely satisfied with the aesthetics of the restorations, while 61 (85.9%) and 58 (89.2%) patients, respectively, were highly satisfied with the restoration function (Table 4). Only 6 and 10 patients with NDIs and 2 and 7 patients with RDIs reported reservations regarding aesthetics and function, respectively. The main reason for reported dissatisfaction was food impaction. The mean patient satisfaction levels were 10.34±3.65 and 13.62±2.94 on a visual analogue scale for NDIs and RDIs, respectively.

Table 3. Influence of implant location and type of prosthesis on technical complications and CBL in NDIs and RDIs

Variable	Technical complication rate	*P* value	CBL (mm)	*P* value
NDI		0.041[a]		0.768
Anterior region	8.1 (5/61)[b]		1.01±0.17 (n=61)	
Posterior region	16.9 (9/53)[b]		1.26±0.31 (n=53)	
RDI		0.824		0.446
Anterior region	1.35 (1/74)		1.25±0.12 (n=74)	
Posterior region	6.3 (3/47)		1.31±0.22 (n=47)	
NDI		0.039[a]		0.022[a]
Single crown	6.5 (3/46)		1.03±0.14 (n=46)	
Splinted crown	13.2 (9/68)[b]		1.51±0.33 (n=68)	
RDI		0.714		0.946
Single crown	2.5 (1/39)		1.19±0.12 (n=39)	
Splinted crown	2.4 (2/82)		1.67±0.25 (n=82)	

Data are shown as mean±standard deviation or number (%).
CBL: crestal bone loss, NDI: narrow-diameter implant, RDI: regular-diameter implant.
[a]Statistically significant difference at $P<0.05$; [b]Statistically significant difference in subgroups between NDIs and RDIs at $P<0.05$.

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Table 4. Overall patient satisfaction

Variable	No. of satisfied patients	No. of unsatisfied patients	Overall satisfaction
NDIs			10.34±3.65
Aesthetics	65 (91.5)	6 (8.5)	
Function	61 (85.9)	10 (14.1)	
RDIs			13.62±2.94
Aesthetics	63 (96.9)	2 (3.1)	
Function	58 (89.2)	7 (10.8)	

Data are shown as mean±standard deviation of visual analog scale or number (%).

DISCUSSION

This study focused on the comparative analysis of NDIs placed in the anterior and posterior regions. Their clinical peri-implant parameters, including plaque levels, bleeding scores, PD, and radiographic evidence of bone loss, were recorded. In addition, technical complication rates and patient satisfaction were evaluated. The results of the present retrospective study suggest that clinical and radiographic parameters showed statistically similar outcomes during the follow-up period. In addition, NDIs placed in both the anterior and posterior regions offered acceptable patient satisfaction and reasonable complication rates.

Clinical peri-implant parameters reflective of health were observed at various follow-up intervals. These were indicative of the meticulous oral hygiene maintenance practiced by all of the patients during follow-up. This relates to the importance of oral hygiene care and implies that dental implants could survive longer if plaque levels were kept low [26,27]. It should be noted that PSs around NDIs placed in the posterior region (26.5%) were higher than those associated with anterior NDIs (18.2%). However, this difference was not statistically significant. Nevertheless, a possible reason for this difference could be that the posterior region is considered to be a difficult-to-maintain area and is a region where effective oral hygiene may not be practiced optimally. In addition, BOP was the only parameter that showed statistical significance—in particular, a statistically significant difference between the posterior and anterior NDIs. This may be related to known inflammatory signs in the posterior region, which in turn may be due to the plaque levels around NDIs placed in the posterior jaw.

None of the NDIs placed in the anterior or posterior region were associated with serious complications, including implant fracture. A previous meta-analysis found 5-year dental implant fracture rates of only 0.08% and 0.5% for single crown restorations and splinted restorations, respectively [28]. This may demonstrate that these implants with a 3.3-mm diameter yield predictable outcomes in the posterior jaw. The technical complications associated with single crowns were also higher than those associated with splinted crowns (6.5% vs. 13.2%, respectively). All 12 fixed restorations either became loosened or had some level of chipping observed in the splinted group. This might explain the significantly higher supra-structure complication rates in splinted restorations compared to single crown restorations.

Statistically significant differences with regard to CBL were observed between splinted and single restorations (P=0.22). These outcomes contradict the results presented in the long- and short-term studies conducted by Shi *et al.* [28] and Al-Aali *et al.* [29], respectively. The study by Shi *et al.* [28] showed that the CBL was 1.2 mm in splinted restorations and 1.3 mm in single restorations at an 8-year follow-up assessment and that the difference between splinted and single restorations was not considered clinically meaningful. This lack of a

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clinically meaningful difference may indicate that both NDI-supported single and splinted crowns could maintain the CBL.

It is noteworthy that the average CBL around splinted crowns was statistically significantly higher than the average CBL around single crowns (1.51 mm vs. 1.03 mm, respectively; P=0.022). This difference might be explained by the higher occlusal force and more persistent inflammation around splinted restorations compared to single restorations [29,30]. The impact on oral cleanliness around splinted restorations is another important factor, as more debris can be retained around splinted crowns, requiring more care.

Some noticeable limitations are present in this study. First, survival analysis using advanced statistical methods such as Kaplan-Meier analysis was not performed. Additionally, with the strict eligibility criteria imposed, the outcomes may not translate to other cohorts, including tobacco smokers and individuals with systemic disorders such as uncontrolled diabetes mellitus. Finally, a limited number of NDIs were studied in the maxillary jaw, even though the maxilla and mandible differ in their bone mineral density, suggesting a potentially different outcome in mandibular NDIs. Therefore, future studies should be undertaken to confirm the clinical efficacy of NDIs in maxillary jaws compared to mandibular jaws.

NDIs placed in the anterior and posterior regions of the jaws function equally well in terms of peri-implant soft and hard tissue health, although NDIs demonstrated an increased risk of prosthetic complications. NDIs placed in both regions offered acceptable patient satisfaction and reasonable complication rates. NDI-supported prostheses in either the anterior or the posterior region could be a promising treatment option, especially in areas where advanced surgical interventions such as bone augmentation should be avoided.

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