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# Impact of Implant Diameter on Success and Survival of Dental Implants: An Observational Cohort Study

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**Abstract:** Narrow-diameter implants (NDIs) can be inserted instead of standard dental implants (SDIs) in sites with limited space and bone availability. The aim of this study was to evaluate the effect of implant diameter on peri-implant bone, attached mucosa, and on the associated probability of implant success and survival. The implants with progressive thread design and platform switching (Ankylos®, Dentsply Sirona; Mannheim, Germany) investigated were identified retrospectively and assigned to two groups based on their diameter: 3.5 mm (NDIs) and 4.5 mm (SDIs). Peri-implant bone loss was analyzed based on available radiographs. Descriptive and implant-associated factors were gathered from patient files. Data were statistically analyzed using the Kolmogorov–Smirnov–Lilliefors test and regression analyses. The level of significance was $p \leq 0.05$. Results: In total, data for 415 implants in 194 patients were included in the study. Ten-year survival was 95.8% (NDIs) and 91.1% (SDIs). Implant diameter had no significant effect on peri-implant crestal bone loss ($p = 0.098$) or on the width of the attached gingiva ($p = 0.052$). Survival and success rates of NDIs were like or slightly better than those of SDIs. Because implant diameter had no effect on peri-implant tissue, NDIs can be recommended in selected cases.

**Keywords:** attached gingiva; dental implant; narrow-diameter implant; peri-implant bone loss; standard dental implant; dentistry; implantology



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## 1. Introduction

Dental implants are an evidence-based restorative option for replacing missing teeth. By restoring masticatory function, implant treatment also improves oral-health-related quality of life [1,2]. The clinical long-term success of an implant-retained restoration is affected by both technical and biological complications [3], the latter of which are often characterized by peri-implant bone loss or soft-tissue loss [4]. In addition to patient-specific factors, such as age and systemic diseases, the incidence of complications is affected by implant-associated parameters [1,3]. Previous studies have described how implant survival and success are affected by implant surface design, the implant–abutment connection, and implant geometry [5,6]. The choice of implant can therefore have a direct impact on the long-term prognosis of treatment.

Implants are selected based on the volume of available bone. Because tooth loss causes anatomical changes to the alveolar bone and subsequent bone loss, a patient's bone availability may be reduced immediately after tooth extraction [7]. Horizontal bone loss in particular cannot be avoided, even if grafting materials are used [8,9]. This means that bone resorption after tooth loss is often greater in width than in height [10]. To insert standard diameter implants (SDIs), however, a minimum bone width of 6 mm is required [11,12]. Bone augmentation can be performed to improve insufficient available bone; however, the procedure is cost- and time-intensive and can lead to complications such as infection, wound dehiscence, damage to surrounding tissue, or gingival recession [13–15].

By contrast, narrow-diameter implants (NDIs) with a diameter of $\leq$3.5 mm can be inserted even in sites with limited space and bone. NDIs thus represent an alternative to SDIs that can be used to expand the range of implant indications [16].

The results for NDIs in the literature have generally been encouraging. A number of systematic reviews are available. For NDIs 3.3 to 3.5 mm in diameter, survival after $\geq$1 year has thus been found to range from 88.9% to 100% and success between 91.4% and 97.6%, with a meta-analysis showing no statistically significant difference in implant survival compared to conventional implants [16]. Four years later, in 2018, the latter finding was confirmed in a similar review both for NDIs 3.3–3.5 mm and for NDIs 3.0–3.23 mm in diameter compared to SDIs [15].

A 2019 systematic review specifically investigating NDIs $\leq$ 3.3 mm in diameter used for single-tooth restorations found the implant success rates to range from 93.8% to 100% over a maximum follow-up of 3 years, without a difference in longevity between NDIs and SDIs [17]. A 2023 systematic review of NDIs versus SDIs for mandibular overdentures found no significant difference between both implant types in terms of implant survival, while NDIs did significantly better than SDIs in terms of general patient satisfaction and oral health-related quality of life [18].

While the same review on mandibular overdentures did not find an implant-specific significant difference with regard to marginal bone loss [18], results to this effect were inconclusive in the above-mentioned review on single-tooth restorations, with a meta-analysis showing greater bone loss around NDIs than SDIs, which, however, was no longer seen once the authors confined their analysis to randomized trials only [17].

To investigate the extent to which implant diameter affects the peri-implant bone and soft tissues, and thus the success and survival of NDIs versus SDIs, we performed a retrospective clinical study of a specific implant design (characterized by a progressive thread and platform switching), which is available in an NDI and an SDI version, both of which have been clinically used over the years at our institution, thus facilitating direct comparison. The following null hypotheses could thus be tested:

1. Peri-implant bone loss is affected by implant diameter.
2. The width of the peri-implant soft tissue is affected by implant diameter.

## 2. Materials and Methods

Data collection and study design. In this study, data were collected retrospectively from the charts of patients who underwent implant treatment and subsequent prosthetic restorations between 1992 and 2016 at the Department of Oral Surgery and Implant Dentistry and the Department of Prosthodontics of the School of Dentistry Center for Dentistry and Oral Medicine (Carolinum), Frankfurt University. The study protocol was independently reviewed and approved by the responsible members of the Ethics committee (decision number: 510/17). Informed consent was not required because data were collected retrospectively and did not include any personal identifying information.

The following study inclusion criteria were defined:

1. Two-piece Ankylos® implant (Dentsply Sirona; Mannheim, Germany).
2. Implant diameter of 3.5 mm or 4.5 mm.
3. Implant in situ for at least two years.
4. Availability of postoperative and follow-up radiographs.

5. Minimum patient age of 16 years.
6. Presence or absence of bone augmentation at the implant site (single-stage approach or separate stage prior to implant placement).
7. Any loading protocol (immediate, early, conventional) and healing mode (submerged, non-submerged).

"Survival" was defined as the implant remaining in situ over the observation period. Implants with crestal bone loss of $\leq$2 mm were defined as "successful" [19,20].

The included implants were subdivided into two groups based on their diameter:

1. SDI group: implant diameter of 4.5 mm
2. NDI group: implant diameter of 3.5 mm.

Bone augmentations, loading protocols, healing modes. As apparent from the above named inclusion criteria, the implants included had been placed in the presence or absence of bone grafting, which could take the form of either horizontal alveolar ridge augmentation or, in maxillary posterior sites, of sinus floor elevation [21]. Grafting procedures were performed either in a single-step approach simultaneously with implant surgery or, using a two-step approach, by surgical pretreatment. Given the long observation period of 25 years, it is beyond this report to elaborate on the precise details of bone grafting, but a common procedure for horizontal ridge augmentation was to use guided bone regeneration (GBR), with the graft itself involving a xenogeneic particulate bone substitute, used either alone or together with autologous bone, then covering and fixating this graft with a collagen membrane via titanium tacks or periosteal sutures [22].

The loading protocols mentioned in the above inclusion criteria refer to the time at which an implant was functionally loaded with a prosthetic restoration. For "conventional loading", a waiting period of 3–8 months was observed, allowing complete healing of all peri-implant tissue. "Early" loading involved a waiting period of $\geq$1 week to <3 months, and "immediate" loading took place no longer than 1 week after implant placement. All of these three concepts are well established [23].

As to the healing modes in the above inclusion criteria, "submerged" refers to a method whereby the surgical site is sutured after insertion in such a way that the implant is completely covered by soft tissue, thus requiring minor surgery to uncover the implant down the line. By contrast, "non-submerged" means that the implant was fitted with a transmucosal healing abutment extending into the oral cavity during healing [24].

"Immediate placement" (sometimes referred to as type-I placement) is used in single-stage procedures comprising both tooth extraction and implant insertion. Hence, the implant is inserted into a fresh extraction socket rather than into a healed site, and sometimes these procedures may even involve immediate loading of the immediately placed implant with a prosthetic restoration [25].

Assessment of peri-implant bone levels and implant-associated factors. For the assessment of bone levels, the postoperative radiographs served as baseline images. Subsequent radiological follow-ups took place during patients' recall appointments.

Radiographic images were produced as panoramic radiographs (Orthophos device, Sirona; Bensheim, Germany) or single-tooth images (Heliodent DS, Sirona; Bensheim, Germany) using the paralleling technique. The radiographs were then scanned (Canon, SilverFast SE, LaserSoft Imaging; Kiel, Germany) and calibrated in a standardized manner based on the known implant length. Next, the bone levels were evaluated. To do this, the distance between the implant shoulder and first visible vertical bony crest was recorded mesially and distally. Data were also recorded on implant length, use of grafting, and mobility (Periotest) scores.

Assessment of peri-implant soft tissue. A standardized protocol was used to record the width and sulcus bleeding index (SBI) of the attached peri-implant mucosa, as well as the plaque index (PI; [26]). The probing pocket depth was measured using a World Health Organization probe and axial pressure of 0.25 N [27]. The values were measured in millimeters from the gingival margin to the sulcus base/pocket base, at four sites per

tooth. The width of the attached mucosa was measured from the gingival margin to the mucogingival junction.

To record the SBI, a blunt probe was gently stroked (approx. force: 0.25 N) along the sulcus and over the gingival margin. The SBI was recorded 20–30 s after probing and classified according to Saxer and Mühlemann [28]. In accordance with the PI by Silness and Loe, plaque accumulation in the area of the gingival margin was recorded for four sites per tooth and subclassified into grades 0–3 [26].

Statistical analysis. All patient data were collated in an Excel table and then evaluated. The Kolmogorov–Smirnov–Lilliefors test was used to determine whether data were normally distributed. Data were analyzed descriptively. A linear mixed model with a logit link function was used to investigate the association between soft tissue parameters and implant diameter, SBI, and PI. Data were analyzed using SPSS version 25 and R version 3.5.1 (R Core Team; Vienna, Austria). Significance ($p$-value), regression coefficient ($r$), standard error of the regression (SER), and odds ratio (OR) were reported. The level of significance was $p \leq 0.05$.

## 3. Results

The patients for this retrospective study were selected by searching the departmental implant database, which is implemented on an impDAT platform (Kea Software, Tutzing, Germany). Over the observation period of 1992 to 2016, a total of 673 patients had received implants either 3.5 mm or 4.5 mm in diameter. A manual review of these patient records led to the exclusion of 479 patients based on the aforementioned selection criteria. Hence, 194 patients could eventually be included for analysis, which, at the implant level, amounted to a total of 415 implants. Eighty-five (44%) of these patients were male and 109 (56%) were female. The median age was 52 years, with an interquartile range (IQR) of 41.75–62.25. Twenty-one implants were lost during the study period. Patient and implant characteristics are presented in Table 1. Compared to other studies dealing with reduced-diameter implants, the number of implants seems appropriate and sufficient to perform a statistical calculation [29,30].

**Table 1.** Patient and implant characteristics in the narrow- and standard-diameter groups.

| | | **Total** | **NDI Group** | **SDI Group** |
|---|---|---|---|---|
| Number of patients | n | 194 | 185 | 56 |
| Age of patients, years | Median<br>IQR | 52<br>41.75–62.25 | 51<br>40–63 | 54<br>44–62 |
| Number of implants | n | 415 | 336 | 79 |
| Observation period, months | Median<br>IQR | 80<br>59–108 | 80<br>56.3–108 | 78<br>66–108 |
| Implant length | | | | |
| 8.0 mm | n | 31 | 17 | 14 |
| 9.5 mm | n | 64 | 39 | 25 |
| 11.0 mm | n | 270 | 241 | 29 |
| 14.0 mm | n | 47 | 37 | 10 |
| 17.0 mm | n | 3 | 2 | 1 |

IQR: interquartile range; NDI: narrow-diameter implant; SDI: standard dental implant.

As seen in Table 2, a total of 394 implants (94.9%) were associated with submerged and 19 implants (4.6%) with non-submerged healing, while 2 implants (0.5%) were inserted in fresh extraction sockets (immediate placement). In the NDI group, 322 implants were associated with a submerged and 13 with a non-submerged healing protocol, and 1 implant was inserted in a fresh extraction socket (immediate placement). In the SDI group, the corresponding figures were 72 (submerged healing), 6, (non-submerged healing), and 1 (immediate placement). Loading protocols refer to the timing selected for the functional loading of each implant with a prosthetic restoration. A conventional loading protocol was

used in the vast majority of cases, including for 313 implants in the NDI group and for 65 implants in the SDI group. An early loading protocol was used on 14 NDIs and 9 SDIs, and immediate loading on 7 or 4 implants, respectively.

**Table 2.** Healing modes and loading protocols following placement of the implants.

| | | Total | NDI Group | SDI Group |
|---|---|---|---|---|
| Implants | n | 415 | 336 | 79 |
| Healing modes after placement | | | | |
| Submerged | n | 394 | 322 | 72 |
| | (%) | (94.9) | (77.6) | (17.3) |
| Non-submerged | n | 19 | 13 | 6 |
| | (%) | (4.6) | (3.1) | (1.4) |
| Immediate placement | n | 2 | 1 | 1 |
| | (%) | (0.5) | (0.2) | (0.2) |
| Loading protocols after placement | | | | |
| Conventional | n | 378 | 313 | 65 |
| | (%) | (91.1) | (75.4) | (15.7) |
| Immediate | n | 11 | 7 | 4 |
| | (%) | (2.7) | (1.7) | (1.0) |
| Early | n | 23 | 14 | 9 |
| | (%) | (5.5) | (3.4) | (2.2) |
| Implant removed | n | 3 | 2 | 1 |
| | (%) | (0.7) | (0.5) | (0.2) |

NDI: narrow-diameter implant; SDI: standard dental implant.

Bone augmentation was performed in 40% of NDIs ($n$ = 134) and in 45.6% of SDIs ($n$ = 36). Procedures of sinus floor elevation were associated with 57.6%, and horizontal bone augmentations with 34.1% of cases. As we have indicated before in Materials and Methods, the precise details of bone grafting are beyond the scope of this report, considering the long observation period of 25 years, and it is similarly difficult to break down the numerical distributions of sinus floor elevation and horizontal ridge augmentation, as both approaches have overlapped in a number of cases. Also, sinus floor elevation can be accomplished in two fundamentally different ways, taking a direct or an indirect approach (lateral-window or transcrestal technique). Suffice it to say that, as evidenced by the case numbers indicated above, bone grafting has been employed on a fairly regular basis for implant placement at our department.

### *3.1. Evaluation of Peri-Implant Bone Levels and Implant-Associated Factors*

The survival and success rates of the implants and the incidence of peri-implant bone loss are shown in Table 3. The number of implants with 0–2 mm of peri-implant bone loss decreased as the observation period increased. The number of implants with bone loss of 2–4 and >4 mm remained approximately the same over time.

The evaluation of peri-implant bone levels showed that implant diameter did not have a significant impact on bone loss at either the mesial or the distal aspect of the implant shoulder (mesial: $p$ = 0.098, $r$ = 0.142, SER = 0.086; distal: $p$ = 0.110, $r$ = 0.142, SER = 0.089). In addition, the parameters "implant length" (mesial: $p$ = 0.355, $r$ = −0.022, SER = 0.023; distal: $p$ = 0.516, $r$ = −0.016, SER = 0.024), "use of augmentation" (mesial: $p$ = 0.066, $r$ = 0.134, SER = 0.073, distal: $p$ = 0.053; $r$ = 0.144, SER = 0.074), and "patient age" (mesial: $p$ = 0.543, $r$ = 0.002, SER = 0.003; distal: $p$ = 0.540, $r$ = 0.002, SER = 0.003) had no significant effect on peri-implant crestal bone resorption.

At the time of implant uncovering, the median Periotest scores were −1 (IQR: −3 to +1, NDI group) and −1.5 (IQR: −3 to +0.25; SDI group). The measurements at the recall appointment were 0 (IQR: −2 to + 1.5, NDI group) and −1 (IQR: −3 to + 1; SDI group).

**Table 3.** Bone loss and survival/success rates for narrow- and standard-diameter implants.

| | 2 Years | | 5 Years | | 10 Years | |
|---|---|---|---|---|---|---|
| | **NDI Group** | **SDI Group** | **NDI Group** | **SDI Group** | **NDI Group** | **SDI Group** |
| Survival rate, % | 98.5 | 97.5 | 97.3 | 94.9 | 95.8 | 91.1 |
| Success rate, % | 96.2 | 91.5 | 89.4 | 85.4 | 69.1 | 68.4 |
| Peri-implant bone loss, *n* | | | | | | |
| ≤2 mm | 252 [a] | 55 [a] | 140 [a] | 42 [a] | 39 [a] | 15 [a] |
| 2–4 mm | 5 [a] | 3 [a] | 8 [a] | 3 [a] | 3 [a] | 1 [a] |
| >4 mm | 5 [a] | 2 [a] | 4 [a] | 2 [a] | 4 [a] | 1 [a] |
| Peri-implant bone loss, % | | | | | | |
| ≤2 mm | 96.2 [a] | 91.6 [a] | 92.1 [a] | 89.4 [a] | 84.8 [a] | 88.2 [a] |
| 2–4 mm | 1.9 [a] | 5 [a] | 5.3 [a] | 6.4 [a] | 6.5 [a] | 5.9 [a] |
| >4 mm | 1.9 [a] | 3.4 [a] | 2.6 [a] | 4.2 [a] | 8.7 [a] | 5.9 [a] |

NDI: narrow-diameter implant; SDI: standard dental implant. Superscript letter "a" indicates no significant differences within the groups.

### *3.2. Evaluation of Peri-Implant Soft Tissues*

Soft-tissue-associated data are shown in Table 4. Implant diameter had no significant effect on the width of the peri-implant attached mucosa ($p = 0.052$), PI ($p = 0.779$, OR = 0.332), or SBI ($p = 0.836$, OR = 0.475).

**Table 4.** Sulcus/plaque scores and attached mucosa for narrow- and standard-diameter implants.

| | | NDI Group | | SDI Group | |
|---|---|---|---|---|---|
| Sulcus Bleeding Index (SBI) | | Uncovering | Recall | Uncovering | Recall |
| | Grade 0 | 86%[a] | 77% [a] | 82% [a] | 75% [a] |
| | Grade 1 | 11% [a] | 19% [a] | 11% [a] | 17% [a] |
| | Grade 2 | 3% [a] | 4% [a] | 7% [a] | 8% [a] |
| | Grade 3 | 0% [a] | 0% [a] | 0% [a] | 0% [a] |
| | Grades 4/5 | 0% [a] | 0% [a] | 0% [a] | 0% [a] |
| Plaque Index (PI) | | Loading | Recall | Loading | Recall |
| | Grade 0 | 87% [a] | 72% [a] | 86% [a] | 64% [a] |
| | Grade 1 | 11% [a] | 25% [a] | 9% [a] | 30% [a] |
| | Grade 2 | 2% [a] | 3% [a] | 5% [a] | 6% [a] |
| | Grade 3 | 0% [a] | 0% [a] | 0 (0%) [a] | 0% [a] |
| Width of Attached mucosa | | Fitting appointment | Recall | Fitting appointment | Recall |
| | Implants, % | 99% [a] | 97% [a] | 98% [a] | 97% [a] |
| | Median, mm | 2.75 [a] | 2 [a] | 2.5 [a] | 2 [a] |
| | IQR, mm | 1.88–3 [a] | 1.5–3 [a] | 1–3 [a] | 1–3 [a] |

IQR: interquartile range; NDI: narrow-diameter implant; SDI: standard dental implant. Superscript letter "a" indicates no significant differences within the groups.

## 4. Discussion

NDIs are a minimally invasive implant option that can be inserted in sites with limited space and low bone volume. Their use can help to reduce postoperative complications, the duration of treatment, and treatment costs. Based on these considerations, the objective of this study was to evaluate the effect of implant diameter on the peri-implant hard and soft tissues and thus on the success and survival of dental implants.

Our study results show that peri-implant crestal bone loss was not significantly affected by implant diameter. The first part of the null hypothesis can therefore be rejected. These results are consistent with either no, or no conclusive, findings of a difference in bone loss between NDIs and SDIs from two recent systematic reviews [17,18].

Bone loss showed an upward trend over the course of the observation period. The survival and success rates of NDIs were slightly higher than those of SDIs. The observed five-year survival rates of 97.3% (NDI) and 94.9% (SDI) are similar to those recorded in other studies. The NDIs with a diameter of 3.5 mm investigated in the present study correspond to category 3 NDIs [16], which have shown a survival rate of 97.7 ± 2.3% after 39 ± 24 months [16].

Previous studies by Chuang et al. and Muelas-Jiménez et al. also found that implant success and survival are unaffected by implant diameter [31,32]. This finding was confirmed by Lemmermann and Lemmermann, who observed a large number of implants ($n$ = 1003) over a period of 15 years [33]. One possible explanation for these similar results might be that NDIs also provide high initial stability and general implant stability [34,35], which has a positive impact on the long-term success of dental implants [36]. In the present study, this was also reflected in the Periotest scores, which showed only a slight decline for both sizes of implant diameter, thus indicating good implant osseointegration [37].

The implant system used in the present study has a conical implant–abutment connection (IAC), which might also account for the high success and survival rates and low incidence of bone loss of more than 2 mm. Compared with flat implant–abutment connections (flat IACs), conical IACs show fewer microgaps between the implant and abutment, which is associated with a reduction in micromovements [38]. Consequently, bacterial contamination is reduced during dynamic loading [39]. This has a positive impact on the peri-implant bone and surrounding soft tissue.

In the present study, this was reflected not only in terms of the peri-implant hard tissue, but also in terms of the surrounding soft tissue. Our results showed a slight decrease in the width of the attached mucosa for NDIs and SDIs at the recall appointment. This decrease was slightly greater for NDIs than for SDIs. Nonetheless, implant diameter did not have a significant effect on the level of peri-implant soft tissues; thus, the second null hypothesis can also be rejected.

One reason for this result might be the patients' good oral hygiene, which was evaluated by means of the PI and SBI. These indices were not affected by implant diameter. As a result, the risk of peri-implant mucositis and peri-implantitis was reduced, and a stable gingival condition was achieved [40].

In dental implantation, the aim is generally to achieve a sufficiently thick and stable amount of keratinized mucosa around the implant, to provide biological protection against bacteria [41]. It has been shown that bone loss is lower around implants placed in thicker peri-implant soft tissue [42]. The peri-implant tissue thus provides improved long-term stability. This can also be seen in our study results, where a relatively stable keratinized mucosa width was accompanied by high implant survival rates. This finding is consistent with that of French et al., who also described less bone loss in implants surrounded by healthy peri-implant tissue [43]. Furthermore, Zweers et al. also found a positive association between keratinized gingiva and peri-implant bone [44].

Nonetheless, several limitations of our results must be considered. It should be noted that the patient data were analyzed retrospectively, and they represent only one implant design with a progressive thread, platform switching, and conical implant-abutment connection. As a result, the size of the two groups differed. In addition, the present study does not consider the type of prosthetic restoration. Although the patients' pocket probing depths were measured by calibrated examiners, the accuracy of the measurements must be viewed with caution [45]. It should also be noted that the patients' mucosa thickness (phenotype) was not considered. However, a standardized protocol was used to try to ensure that the patients' peri-implant bone and soft-tissue status was recorded reliably. Additionally, some recently introduced compounds have been demonstrated as having a significant influence on the oral environment: The use of probiotics, lysates, and postbiotics can modify clinical and microbiological parameters in periodontal patients, so further studies involving these products should be proposed in future clinical trials, to evaluate their possible effects on the long term health of implant-supported prostheses [46–48].

A retrospective study design as used for this investigation not only has its shortcomings, but its advantages should be pointed out as well. Drawing from the entirety of data that organically accumulated in a specific institution over the years will naturally eliminate some of the biases inherent in prospective designs characterized by the highly selective inclusion of cases. Also, an approach like the one herein presented reflects more naturally what transpires in real-life clinical practice on a daily basis.

Similarly, to take full advantage of this potential, and to avoid becoming entangled in a multitude of scenarios, notably within the confines of partial edentulism, we decided to disregard for the purpose of this report the various types of prosthetic restorations, such as fixed versus removable, single crowns versus partial dentures versus full-arch dentures, or the distribution of implants and/or restorations to either anterior or posterior segments of either the maxilla or mandible.

Although the results reported in the literature for NDIs are generally favorable in comparison with SDIs, some of the systematic reviews herein cited have indicated a high risk of bias as the quality of the reported data on the subject left a lot to be desired [15,16]. All other things being equal, it would seem logical to favor NDIs over SDIs as the less invasive option in a more general way. At this point in time, however, the existing body of data does not warrant a sweeping conclusion of this type, considering that the use of SDIs is disproportionately better documented than the use of NDIs.

Hence, even though recent systematic reviews [17,18] and the results of this study confirm comparable results with regard to implant survival rate, marginal bone loss, and patient-reported outcome measures between NDIs and SDIs, future studies on the subject will need to place an additional focus on the prosthetic aspects of treatment with NDIs and will need to report on longer observation periods, so that more solid conclusions can eventually be drawn about the true successes achieved with NDIs in clinical practice.

## 5. Conclusions

Within the limitations of the study, the following conclusions can be drawn:

1. Peri-implant crestal bone loss and soft-tissue loss were not affected by implant diameter around implants with a progressive thread design.
2. The success and survival rates of NDIs were similar to those of SDIs.
3. NDIs with a conical implant–abutment connection and platform switching can be recommended in selected cases.

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